MINIMUM FLOWS AND LEVELS FOR THE MIDDLE SUWANNEE RIVER

DRAFT

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List of Acronyms

AMO	Atlantic multidecadal oscillation
ARC	Alluvial ridge crest
AWS	Area weighted suitability
CLC	Florida Cooperative Land Cover Map
District	Suwannee River Water Management District
DH	Documented-historic
DO	Dissolved oxygen
DOT	Department of Transportation
ECT	Environmental Consulting & Technology, Inc.
EL	Elevations, per the datum NAVD88
EPT	Ephemeroptera, Plecoptera, and Trichoptera
ERC	Environmental Regulation Commission
FAC	Florida Administrative Code
FACW	Facultative wet
FDC	Flow duration curves
FDEP	Florida Department of Environmental Protection
FE	Listed as endangered species at the federal level by the U. S. Fish and Wildlife Service
FFWCC	Florida Fish and Wildlife Conservation Commission
FL	Florida
FLUCCS	Florida Land Use Cover Classification System
FNAI	Florida Natural Areas Inventory
FR	Federal Register
FT	Listed as threatened species at the federal level by the U. S. Fish and Wildlife Service
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HUC	Hydrologic Units classification
LF	Linear feet
LOESS	Locally weighted scatter-plot smoother
MFLs	Minimum flows and levels
MSR	Middle Suwannee River
NFSEG	North Florida Southeast Georgia
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
OBL	Obligate
OFS	Outstanding Florida Spring
OFW	Outstanding Florida Water
POR	Period of record
PRISM	Parameter-elevation Relationships on Independent Slopes Model
PT	Proposed threatened, currently being considered for listing
RF	River flow
RM	River mile
RS	River stage
RTF	Reference timeframe
SAT	Treated as threatened due to similarity of appearance to a species which is federally listed
SAV	Submerged aquatic vegetation
SEFA	System for Environmental Flow Analysis
SGCN	Species of Greatest Conservation Need

SRWMD	Suwannee River Water Management District
ST	State population listed as Threatened by the FFWCC
SWFWMD	Southwest Florida Water Management District
TMDL	Total Maximum Daily Load
UFA	Upper Floridan aquifer
USA	United States of America
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
WL	Water level
Wood	Wood Environment & Infrastructure Solutions, Inc.
WRVs	Water resource values
WSI	Wetland Solutions, Inc.
WY	Water year

EXECUTIVE SUMMARY

The Middle Suwannee River (MSR), a 92-mile portion of the Suwannee River from Ellaville to Wilcox, was evaluated to establish minimum flows and levels (MFLs) that would be protective of various water resource values (WRV). The Suwannee River, Florida's second largest river system, originates in the Okefenokee Swamp in southeastern Georgia and flows south and southwest 246 miles toward the Gulf of Mexico. The river is classified by the FDEP as an Outstanding Florida Water (OFW) and a "special waters" within the OFW designation. The main channel of the Suwannee River and its floodplain provide a diverse array of large, unfragmented habitats for a wide variety of fish and wildlife, including federally designated critical habitat for the Gulf sturgeon (*Acipenser oxyrinchus desotoi*). Springs are an important component of MSR, and 23 springs that contribute flow to it have been prioritized for MFL establishment; MFLs for these priority springs are still in the process of being developed and will be presented in a separate document.

In developing MFLs, current State Water Policy (Rule 62-40.473, Florida Administrative Code [F.A.C.]) provides that consideration be given to natural seasonal fluctuations in water flows or levels, nonconsumptive uses, and ten environmental WRVs. For the MSR, Recreation (WRV 1), Fish/Wildlife Habitat and Fish Passage (WRV 2), and Sediment Load (WRV 8) are important values with suitable assessment data that could be significantly harmed by critical reductions in flow. Addressing these three WRVs led to the establishment of multiple metrics covering a full spectrum of flow and water level conditions within the river channel and over its floodplain.

Transfer of Detrital Matter (WRV 4), Maintenance of Freshwater Storage and Supply (WRV 5), Aesthetic/Scenic Attributes (WRV 6), and Filtration and Absorption of Nutrients and Other Pollutants (WRV 7) are also potentially relevant WRVs that cannot be directly assessed based on the best available information, but that can reasonably be assumed to be protected because specific habitats and riparian corridor features and processes important to these values are addressed through a range of flow conditions (e.g. low, medium and high) for other WRVs.

Water Quality (WRV 9) has sufficient and relevant nutrient pollution data associating pollutants with flow volume. However, these flow associations suggest decreasing spring flow would reduce pollutant concentrations. Since this is antithetical to the overall objectives of MFL regulations, results of this analysis were not used to develop metrics for WRV 9. Navigation (WRV 10) is not relevant because no commercial barges or other large commercial vessels utilize the MSR. Estuarine Resources (WRV 3) is not required because the MSR project area is entirely within the freshwater portion of the river and a separate MFL has been established for the Lower Suwannee River covering the estuarine portion of the river.

Based on the availability of information relating flow to the WRV, analyses were performed to evaluate potential impacts associated with flow reductions on multiple and redundant metrics associated with productive and applicable findings for WRVs 1, 2, and 8. The recommendations select the most protective among these to establish allowable flow reductions. WRVs without sufficient available information to analyse or where available data suggest something antithetical to MFL objectives will be afforded some level of protection by proxy via that protection determined for WRVs 1, 2, and 8, which, by following a variety of applicable, standard, and customary scientific practices, cover a wide gamut of flows and associated water levels.

The conceptual approach to the establishment of MFLs on the MSR started by recognizing that all riverine and floodplain surfaces are dynamic over time, affected by a wide range of river flows including routine flood events. The MSR system cannot be viewed as being static in time and place, as physical, chemical, and biological processes continuously influence the collective suite of habitat surfaces that we see today and have been there historically. The maintenance of the flows that sustain these features through the movement of water and sediment is the basis for how this MFL was framed. This basis covers the full range of the natural and highly variable flow regime of the river, which routinely fluctuates more than 10 vertical feet between wet and dry seasons. It aims to protect critical processes beneficial to aquatic and terrestrial fauna and flora within the 10-year floodplain and main river channel.

An essential component of the establishment of MFLs is identification of a baseline hydrologic record which is representative of unimpacted hydrologic conditions. Water Years (WY) 1933 through 2015 were identified as the baseline period of record (POR) for the MSR using the reference timeframe (RTF) concept. RTF flow time-series estimating the flow that would have been observed in the absence of groundwater withdrawals were developed for this POR. When establishing MFLs from a RTF condition, it is assumed that the RTF condition is protective of water resource and human use values, but that some water may be available for beneficial use without causing significant harm to the resource. If sufficient data are available, flow characteristics that are protective of a WRV, such as magnitude, elevation, frequency, and duration, can be identified with some level of confidence. Two compliance gages were chosen for setting MFLs on the MSR: 1) Ellaville is generally used to protect the portion of the river upstream of River Mile 90 where a major geological constriction of the river valley referred to as the "Knot" occurs; and 2) Branford is used to protect the portion of the river downstream of the Knot.

The overall approach for setting MFLs is a "weight-of-evidence" approach that begins with identifying WRVs relevant to the river (**Section 1** of this report) and continues with the application of hydrologic (**Section 2**) and biologic (**Section 3**) data analyses, the description of metrics and methods used to assess the relevant WRVs (**Section 4**), the determination of critical flows and allowable flow reductions that would not result in significant harm to those metrics (**Section 5**), and culminates with the establishment of MFLs that would remain protective of the WRVs (**Section 6**). Specific metrics assessed in this study include recreational boating passage, general fish passage, Gulf sturgeon passage, deep swamp hydroperiods, bottomland swamp hydroperiods, open water channel maintenance, floodplain geomorphic surface maintenance, and instream habitat suitability for a variety of aquatic fauna, guilds, and life stages. This suite of metrics covers high, medium, and low flows with some fair amount of redundancy in each part of the flow regime. Selecting the most limiting metric in parts of the hydrograph with redundant metrics assures a reasonable prevention of significant harm to fish and wildlife habitats and fish passage.

Once the "critical flow" necessary to protect each metric was determined, the allowable flow reduction resulting in no greater than 15% temporal loss in certain assessed metrics, such as duration of inundation was determined. Use of 15% temporal loss in this manner is a standard and customary peer-reviewed practice in the Southwest Florida and Suwannee River Water Management Districts and elsewhere across the nation (Gore et al. 2002, Munson and Delfino 2007). Such reductions are presumed to represent significant harm, thus defining the resultant "metric flow". The suite of hydrologic shifts associated with 15% temporal loss below RTF conditions were then assessed to formulate overall MFL criteria across the full range of flow conditions.

Based on these analyses, it was determined that a single value flow reduction approach would be taken, using the most restrictive hydrologic shift developed from the evaluated WRVs. In the case of both Ellaville and Branford compliance gages, this corresponds with Gulf sturgeon fall passage and results in a reduction of 346 cfs across the flow duration curve for Ellaville and 400 cfs for Branford. The proposed MFL is applied at the median flow, as follows:

- Ellaville gage – at median flow of 3,822 cfs the change is 346 cfs, or a reduction of 9.1%.
- Branford gage – at median flow of 4,993 cfs the change is 400 cfs, or a reduction of 8.0%.

The proposed river MFLs are implemented as a constant withdrawal to be consistent with how groundwater withdrawals are regulated in the region.

1.0 INTRODUCTION

The Suwannee River Management District (SRWMD or the District) is currently establishing and implementing minimum flows and levels (MFLs) for certain priority water bodies/courses within the District by determining the magnitude of flow reduction from the baseline hydrologic regime that may cause significant harm to the water resources or ecology of the system, and by assessing the current long-term hydrologic regime to determine if such reduction has occurred due to withdrawals. The Middle Suwannee River (MSR) and priority springs are on the MFLs Priority List and Schedule (SRWMD, 2021). In developing MFLs, current State Water Policy (Rule 62-40.473, Florida Administrative Code [F.A.C.]) provides that consideration be given to natural seasonal fluctuations in water flows or levels, non-consumptive uses, and environmental water resource values (WRVs), including:

- WRV 1 Recreation in and on the Water
- WRV 2 Fish and Wildlife Habitats and the Passage of Fish
- WRV 3 Estuarine Resources
- WRV 4 Transfer of Detrital Material
- WRV 5 Maintenance of Freshwater Storage and Supply
- WRV 6 Aesthetic and Scenic Attributes
- WRV 7 Filtration and Absorption of Nutrients and other Pollutants
- WRV 8 Sediment Loads
- WRV 9 Water Quality
- WRV 10 Navigation

In accordance with Florida Statutes and by standard and common practices, MFLs are set based on the applicable, suitable, and best available information. The objective of this document is to present the data and analyses that provide technical support for establishing and adopting MFLs for the MSR. A brief description of the MSR is provided in this section. **Sections 2** and **3** include descriptions of the hydrology and biology of the river system. **Section 4** includes the approach to setting MFLs, **Section 5** includes an evaluation of WRVs, and **Section 6** provides MFL recommendations. **Section 7** provides references used in the development of this document. Note that priority springs MFLs are still in the process of being developed by the District and will be presented in a separate document.

1.1 Watershed and River Description

The Suwannee River Basin encompasses approximately 9,950 mi^2 (25,770 km^2) in Florida and Georgia (**Figure 1-1**). Major tributaries of the Suwannee River include the Alapaha and Withlacoochee Rivers, which are mostly located in Georgia, and the Santa Fe River in Florida. Over half (57%) of the Suwannee River Basin is in Georgia. The Suwannee River is approximately 246 miles long and represents the second largest river system in Florida by drainage area and mean annual flow. The Suwannee River is designated by the State of Florida as an Outstanding Florida Water (OFW). Its headwaters originate in the Okefenokee Swamp in southeastern Georgia and flow south and southwest toward the Gulf of Mexico.

Figure 1-1. Middle Suwannee River study area

1.2 Study Area

The study area includes the freshwater portion of the Suwannee River upstream of the estuary and below its confluence with the Withlacoochee River (**Figure 1-1**). Designated the Middle Suwannee River (MSR), it stretches 92 miles from Ellaville to Wilcox, near Fanning Springs. The MSR is the focus of this MFL study (**Figure 1-2**). The Santa Fe, Ichetucknee, Upper, and Lower Suwannee Rivers are addressed under separate MFL studies.

Figure 1-2. Middle Suwannee River study area and the locations of priority springs

The MSR drains a massive and complex watershed and springshed with three chemically and physically distinct water types – blackwater, brown water, and groundwater. The flow regime is highly variable ranging from baseflow conditions as little as a few thousand cubic feet per second (cfs) to floods well over 30,000 cfs. The largest seasonal flood pulses tend to occur from springtime rainfall in Georgia and northern Florida, staging water several feet deep or more across the floodplain. The river receives clay and silt washload from where this rainfall falls along Georgia tributaries in the northwestern portion of the watershed resulting in turbid brown water conditions during major and seasonal flood pulses. The Okefenokee Swamp and extensive bottomlands along the river and its tributaries are responsible for the river's tannic blackwater. Blackwater flow is derived from rainfall over the organic source areas, and is organic, acidic, soft, and non-turbid. Numerous artesian springs flank the MSR's banks and floodplain delivering crystal clear, hard, non-turbid groundwater baseflow to the river. High river flows can drown the springs and reverse brown water or blackwater flow into the aquifer.

The river and floodplain morphology is complex and is derived from the variable and powerful flow regime, diversity of water sources, and karst geology. That mix of sources delivers ample sediment yield to create substantial alluvial features including natural levees, oxbow swamps, backswamps, crevasse splays, and ridge and swale scrolls in the floodplain. The natural variability in the distribution of the alluvium across the floodplain creates more than several feet of vertical relief across the valley bottomlands. Further, the alluvium is mantled over near-surface and active karst terrain with sinks, swallets, and windows to the Floridan aquifer, adding to the geodiversity of the valley. Springs originating within the floodplain carve and maintain their own open channels through it, creating breaches in the alluvial ridge bordering the river channel and promoting focused areas of water exchange between the open channel and floodplain environments. The river depth is highly variable at normal flow volumes, running over 25 feet deep through large, drowned limestone canyons and less than a few feet deep across several high bedrock shoals. The riverbanks variably present sand, clay, or rock layers depending on how much alluvium has locally deposited and on the water levels.

This overall outstanding geodiversity begets much biodiversity. The bottomland forest is acknowledged as being among the most diverse in Florida. Another exceptional quality of the Suwannee River is that it is free-flowing and is not crossed by in-line dams. This unencumbrance allows the springs to remain naturally exposed and observable, allows for freshwater-spawning estuarine fishes such as Gulf sturgeon to reach their spawning grounds, and preserves a unique natural and native aesthetic within and along the river.

As a result, the MSR includes several important conservation areas, including four state parks, District-owned lands, and various county and municipal parks (**Figure 1-2**). Habitats along the MSR support several species that are federally protected, including the threatened Gulf sturgeon (*Acipenser oxyrinchus desotoi*), West Indian manatee (*Trichechus manatus*), eastern indigo snake (*Drymarchon couperi*), wood stork (*Mycteria americana*), and Suwannee moccasinshell (*Medionidus 4s all*); as well as the endangered oval pigtoe (*Pleurobema pyriforme*) and red-cockaded woodpecker (*Dryobates borealis*). These habitats also support state-protected species including the threatened Suwannee alligator snapping turtle (*Macrochelys suwanniensis*), Florida sandhill crane (*Antigone canadensis pratensis*), little blue heron (*Egretta caerulea*), tricolored heron (*Egretta tricolor*), gopher tortoise (*Gopherus polyphemus*), and short-tailed snake (*Lampropeltis extenuata*).

Springs are an important component of the Suwannee River basin and the MSR. A total of 197 springs have been reported in the basin, many of which are located along the MSR. Twenty-three springs that contribute flow to the MSR have been prioritized for MFL establishment, including all first magnitude springs (with flows greater than 100 cfs) and second magnitude springs (with flows between 10 and 100 cfs) within publicly owned lands. Four of these springs are designated as Outstanding Florida Springs (OFS). A list of priority springs is provided in **Table 1-1** and their locations are shown in **Figure 1-2**. The Suwannee River has an integral hydrologic relationship to each spring. The springs contribute significant baseflow to the river and the stage of the river can be a determining factor for each spring's discharge, as described in **Section 2**. Note that MFLs for MSR priority springs will be presented in a separate document.

Recreation on the MSR includes camping, swimming, boating, fishing, kayaking and canoeing. Similarly, recreation is a major use of the springs, and they are heavily utilized for swimming and diving. The river and springs are an important economic resource in the region.

Table 1-1. Priority springs within the Middle Suwannee River

Priority Spring Name	Magnitude	Distance from River
Lime Springs	2	Adjacent to river
Lime Sink Run	2	~3,200 Linear Feet (LF) spring run draining west
Suwanacoochee Springs	2	Adjacent to Withlacoochee River, 300 ft upstream of the MSR confluence
Falmouth Springs*	1	Connected to Lime Sink Run via extensive cave system >12,500 LF
Anderson Spring	2	Adjacent to river
Charles Springs	2	~175 LF spring run draining west
Allen Mill Pond	2	~2,355 LF spring run draining south/southeast
Lafayette Blue Springs*	1	~150 LF spring run draining east
Bonnet Springs	2	~8,640 LF spring run draining south
Peacock Springs Group*	2	~8,640 LF spring run draining south
Royal Springs	3	~175 LF spring run draining south
Troy Springs*	1	~130 LF spring run draining northeast
Ruth Springs	2	~570 LF spring run draining northeast
Little River Springs	2	~125 LF spring run draining south
Branford Springs	2	Adjacent to river
Turtle Springs	2	Adjacent to river
Pothole Spring	2	Adjacent to river
Rock Bluff Spring	2	~560 LF spring run draining west
Guaranto Springs	2	~100 LF spring run draining east
Rock Sink Spring	2	~1,260 LF spring run draining southeast
Hart Springs	2	~960 LF spring run draining north and then west
Otter Springs	2	~4,575 LF spring run draining southwest
Bell Spring	3	~2,050 LF spring run draining southeast

*Indicates OFS

2.0 HYDROLOGY

The following sections describe the hydrologic and related physiographic characteristics of the MSR. Details about existing streamflow gaging stations, priority springs, and groundwater monitoring locations are provided, as well as information used to determine the baseline period of record (POR) for MFLs assessments.

2.1 Physiography, River Description, Land Use, and Soils

2.1.1 Physiography

The Suwannee River Basin is part of the Aucilla-Suwannee-Ochlockonee Basin (Torak et al. 2010). There are four major physiographic regions within the Suwannee River Basin: Tifton Upland and Okefenokee Basin in Georgia, and Northern Highlands and Gulf Coastal Lowlands in Florida (**Figure 2-1**). A small portion of the basin is within the Tallahassee Hills physiographic region.

The MSR is wholly contained within the Gulf Coastal Lowlands which consist of an extensive karst landform that is characterized by numerous sinkholes, sinking streams, and springs, and a high degree of interconnection between surface water and groundwater systems (**Figure 2-2**). The Upper Floridan aquifer (UFA) is unconfined and is the only aquifer present at the surface. The Tifton Upland is part of a nearly continuous series of topographically high uplands containing gently rolling hills with broad rounded summits. The Northern Highlands include gently rolling topography, generally from 100-200 feet above mean sea level (msl). Soils typically range from sand to clayey sand. Clayey sediments in the subsurface serve as a base for a surficial aquifer and retard infiltration of rainwater into the underlying Floridan Aquifer System, resulting in abundant surface water features (streams, lakes, ponds) throughout the Highlands. The Tifton Upland and Northern Highlands are bounded on the south by a persistent topographic break (i.e. escarpment) referred to as the Cody Scarp (**Figure 2-3**), which denotes a transition between the Tallahassee Hills and Northern Highlands and the relatively flat coastal region of the Gulf Coastal Lowlands.

The Cody Scarp roughly approximates an ancient shoreline of Florida when sea levels were much higher and is the largest continuous topographic break in Florida. The Cody Scarp is the erosional edge of the Hawthorn Group rocks (Scott, 1988; Scott, 1992) and represents a location of intense recharge of surface water to the Floridan aquifer system via sinking streams and sinkholes (expressed at the surface), and in certain areas controls the water chemistry and dissolution of the aquifer (Upchurch and Lawrence, 1984). When sea level was higher and the Cody Scarp area represented the coastline, the clay confining layer was eroded away by wave action and ocean currents. When sea levels receded to the present-day shoreline, it helped to create the perfect geological conditions for a combination of headward erosion by streams as well as the dissolution of carbonate rocks by both streams and groundwater. This enabled the development of some of the unique karst features in the Suwannee River Basin, including the many springs (**Figure 2-3**).

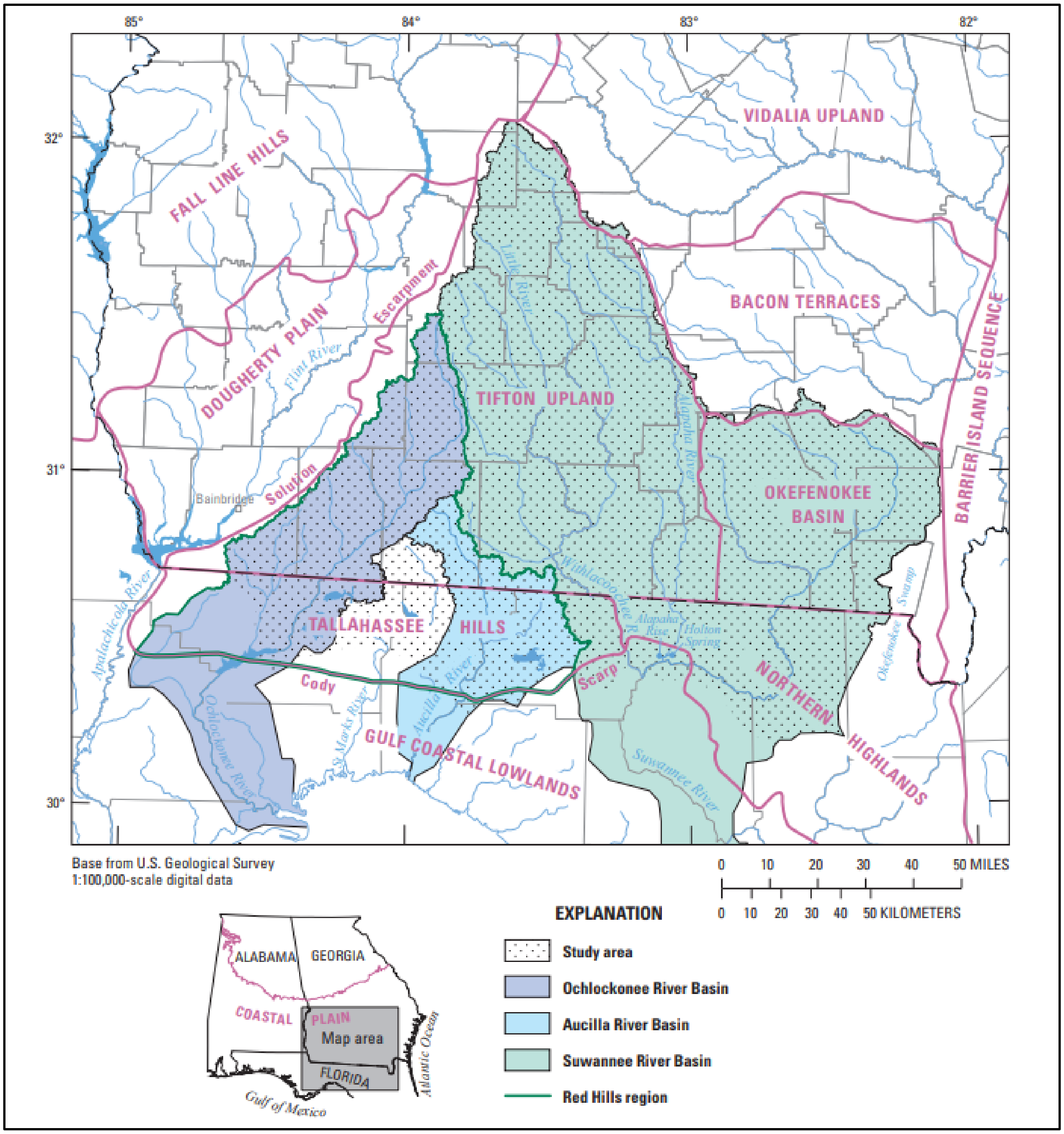


Figure 2-1. Physiographic divisions in the Aucilla-Suwannee-Ochlockonee River Basin (Source: Torak et al. 2010)

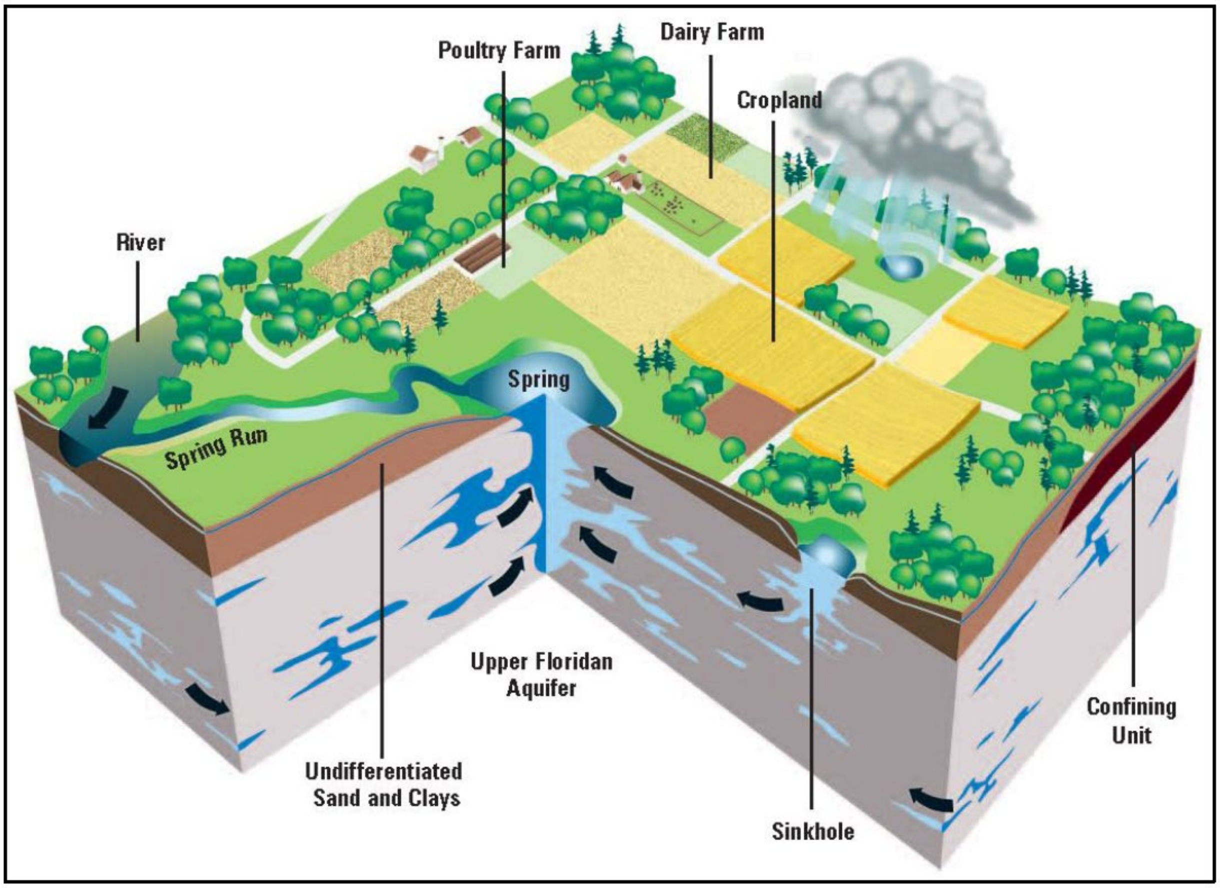


Figure 2-2. General cross-section and surface features in the Gulf Coastal Lowlands
(Source: FDEP 2001)

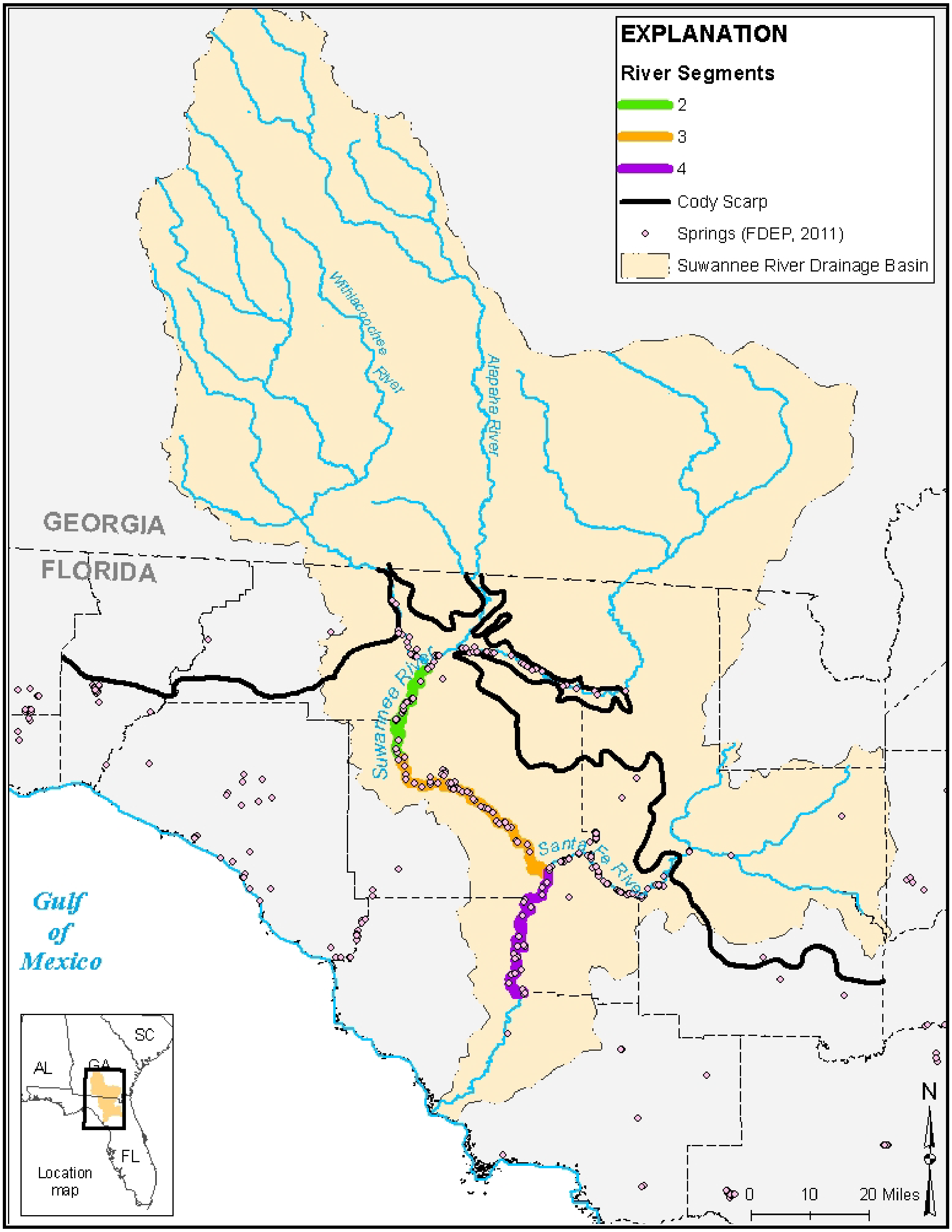


Figure 2-3. Regional map Illustrating location of Cody Scarp relative to the Suwannee River Basin

2.1.2 River Description

Karst features are important in the MSR system. Hornsby et al. (2000) described the MSR as having three of the river's five total limnological river reaches, each differing in their artesian spring discharge and associated water quality and flow volumes. The uppermost MSR reach, Reach 2, extends approximately 21 miles from the Withlacoochee River to Charles Springs and has less cumulative spring input than downstream reaches (**Figure 2-3**). The banks of the river in this reach are relatively high (15 to 24 ft) and steep and are often situated well above the water surface (even during periods of high flow). Karst windows, which occur where the aquifer is directly exposed to the surface, can be found throughout the floodplain in this reach (**Figure 2-4**). Reach 3, extending approximately 41 river miles from Charles Spring to the Santa Fe River confluence, has higher spring inputs. While the banks in this reach are still high (9 to 15 ft), there is more direct interaction between the river and the floodplain in this portion of the river 10s allowing springs adjacent to the river to maintain openings in the riverbanks through which river water can flow into the floodplain. Reach 4, extending approximately 33 river miles from the Santa Fe River confluence to Fanning Springs, has a lower proportion of springs than Reach 3. This reach of the river is relatively wider, and the banks are relatively lower, allowing for more interaction between the river and the floodplain at lower water levels. The MSR valley is divided into two major fluvial geomorphic divisions between Reaches 3 and 4, affecting floodplain width and fluvial processes.

Figure 2-4. Karst window in Twin Rivers State Forest (April 2013)

The karst terrain in the MSR study area floodplain is mantled by varying thicknesses of sand and clay, much of which is generated by alluvial deposits from the river. Shallow shoal areas are found throughout the MSR and can present a potential issue for the passage of fish and boats during low flows. Shoals along the MSR are typically comprised of limestone outcroppings that can become exposed during lower flows, with water moving around the higher portions of the shoal (**Figure 2-5**). The MSR crosses three major bedrock shoals affecting the lower water surface profiles of the river, as shown in **Figure 4-1**. One shoal is referred to as Powerplant Shoal, shown in **Figure 2-5**, and the other two (referred to as Lafayette Blue Shoal and Riverside Shoal) frame a four-mile-long segment of the river so deeply incised that it functions more like a submerged canyon than a floodplain. The downstream end of the canyon occurs near river-mile 90, and that location is referred to as the 'Knot' in this report (**Figure 1-2** and **Figure 2-6**). Some of the water surface profiles of interest exhibit a notable change in slope along the river at the Knot. Further, the floodplain topography is gradually dynamic. Its forests develop on shifting ground, adding a time component to the corridor's biological complexity. While this is true of many large rivers, the MSR floodplain's genesis stems not only from standard fluvial forces and associated sedimentation (alluvial) processes, but also from the fact the river valley is a karst terrain. The interactions between these two dynamic controls on geomorphology (alluvial and geological) create a wide range of elevations within the floodplain that drive much of its habitat heterogeneity.

Figure 2-5. Example of river shoal ("Powerplant Shoal", December 2013)

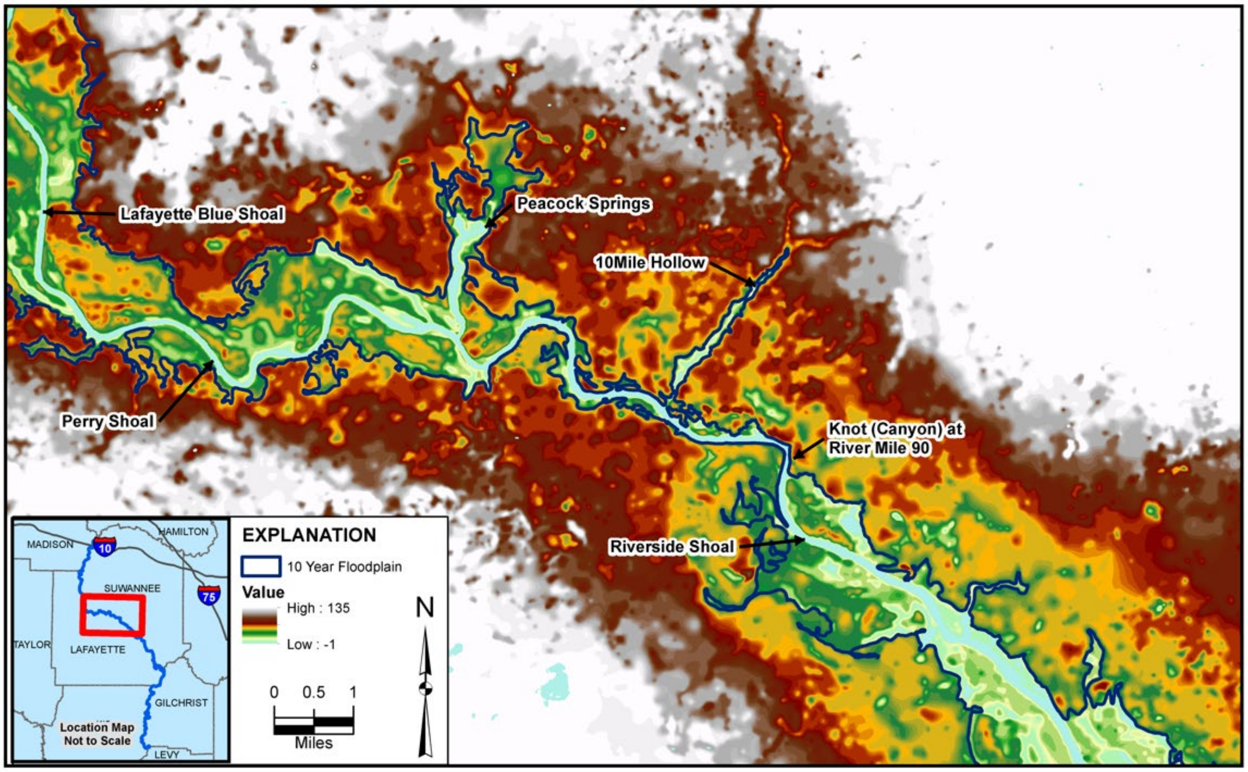


Figure 2-6. Map showing location of the "Knot" at River Mile 90

2.1.3 Land Use

Land use within a system's watershed can affect hydrological processes such as evapotranspiration (ET) and infiltration. Land use within the Florida portion of the MSR basin (roughly 43% of the overall basin) was determined using the District's 2017 Florida Land Use Cover Classification System (FLUCCS) (**Figure 2-7, Table 2-2**). Upland forest is the largest land use cover type, covering 44.4% of the basin within Florida. Agriculture is the next largest land use cover type, covering 19.8% of the basin, followed by wetlands with 16.7% cover.

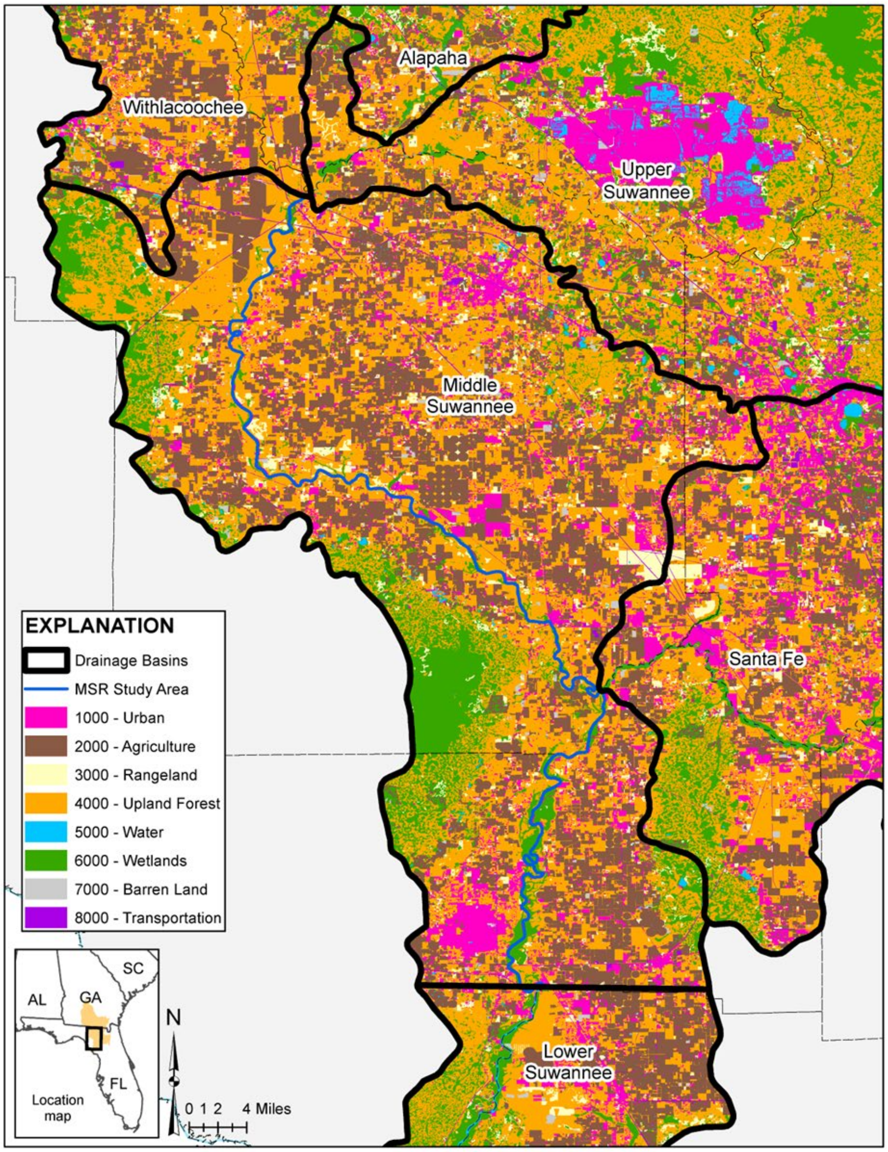


Figure 2-7. Land Use in the Suwannee River basin (zoomed in to the MSR study area)

Table 2-1. Land use percent cover by sub-basin

FLUCCS Classification	Alapaha	Withlacoochee	Upper Suwannee	Middle Suwannee	Santa Fe	Lower Suwannee	Total
1000 - Urban	4.7%	5.8%	10.9%	9.0%	10.7%	6.6%	**9.5%**
2000 - Agriculture	18.5%	30.7%	7.5%	27.4%	18.4%	23.1%	**19.8%**
3000 - Rangeland	5.6%	5.1%	3.1%	4.5%	3.2%	2.9%	**3.7%**
4000 - Upland Forest	47.8%	47.4%	44.6%	44.4%	44.3%	39.8%	**44.4%**
5000 - Water	0.8%	1.3%	1.9%	0.8%	1.8%	2.0%	**1.5%**
6000 - Wetlands	19.8%	7.3%	24.1%	12.2%	15.9%	24.1%	**16.7%**
7000 - Barren Land	1.3%	1.1%	0.8%	0.7%	0.8%	0.6%	**0.8%**
8000 - Transportation	1.5%	1.3%	0.9%	1.0%	1.4%	0.8%	**1.1%**
Unclassified (outside of SRWMD)	0.1%	0.004%	6.2%	0.0%	3.7%	0.003%	**2.6%**
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Notes: 2017 FLUCCS; Florida only

2.1.4 Soils

Soils within a system's watershed can affect hydrological processes such as infiltration and run-off. Soil hydrologic groups within the Florida portion of the MSR basin were determined using the 2018 Natural Resources Conservation Service (NRCS) soils layer (**Figure 2-8, Table 2-2**). Well-drained soils (hydrologic group A) make up the largest soil type, occupying 42.6% of the basin within Florida, while poorly-drained soils (hydrologic group D) make up the smallest soil type, occupying 1.3% of the basin.

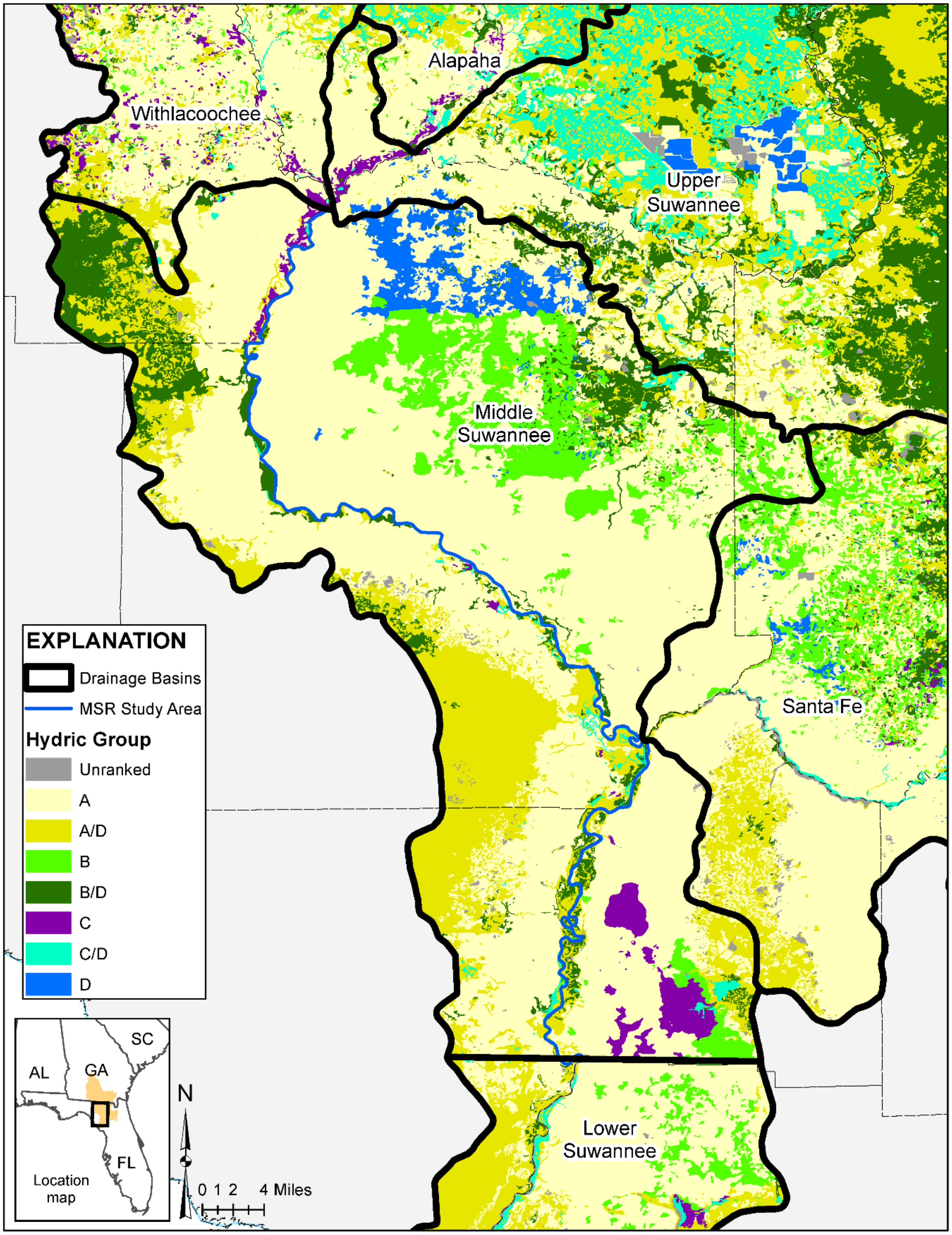


Figure 2-8. Soils in the Suwannee River basin (zoomed in to the MSR study area)

Table 2-2. Soil hydrologic group percent cover by sub-basin

Hydric Group	Alapaha	Withlacoochee	Upper Suwannee	Middle Suwannee	Santa Fe	Lower Suwannee	Total
Unranked	0.8%	2.0%	1.1%	0.9%	2.4%	1.8%	**1.6%**
A	39.7%	65.3%	22.2%	61.3%	34.3%	47.0%	**42.6%**
A/D	24.6%	16.1%	27.6%	16.4%	23.3%	33.2%	**22.5%**
B	1.9%	3.6%	0.8%	8.8%	6.0%	7.0%	**5.5%**
B/D	4.0%	4.2%	32.4%	7.3%	28.3%	3.6%	**19.2%**
C	2.2%	7.1%	0.3%	1.8%	0.4%	0.5%	**1.3%**
C/D	26.7%	1.8%	13.8%	0.7%	4.9%	6.9%	**6.1%**
D	0.0%	0.0%	1.7%	2.8%	0.5%	0.0%	**1.3%**
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Notes: 2018 NRCS Soils; Florida only

2.2 River Flows

2.2.1 Streamflow Monitoring Stations and Period of Record

The MSR has six active USGS gages, spanning from the gage at Ellaville (USGS ID 02319500) to the Wilcox gage (USGS ID 02323500). **Table 2-3** provides a list of the USGS streamflow gages that are present along the MSR and their corresponding period of record (POR). **Figure 2-9** shows the spatial locations of the USGS gages. As indicated earlier, the Santa Fe River is the major surface water tributary of the MSR, entering between the Branford and Bell gages.

Table 2-3. USGS gage information along the Middle Suwannee River

Site Name	Gage Number	Latitude	Longitude	County	Drainage Area (sq. mi)	Period of Record
Suwannee River at Ellaville	02319500	30.38466	-83.1718	Suwannee	6,970	2/1/1927 – current
Suwannee River at Dowling Park	02319800	30.24494	-83.2496	Lafayette	7,190	10/1/1996 – current
Suwannee River at Luraville	02320000	30.09995	-83.1715	Lafayette	7,280	2/1/1927-12/31/1937 9/27/1996 – current
Suwannee River at Branford	02320500	29.95579	-82.9276	Suwannee	7,880	7/1/1931 – current
Suwannee River Near Bell	02323000	29.79134	-82.9243	Gilchrist	9,390	6/1/1932 – 12/31/1956 8/4/2000 – current
Suwannee River Near Wilcox	02323500	29.58968	-82.9365	Levy	9,640	10/1/1930 – 9/30/1931 10/1/1941 – current

Note: Period of record is for daily stage and discharge; current is as of data retrieval time (March 2021)

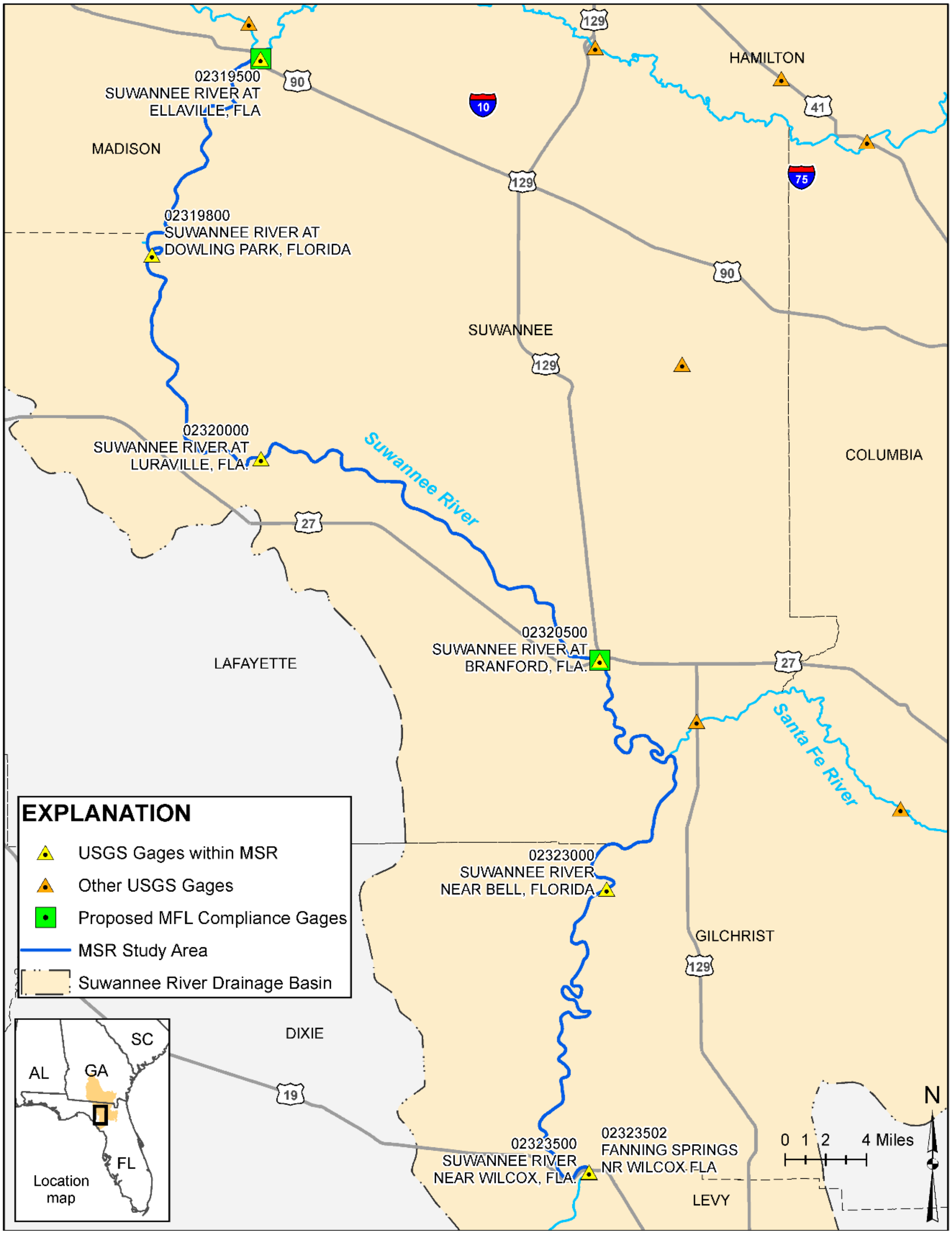


Figure 2-9. USGS river gages

2.2.2 Baseline Period of Record and Gap-Filling

Based on the availability of approved (non-provisional) data and on the availability of water use data needed to create a reference timeframe (RTF) flow time-series (as described in **Section 2.7**), October 1, 1932 through September 30, 2015 (Water Year, WY 1933 through WY 2015) was selected as the period for hydrologic data analysis. **Table 2-4** shows the percent availability of flow and stage data for the six aforementioned USGS gages during this timeframe. The Ellaville and Branford USGS gages provide the longest and most complete observed daily flow records in the study area and were thus specified as compliance gages for the purpose of establishing MFLs within the MSR. Gap-filling methodologies were used to backfill missing records (primarily for Bell and Luraville) and create complete stage and flow time-series for the WY1933-2015 at all MSR gages but Dowling Park, as described in **Appendix I**. Generally, linear interpolation was used to backfill gaps less than 15 days long, a spline interpolation method was applied to gaps between 15 and 60 days, and a multiple imputation technique was used to backfill larger data gaps. The long-term, gap-filled flow time-series were subsequently used to develop RTF flow time-series (**Section 2.7**) and as input to the HEC-RAS model, which was used to determine stage-discharge relationships along the MSR.

Table 2-4. Summary of available data at gages of interest along the Middle Suwannee River (WY1933-2015)

USGS Gage Station ID	USGS Gage Name	Data Type	Number of Records Available	Number of Records Missing**	Percent Data Available
02319500	Ellaville*	Stage	29,878	437	98.6%
		Flow	30,315	0	100.0%
02319800	Dowling Park	Stage	6,707	23,608	22.1%
		Flow	6,937	23,378	22.9%
02320000	Luraville	Stage	8,752	21,563	28.9%
		Flow	8,861	21,454	29.2%
02320500	Branford*	Stage	30,194	121	99.6%
		Flow	30,315	0	100.0%
02323000	Bell	Stage	13,821	16,494	45.6%
		Flow	15,237	15,078	50.3%
02323500	Wilcox	Stage	24,473	5,842	80.7%
		Flow	27,028	3,287	89.2%

*MFL compliance gage
**Prior to gap-filling

2.2.3 Streamflow

Streamflow ranged from 94,700 to 299 cfs at the upstream-most gage (Ellaville) and from 84,700 to 1,070 cfs at the downstream-most gage (Wilcox) during WY 1933 through 2015. Gap-filled daily flow and stage time-series for WY1933-2015 are provided for five of the six MSR gages in **Figure 2-10** and **Figure 2-11**. Note that Dowling Park was not included as this gage had the most limited data and was not gap-filled. Average streamflow by month for these gages are provided in **Figure 2-12**. The highest flows typically occur in March due to the influence of continental fronts, with a less regular secondary rise occurring in the fall from sporadic tropical events, resulting in a bimodal streamflow pattern. Average monthly streamflow generally increases in a downstream direction. Flow duration curves were also generated for five of the six gages (**Figure 2-13**). A mean annual time-series with locally weighted scatter-plot smoothing (LOESS) was compiled for each of the two compliance gages (Ellaville and Branford) (**Figure 2-14** and **Figure 2-15**). These graphs highlight the interannual variability, with WY 1948 exhibiting the highest mean annual flow and WY 1955 exhibiting the lowest mean annual flow at both sites. The LOESS trends generally correspond with warm and cool periods of the Atlantic Multidecadal Oscillation (AMO) (**Figure 2-25, Section 2.4.2.**)

Figure 2-10. Gap-filled daily flow time-series at select USGS river gage stations

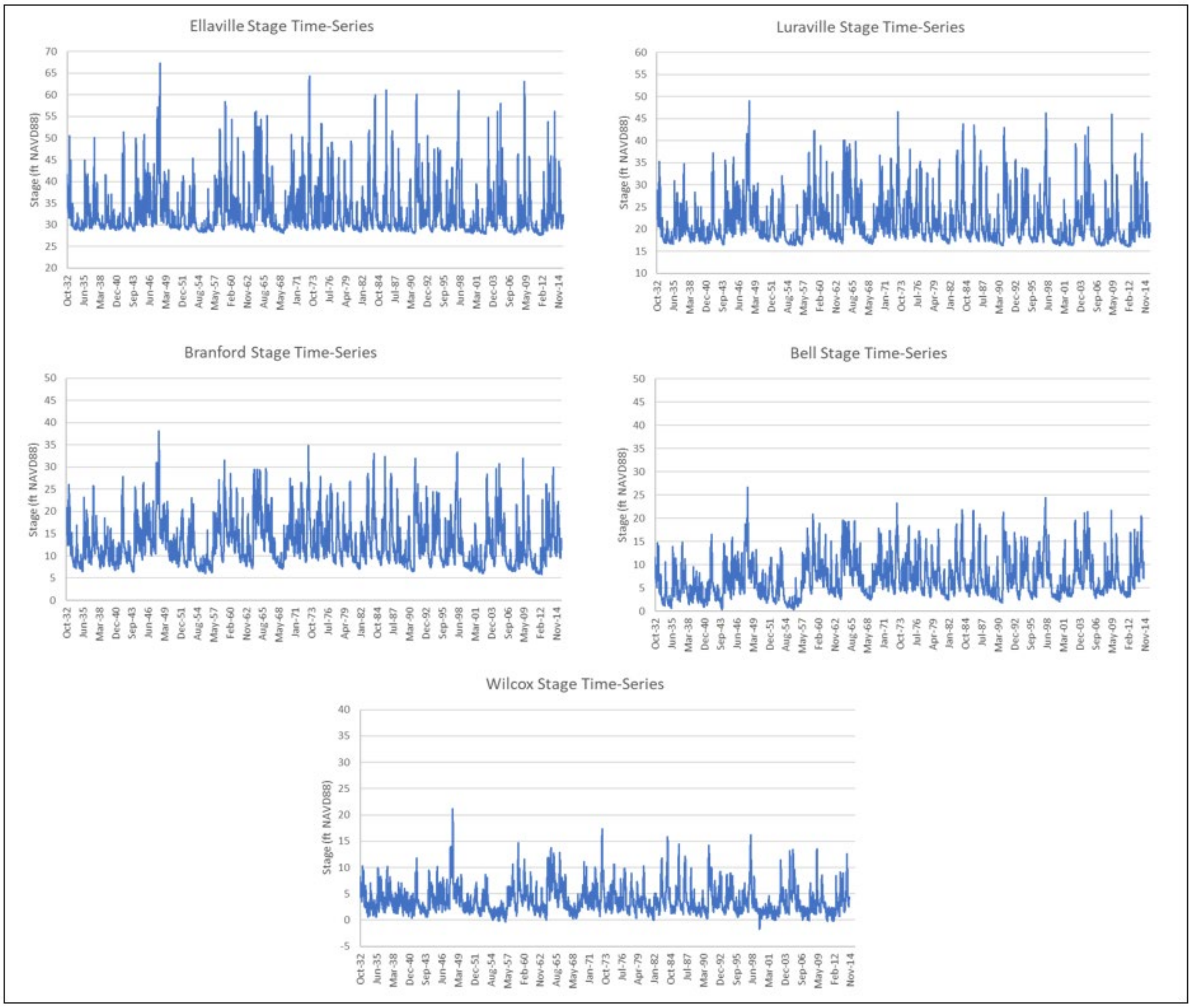


Figure 2-11. Gap-filled daily stage time-series at select USGS river gage stations

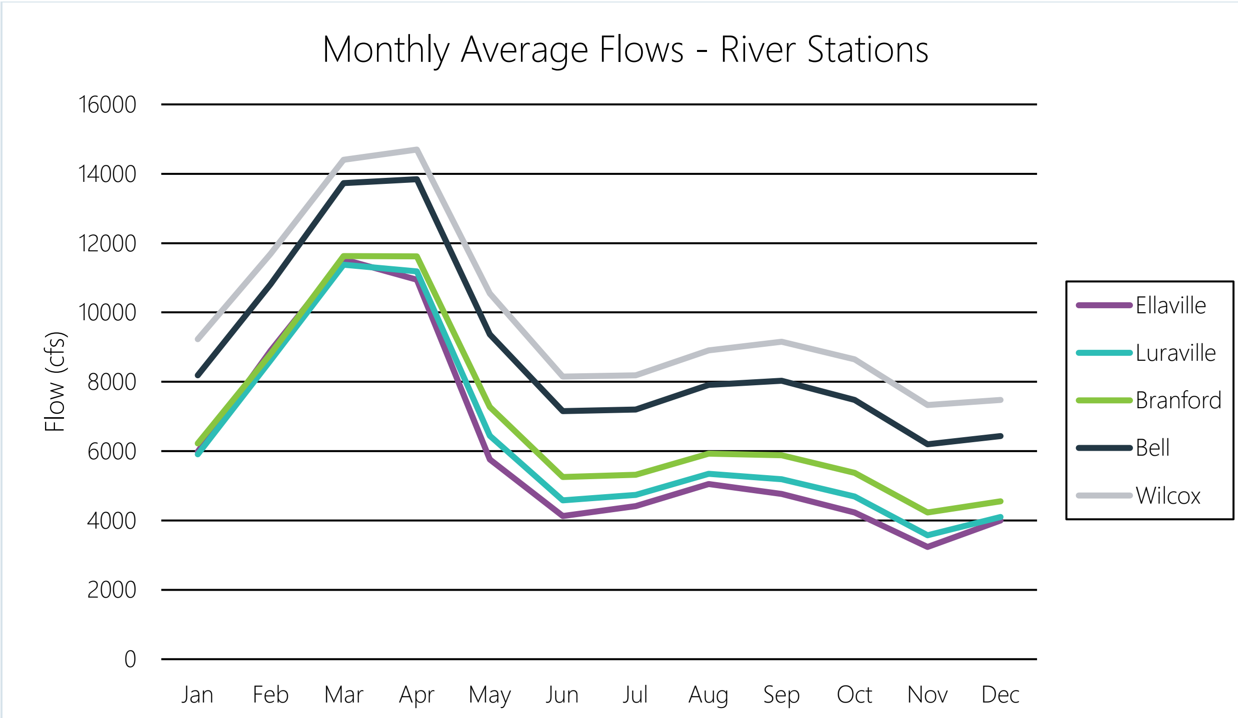


Figure 2-12. Monthly average streamflow at select USGS river gage stations

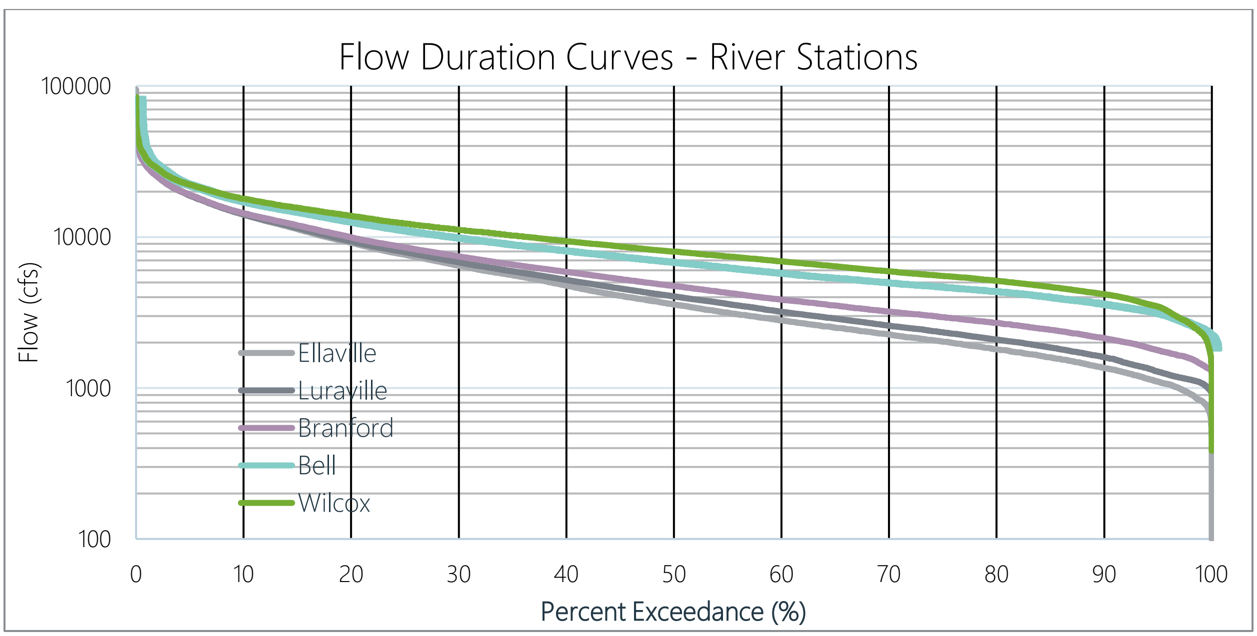


Figure 2-13. Flow duration curves at select USGS river gage stations

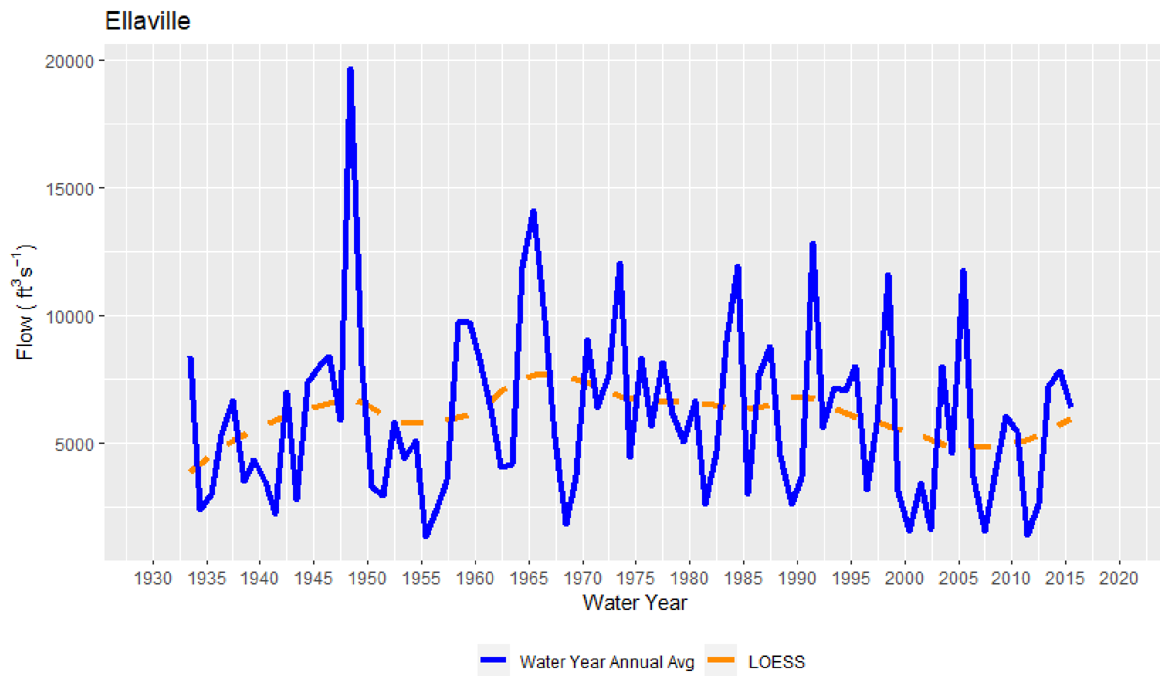


Figure 2-14. Ellaville mean annual flow with LOESS trend for WY1933-2015

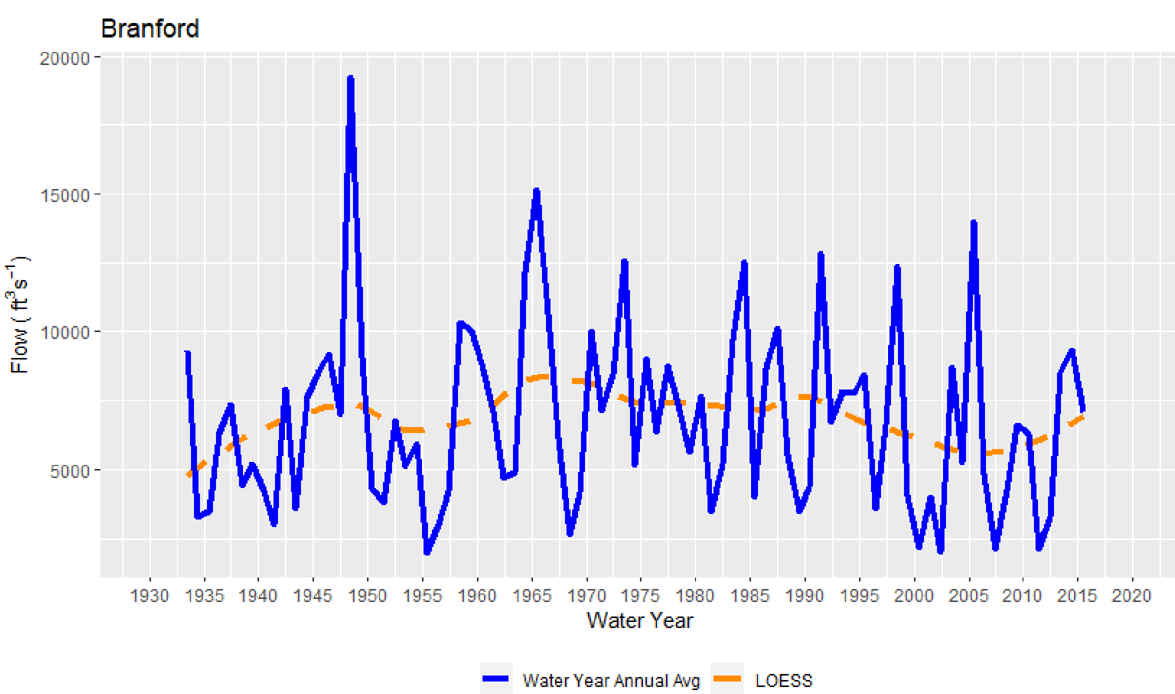


Figure 2-15. Branford mean annual flow with LOESS trend for WY1933-2015

2.3 Spring Flows

Twenty-three springs within the MSR study area are listed as priority springs for MFLs assessment, and MFLs for select priority springs will be set separately from the river MFLs in a separate document (**Table 1-1, Figure 1-2**). Three of the 23 priority springs are categorized as first-magnitude springs with flows that historically exceeded 100 cfs. Eighteen are second-magnitude springs with flows that historically exceeded 10 cfs but did not exceed 100 cfs. Two springs are third-magnitude springs, which have flows that historically exceeded 1 cfs but did not exceed 10 cfs. Four of the springs are designated by Senate Bill 552 under the "Florida Springs and Aquifer Protection Act" as an Outstanding Florida Spring (OFS), including Falmouth Spring, Lafayette Blue Spring, Peacock Springs Group, and Troy Spring. Springs contribute significant baseflow to the river and the stage of the river can be a determining factor for each spring's discharge. The percent baseflow contribution from springs and diffuse groundwater seepage is estimated to be between 24.7% and 31.3% at the Ellaville and between 37.9% and 43.1% at the Branford gage, as described in **Appendix II**.

2.3.1 Spring Monitoring Stations and Period of Record

Data for springs are more limited and variable in terms of availability as compared to the MSR river stations. Manual flow readings were available for each of the 23 priority springs, while continuous data (such as daily stage and specific conductance) were available for seven of the priority springs (**Table 2-5**). Manual measurements vary over time, with the most frequent measurements occurring since 2013 at most MSR priority springs (**Figure 2-16**). Anderson Spring has the fewest manual measurements (3) and Troy has the most (145), while Falmouth Springs has the oldest flow measurement dating back to 1908.

Table 2-5. Summary of available data at MSR priority springs

Spring	USGS or District Station ID	Manual Flow Period of Record[2]	Number of Manual Flow Obs.	Continuous Daily Data Period of Record	Parameters with Continuous Daily Data
Lime Springs	1121903	4/30/1976 - 1/26/2021	26	--	--
Lime Sink Run	LSR010C1	5/14/1998 - 1/26/2021	16	--	--
Suwanacoochee Springs	2319498	11/6/1931 - 1/26/2021	35	--	--
Falmouth Springs	2319520	1/1/1908 - 1/22/2019	66	10/1/2015 – current	Stage, Temp, SpC, DO, pH, NOx
Anderson Spring	1113501	9/22/1997 - 7/5/2007	3	--	--
Charles Springs	2319900	5/13/1927 - 6/26/2020	57	--	--
Allen Mill Pond[1]	2319915	11/26/1973 - 6/10/2020	49	12/19/2013 – 11/8/2017	SpC, Stage
Lafayette Blue Springs[1]	2319950	11/23/1973 - 12/15/2015	122	11/19/2013 – current	SpC, Stage
				6/16/2015 - current	Temp, Discharge, DO, pH, NOx

Spring	USGS or District Station ID	Manual Flow Period of Record[2]	Number of Manual Flow Obs.	Continuous Daily Data Period of Record	Parameters with Continuous Daily Data
Peacock Springs Group[1]	2320048	11/20/1973 - 7/27/2020	47	12/09/2013- current	SpC, Stage
Bonnet Springs	BON010C1	6/2/1998 - 5/28/2015	6		
Royal Springs	2320130	5/19/1977 - 6/26/2020	57	--	--
Troy Springs[1]	2320250	5/15/1927 - 1/27/2021	145	3/2/2002 - 4/16/2018	Stage
				07/3/2014 – current	Temp, SpC, DO, pH, NOx
Ruth Springs	2320260	11/14/1973 – 7/30/2020	103	--	--
Little River Springs	2320400	11/27/1973 - 5/14/2020	125	--	--
Branford Springs	2320502	5/15/1927 - 3/24/2021	37	--	--
Turtle Springs	2322880	11/3/1972 - 3/24/2021	18	--	--
Pothole Spring	POT010C1	9/23/1997 - 1/13/2021	13	--	--
Rock Bluff Spring	2322997	12/8/1942 - 1/13/2021	114	--	--
Guaranto Springs	2323010	5/12/1932 - 3/31/2021	37	--	--
Rock Sink Spring	RKS010C1	8/26/1998 - 5/15/2020	15	--	--
Hart Springs[1]	2323150	3/14/1932 - 1/13/2021	94	2/27/2014- 10/2/2018	SpC, Stage
Otter Springs	2323200	3/14/1932 - 7/29/2020	52	--	--
Bell Spring	BEL010C1	11/1/1972 - 5/15/2020	8	--	--

Notes:

1. Indicates sites where continuous and ambient specific conductance data were compiled for this study
2. Includes non-continuous data. Begin date is first manual sample; end date is most recent manual sample as of April 2021.

- **Bold** indicates OFS
- Current is as of data retrieval time (March 2021)

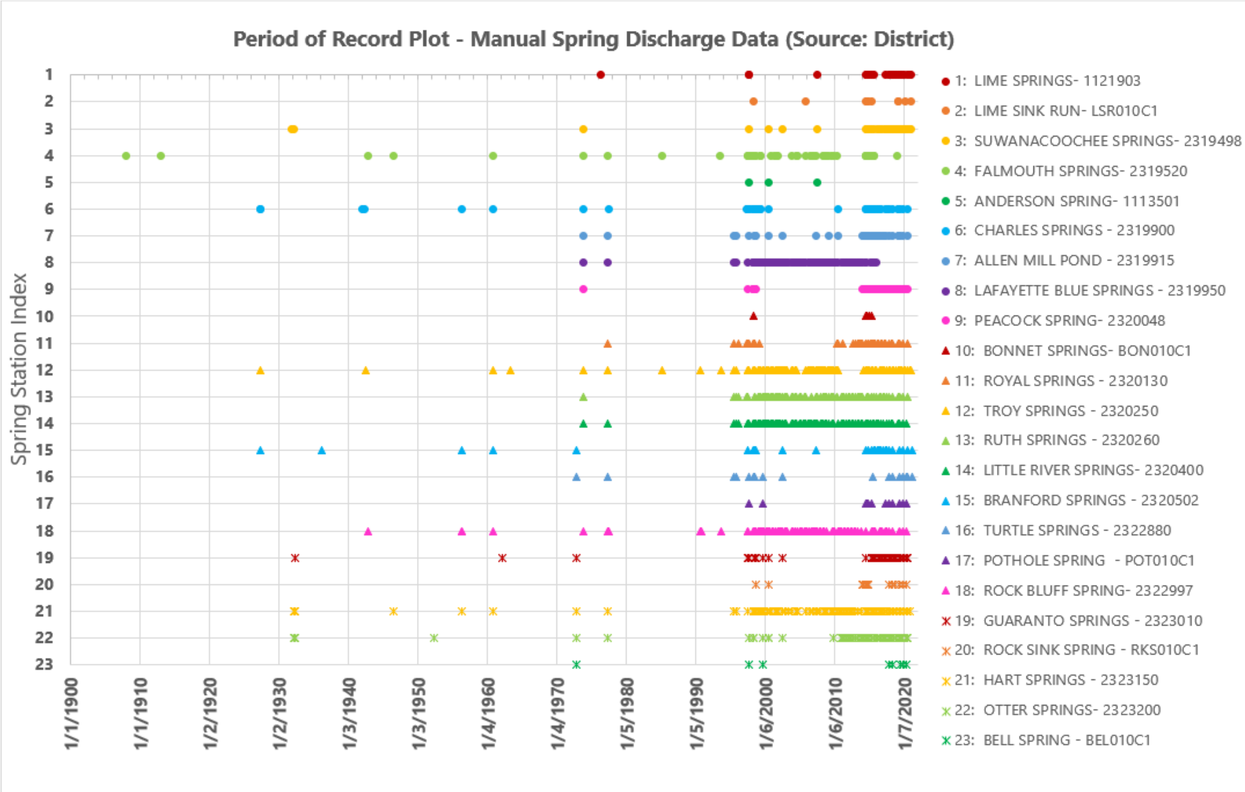


Figure 2-16. Timeline of manual flow measurements at MSR priority springs

2.3.2 Spring Flows

Manual spring flow measurements were provided by the District via the District's Water Portal website. Graphical representations of long-term median flows and boxplots showing the range of manual flow measurements for the MSR priority springs stations are provided in **Figure 2-17** and **Figure 2-18**. Median flow among the priority springs ranged from 6.75 cfs at Rock Sink Spring to 106 cfs at Troy Springs. More detailed long-term spring flow descriptive statistics are provided in **Appendix III**.

Negative (reverse) flows have been manually measured at 12 of the priority springs. "Brown out" conditions, where high tannin laden river flows intrude into a spring pool during a high water event, and flow reversals into a spring's vent are a common phenomenon along the MSR and are largely influenced by river stage. Florida Park staff record approximate daily water clarity observations (including brown outs and flow reversals) dating back to mid-2009 at four priority springs located within state parks (Allen Mill Pond, Lafayette Blue, Peacock, Troy). Based on these State Park data, brown outs and reversals most frequently occur during March when the head difference between the river and the aquifer is typically greatest (**Appendix III**). Brown outs and flow reversals are natural pulsed disturbances that effect multiple springs WRVs, including water quality, recreation, and biology. However, reduced aquifer levels can induce greater frequency and duration of these events with potential harm to spring metabolism and recreation (Hensley & Cohen, 2017).

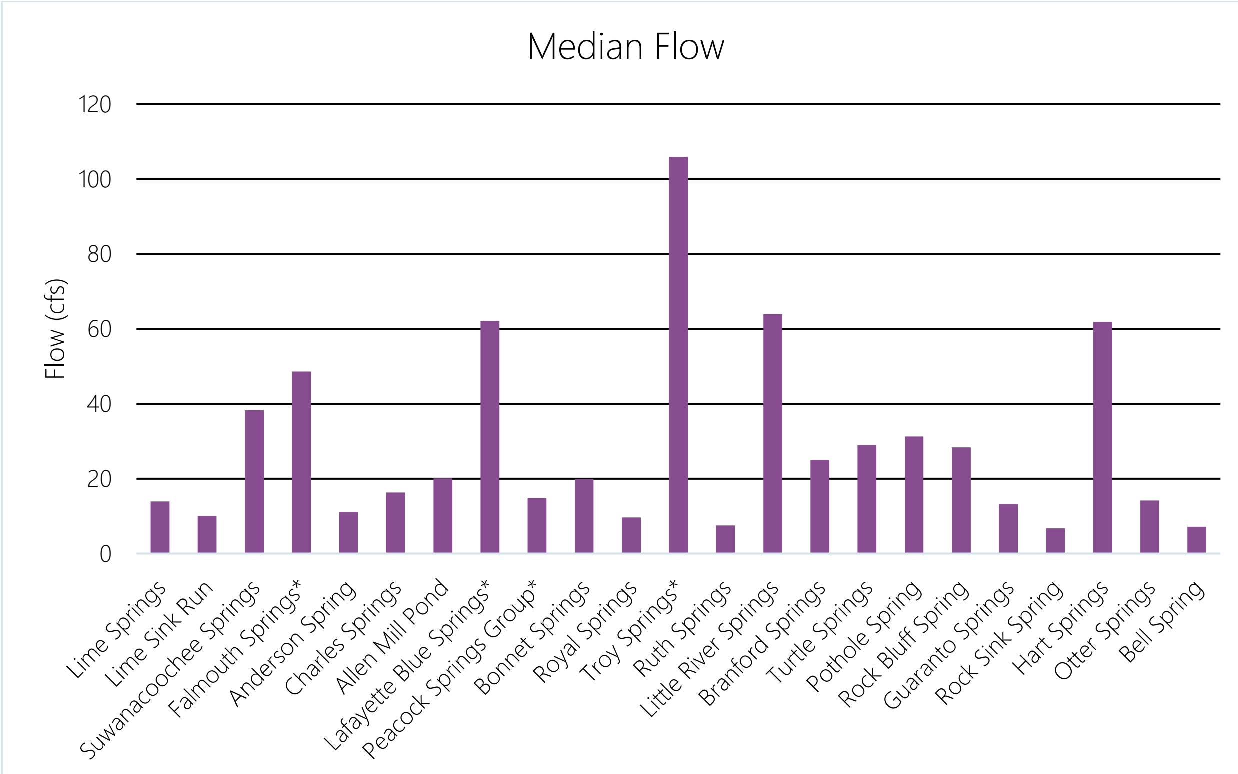


Figure 2-17. Priority springs long-term median flow

*Asterisks denotes OFS

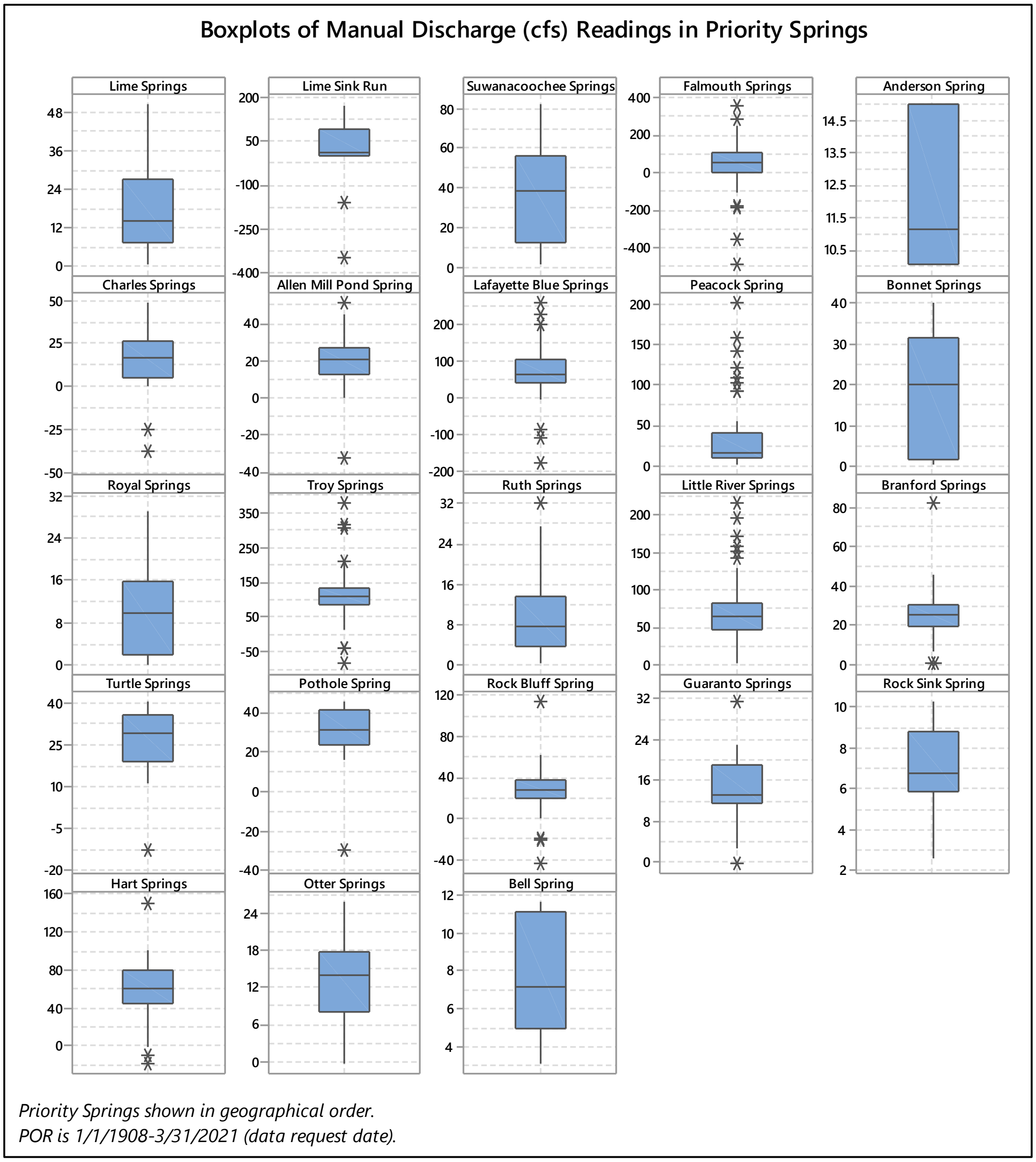


Figure 2-18. Boxplots of springs stations long-term discharge data[1]

[1] Boxplots can be used to evaluate data by comparing data distributions, central tendency, variability, determine whether a sample distribution is symmetric or skewed, and to check for outliers. For each site, the boxplot display consists of the blue shaded box that represents approximately the middle 50% of the observations (interquartile range, 25-75%), the horizontal line inside the smaller box represents the median value, the lines that extend from the outer box (called "whiskers") roughly represent the upper and lower 10% of the distribution (10% and 90%), and asterisks beyond the whiskers represent outliers. Note that the boxplot vertical axes are on different scales among the various sites.

2.3.3 Springs Ratings Curves

None of the springs has long-term daily flow records covering the entire 83-year period (WY1933 through WY2015). Lafayette Blue Springs is the only priority spring with daily flow records, but these readings do not begin until August 2015. Due to the limited amount of spring flow data, SRWMD commissioned a study to develop flow rating curves for multiple springs. Equations were developed using river stage or flow and/or groundwater level at select stations for both long-term and short-term predictions (**Table 2-6** and **Table 2-7**) (HSW, 2015 and 2019). Long-term equations can be used to develop longer flow series, as data at river stations go back as far as 1927 (**Table 2-3**) and the DOT Lake City well dates back to 1948. Wells used for the short-term equations are geographically closer to the springs, but the records do not extend back as far, with the oldest record dating back to 1981. It should be noted that negative manual flow readings were not used in the development of these rating curves; therefore, these curves are not intended to predict negative/reverse flows.

Table 2-6. Long-term spring flow rating analysis

Spring	Spring Flow Equation	River Source (RS-Stage or RF-Flow)	Groundwater WL Source
Lime Spring	Q = -5.37 - 0.00725***RF1** + 0.00746***RF2**	**RF1**-USGS 02319500 SUWANNEE RIVER AT ELLAVILLE **RF2**-USGS 02323500 SUWANNEE RIVER NEAR WILCOX	
Lime Sink Run	Q = -267 - 0.0988***RF1** + 0.129***RF2**	**RF1**- USGS 02319500 SUWANNEE RIVER AT ELLAVILLE **RF2**-USGS 02320500 SUWANNEE RIVER AT BRANFORD	
Suwanacoochee Spring	Q = 8.92*(**WL**-44.6)^1.09		**WL**-S041705001 DOT - Lake City
Falmouth Spring (OFS)	Q = -584.9 + 7.488(**RS**) + 9.033(**WL**)	**RS**-USGS 02319500 SUWANNEE RIVER AT ELLAVILLE	**WL**-S041705001 DOT - Lake City
Allen Mill Pond Springs	Q = 5.28*(**WL**-44.6)^0.941		**WL**-S041705001 DOT - Lake City
Lafayette Blue Spring (OFS)	Q = 20.84 + 0.0532*(**RF1** - **RF2**)	**RF1**-USGS 02320500 SUWANNEE RIVER AT BRANFORD **RF2**-USGS 02319500 SUWANNEE RIVER AT ELLAVILLE	
Peacock Springs Group (OFS)	Q = 0.003*(**GW**-43.26)^4.311		**WL**-S041705001 DOT - Lake City
Troy Spring (OFS)	Q = -23.8 - 6.86***RS** + 7.27***WL**	**RS**-02319500 SUWANNEE RIVER AT ELLAVILLE	**WL**-S041705001 DOT - Lake City
Little River Spring	Q = 0.002*(**GW**-21.04)^3.128		**WL**-S041705001 DOT - Lake City
Branford Spring	Q = -3.62 - 0.00581 ***RF1** + 0.00723***RF2**	**RF1**-USGS 02319500 SUWANNEE RIVER AT ELLAVILLE **RF2**-USGS 02323500 SUWANNEE RIVER NEAR WILCOX	
Turtle Spring	Q = -4.46 - 0.0126***RF1** + 0.0337***RF2**	**RF1**-USGS 02321500 SANTA FE RIVER AT WORTHINGTON SPRINGS **RF2**-USGS 02322500 SANTA FE RIVER NR FORT WHITE	
Rock Bluff Spring	Q = 8.41 - 0.0183***RF1** + 0.00527***RF2**	**RF1**-USGS 02315500 SUWANNEE RIVER AT WHITE SPRINGS **RF2**-USGS 02323500 SUWANNEE RIVER NEAR WILCOX	

Source: HSW, 2019

Table 2-7. Short-term spring flow rating analysis

Spring	Spring Flow Equation	River Source (RS-Stage or RF-Flow)	Groundwater WL Source
Falmouth Spring	Q = 12.9*(**WL** - 31.9)^1.12		**WL** = S021231001 Don Curtis
Peacock Springs	Q = 0.06*(**WL** - 20.5)^2.90		**WL** = S041112005 Revis Moore
Troy Spring	Q = 208 - 10.7***RS** + 0.868***WL**	**RS** = 02319500 SUWANNEE RIVER AT ELLAVILLE	**WL** = S041112005 Revis Moore
Allen Mill Pond Springs	Q = 9.54*(**WL**-44.3)^0.682		**WL** = S031035001 Lafayette Co Commission UFA
Rock Bluff Spring	Q = 119 - 3.93***RS** + 3.02***WL**	**RS** = 02319500 SUWANNEE RIVER AT ELLAVILLE	**WL** = S101506003 Piedmont Farms
Branford Spring	Q = -157 - 0.809***RS** + 6.14***WL**	**RS** = 02319500 SUWANNEE RIVER AT ELLAVILLE	**WL** = S081703001 City of High Springs
Lime Spring	Q = 7.95*(**WL** - 45.7)^0.8		**WL** = S031035001 Lafayette Co Commission UFA
Turtle Spring	Q = 9.01*(**WL** - 16.4)^0.629		**WL** = S081313005 GP8 UFA Rock Sink on 353
Suwanacoochee Spring	Q = 8.92*(**WL** - 44.6)^1.09		**WL** = S041705001 DOT-Lake City
Lime Sink Run	Q = -267 -0.0988*RF1 + 0.129*RF2	**RF1**- USGS 02319500 SUWANNEE RIVER AT ELLAVILLE **RF2**-USGS 02320500 SUWANNEE RIVER AT BRANFORD	
Lafayette Blue Spring	Q = 4.03E-08*(**WL** + 17.79)^5.64		**WL** = S041112005 Revis Moore

Source: HSW, 2015 and 2019

2.4 Precipitation and Temperature

Precipitation and temperature are critical components influencing streamflow. For large watersheds, such as that associated with the Suwannee River, the use of rainfall and temperature data from individual monitoring stations is not successful in capturing the expected rainfall and temperature variability due to very limited spatial coverage as well as gaps in available data. To avoid these limitations associated with monitoring stations, a climate dataset using monthly precipitation and average temperature datasets compiled by the PRISM Climate Group at Oregon State University (http://prism.oregonstate.edu) was developed. The precipitation and temperature data records are available starting in 1895. Oregon State generates the data using their Parameter-elevation Relationships on Independent Slopes Model (PRISM). PRISM uses all available station-based data to generate values on a 4 km X 4 km grid for the contiguous United States.

For this study, available precipitation and temperature PRISM data were downloaded by the District using the bulk-download option as monthly zipped files in the "binary interleaved by line" (bil) format. The data were processed to extract precipitation and temperature for the PRISM cells covering the contributing basins as indicated in **Figure 2-19**. Basin information was derived from the USGS Hydrologic Units classification (HUC) data.

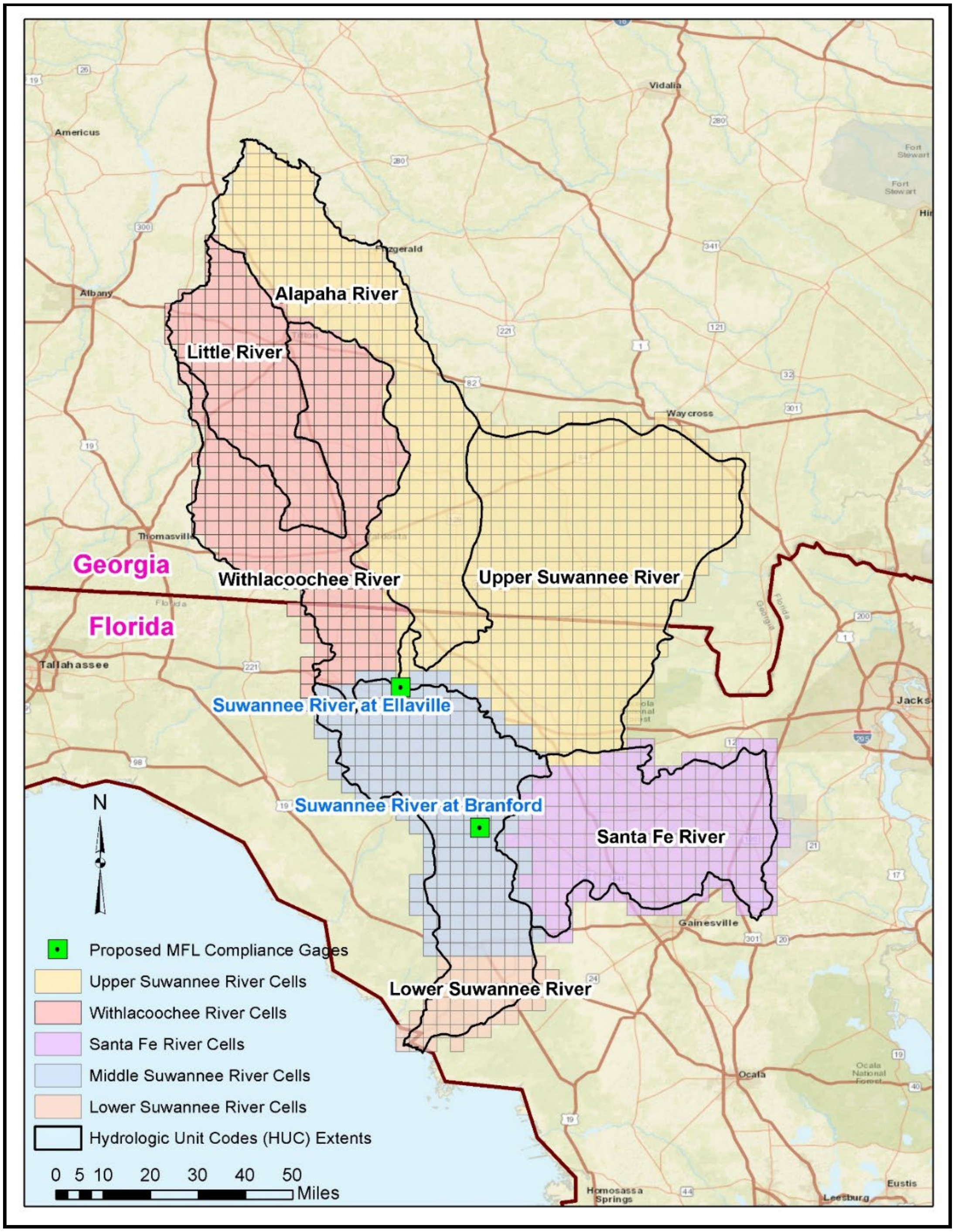


Figure 2-19. HUC extents and PRISM cells indicating different watersheds

Area-weighted annual rainfall estimates were compiled and plotted by water year with LOESS trends for three of the basins: Upper Suwannee River (USR), Lower Suwannee River (LSR), and Santa Fe River (SFR) (**Figure 2-20**). Note that for purposes of this study, the MSR basin was included within the LSR basin. Average monthly rainfall for WY1933-2015 was also plotted for the three basins (**Figure 2-21**). During this period, annual rainfall ranged from 38 to 75 inches with an average of 52 inches in the USR basin, from 42 to 76 inches with an average of 55 inches in the LSR basin, and from 38 to 69 inches with an average of 52 inches in the SFR basin. The highest peaks (WYs 1948, 1964, 1998) correspond with hurricanes and spring floods, while the lowest peaks (WYs 1990, 2000, 2011) correspond with drought conditions (**Figure 2-20**). These annual rainfall patterns correspond well with annual streamflow patterns (**Figure 2-14** and **Figure 2-15**). July is the month with the highest average rainfall, with 6.8 to 7.3 inches among the basins, while November is the month with the lowest average rainfall, with 2.0 to 2.2 inches (**Figure 2-21**).

PRISM temperature data were extracted for the contributing areas to the Ellaville and Branford gages (**Figure 2-19**). During the period of record from WY 1933-2015, annual average temperature at Ellaville ranged from 65.2 to 69.1 degrees Fahrenheit (deg F) (**Figure 2-22**), while annual average temperature ranged from 65.5 to 69.2 deg F at Branford (**Figure 2-23**). January exhibited the lowest annual average temperatures (51 deg F), while July exhibited the highest (81 deg F) (**Figure 2-24**). Trends in average annual temperatures were determined by exponential smoothing (LOESS) and overlain on these plots using a smoothing factor of 0.3.

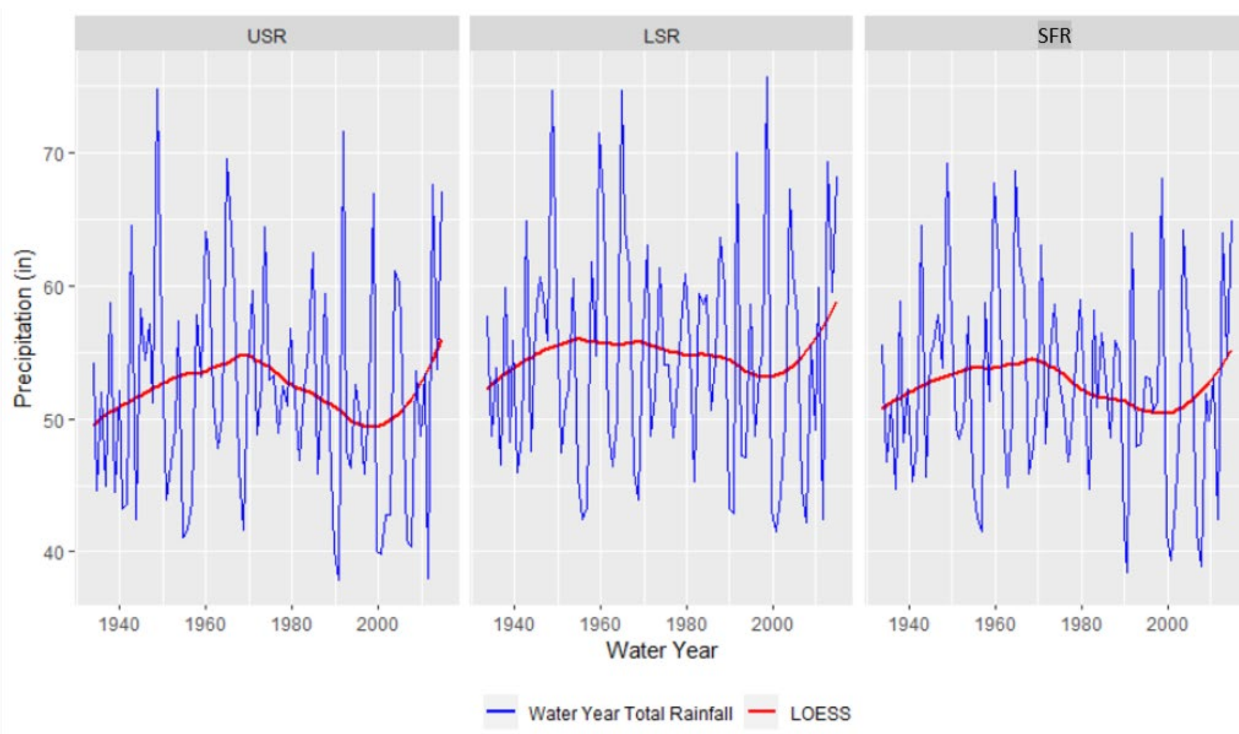


Figure 2-20. Annual rainfall with LOESS trends for three basins (WY1933-2015)

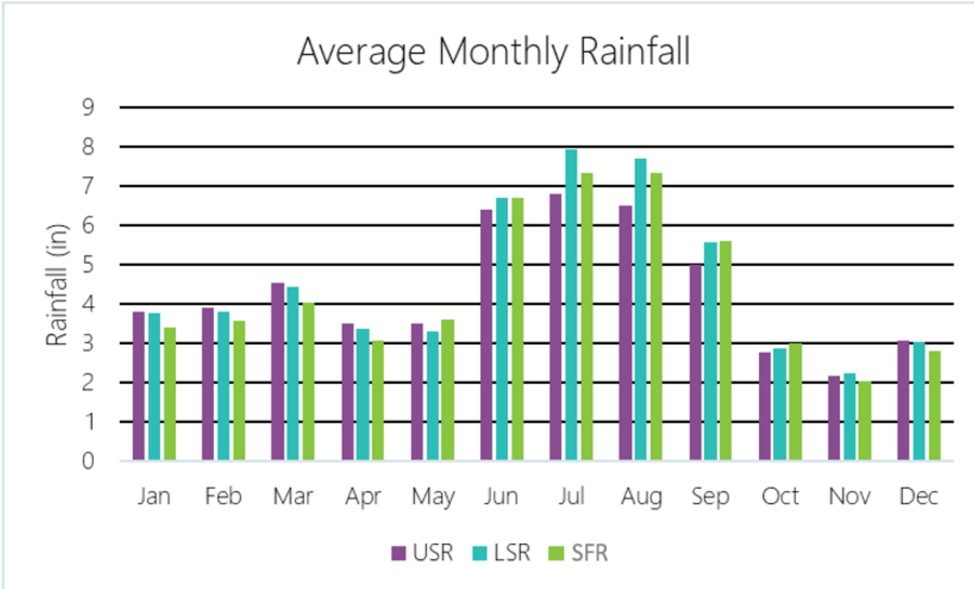


Figure 2-21. Average monthly rainfall for three basins (WY1933-2015)

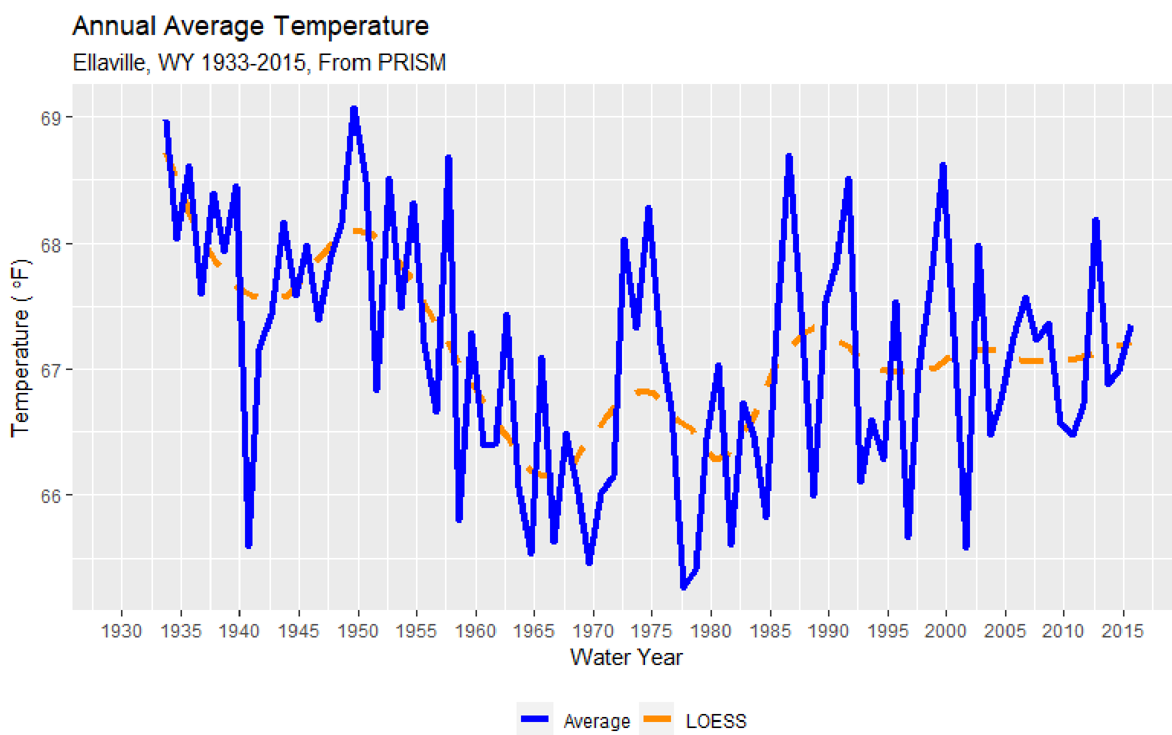


Figure 2-22. Ellaville mean annual temperature with LOESS trend for WY1933-2015

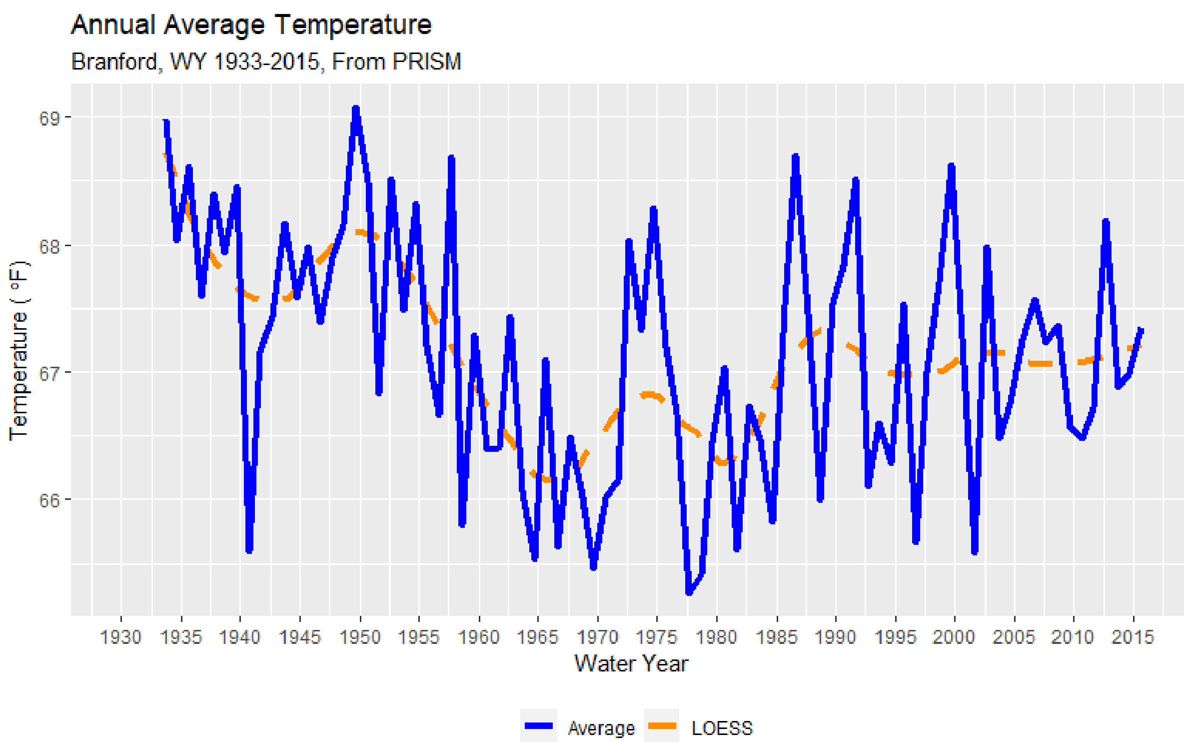


Figure 2-23. Branford mean annual temperature with LOESS trend for WY1933-2015

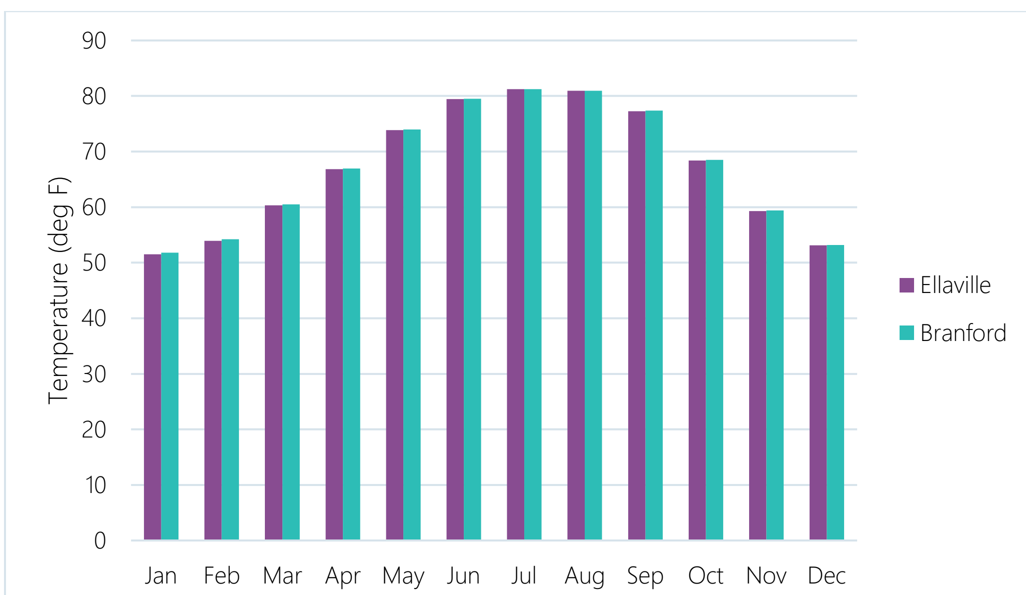


Figure 2-24. Average monthly temperature for Ellaville and Branford for WY1933-2015

2.4.1 Atlantic Multidecadal Oscillation Index

Atlantic Multidecadal Oscillation (AMO) refers to the long-term fluctuations in sea surface temperature and is associated with fluctuations in air temperature, rainfall patterns, and river flow in the southeastern United States, especially in Florida (Kelly 2004). AMO Index data, which is the deviation from the long-term average ocean temperature, show an oscillating pattern with 20-40 year spans of fluctuations (**Figure 2-25**). For the MSR, the early portion of the period analyzed (1930s to 1960) was in a warm period (shown as orange on graph), the middle part (1960 through 2000) was in a cooling period (shown as blue on graph), and the most recent portion (2000 to 2015) is in a warm phase. Streamflow LOESS trends for the two compliance gages appear to be higher during the cooler AMO period and lower during the warmer AMO periods. The long period of analysis for the MSR gages covers multiple AMO cycles; therefore, the FDC used in MFL analyses takes into account the multidecadal variability of rainfall, temperature, and streamflow.

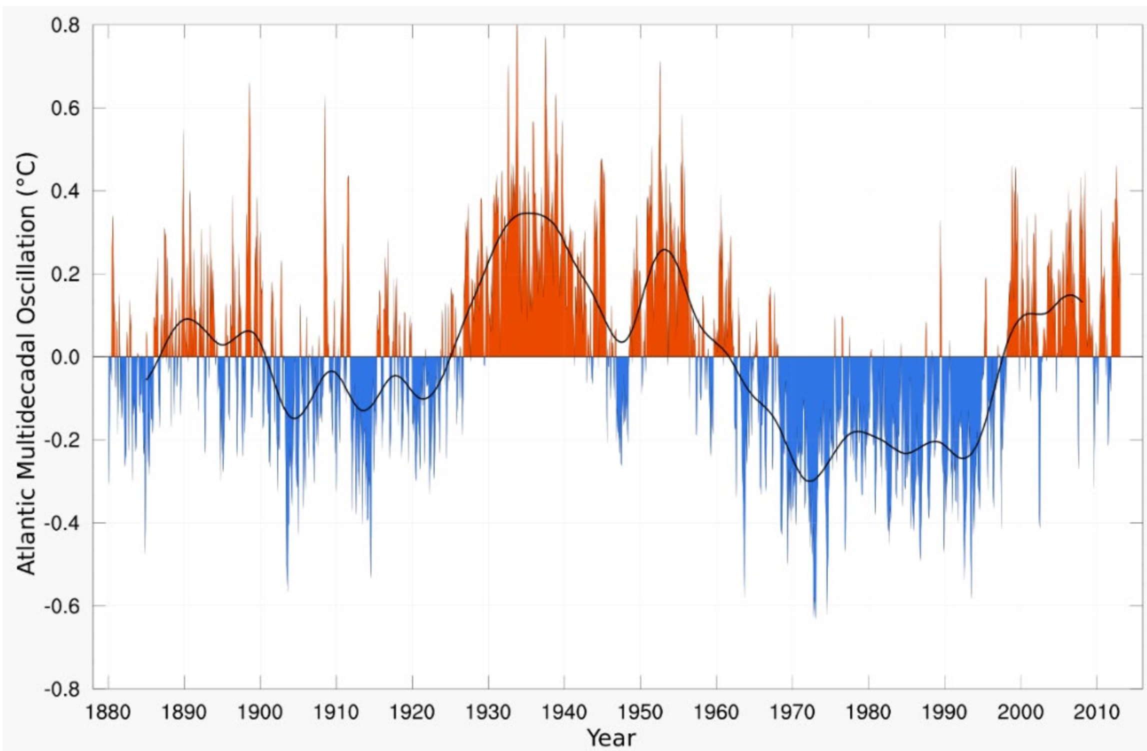


Figure 2-25. AMO index plotted with 10-Year (121 months) smoothed curve (orange = warm period, blue = cool period)

(Source: McCarthy & Haigh, 2015)

2.5 Groundwater Level

Groundwater level data were assessed from two sources. The first data source is a database of long-term Floridan aquifer monitoring wells maintained by the District. Data from six wells with records spanning at least ten years, located within 2.5 miles of wetland transects surveyed for this work effort, were analyzed to determine the potential for aquifer head conditions to drive groundwater to the riparian wetlands (**Table 2-8, Figure 2-26** and **Figure 2-27**). Among the wells assessed, water level fluctuated as high as 29 feet at Advent Christian (S031105006). This information contributed to understanding the relative importance of river flow versus regional groundwater conditions in support of wetland communities. Potentiometric head from the Floridan aquifer occurs at elevations sufficient to maintain wetland conditions in the lowest portions of the study area, in the deep swamps, but is not sufficient to support any of the higher wetland surfaces as wetlands. River flow therefore is an essential component to maintaining the existing wetland extent. It is also critical for maintaining the main floodplain forest types. **Appendix IV** provides additional detail.

Table 2-8. Upper Floridan Aquifer wells assessed

Well Number Name	Closest Transect	Number of Readings	Period of Record	Latitude	Longitude	Data Type
S011232006 Falmouth	Wii15	3,256	2/28/2000 – current	30° 21' 28"	83° 07' 56"	Monthly Manual Readings Until 11/2/2012, then Continuous
S031105006 Advent Christian Village	Wii5	12,551	8/28/1981 – current	30° 14' 55"	83° 14' 17"	Continuous Data with Gaps
S051334013 Troy Spring MW2 TYA	Wi34	5,670	2/28/2003 – current	30° 00' 09"	82° 59' 42"	Continuous Data with Gaps
S061301007 Little River	Wi30	6,592	6/14/1997 – current	29° 59' 47"	82° 57' 58"	Continuous Data with Gaps
S06143006 Carrol Hall	Wi10	47	6/22/2000 - 9/11/2013	29° 55' 31"	82° 54' 16"	Manual Readings
S091420001 Clifton Mikel	X-26	450	11/01/1976 – current	29° 41' 35"	82° 55' 30"	Monthly Manual Readings

Note: Current is as of data retrieval time (March 2021)

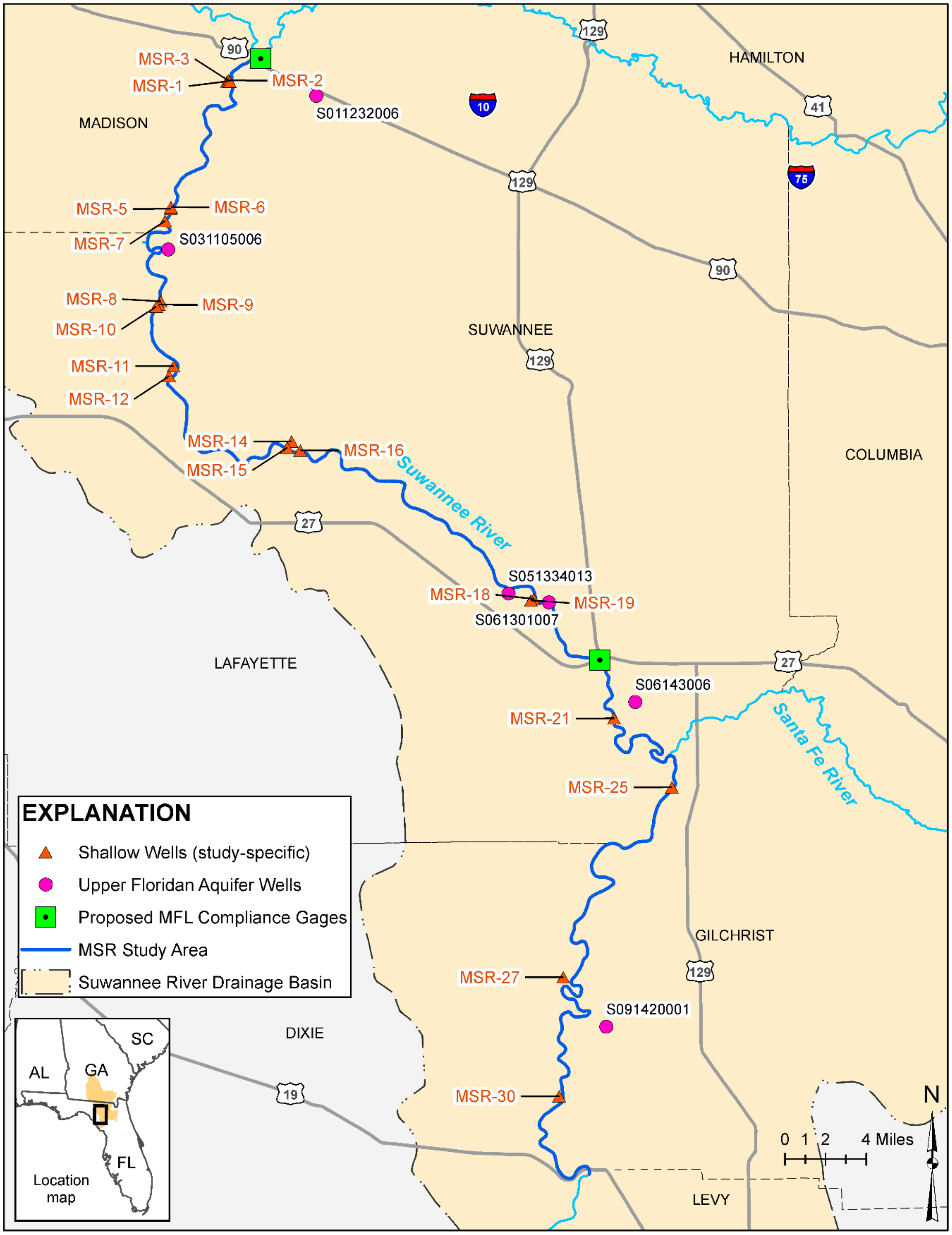


Figure 2-26. Upper Floridan aquifer and shallow well locations

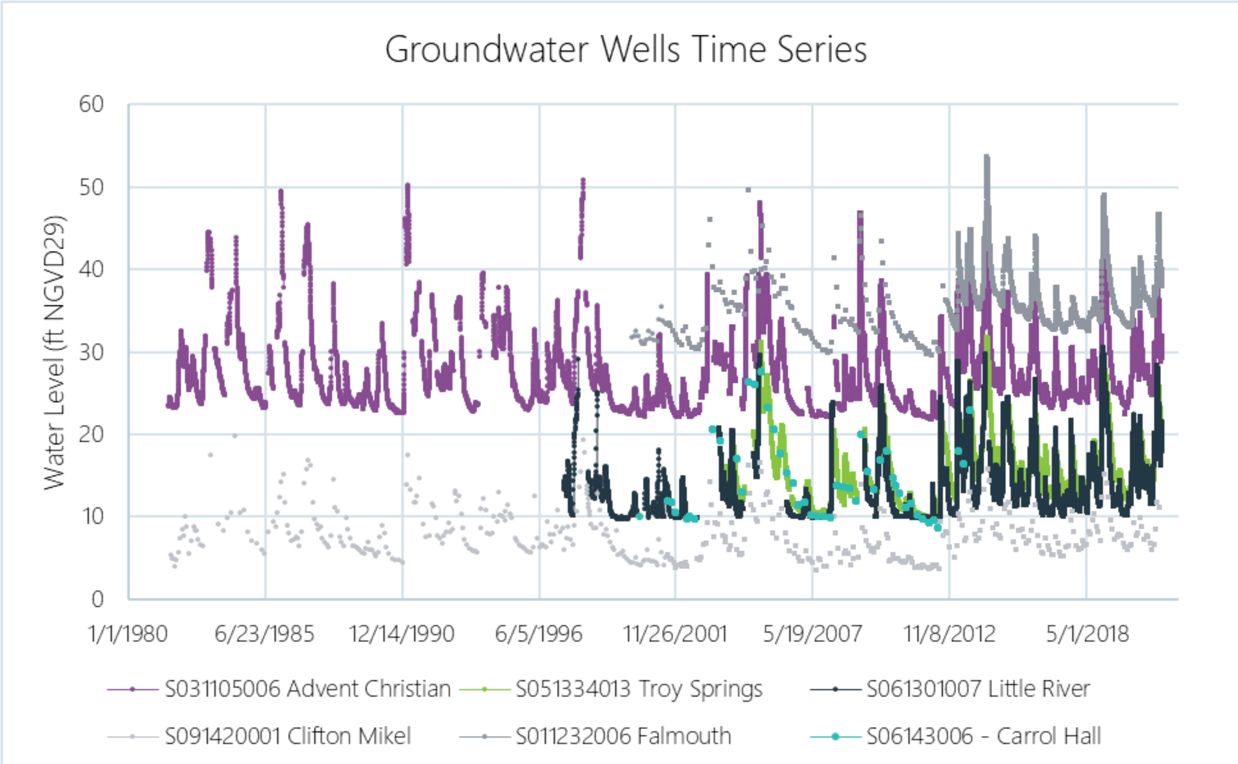


Figure 2-27. Upper Floridan aquifer well level time-series

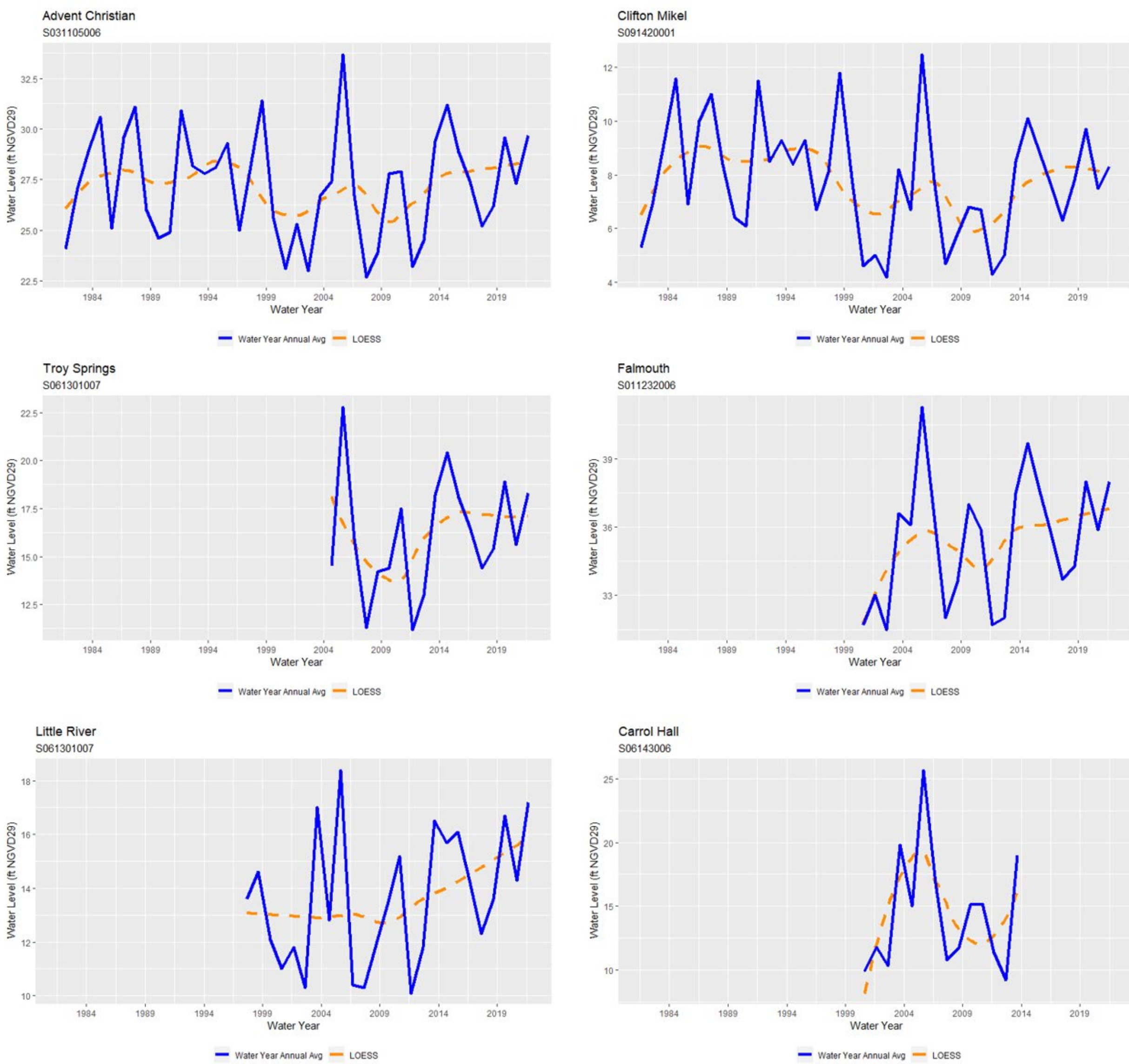


Figure 2-28. Annual water level with LOESS trends for six Upper Floridan aquifer wells

The second groundwater data source includes 20 shallow monitoring wells established throughout the MSR floodplain to assess floodplain hydroperiods for a single annual period (November 2013 through November 2014) (**Figure 2-21**). These wells were installed and monitored specifically for this MFL study to assist in the characterization and comparison of the hydrology among different community types in the floodplain. The construction details and locations of the floodplain wells are described in **Appendix V**. Floodplain well data were examined in concert with 16 surface water staff gages, also described in more detail in **Appendix V**. The monitoring well and concurrent USGS streamflow data confirmed statistically significant hydroperiod differences among wetland types in the floodplain, and added direct weight of evidence that fairly frequent floods (those occurring at least once every five years rising well-above the groundwater table are important drivers in existing plant community distributions (**Appendix IV**). The alluvial ridge represents an upper surface that is actively maintained by sporadic floods, generally occurring at close to a five-year return interval on the lower Suwannee River (Light et al. 2002), as described in **Section 5.3.2**.

2.6 Historical Groundwater Use and Injection Flows

SRWMD conducted a comprehensive study relying on available water use data, historical estimates of population, and per capita water usage to develop a long-term groundwater use time-series (from 1900 through 2015) for each combination of water-use category and County. Published data and different interpolation methodologies were used to develop a continuous water use dataset that was subsequently used to estimate reference timeframe (RTF) flows and levels as described in **Section 2.7**. **Appendix VI** describes the groundwater use hindcasting process in detail.

In addition to the groundwater use dataset, it is important to also quantify injection flows into the groundwater aquifer. The injection flows estimates are useful in understanding the impact of injection on elevating the groundwater level (if any). SRWMD compiled data from the four injection well locations in the North Florida Southeast Georgia (NFSEG) model domain and extrapolated it to generate a long-term (1900 onwards) injection flow time-series. These four injection wells are located near Gainesville, FL and had combined flows of 14.2 MGD in 2010. **Appendix VI** documents the data and methods that were used by the SRWMD to hindcast groundwater injection flows.

2.7 Reference Timeframe Flow

An essential component of the establishment of MFLs is identification of a baseline hydrologic record which is representative of unimpacted hydrologic conditions. For this study, the baseline hydrologic record is established using the reference timeframe (RTF) concept. An RTF flow or level time-series is defined as an estimate of the flow or level time-series that would have been observed in the absence of any groundwater withdrawals. In other words, the RTF is a time-series from which impacts of groundwater withdrawals are removed. **Appendix VII** provides a detailed outline of the methodology undertaken to develop an RTF. The Ellaville and Branford USGS gages provide the longest and most complete observed daily flow records in the study area. Thus, for the purpose of establishing MFLs, the Ellaville and Branford gages were specified as compliance gages along the MSR, and RTF flows for these two gages were developed by adding the adjustment factors shown in **Figure 2-29** to the observed flow record. Adjustment factors ranged from approximately 74 to 339 cfs at Ellaville and from 78 to 371 cfs at Branford, with the largest adjustments occurring in 1991. **Figure 2-30** and **Figure 2-31**Error! Reference source not found. show the observed versus RTF flow duration curves for WY1933-2015 for the two compliance gage locations.

RTF adjustment factors were also determined for a select number of priority springs (Error! Reference source not found.**Figure 2-32**) and groundwater wells. The largest flow adjustment factor is at Troy Springs, with a peak adjustment of approximately 2.9 cfs in 2002.

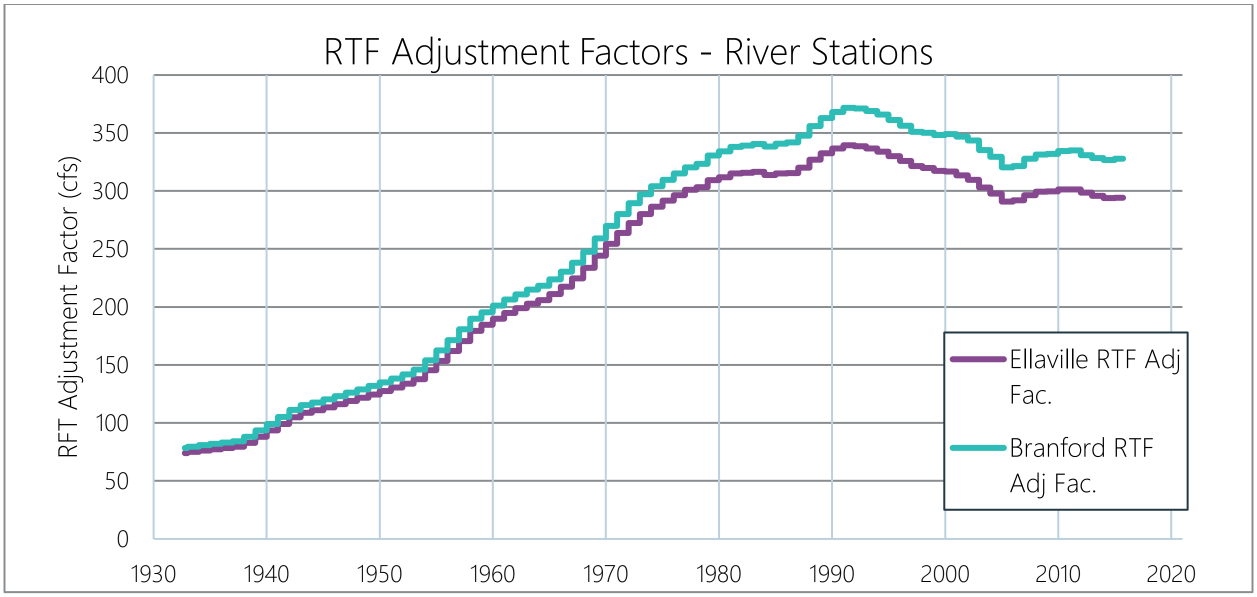


Figure 2-29. Ellaville and Branford RTF adjustment factors

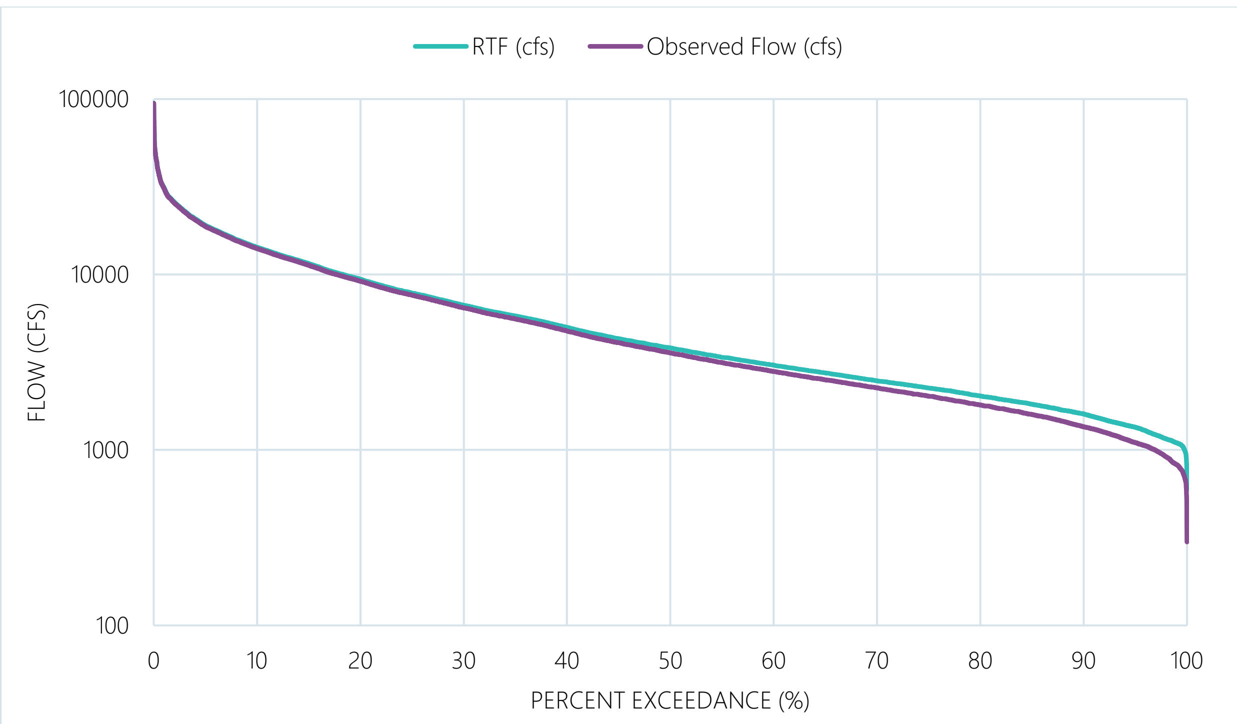


Figure 2-30. Ellaville RTF versus observed flow duration curve

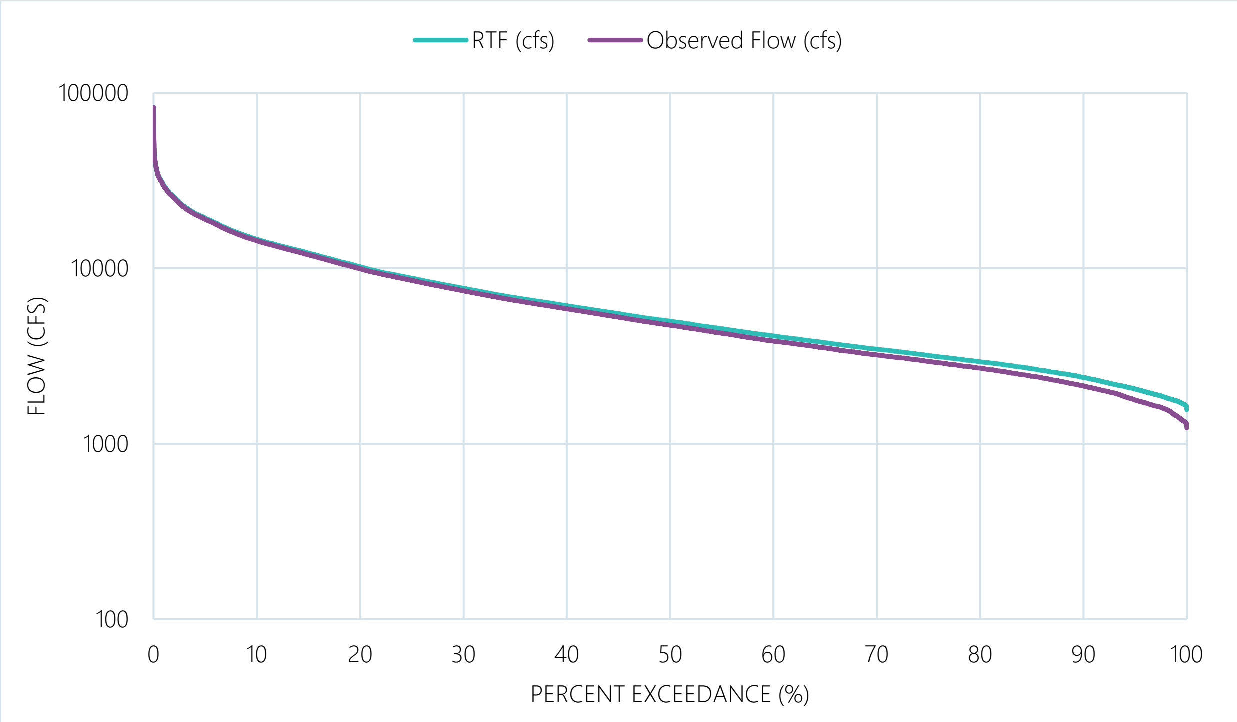


Figure 2-31. Branford RTF versus observed flow duration curve

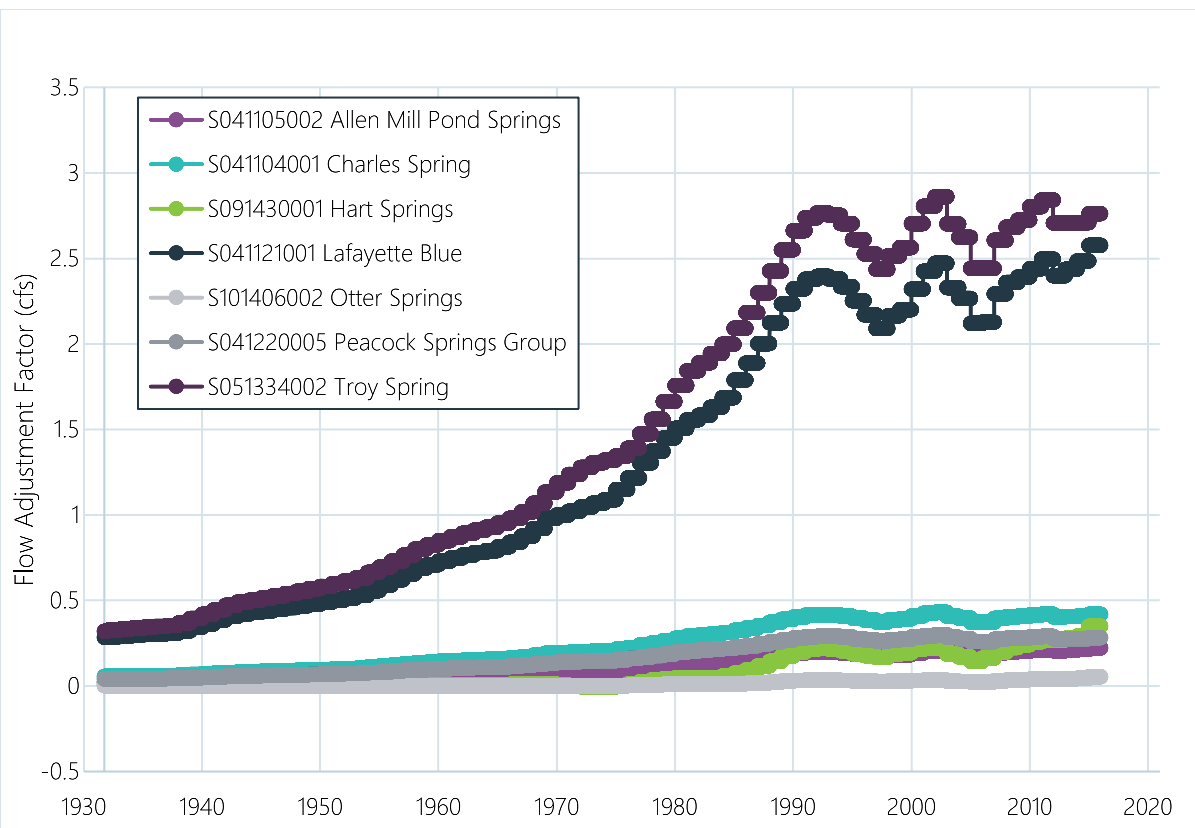


Figure 2-32. Select Priority springs RTF adjustment factors

2.8 Water Quality

Water quality is an important parameter to consider when setting MFLs due to the impact that water quality has on organisms and recreational activities. In Florida, nutrient enrichment and eutrophication processes are the primary issues associated with water quality, which can result in filamentous algal mat blooms, poor water clarity, and substandard habitat for organisms (SWFWMD, 2019). People who encounter water or seafood from an area experiencing an algal bloom can potentially become sick from exposure to increased toxins and bacteria (EPA, 2021).

Section 303(d) of the Federal Clean Water Act requires each state to identify and list "impaired" waters where applicable water quality criteria are not being met. FDEP identified more than 70 waterbody (WBID) impairments within the SRWMD boundaries (ESA, 2017). FDEP has developed and adopted Total Maximum Daily Loads (TMDLs) for waterbodies that have been listed as impaired within the MSR basin (**Figure 2-33**). A TMDL is the maximum amount of a pollutant that a waterbody can receive and still maintain its designated uses. Waterbodies within the Suwannee River Basin are designated as Class III waters and must support recreation and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife (62-302.400, F.A.C.). Nutrient concentrations have been found to be increasing over time in many Florida springs due to land use changes and associated increased application of nitrogen to the land surface and groundwater systems (Upchurch et al., 2007). A Suwannee River Basin Management Action Plan (BMAP) has been adopted and is being implemented by FDEP and stakeholders to reduce nutrient loads to the watershed.

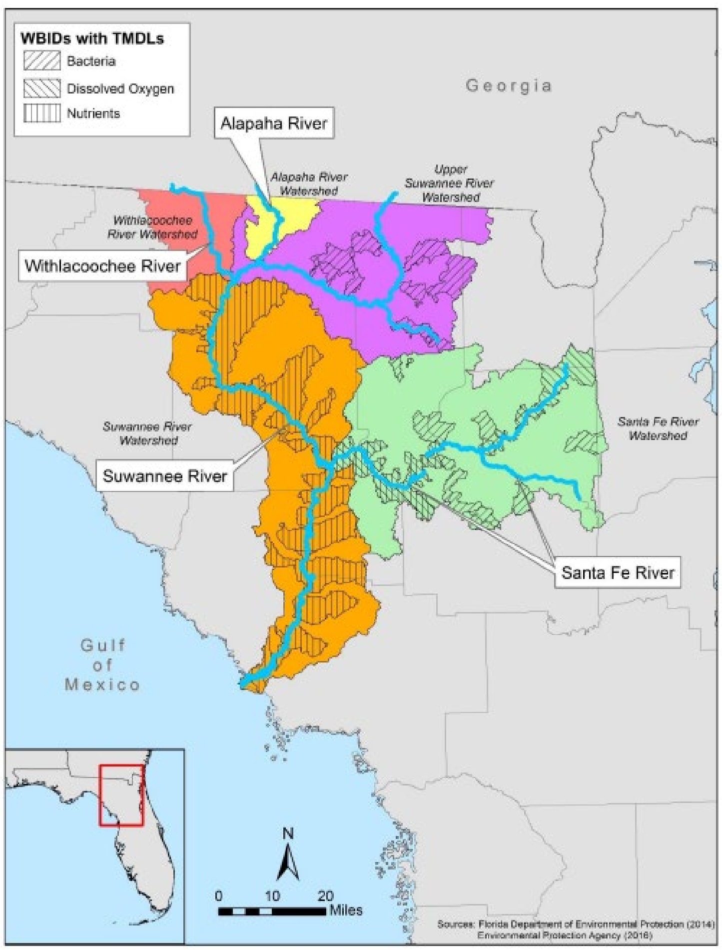


Figure 2-33. Map showing areas covered by TMDLs in the Suwannee River Basin (ESA, 2017)

Water quality data are collected at river and spring stations along the MSR. Ambient grab water chemistry samples are collected approximately quarterly at the six USGS river stations and the 23 priority springs, while continuous *in-situ* (daily) data for select water quality parameters are collected at select sites (**Table 2-5**). **Appendix III** describes the water quality analysis that was conducted for the MSR. The primary purpose of the assessment was to compile and analyse water quality and flow distributions and to conduct correlations of certain water quality parameter concentrations with flow within the study reach. The effort focused on water quality and flow data for select MSR river and springs stations within the study area. Relationships between flow and key water quality parameters such as specific conductance (SpC) and nitrate-nitrite nitrogen (NOx) were provided.

Specific tasks that were conducted to determine if water quality could be considered a relevant WRV included:

- summarizing data for available water quality parameters,
- conducting annual medians analyses for the key parameters using cumulative concentration frequency distribution curves, and
- identifying concentration-flow associations using scatterplot smoothing (LOWESS) graphs and nonparametric correlations (Spearman's Rho).

Water quality and flow data were analysed for five river stations, which included Ellaville, Luraville, Branford, Bell, and Wilcox. Data were also analysed for relationships between flow and water quality parameters for three springs stations, including Troy, Lafayette Blue, and Ruth Springs. The potential for spring flow reversals was evaluated for Troy Spring using continuous *in-situ* and ambient grab water chemistry sample data; however, this evaluation will be further investigated separately during the development of priority spring MFLs. Selection of stations for each type of analysis was limited to available data for key water chemistry parameters.

All five river stations exhibited statistically significant inverse relationships between flow and NOx and flow and SpC (**Figure 2-34**). Spring flows generally exhibit greater NOx concentrations and SpC than river flow and may provide a greater contribution of these chemical constituents to total river flow during dry periods, or when spring discharge to the river increases (Upchurch et al., 2008). Conversely, lower NOx concentration and SpC dominates river water chemistry during higher flows. NOx and SpC could theoretically be reduced in the river by decreasing spring flow and somehow augmenting river flow, but such a scenario would shift the basic limnological reaches of the river, perhaps with harmful consequences to some fish and wildlife populations, floodplain vegetation, and aesthetics. Instead, the basic water source and NOx/SpC pattern is likely to be broadly sustained by the proposed MFLs which address flow maintenance ranging from low to high extremes in the river.

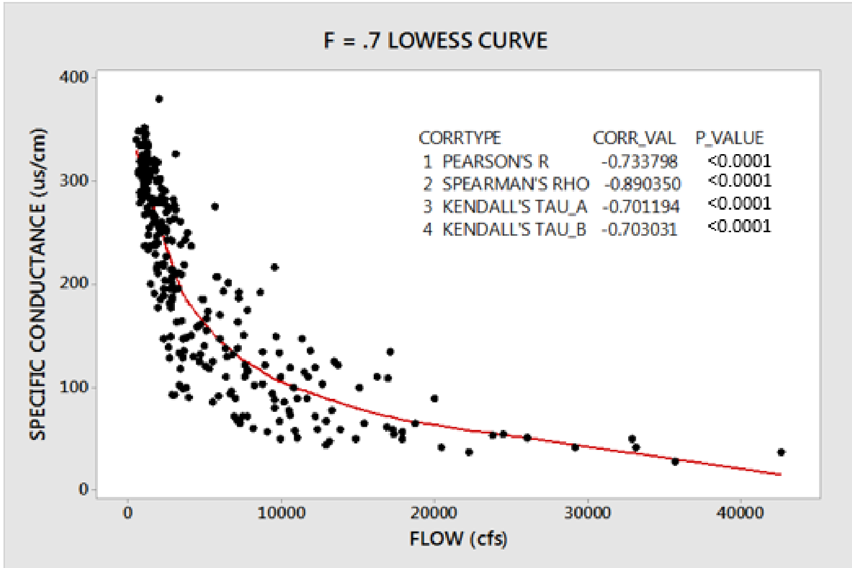


Figure 2-34. Example of negative correlation between flow and SpC for the Ellaville River station from 1989-2014. Note p-value of 0 indicates p<0.0001

The relationships between flow and NOx, and flow and SpC were inconsistent among the three springs assessed (**Figure 2-35**). Based on the correlation results between flow, specific conductance, and nitrate, the three assessed springs likely receive water from different water sources, with the dominant source being dependent on discharge levels and flooding conditions. Concentrations of potential pollutants are driven by variations in land use and geology. These kinds of differences can likely be extrapolated to many other springs within the MSR basin. The results from this MSR water quality analysis are supported by a 2008 study which found that 50% of springs analysed had an increase in NOx concentrations as spring discharge increased, while 45% of springs analysed had no correlation between spring discharge and NOx (Upchurch et al., 2008). In the 2008 study, variations in the relationships between NOx, SpC, and spring flow were primarily driven by the geology of the spring and how it received its source water, either by conduit flow or disperse flow. In some cases, the flow associations for the MSR water quality analysis and the 2008 study suggest decreasing spring flow would reduce NOx and SpC concentrations, which is clearly antithetical to the overall objectives of MFL regulations.

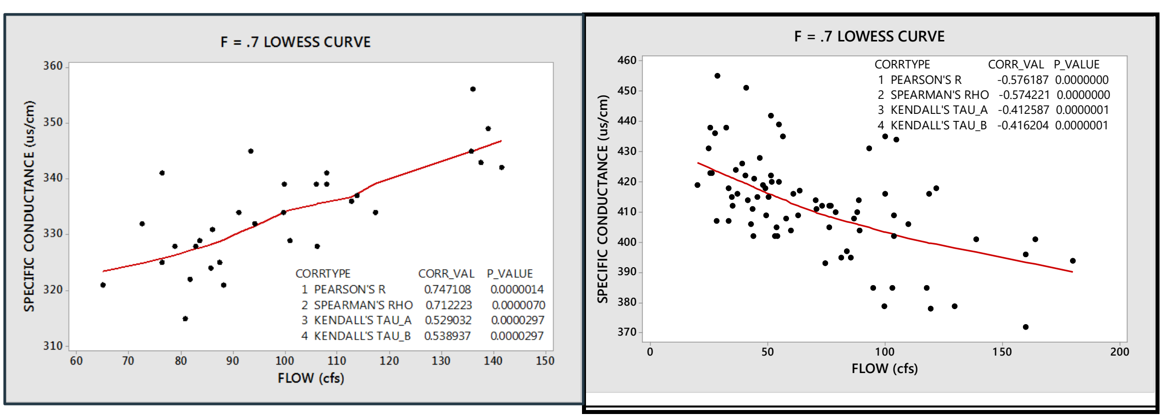


Figure 2-35. Example of contrasting relationships of SpC to flow discharging from Troy Springs (left) and Lafayette Blue Springs (right) from 1997-2013

The MSR and its springs exhibited no consistent data for directly establishing water quality based MFL metrics, and Upchurch et al. (2008) concluded that "…minimum flows and levels (MFLs) cannot be utilized to control nitrate discharging from the springs by promoting high discharge." However, the exploratory analyses detailed in **Appendix III** provide a framework for future investigation into the source of groundwater contribution to individual springs using water quality as a signature for respective sources; and in this context, water quality may be valuable in determining their respective MFLs provided sufficient data exists.

2.9 Hydrology Summary and Relevance to the MFLs Assessment

Detailed hydrologic characterization of the MSR basin was conducted using the best available data and information from streamflow gages, springs, and groundwater wells. The observed streamflow and stage data were gap-filled to develop long-term continuous time-series that were subsequently used for several other hydrologic evaluations. USGS gages at Ellaville and Branford were specified as compliance gages for the purpose of MFL establishment. The period of analysis was set as WY1933 through WY2015, and RTF flows were established for the two compliance gages to provide a time-series from which impacts of groundwater withdrawals are removed. This RTF flow record is used for quantification of critical flows associated with each WRV of interest (as described in subsequent sections).

3.0 BIOLOGY

Regionally significant riverine and floodplain ecological communities occur in and around the Middle Suwannee River. Flow reductions in the MSR have the potential to alter the hydrology of wetland and instream aquatic habitats (Darst et al. 2002). Alterations could potentially:

- decrease hydroperiods in different wetland community types thereby promoting a shift to more upland species,
- reduce the types and the quantity of aquatic habitats preferred/required by select invertebrate and vertebrate species, and
- decrease sediment loads which are crucial in forming the surfaces on which various communities exist.

The MFLs assessment of fish and wildlife habitat was performed within the context of a conceptual model that is representative of the MSR system. The conceptual model is described in the next section, followed by descriptions of habitats and species of particular concern in the MSR system.

3.1 Conceptual Ecological System Model

The conceptual approach to the Middle Suwannee River MFL starts by recognizing that all riverine and floodplain surfaces are dynamic over time, affected by a wide range of river flows including routine flood events. The MSR system cannot be viewed as being static in time and place, as physical, chemical, and biological processes continuously influence the collective suite of habitat surfaces that we see today and have been there historically. **Figure 3-1** shows the conceptual model hierarchy used to guide the establishment of MFLs on the MSR: 1) maintenance of dynamic alluvial surfaces, 2) maintenance of floodplain communities, and 3) maintenance of open channel systems. Maintenance of the flows that sustain these features through the movement of water and sediment is the basis for how this MFL was framed. This basis covers the full range of the natural and highly variable flow regime of the river, which routinely fluctuates more than 10 vertical feet between annual wet and dry seasons. This approach serves to prevent significant harm to aquatic and terrestrial fauna and flora within the 10-year floodplain and main river channel.

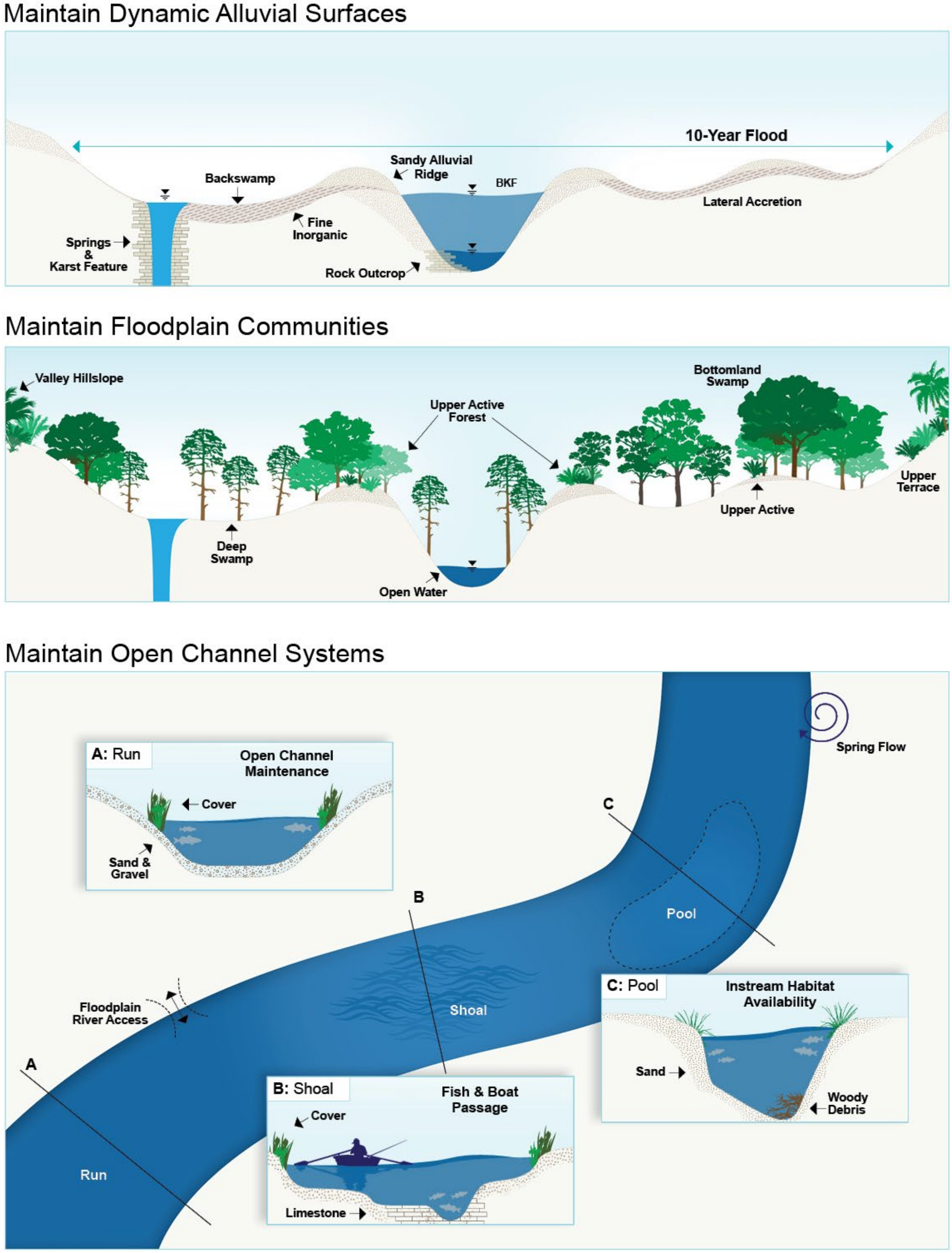


Figure 3-1. Conceptual ecological system model

First, the MSR flow regime maintains dynamic alluvial surfaces, including the open channel, alluvial ridges, backswamps, and lateral accretions (**Figure 3-1**). The open channel is defined as the main river conduit through which water and sediment are transported below the bankfull stage. Alluvial ridges are formed by sand depositing close to the river margins as flood waters rise; it is the first place the river can drop the heavier sediments it is carrying during a flood and most alluvial rivers have such ridges. Backswamps are areas beyond the alluvial ridge where finer sediments settle out during overbank events. Lateral accretions can be described as places where sediment has been deposited over time as the river migrates laterally by eroding at outer bends (cutbanks) and accumulating sediment at inner bends (point bars). Additionally, karst features such as springs, karst windows, and limestone outcroppings are present in the MSR, but these are under geologic control, rather than alluvial control. Notably, the karst features are variably mantled by alluvium, leading to a very rough and dynamic floodplain topography.

Second, the suite of surfaces found in the MSR maintains a variety of floodplain communities, as different communities prefer different surfaces based on interactions between hydrology, geomorphology, and vegetation (**Figure 3-1**). Ecological communities found within the MSR include open water, deep swamps, bottomland swamps, and uplands (upper active and upper terrace). These communities are described in more detail in the following section.

Third, the MSR flow regime maintains open channel systems and the associated habitats found there, including pools, shoals, and runs (**Figure 3-1**). This is a riverine MFL, therefore aspects of the flow regime that maintain those surfaces in the main channel were considered, and standard hydraulic protocols were followed for assessing instream communities and recreational values of the open channel. The open channel interacts with floodplain features in particular ways, not only with overbank flows but also in focused areas where the river and the floodplain readily exchange water, sediment, fish, and other wildlife species via openings in the bank that are maintained by perennial spring discharge. Therefore, such openings were assessed.

3.2 Floodplain Habitats

Many fish and wildlife species use both instream and floodplain habitats as available. Use of habitats adjacent to the main river channel and movement into the floodplain during high water varies by species (Toth 1991, 1993). Floodplains provide feeding and spawning habitats (Guillory 1979, Ross & Baker 1983) and a refuge for juveniles (Graff & Middleton 2001, Finger & Stewart 1987). As part of this MFL, extensive fieldwork was conducted to characterize the MSR's floodplain communities. **Appendix V** summarizes data collection efforts, which involved the identification of ecological community breaks based on vegetation, soils, and alluvial features along 23 main river floodplain transects and 11 spring run floodplain transects: and the collection of quantitative plant and soils data within 79 main river floodplain plots and 21 spring run floodplain plots. **Appendix IV** describes the characterization of ecological communities based on the collected data using various statistical analyses. Based on the floodplain work that was conducted, four main ecological communities were found to exist within the MSR floodplain: deep swamps, bottomland swamps, upper active uplands, and upper terrace uplands. Examples of how these communities are distributed throughout the MSR study area are provided in **Figure 3-2** and **Figure 3-3**, and brief descriptions of each are provided below.

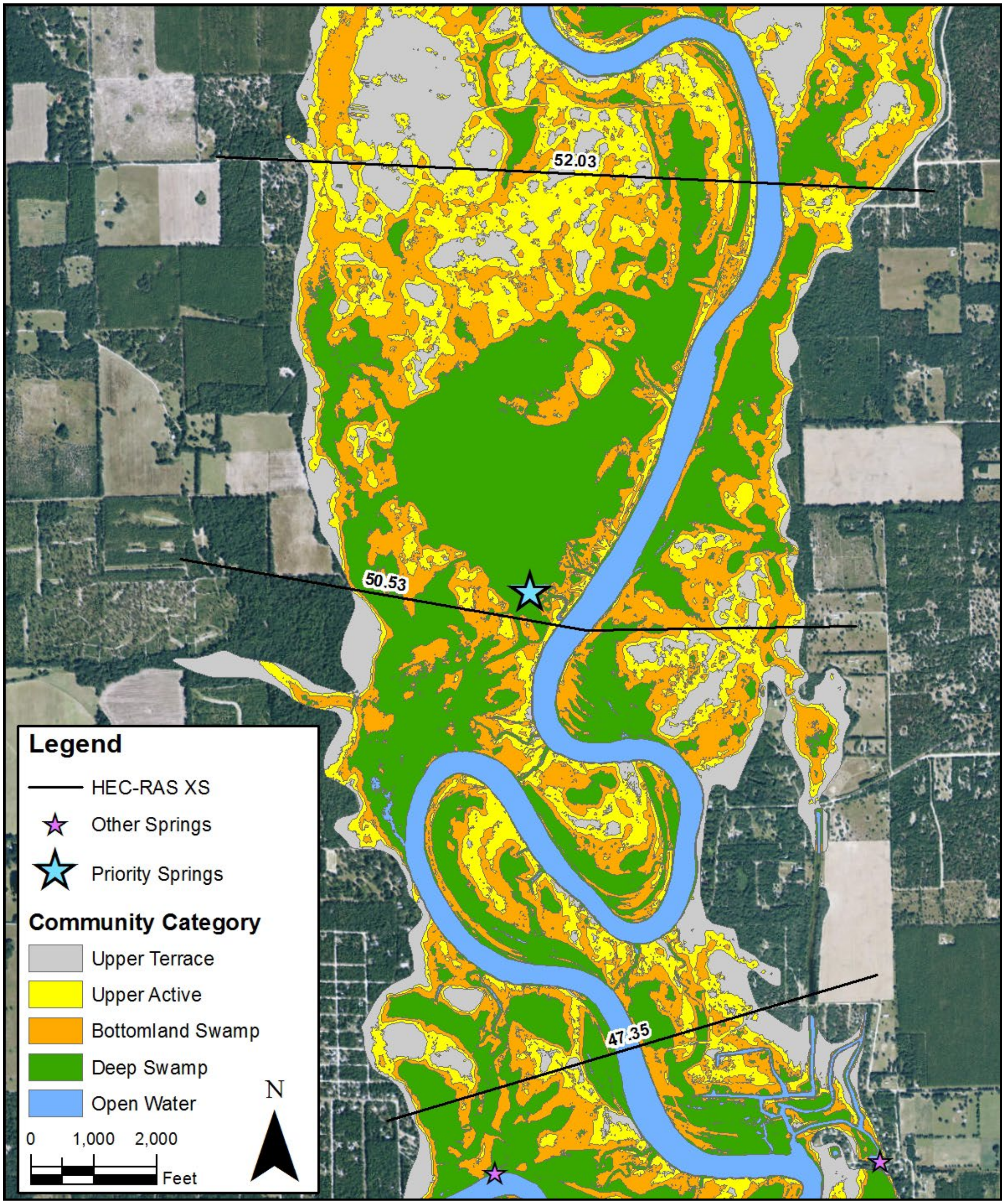


Figure 3-2. Segment of Middle Suwannee floodplain communities downstream of the Santa Fe River confluence

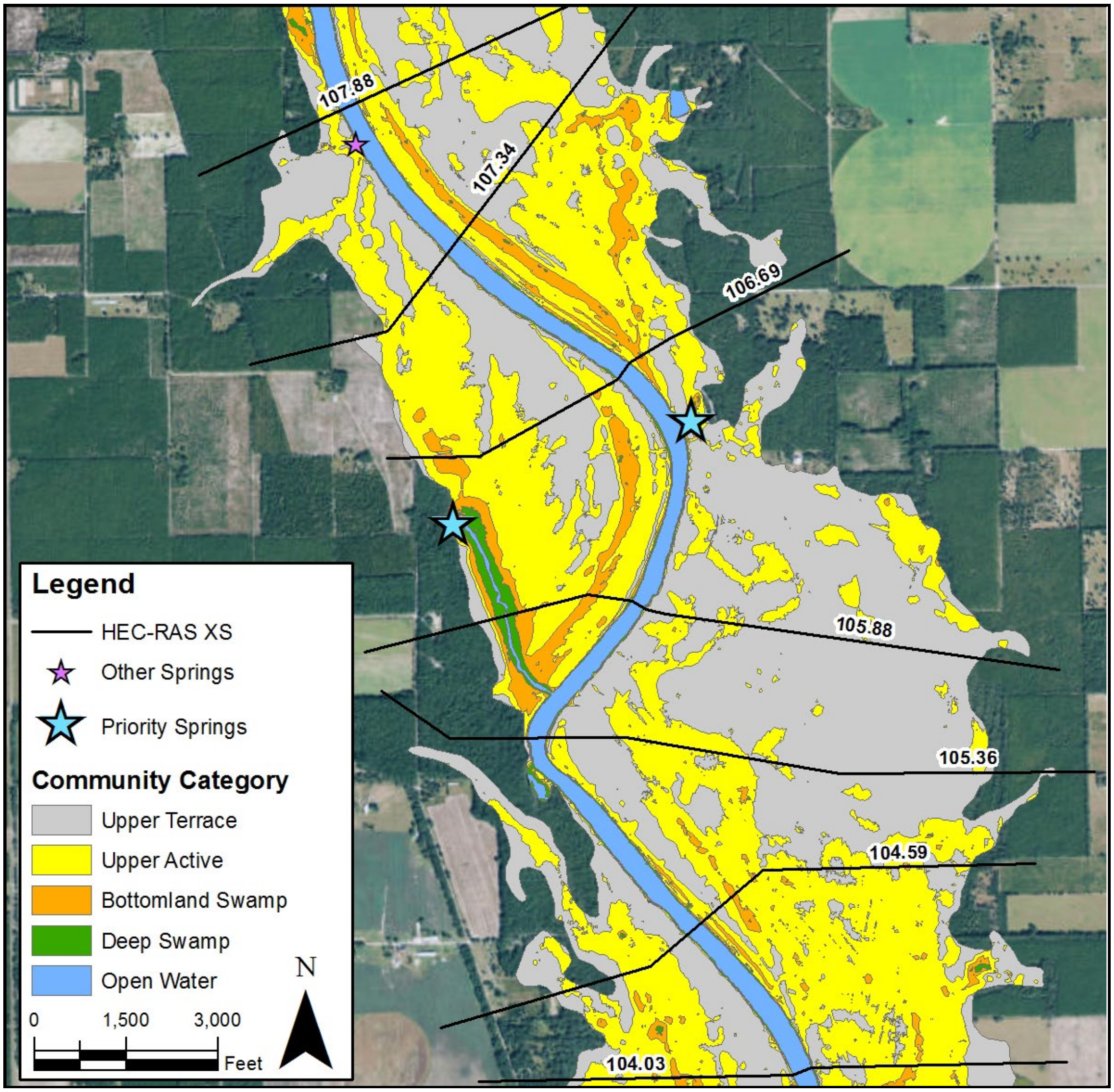


Figure 3-3. Segment of Middle Suwannee floodplain communities upstream of the Knot with the Allen Mill Pond spring run

3.2.1 Deep Swamps

Deep Swamps throughout the MSR floodplain typically have a nearly closed canopy stratum of predominately Facultative Wet (FACW) and Obligate (OBL) species (62-340.450, F.A.C.), often with very large and mature trees, moderate amounts of understory cover, and low amounts of groundcover (**Appendices III** and **IV**). The moderate shrub and low groundcover levels likely are associated with the greater depths and longer hydroperiods achieved in these wetlands, which stress and increase mortality of vegetation that typically tolerate brief periods of saturation by completely submerging it for weeks at a time. Forest composition is generally dominated by cypress trees, with some large patches alternatively or collectively dominated by overcup oak (*Quercus lyrata*), planer tree (*Planera aquatica*), popash (*Fraxinus caroliniana*), and water locust (*Gleditsia aquatica*). Some of the canopy species are also common understory components in these forests including popash, planer tree, and water locust. The understory is not always simply a younger version of the canopy. It is not uncommon to have one of these three species dominating the canopy while one or two of the others form most of the understory. This suggests a rather dynamic forest condition where spatial shifts in species composition may occur on a temporal scale in the floodplain. Swamp privet (*Forestiera acuminata*) and buttonbush (*Cephalanthus occidentalis*) also occur in patchy abundance, and some areas take on an appearance of a swamp privet thicket. Some of the shrubs occupy hummocks, which are microtopograhical features at higher elevation than the base of the swamp. Soil layers are most often thick accumulations of fines (silt and clay); complex deposits of sand, clay and loam occurring in the upper 18 inches; or deposits of fines over sand. The frequent absence of muck is notable for a major Florida river. It indicates that soil building processes are mostly physical rather than biological for this system, consistent with its major fluvial forces and wide-ranging water fluctuations.

Deep Swamp at Allen Mill Pond spring run

The greatest concentrations of these swamps occur in the lower half of the MSR, with the most expansive areas found downstream of the confluence with the Santa Fe River where the floodplain is almost twice as wide as it is upstream (**Figure 3-2**). These communities frequently associate with karst features such as spring runs and subsidence depressions. In the upper reaches of the MSR, some of the only Deep Swamps in the area occur along spring runs or other karst depressions.

Deep Swamp at Rock Sink spring run

The Florida Cooperative Land Cover Map (CLC) is a state-wide map of land cover developed by the Florida Fish and Wildlife Conservation Commission (FFWCC) in partnership with the Florida Natural Areas Inventory (FNAI). When compared to the CLC version 3.4, these Deep Swamp communities most frequently overlap with the Floodplain Swamp and Freshwater Forested Wetlands CLC land cover classes (FFWCC 2019a). The CLC classes follow the Florida Land Cover Classification System (FFWCC 2018). Based on the classification system, a Floodplain Swamp is described as occurring along or near rivers, being typically inundated, and dominated by cypress, tupelo, and/or black gum. Freshwater Forested Wetlands are a higher-level class that encompasses floodplain or depression wetlands dominated by wetland trees.

3.2.2 Bottomland Swamps

Bottomland Swamps throughout the MSR floodplain typically have a nearly closed canopy stratum of predominantly FACW species, often dominated by fast growing and comparatively short-lived tree species with low amounts of understory cover and relatively dense groundcover (**Appendices III** and **IV**). The moderate shrub and high groundcover levels likely are associated with the shallower depths and shorter durations of flooding experienced by these communities versus the Deep Swamps. Forest composition is diverse, dominated by hardwood species in most areas although some places have pines and cypress. Four main groupings of species tend to comprise the canopy in large patches. These include live oak (*Quercus virginiana*) galleries often fringing Deep Swamps; patches dominated by various combinations of ironwood (*Carpinus caroliniana*), red maple (*Acer rubrum*), and sweetgum (*Liquidamber styraciflua*); and broad areas dominated by either laurel oak (*Quercus laurifolia*), water hickory (*Carya aquatica*), or river birch (*Betula nigra*). Understory is more diverse than that of the Deep Swamps, with shorter statured and shrubby species such as Florida bully (*Sideroxylon reclinatum*), titi (*Cyrilla racemiflora*), parsley hawthorn (*Crataegus marshallii*), cedar elm (*Ulmus crassifolia*), possumhaw (*Ilex decidua*), mayhaw (*Crataegus aestivalis*), swamp dogwood (*Cornus foemina*), and bluestem palm (*Sabal minor*). The bluestem palm is a dwarf tree with seeds distributed by flood waters. Some of the most common understory plants are also canopy species including sweetgum, red maple, ironwood, American elm (*Ulmus americana*), and laurel oak.

Bottomland swamp within MSR floodplain

Geomorphic surfaces on which Bottomland Swamps are found throughout the MSR floodplain include the intermediate elevations of the floodplain on undulating surfaces, along Deep Swamp margins at the upper hillslopes along spring runs, oxbow depressions, and large polygonal depressions. They also occur within somewhat linear areas including shallow swales and lower ridges of lateral accretions, karst lineaments, and oxbow bottoms. Some are found on the lower lying alluvial ridges as well. Soil layers can be any of the textural sequences observed in the study area, except muck. This includes

Bottomland swamp within MSR floodplain sand; sand over fines; fines over sand; complex layers of sands, loam and/or fines; and silt and clay.

Bottomland swamp within MSR floodplain

Because this is a transitional community between the Deep Swamps and Upper Surfaces, some patches may classify as uplands, but the vast majority are clearly wetlands. As such, these communities are distributed virtually throughout the MSR, but are seldom the dominant community along the river valley (**Figure 3-3**).

Like the Deep Swamp communities, the Bottomland Swamp communities most frequently overlap with the Floodplain Swamp and Freshwater Forested Wetlands CLC land cover classes (FFWCC 2019a).

3.2.3 Upper Surfaces

The Upper Surface community typically has a nearly closed canopy stratum, with comparatively dense understory and groundcover among the community types (**Appendices III** and **IV**). The high shrub and high groundcover levels likely are associated with the shallower depths and shorter durations of flooding experienced by these communities versus the other communities.

Upper surface within MSR floodplain

Forest composition is diverse, dominated by hardwood species in most areas although some places have pines. Four main groupings of species tend to dominate the canopy in large patches. These include mature live oak hammocks; broad areas dominated by fast growing water oaks (*Quercus nigra*) with black gum (*Nyssa sylvatica*); mesic hammocks without a clear dominance of species but often including some combination of American holly (*Ilex opaca*), pignut hickory (*Carya glabra*), juniper (*Juniperus spp*.), cabbage palm (*Sabal palmetto*) or sweetleaf (*Symplocos tinctoria*); and patches dominated by either red maple and/or sweetgum.

The understory is more diverse than that of the other communities and many of these forests resemble thickets. Three main groupings of understory assemblages are most common including a mesic hammock group consisting of about 20 hardwood shrub and tree species; palmetto thickets; and a short-statured oak species and ericaceous shrub grouping. Statistically significant differences in the wetness preferences of the canopy versus the understory were reversed from that found in the Bottomland Swamp community. About 28% of the Upper Surface plots had a wetter canopy than understory composition, while only 16% exhibited a drier canopy than understory. Once again there is some indication that forest composition layers are not merely a shorter statured (younger) reflection of one another but also that vegetation succession patterns are shaped by punctuated hydrologic events.

Alluvial ridge community within MSR floodplain

This community strongly associates with thick sandy soils. The exceptions occurred on sand over fines, fines over sand, and mixed loam/sand/or fines layers. This community did not occur on thick pure silt or clay layers or muck. These assemblages are found on the best drained soils occurring on the floodplain's highest elevations.

Geomorphic surfaces include the broad valley flat, which could be viewed as the parent surface of the floodplain which is otherwise dissected by a variety of lower lying surfaces. In many Florida rivers, the analogous surface is much lower lying and wetter. Alluvial ridges and the ridges of lateral accretions are other characteristic and common surfaces for this community. It also occurs along the main valley hillslope where it is transitioning from the floodplain into the adjacent palustrine longleaf pine forests and other non-riparian communities.

Canopy cover averages 59% FACW+OBL, well below the regulatory wetland threshold of 80%. Hydric soil indicators averaged 16 inches below the land surface among the plots in this community, which is well below the upper 6 inches necessary to classify the soil as hydric for most indicators. The maximum depth of hydric indicators was found at 54 inches for this community. Because this is a transitional community often adjacent to the Bottomland Swamps, some of the plots are jurisdictional wetlands due to inundation frequency, rather than hydric soil conditions and species wetness indices.

Upper Surface within MSR floodplain

These communities are distributed at appropriate elevations throughout the MSR floodplain and are the most expansive type found in roughly the upper two-thirds of the study area upstream of the Santa Fe River confluence. The usual pattern is for these communities to form large 'islands' between the various types of lower-lying fluvial and karst dissections of the floodplain (**Figure 3-3**). The community is reduced in relative importance downstream of the Santa Fe River where Deep Swamps are more dominant (**Figure 3-2**). The portions of the Upper Surfaces community located throughout the floodplain at elevations above that of the alluvial ridge crest (ARC) appear to have more intense anthropogenic land use patterns and the portions below that boundary are more likely to be alluvially active. For these reasons, the Upper Surface community has been subdivided and mapped as an Upper Terrace above the alluvial ridge crest elevation and as an Upper Active community below it. In general, the Upper Active community tends to achieve its greatest cover in the upper half of the study area (**Figure 3-2** and **Figure 3-3**), perhaps because flood levels and sand availability are greater closer to the Withlacoochee River.

The Upper Surfaces community type most frequently overlapped with the Tree Plantations and Mixed Hardwood-Coniferous CLC land cover classes. Another CLC land cover that was largely represented in the mapped Upper Surfaces was the Freshwater Forested Wetlands class (FFWCC 2019a). Based on the Florida Land Cover Classification System, Tree Plantations is a higher-level class that encompasses Hardwood Plantations, Coniferous Plantations, and Wet Coniferous Plantations. These Tree Plantation classes are described in the classification system as being artificially generated through planting (FFWCC 2018). The Mixed Hardwood-Coniferous class is described as an area with co-dominance between hardwood and coniferous trees (FFWCC 2018).

3.3 Riverine and Riparian Habitat

Riverine, or instream, habitats such as pools, shoals, snags, submerged aquatic vegetation (SAV), roots, and rock provide protective cover and sources of food within an aquatic environment used by benthic macroinvertebrates, fish, and other aquatic wildlife. Benthic substrates in the river vary from fine grained muck sediments to coarse sand to limestone shoals with pebbly gravel and large exposed rock.

Naturally occurring snags are an important habitat component that provide protection from strong currents and overhead cover for fish, habitat for aquatic invertebrates, and basking sites for aquatic turtles. Snags can also be an important source of particulate organic matter adding to the system's primary productivity, and play a role in defining channel morphology by enhancing scouring and producing localized pools.

Aquatic vegetation varies widely depending upon velocities, substrate, water chemistry, and water clarity. Overall, submersed aquatic vegetation (SAV) is uncommon within the MSR channel due to deep, powerful currents and dark-colored water limiting light penetration. However, SAV is more common in MSR spring runs such as Peacock Springs and Otter Springs where water clarity is high.

Riparian, or bank, habitats along the river provide protective cover and sources of food in the form of snags, tree roots, leaves, and vegetation. Rocky limestone outcroppings and ledges also provide habitat along the banks in some sections of the river where species can attach or hide. The steep side slopes of the riverbanks typically have comparatively sparse woody vegetation between the baseflow and bankfull stages; however, a discontinuous, but persistent line of bald cypress (*Taxodium distichum*) was observed along the lower banks throughout the MSR. It was determined that the lower extent of this tree line could be used to distinguish between the open water channel and riparian bank habitat (**Appendix IV**). This breakline is useful for establishing MFLs that are protective of maintaining open water channel features.

Natural Rivers and Streams is the CLC land cover class equivalent to the Riverine and Riparian Habitat communities. This CLC class overlaps almost exclusively with mapped Riverine and Riparian communities (FFWCC 2019a). The Florida Land Cover Classification System describes Natural Rivers and Streams as stream communities with limited modification caused by human activities or where native biota are dominant (FFWCC 2018).

3.4 Biota of Particular Interest

Best available data were used to describe the biotic species in the MSR and their habitats. As described and listed in **Appendix VIII**, various taxonomic lists of invertebrates, vertebrates, and plants were reviewed to identify "at-risk species" dependent on the river's aquatic habitats and wetlands that could be affected by changes in river flows. The USFWS Southeast Region has defined "at-risk species" as those species that have either been proposed for listing, are candidates for listing, or have been petitioned for listing.

Additionally, FNAI biodiversity matrix data was reviewed, and a summary of the listed species identified as documented or potentially occurring within the MSR and its adjacent floodplain is provided in **Table 3-1** below.

Table 3-1. Listed species documented or having the potential to occur in the MSR and adjacent floodplain

Species	Common Name	FNAI State Element Rank	Florida State Listing	Federal Listing	FNAI Occurrence Status
Invertebrates					
Aphodius aegrotus	Small pocket gopher Aphodius beetle	S3?	N	N	D
Aphodius hubbelli	Hubbell's pocket gopher Aphodius beetle	S3?	N	N	D
Aphodius laevigatus	Large pocket gopher Aphodius beetle	S3?	N	N	D
Dromogomphus armatus	Southeastern spinyleg	S3	N	N	P
Gomphus geminatus	Twin-striped clubtail	S3	N	N	L
Hydroperla phormidia	A stonefly	S2	N	N	DH
Macromia alleghaniensis	Allegheny River cruiser	S1	N	N	P
Medionidus walkeri	Suwannee moccasinshell	S1	FT	T	DH, L
Mycotrupes gaigei	North peninsular Mycotrupes beetle	S2S3	N	N	D
Procambarus pallidus	Pallid cave crayfish	S2S3	N	N	L, P
Ptomaphagus geomysi	Elongate pocket gopher Ptomaphagus beetle	S2	N	N	D
Ptomaphagus schwarzi	Schwarz' pocket gopher Ptomaphagus beetle	S3	N	N	D
Selonodon simplex	Simple Cebrionid beetle	S1	N	N	DH, P
Utterbackia peninsularis	Peninsular floater	S2S3	N	N	D

Species	Common Name	FNAI State Element Rank	Florida State Listing	Federal Listing	FNAI Occurrence Status
Fish					
Acipenser oxyrinchus desotoi	Gulf sturgeon	S2?	FT	T	D, L
Ameiurus serracanthus	Spotted bullhead	S3	N	N	DH, P
Cyprinella leedsi	Bannerfin shiner	S3	N	N	P
Micropterus notius	Suwannee bass	S3	N	N	DH, P
Birds					
Antigone canadensis pratensis	Florida sandhill crane	S2	ST	N	P
Aramus guarauna	Limpkin	S3	N	N	D
Athene cunicularia floridana	Florida burrowing owl	S3	ST	N	P
Dryobates borealis	Red-cockaded woodpecker	S2	FE	E	P
Dryobates villosus	Hairy woodpecker	S3	N	N	DH
Egretta caerulea	Little blue heron	S3	ST	N	D, P
Egretta tricolor	Tricolored heron	S4	ST	N	P
Elanoides forficatus	Swallow-tailed kite	S2	N	N	D
Eudocimus albus	White ibis	S4	N	N	D, P
Falco sparverius paulus	Southeastern American kestrel	S3	ST	N	D
Mycteria americana	Wood stork	S2	FT	T	L
Peucaea aestivalis	Bachman's sparrow	S3	N	N	D, P
Mammals					
Corynorhinus rafinesquii	Rafinesque's big-eared bat	S1	N	N	P
Eptesicus fuscus	Big brown bat	S3	N	N	D
Mustela frenata olivacea	Southeastern weasel	S3?	N	N	P
Myotis austroriparius	Southeastern bat	S3	N	N	P
Neovison vison halilimnetes	Gulf salt marsh mink	S2	N	N	P
Podomys floridanus	Florida mouse	S3	N	N	DH, P
Trichechus manatus	West Indian manatee	S2	FT	T	L
Ursus americanus floridanus	Florida black bear	S4	N	N	L, P
Reptiles & Amphibians					
Alligator mississippiensis	American alligator	S4	FT(S/A)	SAT	P
Ambystoma tigrinum	Tiger salamander	S3	N	N	P
Amphiuma pholeter	One-toed amphiuma	S3	N	N	P
Crotalus adamanteus	Eastern diamondback rattlesnake	S3	N	N	DH, P
Crotalus horridus	Timber rattlesnake	S3	N	N	DH
*Dermochelys coriacea**	Leatherback sea turtle*	S2	FE	E	P

Species	Common Name	FNAI State Element Rank	Florida State Listing	Federal Listing	FNAI Occurrence Status
Drymarchon couperi	Eastern indigo snake	S3	FT	T	D, DH, L, P
Gopherus polyphemus	Gopher tortoise	S3	ST	C	D, DH, L, P
Heterodon simus	Southern hognose snake	S2S3	N	N	P
Lampropeltis extenuata	Short-tailed snake	S3	ST	N	P
Lithobates capito	Gopher frog	S3	N	N	P
Macrochelys suwanniensis	Suwannee alligator snapping turtle	S1S2	ST	PT	D, P
Pseudemys concinna suwanniensis	Suwannee cooter	S3	N	N	D, DH, P
Plants					
Agrimonia incisa	Incised groove-bur	S2	T	N	P
Andropogon arctatus	Pine-woods bluestem	S3	T	N	P
Carex chapmannii	Chapman's sedge	S3	T	N	P
Forestiera godfreyi	Godfrey's swampprivet	S2	E	N	L, P
Gymnopogon chapmanianus	Chapman's skeletongrass	S3	N	N	P
Leitneria floridana	Corkwood	S3	T	N	P
Litsea aestivalis	Pondspice	S2	E	N	P
Magnolia ashei	Ashe's magnolia	S2	E	N	P
Matelea floridana	Florida spiny-pod	S2	E	N	P
Phyllanthus liebmannianus ssp. platylepis	Pinewoods dainties	S2	E	N	D, P
Physostegia godfreyi	Apalachicola dragon-head	S3	T	N	P
Platanthera integra	Yellow fringeless orchid	S3	E	N	P
Pteroglossaspis ecristata	Giant orchid	S2	T	N	D, P
Pycnanthemum floridanum	Florida mountain-mint	S3	T	N	D, L, P
Rhexia parviflora	Small-flowered meadowbeauty	S2	E	N	P
Salix floridana	Florida willow	S2	E	N	P
Sideroxylon lycioides	Buckthorn	S2	E	N	P
Spigelia loganioides	Pinkroot	S2	E	N	P

Notes:

- *While the leatherback sea turtle was captured by the FNAI biodiversity matrices that overlap with the MSR and adjacent floodplain, this species is unlikely to be found in this area due to their habitat and foraging requirements (FFWCC 2021e).

Table data sources:

- Occurrence data: FNAI Biodiversity Matrix Map Server, reports generated on 2021-08-29. Website accessed August 2021: https://www.fnai.org/BiodiversityMatrix/index.html
- Rank data and explanation of ranks (unless otherwise cited): FNAI – Element Tracking Summary 2019-04-19. Website accessed August 2021: https://www.fnai.org/PDFs/tracking/Element_tracking_summary_current.pdf

Explanation of ranks and listings:

- C = Candidate species for which federal listing agencies have sufficient information on biological vulnerability and threats to support proposing to list the species as Endangered or Threatened.
- E = Endangered: species in danger of extinction throughout all or a significant portion of its range.
- FE = Listed as Endangered Species at the Federal level by the U. S. Fish and Wildlife Service
- FT = Listed as Threatened Species at the Federal level by the U. S. Fish and Wildlife Service
- FT(S/A) = Federal Threatened due to similarity of appearance
- N = Not currently listed, nor currently being considered for listing.
- PT = Proposed threatened, currently being considered for listing.
- S1 = Critically imperiled in Florida because of extreme rarity (5 or fewer occurrences or less than 1000 individuals) or because of extreme vulnerability to extinction due to some natural or man-made factor.
- S2 = Imperiled in Florida because of rarity (6 to 20 occurrences or less than 3000 individuals) or because of vulnerability to extinction due to some natural or man-made factor.
- S2? = Possibly imperiled in Florida because of rarity (6 to 20 occurrences or less than 3000 individuals) or because of vulnerability to extinction due to some natural or man-made factor (FNAI 2021).
- S3 = Either very rare and local in Florida (21-100 occurrences or less than 10,000 individuals) or found locally in a restricted range or vulnerable to extinction from other factors.
- S3? = Possibly either very rare and local in Florida (21-100 occurrences or less than 10,000 individuals) or found locally in a restricted range or vulnerable to extinction from other factors (FNAI 2021).
- S4 = Apparently secure in Florida (may be rare in parts of range).
- SAT = Treated as threatened due to similarity of appearance to a species which is federally listed such that enforcement personnel have difficulty in attempting to differentiate between the listed and unlisted species (FNAI 2021).
- ST = State population listed as Threatened by the FFWCC. Defined as a species, subspecies, or isolated population which is acutely vulnerable to environmental alteration, declining in number at a rapid rate, or whose range or habitat is decreasing in area at a rapid rate and as a consequence is destined or very likely to become an endangered species within the foreseeable future.
- T = Threatened: species likely to become endangered within the foreseeable future throughout all or a significant portion of its range.

Explanation of occurrence status:

- D = Documented - There is a documented occurrence in the FNAI database of the species or community within this Matrix Unit.
- DH = Documented-Historic - There is a documented occurrence in the FNAI database of the species or community within this Matrix Unit; however, the occurrence has not been observed/reported within the last twenty years.
- L = Likely - The species or community is known to occur in this vicinity, and is considered likely within this Matrix Unit because: 1. a documented occurrence overlaps this and adjacent Matrix Units, but the documentation isn't precise enough to indicate which of those Units the species or community is actually located in; or 2. there is a documented occurrence in the vicinity and there is suitable habitat for that species or community within this Matrix Unit.
- P = Potential - This Matrix Unit lies within the known or predicted range of the species or community based on expert knowledge and environmental variables such as climate, soils, topography, and landcover.

The preceding species occurrences represent the river main stem, as well as several natural floodplain communities, including alluvial forest, bird rookery, blackwater stream, bottomland forest, floodplain swamp, geological feature, sandhill, spring-run stream, upland hardwood forest, and xeric hammock. Fluvial dynamics are instrumental in creating and maintaining adjacent surfaces/communities and thus their support of listed, rare, and non-aquatic/wetland-dependent species and commensals is a critical component of this MFL.

3.4.1 Freshwater Invertebrates

Invertebrates play an important role in freshwater food webs and are frequently used to assess the health of a waterbody. **Table 3-1** provides a list of 14 invertebrates identified by FNAI as having the potential to occur in the MSR and adjacent floodplain based on FNAI's occurrence data. Of those 14 species identified by FNAI, one species in federally listed as threatened, the Suwannee moccasinshell (*Medionidus walkeri*). The rest of the species identified by FNAI are listed as living within the MSR habitat but are not currently listed as threatened or endangered at the state or federal level. **Appendix VIII, Table 7** provides a more exhaustive list of 47 freshwater invertebrate species (5 of which overlap with FNAI) that the FFWCC considers to be of conservation need in the Suwannee River basin, including mussels, snails, crustaceans, and insects. Species that both FNAI and FFWCC identified include the southeastern spinyleg (*Dromogomphus armatus*), *Hydroperla phormidia*, Suwannee moccasinshell, Pallid Cave crayfish (*Procambarus pallidus*), and peninsular floater (*Utterbackia peninsularis*).

On the list of invertebrate species identified by FFWCC, one species is federally designated as endangered: the oval pigtoe (*Pleurobema pyriforme*) mussel, described in more detail below. Two species are federally designated as threatened: the Squirrel Chimney cave shrimp (*Palaemonetes cummingi*) and the Suwannee moccasinshell. The Suwannee moccasinshell is described in more detail below. The Squirrel Chimney cave shrimp has only been found in the Squirrel Chimney sinkhole near Gainesville, Alachua County, Florida and for which scant records exist. Six species are under review for federal listing: Ichetucknee siltsnail (*Floridobia mica*), Santa Fe cave crayfish (*Procambarus erythrops*), Pallid Cave crayfish, Spider Cave crayfish (*Troglocambarus maclanei*), Florida cave amphipod (*Crangonyx grandimanus*), and Hobbs' cave amphipod (*Crangonyx hobbsi*). These six species are still under review and were proposed under a petition from the Center for Biological Diversity to list 404 aquatic, riparian, and wetland species from the Southeast as endangered or threatened with critical habitat (Center for Biological Diversity 2010; Federal Register 2011). The remaining species identified by FFWCC as being imperilled in the Suwannee River basin are either designated as Species of Greatest Conservation Need (SGCN) or not listed. The SGCN designation prioritizes these species for research but carries no regulatory authority. More information regarding the SGCN designations is provided in Florida's State Wildlife Action Plan (FFWCC 2019b). Mayflies (Ephemeroptera) and caddisflies (Trichoptera) dominate the list with 24 and 10 species, respectively. Their life stages and feeding patterns are such that the combined protection of Ephemeroptera, Plecoptera, and Trichoptera (EPT) is presumed to be protective of these insects.

Oval Pigtoe Mussel

The federally endangered oval pigtoe mussel is a unionid mussel that has been found historically in the Suwannee River basin. The oval pigtoe occurs in small to medium-sized creeks to small rivers where it inhabits silty sand to sand and gravel substrates, usually in slow to moderate current (Williams & Butler, 1994). Stream channels appear to offer the best habitat for this species. The basin status survey located 85% of the specimens in sandy substrates associated with either detritus, or clay, or silt, or cobble (Brim & Williams, 2000). In the Suwannee River drainage, specimens of the oval pigtoe were associated with sandy mud and coarse sand sediments with little to no detritus (Blalock-Herod, 2000). Critical habitat for the oval pigtoe was proposed in 2006 (71 FR 32746) and the final rule published in 2007 (72 FR 64286). Critical habitat for this species within the SRWMD is limited to segments of the Santa Fe and New Rivers (72 FR 64286).

Little is known regarding the habitat requirements of the oval pigtoe. The larvae (glochidia) of mussels, however, are parasitic, living typically on the gills of fins of a host fish. Williams and O'Brien (2002) considered only the sailfin shiner, *Pleronotropis hypselopterus*, as a primary host fish, but were also able to transform juvenile specimens on the gills of eastern mosquitofish (*Gambusia affinis*) and guppies (*Poecilia reticulata*) in the laboratory. The sailfin shiner now belongs to a species complex that was phylogenetically divided into 5 species (Mayden and Allen, 2015) and the species which occurs in the Suwannee River is now considered to be the metallic shiner (*Pteronotropis metallicus*). The metallic shiner is generally common and occurs from the Apalachicola River east to the St. Mary's River and south to the Alafia River in Florida (Robins et al., 2018). Metallic shiners prefer habitat near vegetation and woody debris in sandy and muddy pools and runs of headwaters, creeks, and small to medium rivers (Robins et al., 2018). The metallic shiner was used as a surrogate for the occurrence and protection of the oval pigtoe (and other mussels) in this MFL.

Suwannee Moccasinshell

The federally threatened Suwannee moccasinshell is a small freshwater mussel endemic to the Suwannee River Basin in Florida and Georgia. In 2012, the Suwannee Moccasinshell was rediscovered after a 16-year hiatus between collections (Johnson et al. 2016). Subsequently, this species was listed as federally threatened under the Endangered Species Act in October 2016 (81 FR 69417). In 2019, the USFWS proposed designating the mainstem Suwannee River, additional portions of the Santa Fe River, and the Withlacoochee River, as critical habitat for the Suwannee Moccasinshell (84 FR 65325). In 2021, the final rule was published for the designation of critical habitat along approximately 116 miles of the Suwannee River, 27 miles of Upper Santa Fe River, and 47 miles of the Withlacoochee River (86 FR 34979). The Suwannee moccasinshell typically inhabits small to large rivers where it lives in bottom substrates composed of fine sand or sand with some gravel, in areas with slow to moderate current. Individuals are often found near embedded logs and other stable woody material which may provide a flow refuge and shelter. The Suwannee moccasinshell's historical range includes the lower and middle Suwannee River and the Santa Fe River sub-basin in Florida, and the lower reach of the Withlacoochee River in Florida and Georgia. Its range has declined in recent decades, and it is presently known only from the Suwannee River main channel and the lower Santa Fe River in Florida. Holcomb et al. (2018) studied hydrologic factors influencing the presence of the Suwannee moccasinshell and found that this species was more likely to be found in areas where upstream springs had cumulative discharge inputs exceeding 28 cubic meters per second. Furthermore, on June 3, 2021, one live individual was observed at the Ruth Springs Conservation Area, along the shore of the Suwannee River downstream of Ruth Springs (personal communication, Sky Notestein - SRWMD, 6/7/2021). In laboratory trials, Suwannee moccasinshell glochidia transformed primarily on the blackbanded darter and to a lesser extent on the brown darter (Johnson et al. 2016). Other species that were exposed to Suwannee moccasinshell glochidia but did not result in juvenile mussels include the dollar sunfish (*Lepomis marginatus*), weed shiner (*Notropis texanus*), hogchoker (*Trinectes maculatus*), speckled madtom (*Noturus leptacanthus*), swamp darter (*Etheostoma fusiforme*), and eastern mosquitofish (*Gambusia holbrooki*). Darters were used as surrogates for the occurrence and protection of the Suwannee moccasinshell (and other mussels) in this MFL.

3.4.2 Fish

FFWCC has documented the presence of 119 species of fish within the Suwannee River and its tributaries. FFWCC provided two sets of fisheries data collected primarily by electroshocking. These were reviewed and summarized in **Table 3-2**. The historical database provides survey results obtained from 1972 to 1973 and 1982 to 1999, and the more contemporary dataset contains results spanning 2017 to 2019. The Gulf sturgeon (*Acipenser oxyrinchus desotoi*), described in more detail below, is the only listed fish species found in the MSR. Also described below is the Suwannee bass, an important sport fish which has an FNAI State Element Rank of S3, marking it as a potentially rare species due to limited occurrences, range, or vulnerability.

Table 3-2. Species of fish in the Suwannee River Reported by FFWCC (1972-2019)

Genus	Species	Common Name
Acantharchus	*pomotis*	Mud sunfish
Acipenser	*oxyrinchus desotoi*	Gulf sturgeon
Alosa	*alabamae*	Alabama shad
Ameiurus	*catus, natalis, nebulosus, serracanthus*	White bullhead, yellow bullhead, brown bullhead, spotted bullhead
Amia	*calva*	Bowfin
Anchoa	*mitchilli*	Bay anchovy
Anguilla	*rostrata*	American eel
Aphredoderus	*sayanus*	Pirate perch
Archosargus	*probatocephalus*	Sheepshead
Bairdiella	*chrysoura*	Silver perch
Bathygobius	*soporator*	Frillfin goby
Brevoortia	*sp.*	Menhaden sp.
Centrarchus	*macropterus*	Flier
Centropomus	*undecimalis*	Common snook
Chaenobryttus	*gulosus*	Warmouth
Ctenogobius	*shufeldti*	American freshwater goby
Cynoscion	*arenarius, nebulosus, nothus*	Sand weakfish, spotted seatrout, silver seatrout
Cyprinella	*leedsi, venusta*	Bannerfin shiner, blacktail shiner
Dormitator	*maculatus*	Fat sleeper
Dorosoma	*cepedianum, petenense*	American gizzard shad, threadfin shad
Elassoma	*evergladei, okefenokee, sp., zonatum*	Everglades pygmy sunfish, Okefenokee pygmy sunfish, pygmy sunfish sp., banded pygmy sunfish
Eleotris	*pisonis*	Spinycheek sleeper
Enneacanthus	*chaetodon, gloriosus, obesus*	Blackbanded sunfish, bluespotted sunfish, banded sunfish
Erimyzon	*sucetta*	Lake chubsucker
Esox	*americanus, americanus vermiculatus, niger*	Redfin pickerel, American pickerel, chain pickerel
Etheostoma	*edwini, fusiforme, sp.*	Brown darter, swamp darter, darter sp.
Eucinostomus	*argenteus, gula, harengulus, sp.*	Silver mojarra, jenny mojarra, tidewater mojarra, mojarra sp.
Fundulus	*chrysotus, confluentus, escambiae, grandis, lineolatus, seminolis*	Golden topminnow, marsh killifish, russetfin topminnow, Gulf killifish, lined topminnow, Seminole killifish
Gambusia	*affinis, holbrooki*	Mosquitofish, eastern mosquitofish
Gobiosoma	*bosci, robustum, hastatus*	Naked goby, code goby, highfin goby
Heterandria	*formosa*	Least killifish
Ictalurus	*punctatus*	Channel catfish

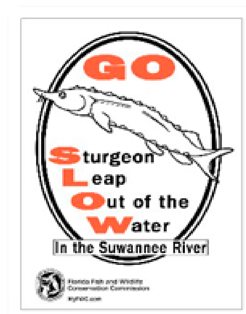
Jordanella	*floridae*	Florida flagfish
Labidesthes	*sicculus*	Brook silverside
Lagodon	*rhomboides*	Pinfish
Lepisosteus	*osseu, platyrhincus*	Longnose gar, Florida gar
Lepomis	*auritus, punctatus x L. miniatus, punctatus, microlophus, marginatus, macrochirus, gulosus*	Redbreast sunfish, spotted sunfish hybrid, spotted sunfish, redear sunfish, dollar sunfish, bluegill, warmouth
Leptolucania	*ommata*	Pygmy killifish
Lucania	*goodei, parva*	Bluefin killifish, rainwater killifish
Lutjanus	*griseus*	Gray snapper
Menidia	*beryllina, peninsulae*	Inland silverside, tidewater silverside
Micropogonias	*undulatus*	Atlantic croaker
Micropterus	*notius, salmoides*	Suwannee bass, largemouth bass
Minytrema	*melanops*	Spotted sucker
Morone	*chrysops x M. saxatilis*	Hybrid striped bass, morone
Mugil	*cephalus, curema*	Striped mullet, white mullet
Myrophis	*punctatus*	Speckled worm eel
Notemigonus	*crysoleucas*	Golden shiner
Notropis	*petersoni, texanus, maculatus, harperi*	Coastal shiner, weed shiner, taillight shiner, redeye chub
Noturus	*gyrinus, leptacanthus*	Tadpole madtom, speckled madtom
Oligoplites	*saurus*	Leatherjacket
Opsopoeodus	*emiliae*	Pugnose minnow
Paralichthys	*albigutta, lethostigma, dentatus*	Gulf flounder, southern flounder, summer flounder
Percina	*nigrofasciata*	Blackbanded darter
Poecilia	*latipinna*	Sailfin molly
Pogonius	*cromis*	Black drum
Pomoxis	*nigromaculatus*	Black crappie
Pteronotropis	*hypselopterus, metallicus*	Sailfin shiner, metallic shiner
Sciaenops	*ocellatus*	Red drum
Strongylura	*marina*	Atlantic needlefish
Syngnathus	*scovelli*	Gulf pipefish
Trinectes	*maculatus*	Hogchoker
Umbra	*pygmaea*	Eastern mudminnow

Gulf Sturgeon

The Gulf sturgeon (*Acipenser oxyrinchus desotoi)*, listed as threatened by the USFWS, is an iconic fish of the Suwannee River. The Gulf sturgeon is an anadromous fish (breeds in freshwater after migrating upriver from marine and estuarine environments), which inhabits coastal rivers from Louisiana to Florida during warmer months and winters in estuaries, bays, and the Gulf of Mexico (68 FR 13370). With the exception of the Suwannee River, which supports the largest and most viable Gulf sturgeon population in all the coastal rivers of the Gulf of Mexico, dams, pollution, and overfishing have severely depleted most stocks of Gulf sturgeon (Carr et al. 1996). The Suwannee River main stem, beginning from its confluence with Long Branch Creek in Hamilton County, downstream to the mouth of the Suwannee River, has been federally designated as critical habitat for the Gulf sturgeon, falling under the joint jurisdiction of the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) (50 CFR 226.214).

Gulf sturgeon observed jumping in MSR

Adult Gulf sturgeon range from four to eight feet in length, with adult females larger than males (68 FR 13370). They can weigh up to 300 pounds and have dorso-ventral body depths of 12 to 18 inches. These dimensions generally define the passage depth and channel width requirements for Gulf sturgeon. Food habits of the adult Suwannee River population focus primarily on brachiopods, followed by amphipods, brittle stars, and other smaller prey (Price, 2019). Feeding areas for Gulf sturgeon are focused on the Suwannee estuary benthic habitats with a near absence of feeding during spawning.



The MSR is important to Gulf sturgeon both as a passageway to and from spawning grounds located in the upper reaches of the Suwannee and as a “holding area” where sturgeon reside during their time in the river. Peak migrations from the Gulf of Mexico into the Suwannee River occur during March and April, and soon after they enter the river, adult fishes move into the upper reaches of the river and spawn (Chapman & Carr, 1995). Sturgeon require gravel substrate for spawning, which is rare in the Suwannee, and there are only four documented spawning grounds in the Suwannee mainstem, all located upstream of the MSR study area (Sulak & Randall, 2009) (**Figure 3-4**). A study conducted on the Suwannee River by Sulak et al. (2013) resulted in some of the most comprehensive discoveries and information regarding the spawning and early life history of the Gulf sturgeon. Following spring spawning, adults descend downriver and congregate with immature fish and non-spawning adults for most of the year (8 to 9 months) in holding areas, which are river reaches that appear to have hydrodynamic characteristics favorable to sturgeon (Randall & Sulak, 2007). There are eight distinct holding areas along the Suwannee mainstem, five of which are located within the Middle Suwannee River (**Figure 3-5**). Note that the holding area at RKM 55 (RM 34) is located downstream of the mouth of Fanning Springs, which is located just outside the project area.

During their time in the holding areas, Gulf sturgeon movement and feeding activity essentially ceases, which is probably important to energy conservation (Sulak et al. 2007). A typical sturgeon holding area on the Suwannee consists of a 1,600 to 6,500 ft long, ten to 13 ft deep, sand-bottom run lying just downstream of a 13 to 23 ft deep scour hole and is further limited downstream by a three to seven ft deep sand shoal (Sulak et al. 2007). Some holding areas occur near a named spring, such as Anderson Spring, Pothole Spring, and Fanning Spring, and some occur near river confluences (such as the confluence with the Santa Fe River) and major river bends. Spring outflows, like river confluences and river bends, are an important erosional agent over time, scouring deep holes that can become holding areas (Sulak & Randall, 2009). These geomorphic associations with holding areas indicate features maintained by interactions between fluvial forces and sediment transport that occur mainly during bankfull and flood events in the river, thus adding bearing on maintaining these processes for the direct benefit of sturgeon. It also indicates that maintaining spring flows as scour agents may be important.

A second spawning event occurs in the fall, from September-October (Randall and Sulak 2012), due to unsynchronized gonad maturation in the adult sturgeon population and the sturgeon delaying spawning if conditions during the spring migration are not conducive to spawning or larvae survival (Sulak et al., 2013). In some years, the fall spawn could contain more mature spawning individuals than the spring spawn, depending on the conditions of the river and mature sturgeon population (Sulak et al., 2013). After taking advantage of the fall spawning season, as river water temperatures cool in the fall, starving adult and immature sturgeon migrate back to the Gulf from September through November to forage in the productive waters (Price, 2019).

The USGS has maintained a mark-recapture database of Gulf sturgeon in the Suwannee River since 1986, with approximately 10,000 tagged individuals over the years (personal communication, Michael Randall ;)-USGS, 4/12/2021). Many of the netting sites have been in the MSR. Since 2007, the USGS has maintained some version of a passive telemetry array in the river, using Vemco tags and equipment. Currently, 19 receivers are deployed between the river mouth and Woods Ferry, with approximately 50 active tags in sturgeon. In the MSR, receivers are located at Ellaville, Dowling Park, Mayo, Troy Springs, Hatch Bend, Rock Bluff, Old Town Trestle, and Wilcox. Price (2019) used these data and the deployment of egg pads to identify potential new spawning locations (**Figure 3-6**). It is unclear whether the newly identified spawning locations are a result of spawning range expansion or advancements in technology allowing for enhanced biological inference.

As part of the MFLs assessment, Gulf sturgeon passage depths were assessed at prominent shoals along the MSR to determine the limiting shoal and associated flow for a sturgeon passage MFL. Both the February-April and the September-November migrations were assessed for seasonality. Additionally, instream physical habitat modeling was conducted to assess Gulf sturgeon habitat, as described in **Section 5.2.2**.

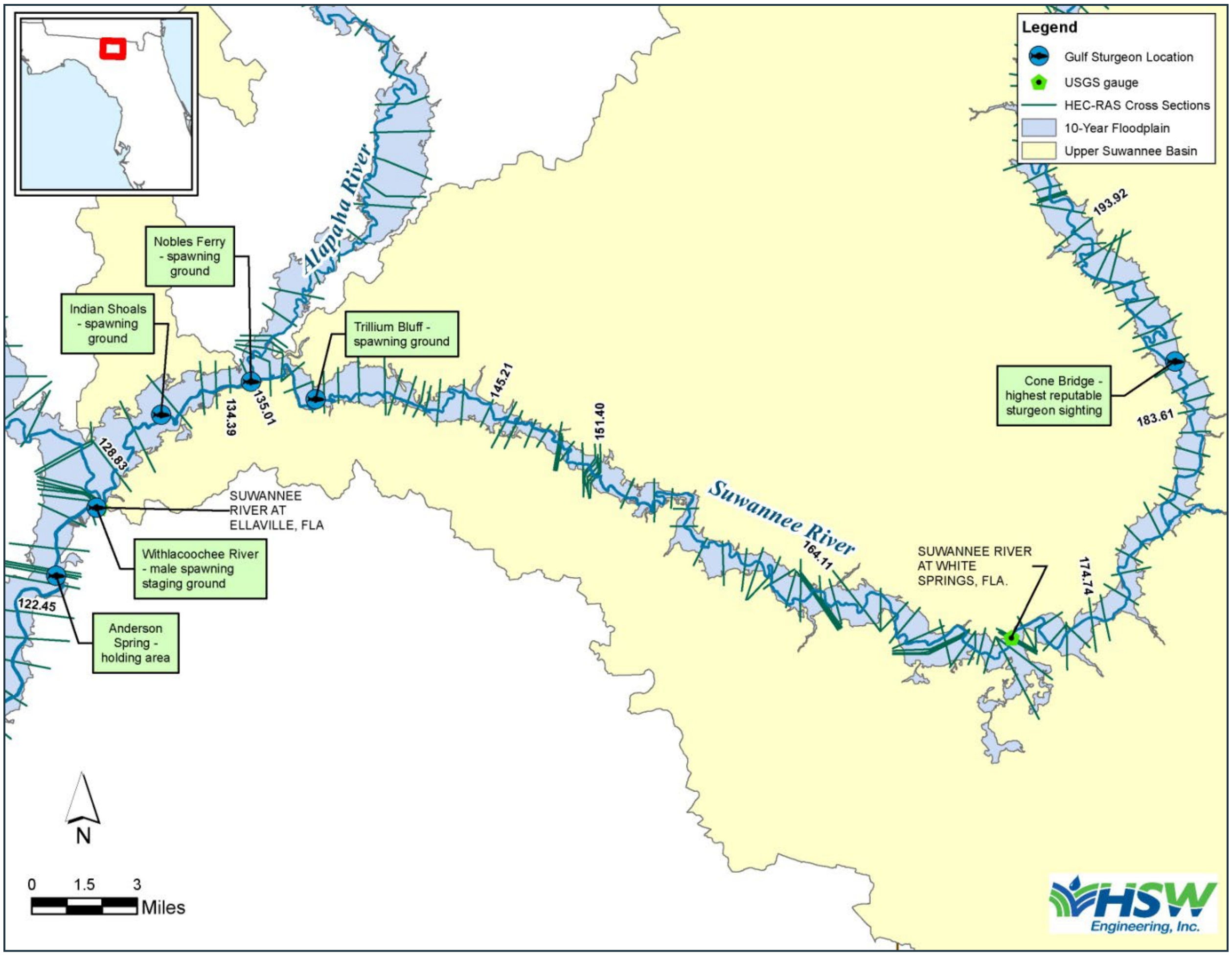


Figure 3-4. Gulf Sturgeon spawning locations
(Source: HSW, 2016)

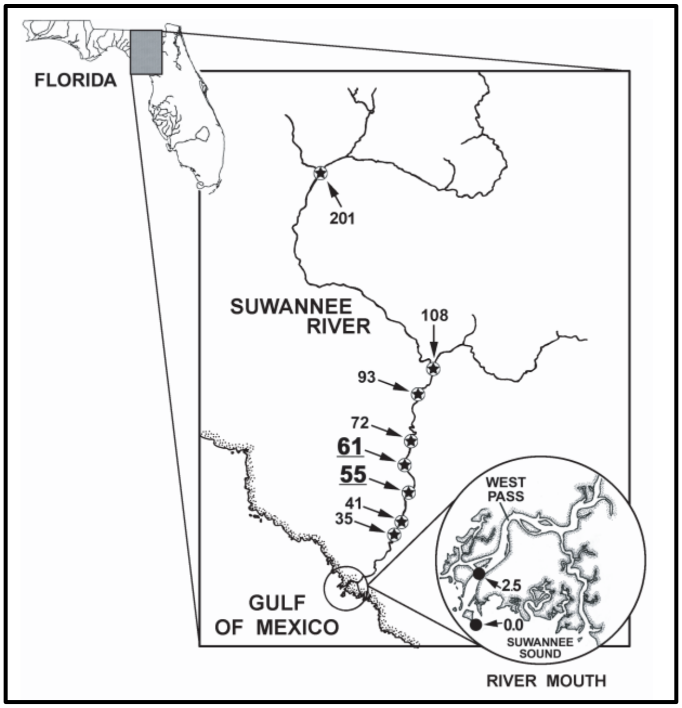


Figure 3-5. Gulf Sturgeon holding areas (by river kilometer) (Source: Sulak et al. 2007)

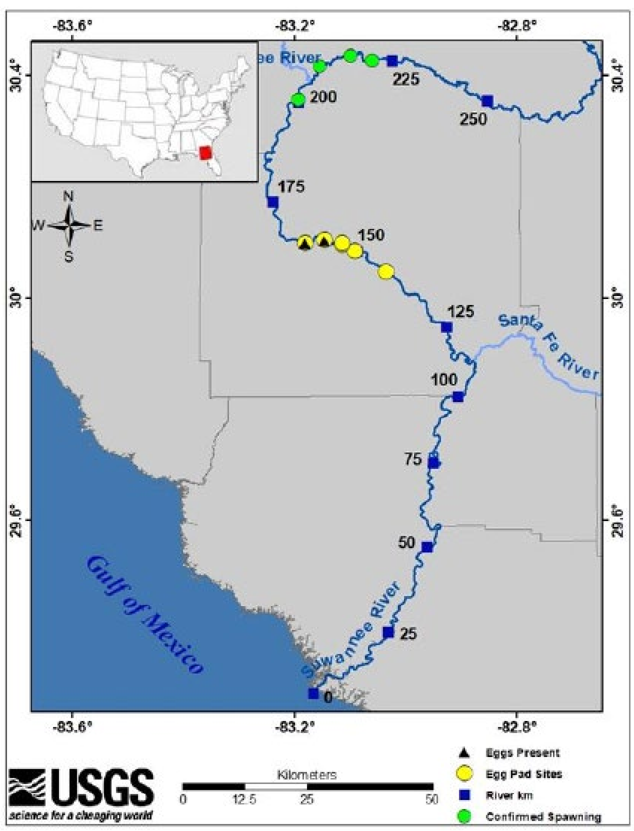


Figure 3-6. Map of deployed egg pads in the Suwannee River (Source: Price, 2019)

Suwannee Bass

The Suwannee bass (*Micropterus notius*) is not listed as a threatened or endangered species; however, it is listed as S3 under the FNAI State Element Rank. An S3 rank is assigned by FNAI to species that are "*either very rare and local in Florida (21-100 occurrences or less than 10,000 individuals) or found locally in a restricted range or vulnerable to extinction from other factors*" (FNAI 2021).

The Suwannee bass is a heavy-bodied bass, which inhabits rivers in northern Florida up to southern Georgia (FFWCC 2021a). The Suwannee Bass is differentiated from the largemouth bass by the presence of teeth on the tongue (FNAI 2018), and the upper jaw does not extend beyond the eye. The Suwannee bass typically occurs in rivers with limestone or woody armoring where the current is moderate to fast (FFWCC 2021a). Adult Suwannee bass measure between 12 to 16 inches and have a similar coloration to the largemouth bass (FNAI 2018, FFWCC 2021a). Preferred habitat for the Suwannee bass is characterized by neutral or basic water occurring near springs connected to the limestone aquifer (FNAI 2018). Based on the preferred habitat, the MSR provides important and stable habitat for the Suwannee bass. Within the Suwannee River, this species is most common in the middle reach of the river, occasionally found in the coastal portion of the river, and rarely found in the upper reaches near the Okefenokee Swamp (FNAI 2018).

3.4.2.1 Seasonality

Fish commonly found in the Suwannee River system spawn three to four months during spring and summer (**Table 3-3**). Other species, such as the Gulf sturgeon, spawn for two months in the spring and then a separate two months in the fall, while the bluegill sunfish and spotted sunfish have extended spawning periods. Spawning seasons are dependent on food availability and environmental factors including temperature, water chemistry, water depth, and water velocity. Critical to the seasonality of spawning and fry, spawning habitat must be readily available and meet appropriate environmental factors.

Table 3-3. Seasonality of Relevant Fish Species Spawning

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Reference
Gulf sturgeon													Chapman & Carr, 1995; Sulak & Randal, 2009
Suwannee bass													Strong et al. 2010
Largemouth bass			X	X	X	X	X						Rogers & Allen 2010
Bluegill sunfish				X	X	X	X	X	X	X	X		Bass Fishing Florida 2021a
Channel catfish				X	X	X	X						Chapman 2018
Redbreast sunfish					X	X	X	X	X				Bass Fishing Florida, 2021b
Spotted sunfish			X	X	X	X	X	X	X	X			Hill & Cichra, 2005

Note(s):

- Highlighted cells indicate spawning months; X indicates fry seasonality (Source for fry seasonality is personal communication with Eric Nagid - FFWCC, September 2021)

3.4.3 Birds

As shown in **Table 3-1**, the MSR and adjacent floodplain offers suitable habitat for twelve listed bird species. The federally endangered red-cockaded woodpecker (*Dryobates borealis*) resides in pine ecosystems adjacent to the Suwannee River. The federally threatened wood stork (*Mycteria americana*) prefers to feed in shallow water areas. Three species listed as threatened by the State of Florida, the little blue heron (*Egretta caerulea*), tricolored heron (*Egretta tricolor*), and Florida sandhill crane (*Antigone canadensis pratensis*) are dependent upon wetland/river/stream/lake systems for their food and upon shoreline woody vegetation for their nesting/reproductive activities. Two additional state threatened species that inhabit open prairie and sparsely vegetated areas within the MSR floodplain are the Florida burrowing owl (*Athene cunicularia floridana*) and the southeastern American kestrel (*Falco sparverius paulus*). The five remaining species that are not listed as threatened or endangered have FNAI State Element Rank and also utilize habitats found within the MSR: limpkin (*Aramus guarauna*), swallow-tailed kite (*Elanoides forficatus*), white ibis (*Eudocimus albus*), Bachman's sparrow (*Peucaea aestivalis*), and hairy woodpecker (*Dryobates villosus*). By protecting various instream and floodplain communities across a wide range of seasonal and interannual flow variability, these species are presumed to be protected by the MFL.

3.4.4 Mammals

As shown in **Table 3-1**, the MSR and adjacent floodplain support two species with FNAI State Element Ranks, the big brown bat (*Eptesicus fuscus*) and the southeastern weasel (*Mustela frenata olivacea*). Additional species listed as living within the MSR habitat, but are not currently listed as threatened or endangered at the state or federal level, include Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), southeastern bat (*Myotis austroriparius*), Gulf salt marsh mink (*Neovison vison halilmnetes*), Florida mouse (*Podomys floridanus*), and the Florida black bear (*Ursus americanus floridanus*). The West Indian manatee (*Trichechus manatus*) is known to occur within the MSR and is described in more detail below.

<u>*West Indian Manatee*</u>

The threatened West Indian manatee, or Florida manatee (*Trichechus manatus latirostris*), utilizes portions of the Suwannee River. While the USFWS has not established any portion of the Suwannee River as critical habitat and none of the MSR springs has been identified as primary warm water refugia for manatees, the basin's springs and submerged aquatic vegetation (SAV) are important resources available for manatees. The Suwannee River Springs complex, which includes Hart, Troy, Otter, and other springs, is listed in the FWC's Warm-Water Action Plan as a secondary refuge with unpredictable manatee use (Valade et al, 2020). The use and importance of the Suwannee River Springs Complex as a warm-water refuge is likely to increase in the near future as power plant thermal discharges are reduced or eliminated (personal communication, Eric Nagid - FFWCC, 7/1/2021). The secondary refuge classification is described in the Florida Manatee Warm-Water Habitat Action Plan as follows:

- *"Site is established with either predictable or unpredictable use by manatees. Site is regionally important.*
- *Thermal quality is typically medium or low and may be unreliable in cold weather and is unreliable in severe weather*
- *Typically, medium or low manatee use in mild or cold weather, but low or no manatee use in severe weather.*
- *Site is often a low flow spring, inconsistent power plant or passive thermal basin."*

Currently manatees appear to be infrequent in the MSR, particularly upstream of Branford. Manatees are known to travel up the Suwannee River into the Santa Fe River and into the Ichetucknee River, which has large SAV meadows. Ichetucknee Springs State Park maintains manatee sighting records with over 450 sightings recorded to date; while only five manatee sightings have been recorded at Troy Springs State Park (based on OFS database; WSI, 2021). Parks along the MSR (Troy Springs, Peacock Springs, Lafayette Blue, and Suwannee River State Parks) either have not documented manatee sightings as rigorously as has been done in the Ichetucknee or manatees infrequently travel upstream of Branford.

Although manatees are rarely sighted upstream of Branford where shoals are a concern, consideration was given to their depth requirements. The minimum observed water depth that a manatee can use as a means of travel is 2.7 ft, as described by Worthy in 2005 (SWFWMD, 2008). A more conservative minimum water depth for travel is 3.0 ft, as initially used in the Weeki Wachee MFL 2008 report. It is acknowledged that a more comprehensive depth value that takes into account the thermal refuge needs of manatees is 3.8 ft, which has been used in several MFL reports, including St. Mark's River Rise MFL report (2019); Wakulla Springs MFL report (2021); and ultimately the Weeki Wachee MFL report (2008). However, since manatees are rarely sighted above Branford in areas where shoals could prevent passage and the MSR is not a primary thermal refuge, the elevation determined for Gulf sturgeon passage, at which at least 3 feet of water covers 15 feet of streambed (HSW, 2021), should provide sufficient water depth for the safe passage of manatees.

3.4.5 Reptiles and Amphibians

The MSR supports one federally-threatened species, the eastern indigo snake (*Drymarchon couperi*), described in more detail below; one federally-threatened due to similarity of appearance species, the American alligator (*Alligator mississippiensis*); three state threatened species, the gopher tortoise (*Gopherus polyphemus*), short tailed snake (*Lampropeltis extenuata*), and the Suwannee alligator snapping turtle (*Macrochelys suwanniensis*); and seven species with a FNAI State Element Rank, the eastern diamondback rattlesnake (*Crotalus adamanteus*), southern hognose snake (*Heterodon simus*), tiger salamander (*Ambystoma tigrinum),* one-toed amphiuma (*Amphiuma pholeter*), timber rattlesnake (*Crotalus horridus*), gopher frog (*Lithobates capito*), and Suwannee cooter (*Pseudemys concinna suwanniensis*) (**Table 3-1**).

<u>*Eastern Indigo Snake*</u>

The eastern indigo snake (*Drymarchon couperi*) is a large nonvenomous snake native to the Eastern United States. It is considered to be the longest native snake in the US. It prefers upland habitats with well-drained, sandy soils, such as that shown in **Figure 3-7**. The same area photographed is mined with gopher tortoise (*Gopherus polyphemus*) burrows. Indigo snakes also take advantage of a wide array of seasonally exposed floodplain wetland habitats throughout the study area. Thus, this species is presumed to be protected by protecting all of the non-perennially flooded habitats in MSR.

Figure 3-7. Eastern indigo snake at Peacock Springs Conservation Area (October 2014)

American Alligator

The American alligator (*Alligator mississippiensis*) is a large aquatic reptile native to Florida (FFWCC 2021b). This species is listed as federally threatened due to its similarity of appearance to the federally threatened American crocodile (*Crocodylus acutus*) (52 FR 21059 21064). American alligators can be differentiated from American crocodiles by comparing the snouts and body color. American alligators are typically dark gray and have broader snouts with no bottom teeth visible when closed (FFWCC 2021b). American crocodiles have a narrower snout and are typically paler than alligators with a brownish gray body color (FFWCC 2021b). The range of the American alligator fully encompasses the state of Florida and extends throughout most of the southeastern United States (FFWCC 2021b). This species can be found in freshwater and brackish wetland habitats throughout the state, but they prefer lakes and slow-moving rivers (FFWCC 2021b). Threats to the American alligator include habitat loss and degradation primarily related to human development (FFWCC 2021b). In addition to that, it is estimated that a third of all nests are destroyed by predators or flooding (FFWCC 2021c).

Suwannee Alligator Snapping Turtle

The Suwannee alligator snapping turtle (*Macrochelys suwanniensis*) is a large freshwater turtle with a dark brown shell exhibiting three raised keels (USFWS 2021). This species is federally proposed threatened (86 FR 18014) and is state listed as threatened in Florida. In 2014 and 2015 multiple genetic studies were conducted and it was determined that the data supported distinguishing the Suwannee alligator snapping turtle as a distinct species to be separated from the Alligator snapping turtle (*Macrochelys temminckii*) species (86 FR 18014). The Suwannee alligator snapping turtle is endemic to the Suwannee River Basin and is most abundant in the middle reaches of the Suwannee River (86 FR 18014). This species is typically found in freshwater habitats with submerged woody debris and plants (86 FR 18014). Currently, major threats to this species are considered to be poaching, fishing bycatch, nest predation, habitat alteration, and hook ingestion (USFWS 2021).

Suwannee Cooter

The Suwannee cooter (*Pseudemys concinna suwanniensis*) is a large turtle in the Emydidae family with yellow markings apparent on its neck, head, and lower shell (FFWCC 2021d). This species does not have a federal or state listing status but is included in the Florida Imperiled Species Management plan (FFWCC 2021d). The range of this species is limited to north central Florida, and it is typically found in blackwater, alluvial, and spring-fed rivers (FFWCC 2021d). Primary threats to this species include habitat degradation and increased predation (FFWCC 2021d). Additionally, threats to plant communities throughout its range can negatively impact the Suwannee cooter, which feeds mostly on aquatic plants (FFWCC 2021d).

3.4.6 Plants

The MSR floodplain is host to a diverse assemblage of plant species, some of which are state designated as threatened or endangered (**Table 3-1**). Various floodplain communities support these plants, as described in **Appendix IV**; therefore, MFLs were developed to protect the maintenance of these ecological communities.

3.5 Biological Water Resource Value Indicators

Based on the District's experience with species used for other rivers and the preceding review, the individual species and vegetative communities shown in **Table 3-4** were used within the subsequent MFL analyses for the MSR. The selected organisms have water depth, velocity, and substrate requirements for their life stages, and the selected ecological communities have flood duration, frequency, and depth requirements for maintaining vegetative communities. These requirements could be translated into relevant hydrologic indicators related to flow variation.

More specifically, instream physical habitat modeling was performed using the System for Environmental Flow Analysis (SEFA) software, which relies upon field surveys of channel characteristics and hydraulics, to determine potential reductions in flow that would not cause significant harm to specific species or guilds, as described in detail in **Appendix VIII** and summarized in **Section 4** of this report. To determine potential reductions in flow that would not cause significant harm to certain floodplain community types, field data were used in concert with the HEC-RAS model to determine the critical flows that maintain these communities, as is also described in detail in **Appendix VIII** and summarized in **Section 4** of this report. The conceptual basis for this MFL is that if riverine and floodplain habitats are protected, the associated species will be protected.

Table 3-4. Relevant biotic indicators for the Middle Suwannee River

Species/Guild/Community	Relevance for MFL Establishment
Deep Swamp, Alluvial Ridge Crest	Important longer hydroperiod wetland habitat for fish and wildlife
Bottomland Swamp, Alluvial Ridge Crest	Important shorter hydroperiod wetland habitat for fish and wildlife
Open Water, Bankfull	Important for maintaining habitat features within the open water channel
Suwannee Bass	Apex predator and important game fish
Redbreast Sunfish	Important game fish, important food source
Guilds = Shallow/Slow, Shallow/Fast, Deep/Slow, Deep/Fast	Protective of various species
Channel Catfish	Important game fish
Darters	Important food source, potential host for important mussel larvae (e.g., Suwannee moccasinshell)
Metallic Shiner	Potential host for important mussel larvae (e.g., oval pigtoe)
Macroinvertebrates = Ephemeroptera, Plecoptera, Trichoptera, EPT Total, *Pseudocloeon ephippiatum*, Hydropsychidae - Total, *Tvetenia vitracies*	Important food source
Largemouth Bass	Apex predator and important game fish
Bluegill	Important food source, important game fish
Spotted Sunfish	Important game fish, important food source
Cyprinidae	Important food source
Gulf Sturgeon	State and federally listed species

4.0 APPROACH TO SETTING MFLS

The results of the hydrologic assessment and the background literature review are presented in previous sections of this report and form the basis for evaluating water resource values (WRVs) and developing MFLs for the MSR. The technical approach makes use of the reference timeframe (RTF) flows presented in **Section 2** and described in detail in **Appendix I**. Water Years (WY) 1933 through 2015 were identified as the RTF POR for the MSR. When developing MFLs, it is assumed that the RTF condition is protective of water resource and human use values, but that some water may be available for beneficial use without causing significant harm to the resource. If sufficient data are available, flow characteristics that are protective of a WRV can be identified with some level of confidence. Two compliance gages were chosen for setting MFLs on the MSR: 1) generally, Ellaville will be used to protect the portion of the river upstream of RM90 where a major geological constriction of the river valley referred to as the "Knot" occurs (**Figure 2-6**); and 2) Branford will be used to protect the portion of the river downstream of the Knot.

The overall approach for setting MFLs is a "weight-of-evidence" approach that begins by identifying relevant WRVs, applying the results of hydrologic (**Section 2**) and biologic (**Section 3**) data analyses, and culminates by systematically analyzing flow reduction scenarios protective of the WRVs (**Section 5**). This section provides a description of the screening and identification of relevant WRVs process, the various metrics used to assess relevant WRVs, and the criteria used to determine the "critical flow[2]" to protect the respective WRV metrics. It also describes the methodology used to determine the allowable flow reduction, or hydrologic shift, resulting in no greater than 15% spatial or temporal loss in certain metrics such as usable area or inundation time. Such reductions are presumed to represent the limit of significant harm. Use of 15% spatial or temporal reduction in this manner is a standard and common practice in the Southwest Florida and Suwannee River Water Management Districts and elsewhere across the nation (Gore et al. 2002, Munson & Delfino 2007). The suite of 15% reductions for all WRV metrics below the RTF condition is then assessed to formulate overall MFL criteria across the full range of flow conditions.

4.1 SCREENING AND IDENTIFICATION OF RELEVANT WRVS

Ten WRVs and their applicability to the establishment of MFLs on the MSR were evaluated. WRVs are evaluated based on their likelihood to be significantly harmed by flow or water level reductions in the study area, and they are necessarily based on the suitability of the best available data. Many freshwater river MFL assessments in Florida have focused on WRVs 1 and 2, because the data and analytical techniques necessary to assess them are typically available. Further, multiple metrics commonly used in environmental flow studies are available to address those two WRVs, covering a wide range of flow conditions from low to high. It is reasonable to assume the eight other WRVs, lacking sufficient data, are indirectly addressed because WRVs 1 and 2 cover such a wide gamut of flows and associated water levels. WRV applicability specific to establishing MFLs on MSR priority springs will be addressed in a separate document.

4.1.1 WRV 1 - Recreation In or On the Water

Recreation along the MSR is an important WRV, with many recreational activities involving boat access to the river. The Suwannee River is classified by the Florida Department of Environmental Protection (FDEP) as an Outstanding Florida Water (OFW) and is part of Florida's State-wide System of Greenways and Trails. The designated Suwannee River Wilderness Trail offers boaters and kayakers a variety of opportunities to see unique karst formations, various wetland communities, and many birds and wildlife. Within the OFW

[2] Critical flow is defined as the flow required to meet a MFL metric.

designation, the Suwannee River is a "Special Water." For a body of water to be designated a special water, the Environmental Regulation Commission (ERC), a seven-member citizens' body appointed by the Governor that functions within the FDEP, has to make two findings: a) the water body has either exceptional ecological significance or exceptional recreational significance, and b) the environmental, social, and economic benefits of the designation outweigh the environmental, social, and economic costs. "Exceptional recreational significance" means the river offers unusual value as a resource for outdoor recreation activities such as fishing, boating, canoeing, water skiing, swimming, scuba diving, or nature observation. The exceptional significance may be in the intensity of present recreational usage, in an unusual quality of recreational experience, or in the potential for unusual future recreational use or experience. "Exceptional ecological significance" means that a water body is a part of an ecosystem of unusual value. The exceptional significance may be in unusual species, productivity, diversity, ecological relationships, ambient water quality, scientific or educational interest, or in other aspects of the ecosystem's setting or processes (Shaw 2007; see also Rule 62-302.700, F.A.C.).

For purposes of the MFL assessment, sufficient data exist to determine critical flows for recreational boat passage in the MSR and subsequent allowable flow reductions. This assessment will ensure that WRV 1 is protected by MSR MFLs.

4.1.2 WRV 2 - Fish and Wildlife Habitats and the Passage of Fish

The MSR includes 92 miles of un-dammed river channel, almost 40,000 acres of native floodplain forests and other native habitats[3], and numerous freshwater springs. It provides a diverse array of large, unfragmented habitats for fish and wildlife. The importance of fish and wildlife habitats is also evidenced by the Suwannee River's Special Waters designation. Different plant and animal species require different ranges in water depths, velocities, substrate, and temperatures to thrive. Fish and wildlife need multiple habitats for various reasons (foraging, spawning, shelter, etc.), and the MSR is an important source of these habitats for a variety of wildlife, including a number of rare, threatened and endangered species. More than 40 species of animals and plants are assigned by Florida Natural Areas Inventory (FNAI) or noted by the Florida Fish and Wildlife Conservation Commission (FFWCC) as rare or imperilled. Several species are federally listed, including the wood stork (*Mycteria americana*), eastern indigo snake (*Drymarchon couperi*), Suwannee moccasinshell (*Medionidus walker*), West Indian manatee (*Trichechus manatus*), and Gulf sturgeon (*Acipenser oxyrinchus desotoi*), which are listed as threatened, along with the oval pigtoe (*Pleurobema pyriforme*), which is listed as endangered. The Suwannee River main stem, beginning from its confluence with Long Branch Creek downstream to the mouth of the Suwannee River, has been federally designated as critical habitat for the Gulf sturgeon, falling under the joint jurisdiction of the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) (50 CFR 226.214).

For purposes of the MFL assessment, sufficient data exist to determine critical flows for a variety of metrics including general fish passage, Gulf sturgeon fish passage, fish passage into and out of select spring runs, instream habitat suitability for various species and life stages, riparian habitat, and floodplain wetland habitat communities. Subsequent allowable flow reductions can be determined from these critical flows, which will ensure that WRV 2 is protected under proposed MFLs. As discussed, the suite of related metrics cover high, medium, and low flows with some fair amount of redundancy in each part of the flow regime. Selecting the most limiting metric across the hydrograph assures a reasonable prevention of significant harm to fish and wildlife habitats and fish passage.

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[3] The study area includes the entire 10-year floodplain, totaling 56,536 acres, of which 39,824 acres (70%) were in native habitat based on the 2010 SRWMD landuse GIS shapefile.

4.1.3 WRV 3 - Estuarine Resources

Estuarine resources are the flora and fauna that inhabit brackish water with salinity between 0.5 and 30 parts per thousand (ppt). While the downstream most portion of the MSR can be affected by tide, the project area is entirely freshwater; therefore, this WRV is not internally applicable for the MSR. Estuarine resources are directly addressed in the Lower Suwannee River and Estuary MFL (WRA, 2005).

4.1.4 WRV 4 - Transfer of Detrital Material

Detrital material is a food source for detritivores, primary consumers that obtain nutrients by consuming decomposing plant and animal material that are crucial to benthic ecosystems. Detritus is commonly transferred into the water column from the adjacent riparian zone when high water levels occur. Flow reduction could reduce lateral and downstream transfer of this organic energy source. This WRV will be addressed by the protection of floodplain communities (WRV 2), which are maintained by higher flows, and also by assessment of select areas where concentrated flow exchanges occur between the floodplain and river channel.

4.1.5 WRV 5 - Maintenance of Freshwater Storage and Supply

Maintaining freshwater storage and supply involves the protection of non-consumptive uses and environmental values associated with riverine, spring, aquatic, and wetlands ecology. The MSR study area occupies a potentiometric low for the upper Floridan aquifer, serving as a groundwater outlet for numerous springs naturally draining the aquifer, which is a major regional freshwater storage feature. The MSR also receives seasonal flood pulses in most years with much of the water being detained for at least several weeks in the floodplain. The proposed river MFL protects floodplain communities against adverse dewatering via WRVs 1, 2, and 8; and is therefore assumed to prevent significant harm to the maintenance of freshwater storage in the region. Additionally, MSR priority springs MFLs, which will be addressed in a separate document, will protect spring flows by maintaining critical aquifer levels.

4.1.6 WRV 6 - Aesthetic and Scenic Attributes

This WRV refers to features of a waterscape usually associated with passive uses, such as sightseeing, hiking, photography, contemplation, and other forms of relaxation. The aesthetic and scenic attributes of the Suwannee River are defining features of this river, with its limestone outcroppings, copious springs, and expansive swamps. The natural setting is appealing to nature-lovers and economically important to the eco-tourism industry. This WRV is considered relevant, with its importance a logical consequence of the designation of the river as Special Waters within the OFW classification. This WRV will be addressed by the protection of wildlife habitat, including instream, riparian, and floodplain features (WRV 2).

4.1.7 WRV 7 - Filtration and Absorption of Nutrients and Other Pollutants

This WRV refers to the reduction in concentration of nutrients and other pollutants through the process of filtration and absorption (i.e., removal of suspended and dissolved materials) as these substances move through the water column, soil or substrate, and associated organisms. Many species feed on benthic organisms whose populations are threatened by proliferation of undesirable plants or other eutrophic conditions such as hypoxia. Existing wetlands within the MSR floodplain provide filtration and absorption of excess nutrients and other pollutants. This WRV will be protected as a consequence of protecting other WRVs, especially those metrics related to maintaining the major natural treatment surfaces in the floodplain, their plant communities, and river flow exchanges into those communities (WRVs 1, 2, and 8).

4.1.8 WRV 8 - Sediment Loads

Rivers are conduits for the transport of water and sediment. Sediment loads refer to the transport of inorganic material, suspended in water, which may settle or rise. A load, by definition, is the product of flow and sediment concentration; thus, flow reductions would likely reduce sediment loads. The MSR valley is dominated by inorganic soils with a very rough topography that is maintained extensively by alluvial deposits and scour from the migrating river channel and overbank floods. Addressing sediment loads for this river is important because it is so geomorphically active, and that activity creates a physical and biological dynamic that should be maintained to help assure the biodiversity of the valley.

Sediment load data are limited in their availability and are often inaccurate. Therefore, surrogates for sediment transport such as the bankfull flow and overbank flood events corresponding with the alluvial ridge crest (ARC) elevation were used to estimate the movement of sediment through the system. More specifically, the bankfull flow assures maintenance of channel macro habitat forms and dimension while the ARC flow maintains the diversity and extent of floodplain surfaces.

For purposes of the MFL assessment, sufficient data exist to determine critical flows for the bankfull and the alluvial ridge crest profiles. Subsequent allowable flow reductions can be determined from these critical flows, which will ensure that WRV 8 is protected under proposed MFLs.

4.1.9 WRV 9 - Water Quality

Water quality refers to the chemical and physical properties of water not included in WRV 7. Water quality impacts organisms and recreational activities. Fish populations depend on sufficient levels of dissolved oxygen and an absence of elevated levels of pollutants, such as nutrients, sediment, metals, and toxins. Nutrient enrichment can result in filamentous algal mat blooms, poor water clarity, and substandard habitat for organisms.

Available water quality data for river and spring monitoring stations within the MSR study area were compiled and analysed to assess relationships between certain water quality parameter concentrations with flow. All five river stations assessed exhibited significant inverse relationships between flow and NOx and flow and SpC (see Section 2.8). Spring flows generally exhibit greater NOx concentrations and SpC than river flows and may provide a greater contribution of these chemical constituents to total river flow during dry periods, or when spring discharge to the river increases (Upchurch et al., 2008). NOx and SpC could theoretically be reduced in the river by decreasing spring flow and somehow augmenting river flow, but such a scenario would shift the basic limnological reaches of the river, perhaps with harmful consequences to some fish and wildlife populations, floodplain vegetation, and aesthetics. This would be clearly antithetical to the overall objectives of MFL regulations. Instead, the basic water source and NOx/SpC pattern is likely to be broadly sustained by the WRVs which address flow maintenance ranging from low to high extremes in the river.

4.1.10 WRV 10 – Navigation

While navigation is directly related to flow, it is not a relevant WRV for the MSR because no commercial barges or other large commercial vessels utilize the river. Small boat traffic and commercial guide operations will be protected under WRV 1.

4.1.11 WRV Summary

By standard and customary practice, MFLs are set based on the applicable, suitable, and best available information. Suitable information was available to establish quantitative variables addressing important components applicable to WRVs 1, 2, 5, 8, and 9. WRVs 4, 6, and 7 are addressed qualitatively as they are appurtenant values associated with the habitats and processes quantitatively addressed – namely the balanced exchange of water and sediment necessary to protect the function and form among the river, springs, and floodplain. The outcome of this analysis is that the pattern, dimension, and processes of habitats that drive aesthetics, detrital transfer, and pollutant filtration are concomitantly protected in evaluation of WRVs centred on recreation; fish and wildlife habitat; sediment loads (sustaining river and floodplain morphology); and water quality.

4.2 CRITICAL FLOW DETERMINATION

Based on the availability of data and literature to quantitatively define the relationship between flow and impacts to WRVs, a table summarizing a list of specific metrics used to assess relevant WRVs was prepared (**Table 4-1**). This table provides details regarding the general portion of the flow pattern applicable to a particular metric, the applicable compliance gage, and the criteria used to determine the critical flow. The critical flow is the flow required for a particular metric to be maintained. Critical flows for the various metrics were determined using a variety of methods, described in detail in **Appendix VIII** and summarized below.

Table 4-1. Summary of directly assessed WRVs for MSR MFL development

WRV	Metric	General Flow Regime	Applicable Gage	Criteria Used to Determine Critical Flow
Fish Passage	General Fish Passage	Low	Ellaville, Branford	Minimum 0.8 ft depth over 25% of the channel width, with no single width increment <10%, using HEC-RAS
Fish Passage	Gulf Sturgeon Passage	Low	Ellaville, Branford	Minimum of 3 ft deep over 15 ft width, using HEC-RAS
Recreation	Recreational Boating	Low	Ellaville, Branford	Minimum of 2 ft deep over 30 ft width, using HEC-RAS
Habitat - Instream	47 various species/life stages	Low to medium	Ellaville, Branford	No greater than 15% reduction in habitat area (measured as Area Weighted Suitability)*, using SEFA
Habitat – Riparian Bank	Open Water	Low	Ellaville, Branford	Regression of open water elevation with river mile, determined from field survey
Fish Passage	Fish Passage in/out Otter Springs	Low	Branford	Minimum of 0.8 ft depth over 25% of the channel width, with no single width increment <10%, using HEC-RAS
Fish Passage	Fish Passage in/out Allen Mill Pond and Peacock Springs	Medium	Ellaville	Minimum of 0.8 ft depth over 25% of the channel width, with no single width increment <10%, using HEC-RAS

Sediment Load	Bankfull	Medium	Ellaville, Branford	Regression of bankfull elevation with river mile, determined from field survey
Habitat - Floodplain	Deep Swamp	High	Ellaville, Branford	Regression of maximum community elevation with river mile, determined from field survey
Habitat - Floodplain	Bottomland Swamp	High	Ellaville, Branford	Regression of maximum community elevation with river mile, determined from field survey
Sediment Load	Alluvial Ridge Crest	High	Ellaville, Branford	Top of ridge regression with river mile, determined from field survey

*Area Weighted Suitability (AWS): The measure of usable instream habitat area (ft^2/ft), determined using System for Environmental Flow Analysis (SEFA).

Critical flows for metrics involving passage over shoals including general fish passage, Gulf sturgeon passage, and recreational boating passage were determined because flow reductions may reduce the number of passable days at limiting shoals. When determining these critical flows, the limiting shoal in each section of the MSR (upstream of RM90 and downstream of RM90) was first identified. The Suwannee River HEC-RAS model, updated by ECT in 2013 (**Appendix IX**), was used to identify those limiting shoals in the MSR (**Figure 4-1**) and to extract the cross-sectional geometry of the shoals. Critical stages were subsequently determined using the applicable criteria shown in **Table 4-1**, and the limiting shoal was selected based upon higher relative river-bottom elevation. This stage was then related to a particular flow value at the limiting shoal using the HEC-RAS model and ultimately interpolated to the compliance gage of interest (Ellaville for the portion of the river above RM90 and Branford for the portion of the river below RM90).

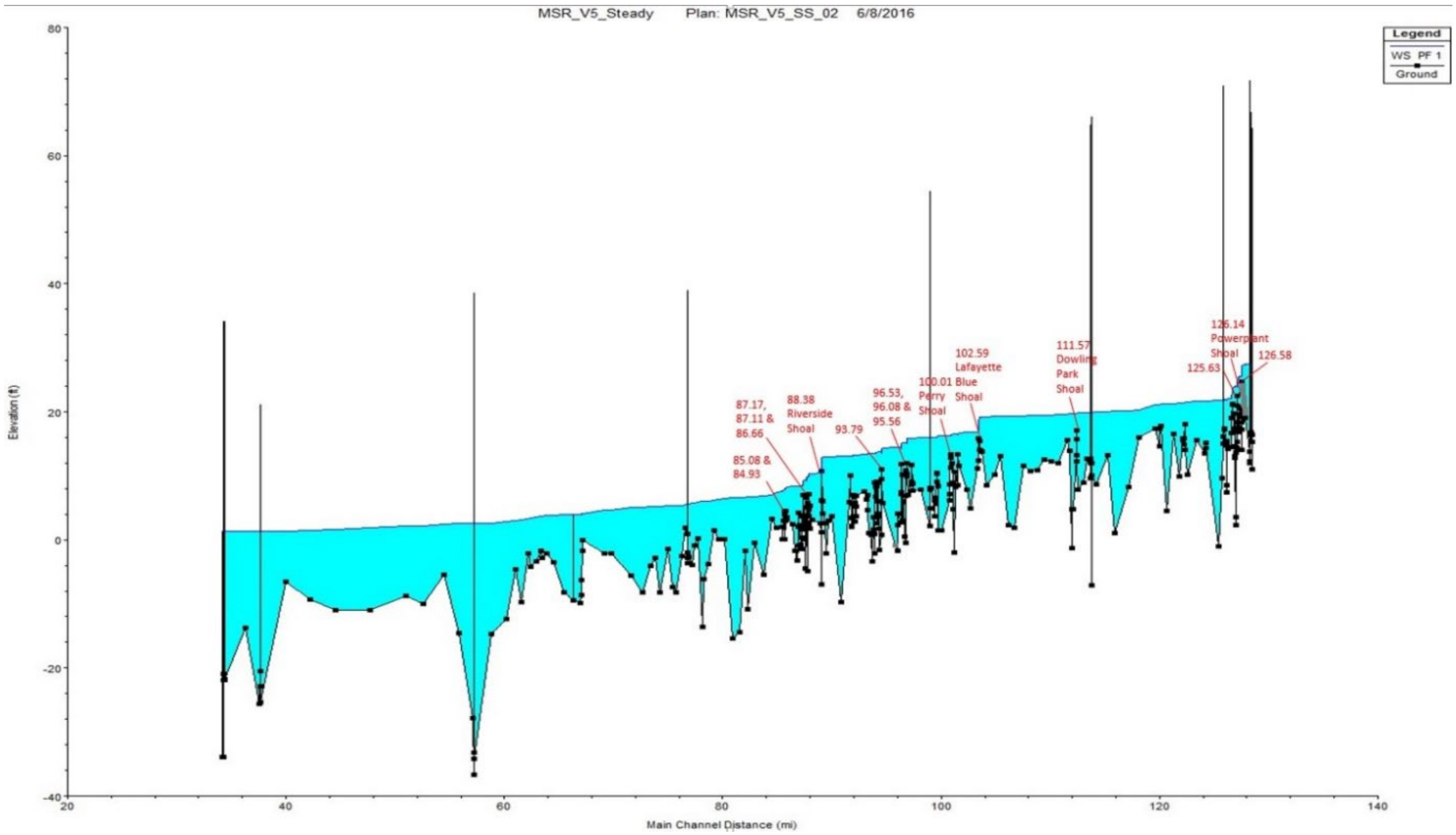

Figure 4-1. HEC-RAS profile for use in identifying shoals[4]

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[4] The x-axis represents river mile, beginning at the downstream of the MSR near Wilcox and extending to Ellaville. The y-axis represents elevation (NAVD88). River miles are given for individual shoals (red labels). The *Knot*, which occurs at RM90, separates Riverside Shoal and that labelled 93.79. The water surface profile shown above represents the 99.9% exceedance.

Critical flows for metrics involving certain ecological communities, such as deep swamp, bottomland swamp, and open water were determined because reduction in flows could reduce the number of days particular community types are inundated. First, regressions were developed based on field surveys relating the maximum elevations at which these communities occur to river mile (**Appendix IV**). These elevations were then related to the flow at the nearest HEC-RAS transect, and then interpolated to the compliance gage of interest (Ellaville for the portion of the river above RM90 and Branford for the portion of the river below RM90). Critical flows for sediment flow metrics, including bankfull and alluvial ridge crest were determined in the same way.

Critical flows for instream habitat were determined because reduction in flows could reduce habitat availability and suitability for fish and macroinvertebrates. SEFA was used to identify critical species and the associated allowable flow reductions that would not result in a greater than 15% loss in area weighted suitability (AWS). The SEFA model has a range of applicable flows based on the flows observed during field data collection (**Appendix VIII**).

4.3 RTF FLOW AND HYDROLOGIC SHIFT DETERMINATION

As discussed in **Section 2.4**, RTF flow levels were determined as an estimate of the observed flow record that would have resulted in the absence of withdrawals (see **Appendix VII**). From these RTF flow levels, MFL thresholds were determined below which the WRVs would no longer remain protected from significant harm and were related to a prescribed harmful change in the WRV critical flow criteria (**Table 4-1**). For a given WRV, the MFL flow was estimated using an iterative flow reduction approach. The daily flow values in the RTF period of record were reduced in 1% increments, and the resultant number of days that the reduced flow time-series exceeded the critical flow was summed. The percentage of flow reduction that resulted in the cumulative number of days to reduce by 15% (the significant harm threshold) was used to determine the RTF flow and resulting hydrologic shift.

Figure 4-2 shows an example of an iterative flow reduction curve for the Ellaville Open Water metric. The x-axis on the graph represents the percent flow reduction applied to the RTF flow time-series while the y-axis represents the cumulative number of days the critical flow is exceeded. The first vertical bar corresponding to zero-percent flow reduction represents the RTF flow time-series, with 25,094 days when critical flow is exceeded. The blue horizontal line represents the allowable 15% reduction in the cumulative number of days to 21,329 days. The flow reduction percentage (or hydrologic shift) which caused the cumulative number of days to reach the 15% threshold was 22% in this case.

Figure 4-3 provides an example of another way to illustrate the determination of the RTF flow and hydrologic shift using a flow duration curve for the Ellaville Open Water metric. The critical flow (A) of 1,916 cfs is equalled or exceeded 82.8% of the time or 302 days per year on average. Reducing those days by 15% results in an RTF flow (F) of 2,461 cfs that occurs an average of 257 days or 70.4% of the time. Subtracting the critical flow from the RTF flow provides the available flow for withdrawal, resulting in a hydrologic shift (H) of 545 cfs. This hydrologic shift represents a 22% reduction in flow between the calculated RTF flow and the determined critical flow. These values are also shown in tabular form in **Table 4-2**.

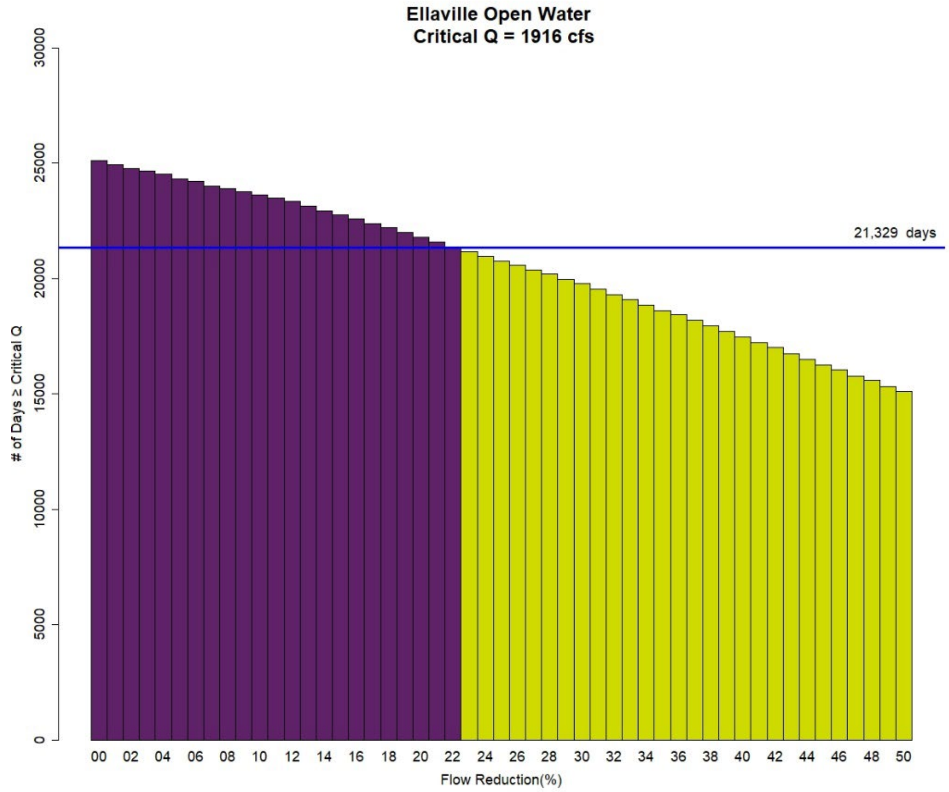


Figure 4-2. Example of an iterative flow reduction curve.

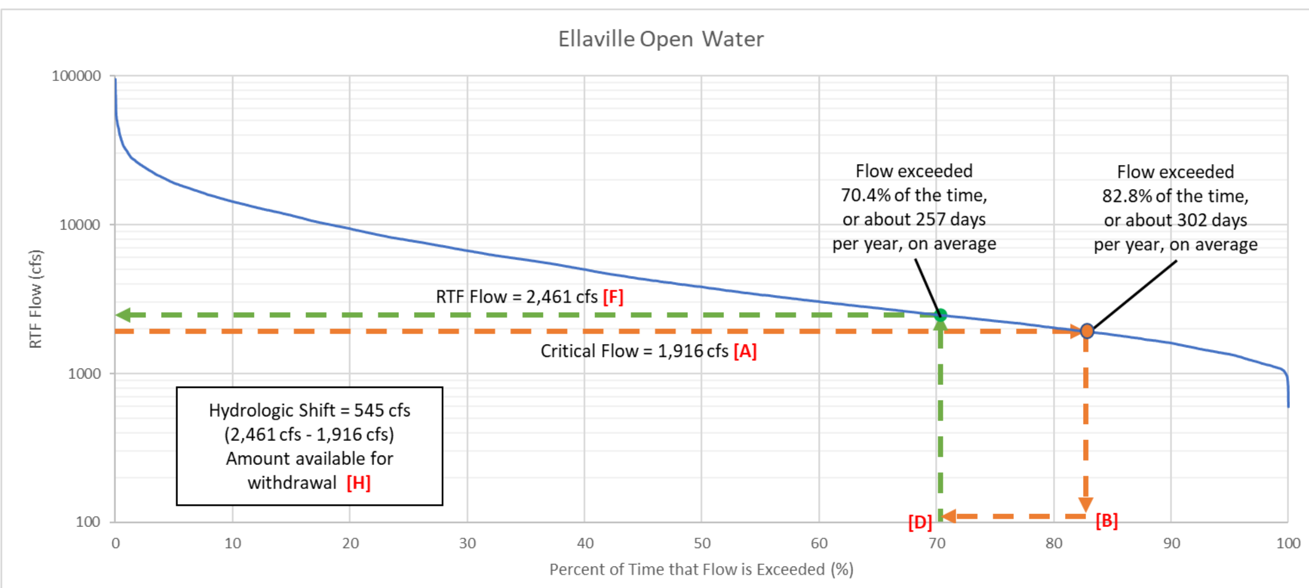


Figure 4-3. Example of an RTF daily flow duration curve depicting critical flow, RTF flow, and hydrologic shift.

Table 4-2. Example of flow reduction associated with decrease in time critical flow is exceeded.

WRV	Critical Flow Variables			Reduced Flow Variables			MFL Variables		
	Critical Flow (cfs)	Associated Percent Exceedance (%)	Avg Days per Year Critical Flow Exceeded	Percent Exceedance Resulting from a 15% Decrease in Time Exceeded (%)	Avg Days per Year Critical Flow Exceeded in Reduced Flow	RTF Flow Resulting from a 15% Decrease in Time Exceeded (cfs)	Change in Avg Days per Year Critical Flow Exceeded	Hydrol-ogic Shift (cfs)	Percent Flow Reduction Resulting in 15% Decrease in Avg Days per Year Critical Flow Exceeded (%)
Index	A	B	C	D	E	F	G	H	I
Ellaville - Open Water	1,916	83	302	70	257	2,461	45	545	22

Critical flow day plots illustrating the number of days per water year that the critical flow for a given WRV is equaled or exceeded during the RTF period of record as well as the time series for reduced flow conditions (after applying the hydrologic shift) allows for visualizing the expected inter-annual changes in the flow regime under the reduced flow scenario (**Figure 4-4**). **Figure 4-4** shows the plot for the Ellaville Open Water metric with RTF flow conditions in solid line and dashed lines representing the conditions corresponding to the reduced-flow time series after application of a hydrologic shift of 545 cfs (22% decrease) in the daily flow values. **Section 5** of this report describes all the metrics of interest and the corresponding iterative flow reductions and plots showing the critical flow and reduced flow exceedance days per year or season.

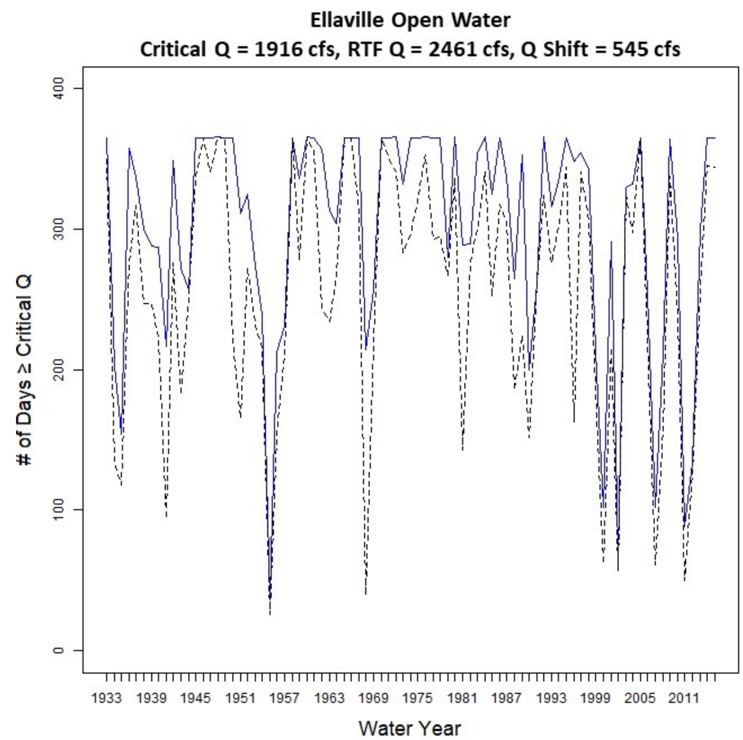


Figure 4-4. Example of a plot showing number of days critical flow was equalled or exceeded per year for the RTF period of record (solid line) and the number of days critical flow was equalled or exceeded per year using a reduced flow series (dashed line)

5.0 EVALUATION OF WATER RESOURCE VALUES

This section summarizes the results of critical flow[5] and hydrologic shift[6] determinations for the various WRV metrics shown in **Table 4-1**. Analyses are made using the RTF flow record for the two compliance gages (Ellaville and Branford). Additional information regarding critical flow determinations can be found in **Appendix VIII**. The hydrologic shifts provided in this section are an allowable withdrawal from the RTF flow condition. Flow scenarios protective of the assessed WRVs are assumed to be sufficient to protect the overall structure and function of the river system, as the WRVs cover a wide range of flows.

5.1 RECREATION IN AND ON THE WATER

The Suwannee River is designated an Outstanding Florida Water (OFW). Recreational activities such as canoeing, kayaking and small power boating are popular on the MSR. Shallow shoals may pose a challenge to boaters, and the District's Suwannee River Wilderness Trail guide warns that shoals above Walker Tract Launch, located at River Mile 83.7, "could damage boat motors during low water periods."

To determine the critical elevation for recreational boating passage at river shoals located throughout the project area, a depth of two feet over a 30-foot width was used to account for an outboard motor and to allow for the passage of two 15-foot long boats passing each other, even if both are sideways in the current (SRWMD, 2016). Once the boat passage critical elevations were determined for each assessed HEC-RAS cross-section, the model was used to determine the flows associated with those elevations. Of the assessed shoals, the shoal with the flow corresponding to the lowest exceedance was determined to be the limiting shoal for recreational boat passage. The critical flow at the limiting shoal was then associated with that of the corresponding flow at the appropriate compliance gage to determine a passage MFL for each compliance gage (Ellaville for the reach above RM 90 and Branford for the reach below RM 90).

For recreational boating within the portion of the river above RM 90, station 102.59 was the limiting shoal with a critical flow of 1,908 cfs at the Ellaville gage (**Figure 5-1**). For the 83-year RTF flow record assessed, this critical flow was exceeded about 83% of the time: 25,139 days or 303 passable days per year on average. A no greater than 15% reduction in the number of passable days corresponds with a 22% allowable flow reduction at the Ellaville gage, which results in an RTF flow of 2,457 cfs and a hydrologic shift of 549 cfs. This allowable flow reduction would result in 21,368 passable days for the 83-year record or 257 passable days per year on average. Graphic representations of these results are provided in **Figure 5-3**.

[5] Critical flow is the amount of flow necessary to protect a resource

[6] Hydrologic shift is the allowable flow reduction that will not cause significant harm to the resource

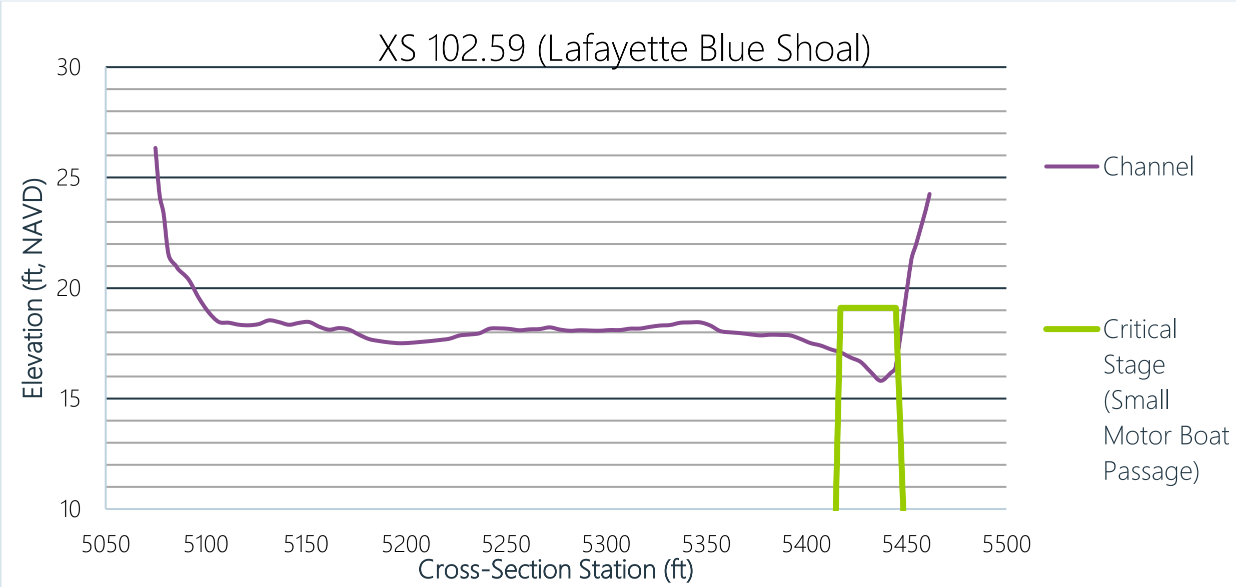


Figure 5-1. Critical shoal for boat passage for portion of river above RM 90.

For the portion of the river below RM 90, station 88.38 was the critical shoal with a critical flow of 1,778 cfs at the Branford gage (**Figure 5-2**). For the 83-year RTF flow record assessed, this critical flow was exceeded about 99% of the time: 29,917 days or 360 passable days per year on average. A no greater than 15% reduction in the number of passable days corresponds with a 35% allowable flow reduction at the Branford gage, which results in an RTF flow of 2,738 cfs and a hydrologic shift of 960 cfs. This allowable flow reduction would result in 25,429 passable days for the 83-year record or 306 passable days per year on average. Graphic representations of these results are provided in **Figure 5-4**.

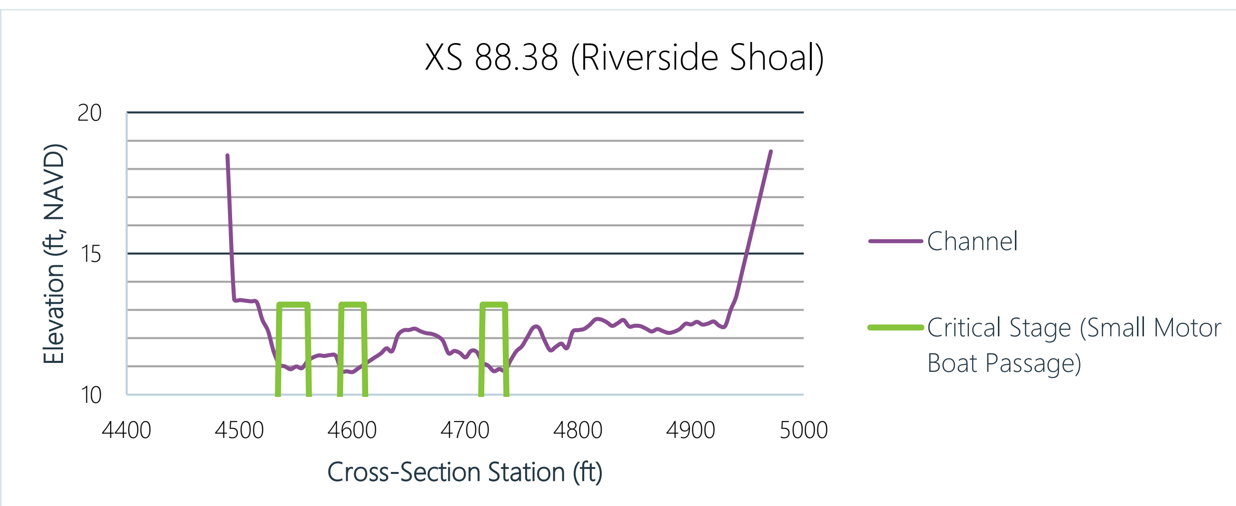
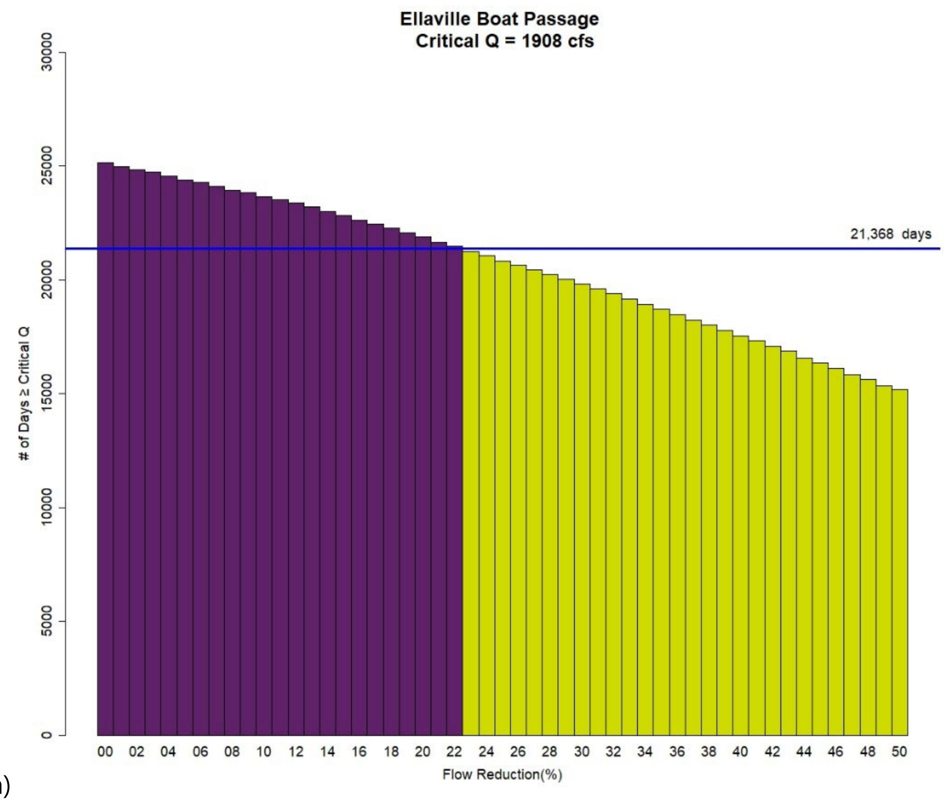


Figure 5-2. Critical shoal for boat passage for portion of river below RM 90.



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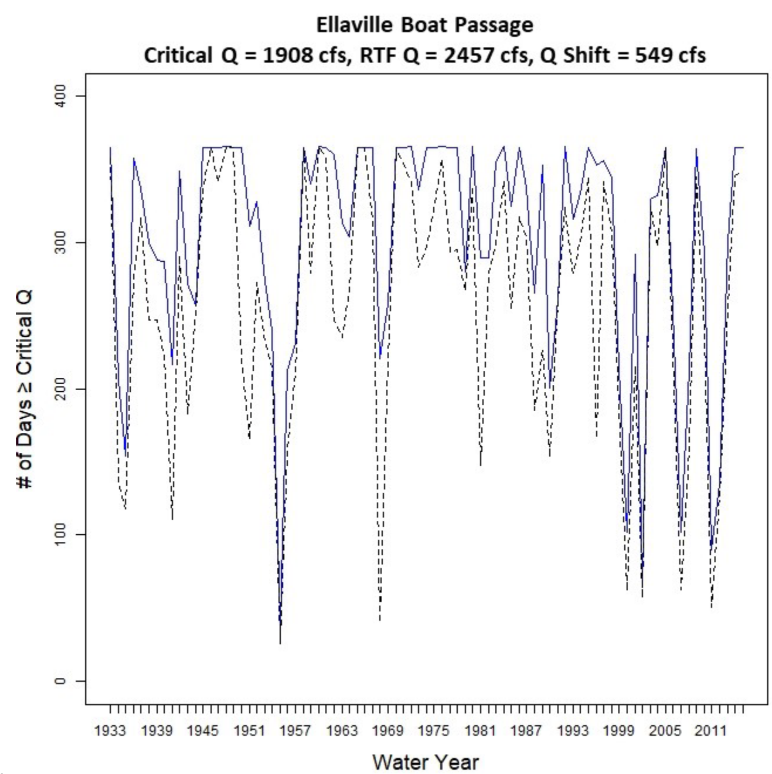
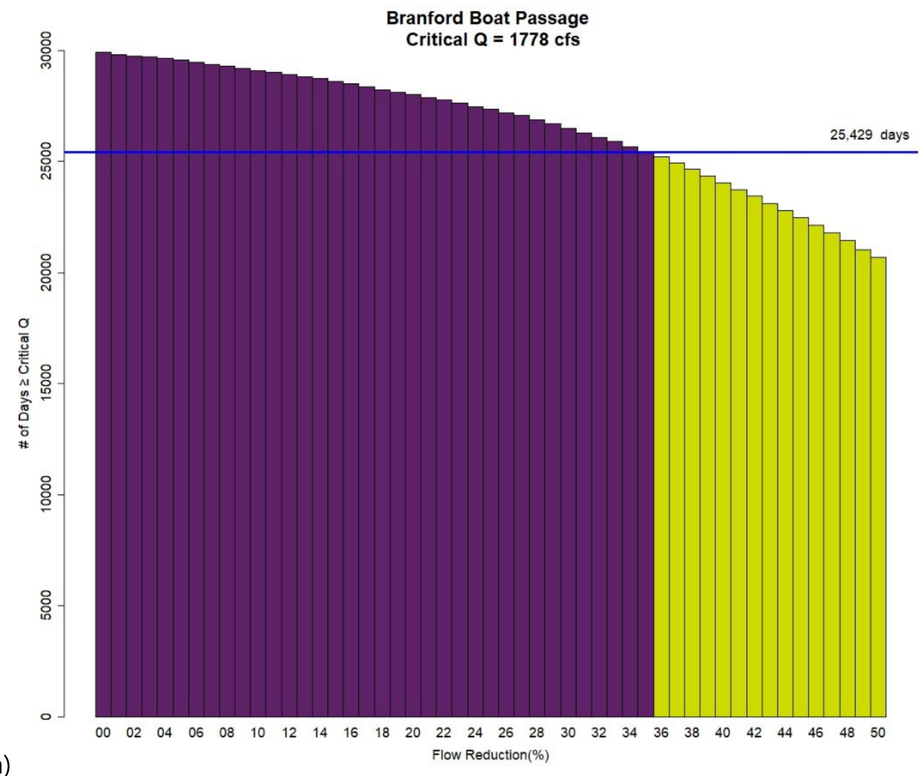


b)

Figure 5-3. Ellaville recreational boating passage results: a) iterative flow reduction graph; b) days per year above critical flow for RTF flow (solid line) and RTF flow reduced by 549 cfs (dashed line)



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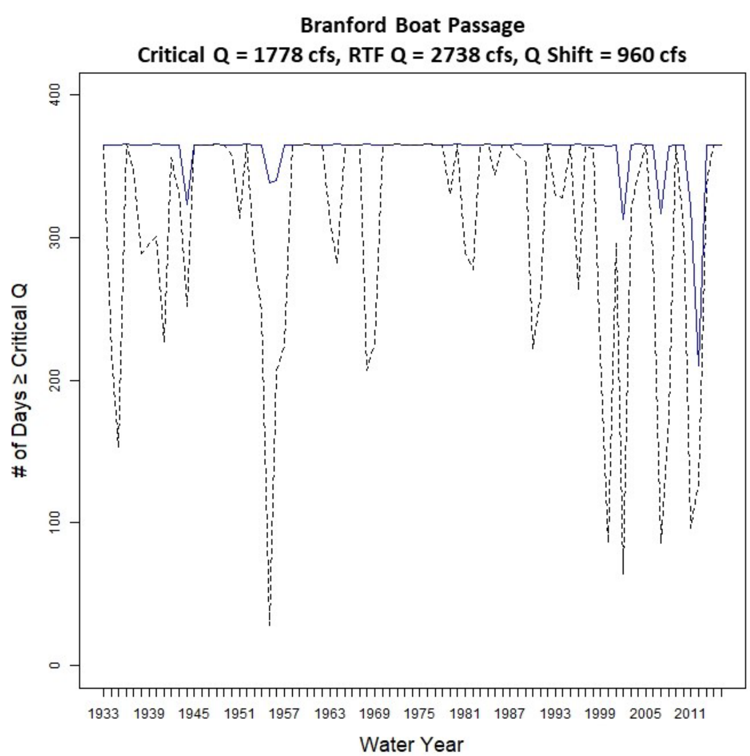

b)

Figure 5-4. Branford recreational boating passage results: a) iterative flow reduction graph; b) days per year above critical flow for RTF flow (solid line) and RTF flow reduced by 960 cfs (dashed line)

5.2 FISH PASSAGE AND FISH AND WILDLIFE HABITAT

5.2.1 Fish Passage

The Suwannee River is characterized by drastic water level fluctuations, resulting in a dynamic fishery environment. Shallow limestone shoals located along the MSR can present a potential issue for the passage of fish during periods of low flow. Critical flows were determined for several fish passage metrics, including general fish passage, Gulf sturgeon passage, and fish passage from the main river into select spring runs, as described below.

<u>*General Fish Passage*</u>

General fish passage was determined as the elevation at which at least 0.8 foot of water would collectively cover 25% of the channel width, with single increments in width no less than 10% of the channel.[7] **Figure 5-5** illustrates the water level at which these criteria for fish passage are met at a particular shoal where two "blocks" are necessary. This block approach ensures that schools of fish have sufficient width to pass through the shoal and also considers vulnerability to predation (Bovee, 1982). Channel width was determined by using the width at the bankfull elevation; in **Figure 5-5** a cumulative 70 ft is at the least 0.8 feet deep for 25% of the cross-sectional width at a bankfull elevation of 35.1 ft NAVD88. This includes 26 ft (sta. 3548-3574) and 44 ft (sta. 3708-3752) increments, respectively. This method was deemed preferable to a top-of-bank approach because top-of-bank is highly variable along the river. Once the general fish passage elevation was determined for each assessed cross-section, the HEC-RAS model was used to determine the flow associated with that elevation. Of the assessed shoals, the shoal with the lowest exceedance flow was determined to be the "limiting" shoal for general fish passage. The flow at the limiting shoal was then cross-referenced with the corresponding exceedance flow at the corresponding compliance gage (Ellaville for stations above RM 90 and Branford for stations below RM 90) to determine a general fish passage MFL.

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[7] These parameters follow the approach used for general fish passage in the Lower Santa Fe and Ichetucknee Rivers MFL Re-evaluation Report, citing Thompson, 1972 (HSW, 2021).

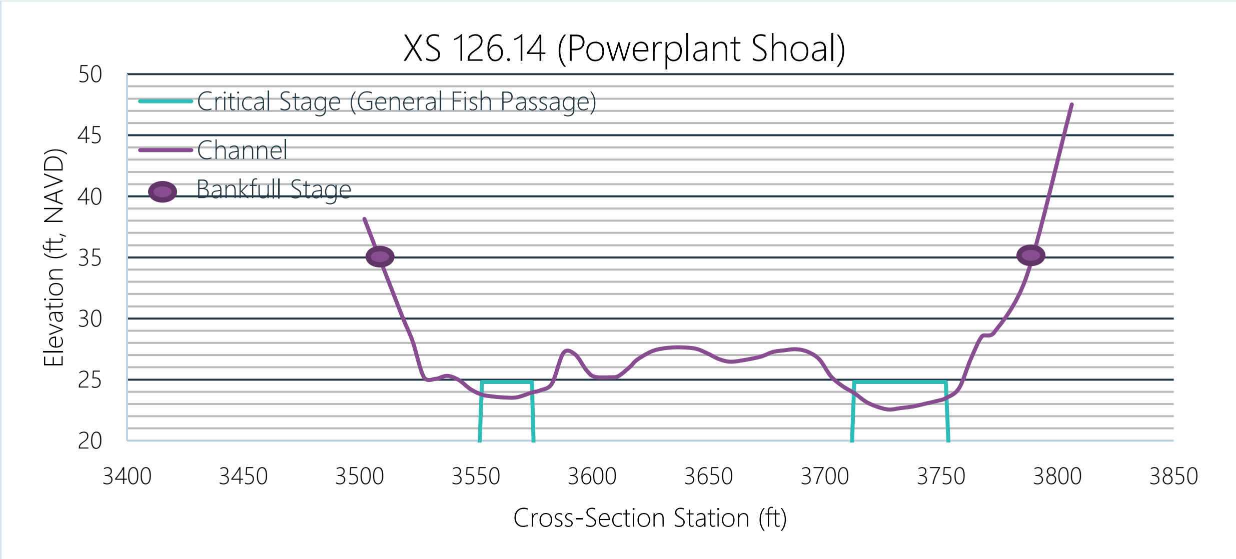


Figure 5-5. Example of water level allowing for at least 0.8 ft of water to collectively cover 25% of the channel width, with no single increment in width less than 10% of the channel

For general fish passage within the portion of the river above RM 90, station 102.59 was the limiting shoal with a critical flow of 1,045 cfs at the Ellaville gage (**Figure 5-6**). This shoal occurs near Lafayette Blue Spring (**Figure 4-1**). For the 83-year RTF flow record assessed, this critical flow was equalled or exceeded about 100% of the time: 30,194 days or 364 passable days per year on average. A no greater than 15% reduction in the number of passable days corresponds with a 43% allowable flow reduction at the Ellaville gage, which results in an RTF flow of 1,840 cfs and a hydrologic shift of 795 cfs. This allowable flow reduction would result in 25,664 passable days for the 83-year record or 309 passable days per year on average. Graphic representations of these results are provided in **Figure 5-8**.

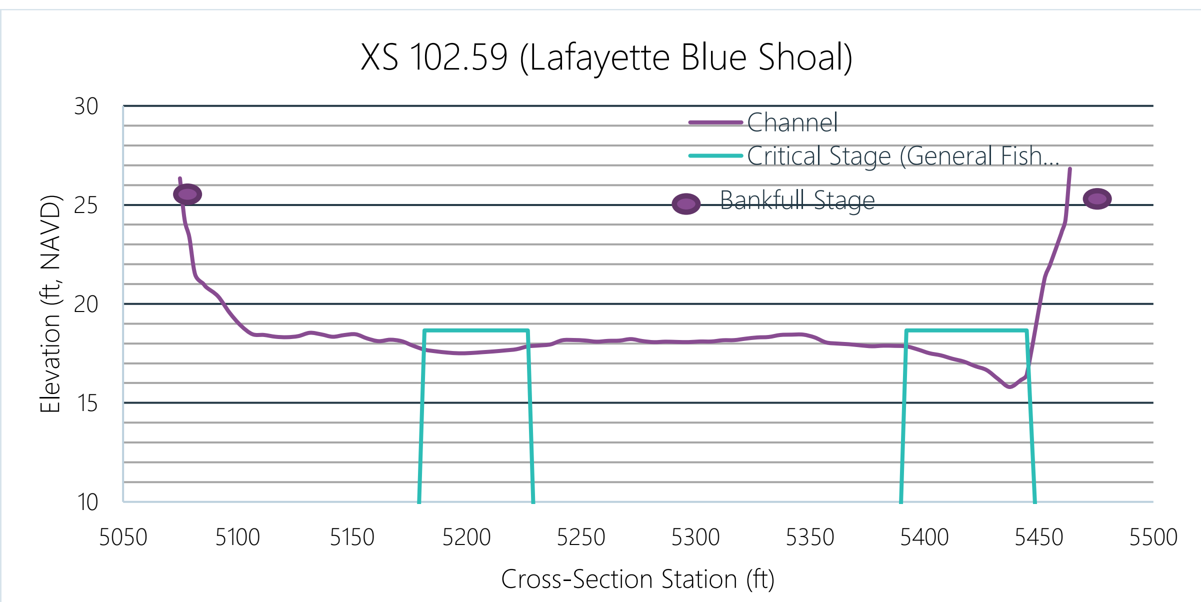


Figure 5-6. Critical shoal for general fish passage for portion of river above RM 90.

For the portion of the river below RM 90, station 87.17 was the critical shoal with a critical flow of 2,042 cfs at the Branford gage (**Figure 5-7**). This shoal occurs near Owen Spring (Lafayette County). For the 83-year RTF flow record assessed, this critical flow was equalled or exceeded about 95% of the time: 28,819 days or 347 passable days per year on average. A no greater than 15% reduction in the number of passable days corresponds with a 30% allowable flow reduction at the Branford gage, which results in an RTF flow of 2,898 cfs and a hydrologic shift of 856 cfs. This allowable flow reduction would result in 24,496 passable days for the 83-year record or 295 passable days per year on average. Graphic representations of these results are provided in **Figure 5-9**.

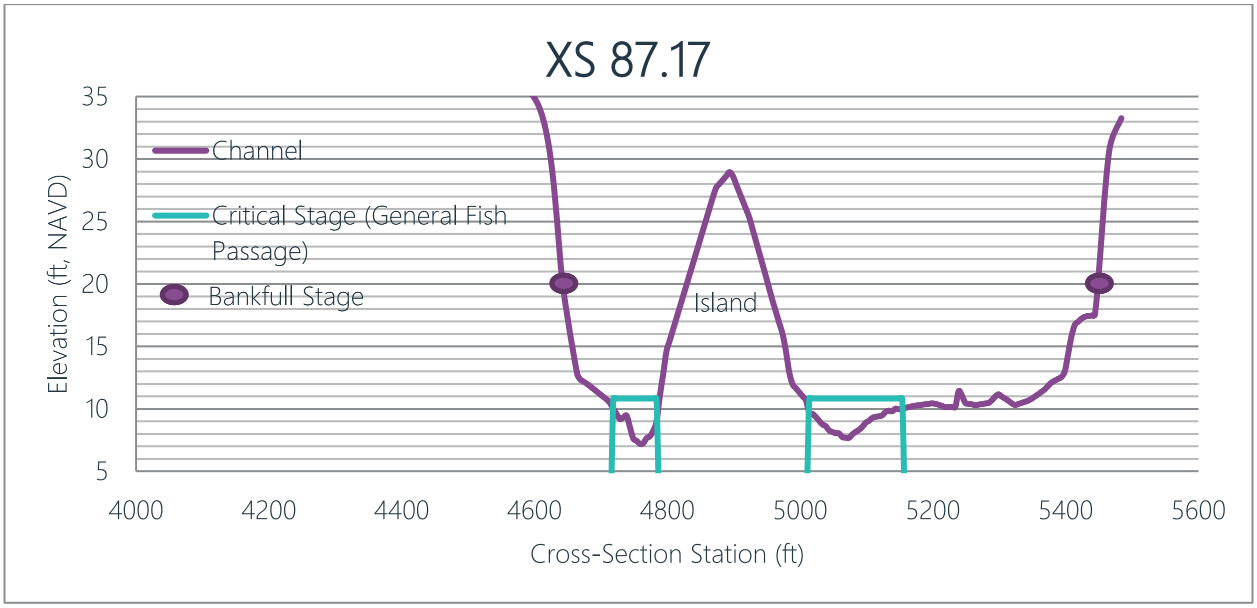
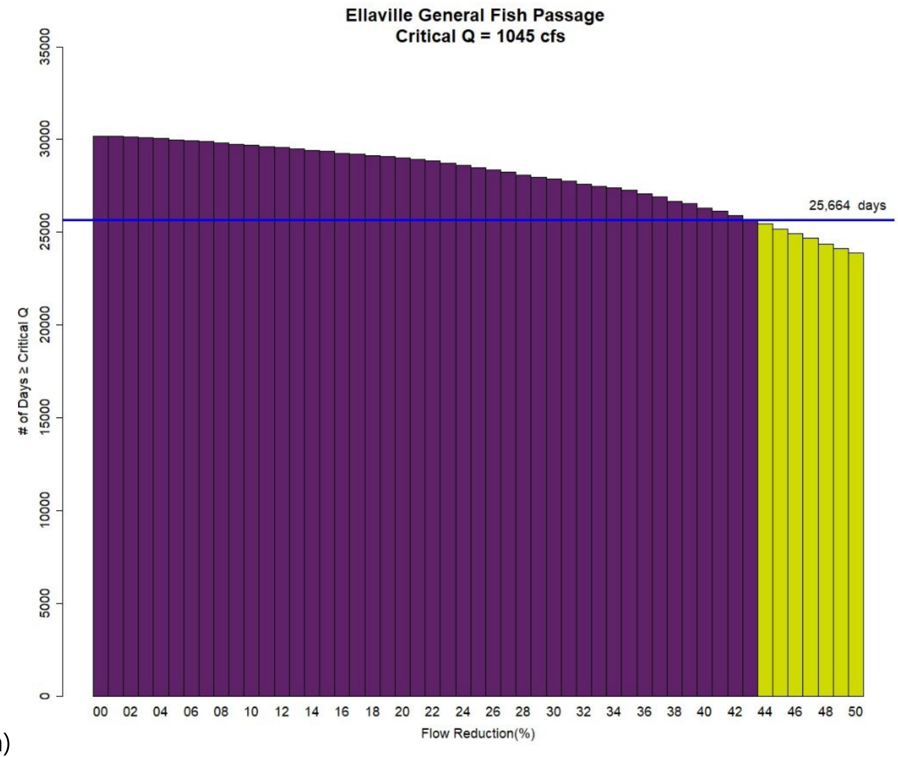


Figure 5-7. Critical shoal for general fish passage for portion of river below RM 90.



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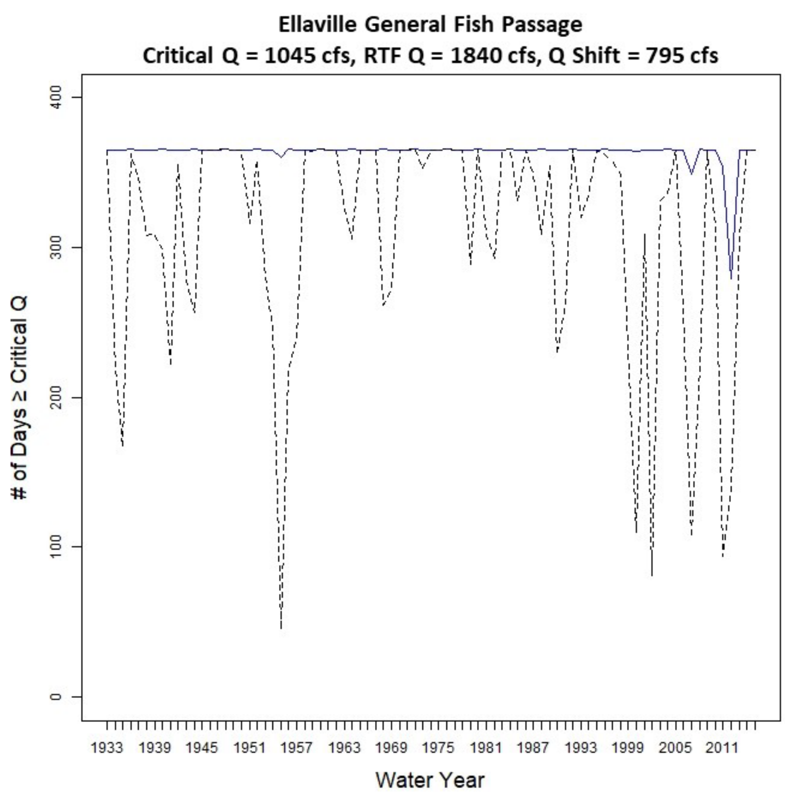
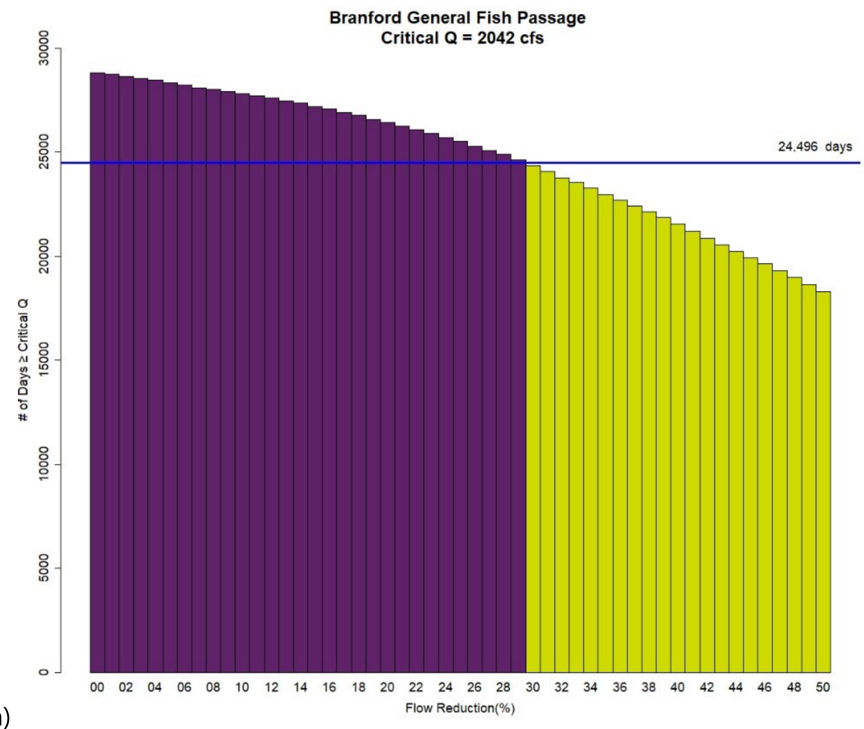


b)

Figure 5-8. Ellaville general fish passage results: a) iterative reduction graph; b) days above critical flow for RTF flow (solid line) and RTF flow reduced by 795 cfs (dashed line) on an annual basis



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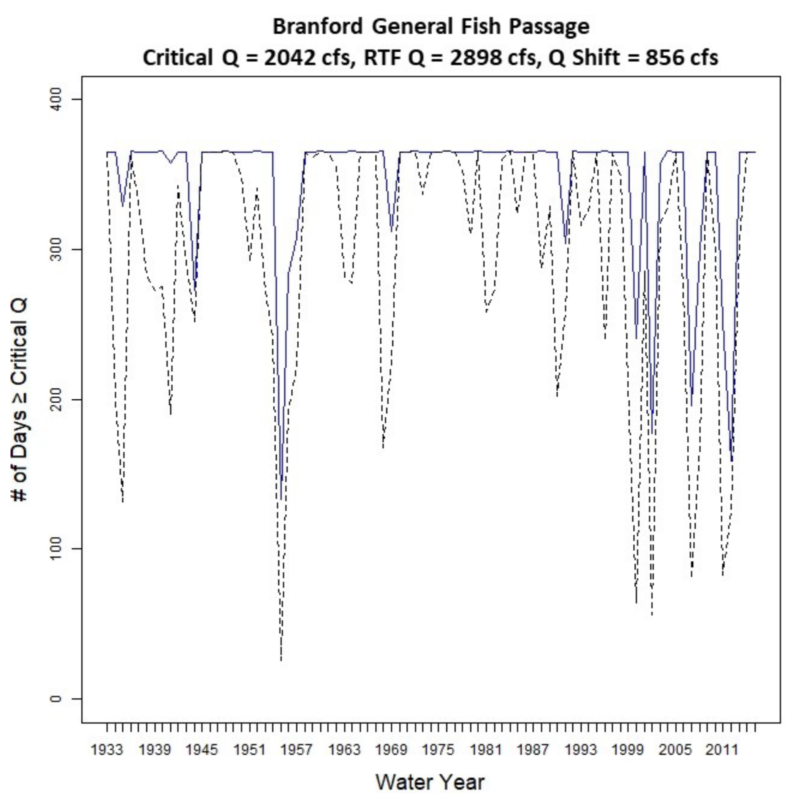


b)

Figure 5-9. Branford general fish passage results: a) iterative reduction graph; b) days above critical flow for RTF flow (solid line) and RTF flow reduced by 856 cfs (dashed line) on an annual basis

Gulf Sturgeon Passage

The elevation at which at least 3 feet of water covers at least 15 feet of streambed was identified as the criteria protective of Gulf sturgeon passage (Table 4-1).[8] **Figure 5-10** illustrates the water level at which these criteria for sturgeon passage are met at an example shoal. Once this elevation was identified for each assessed cross-section, the HEC-RAS model was used to determine the flow associated with that elevation. Of the assessed shoals, the shoal with the lowest exceedance flow was determined to be the limiting shoal for sturgeon passage. This flow was then cross-referenced with concurrent flow at the appropriate compliance gage to determine a sturgeon passage MFL. Sturgeon travel up and down the Suwannee at certain times of year, so the critical flow was further assessed by season (February-April and September-November). **Figure 5-11** shows the difference in the flow duration curves (FDC) between the two seasons and the full year RTF FDC for both the Ellaville and Branford gages. Note that spring flows (February-April) are above the annual RTF flow and the fall flows (September-November) are below.

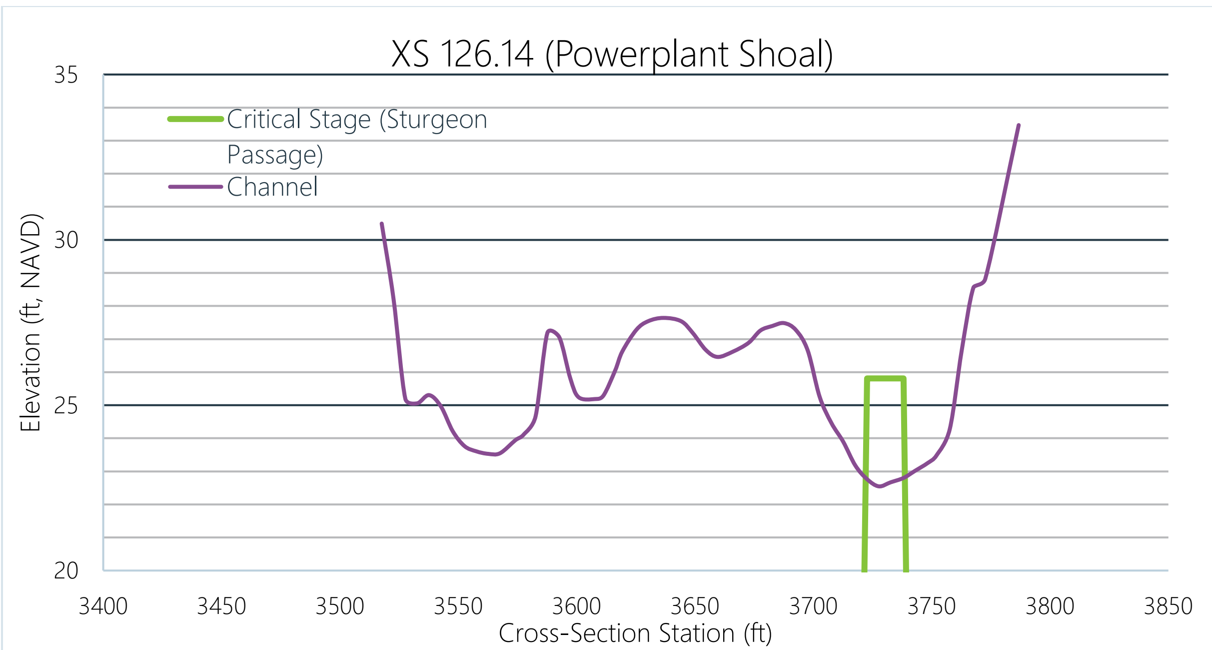
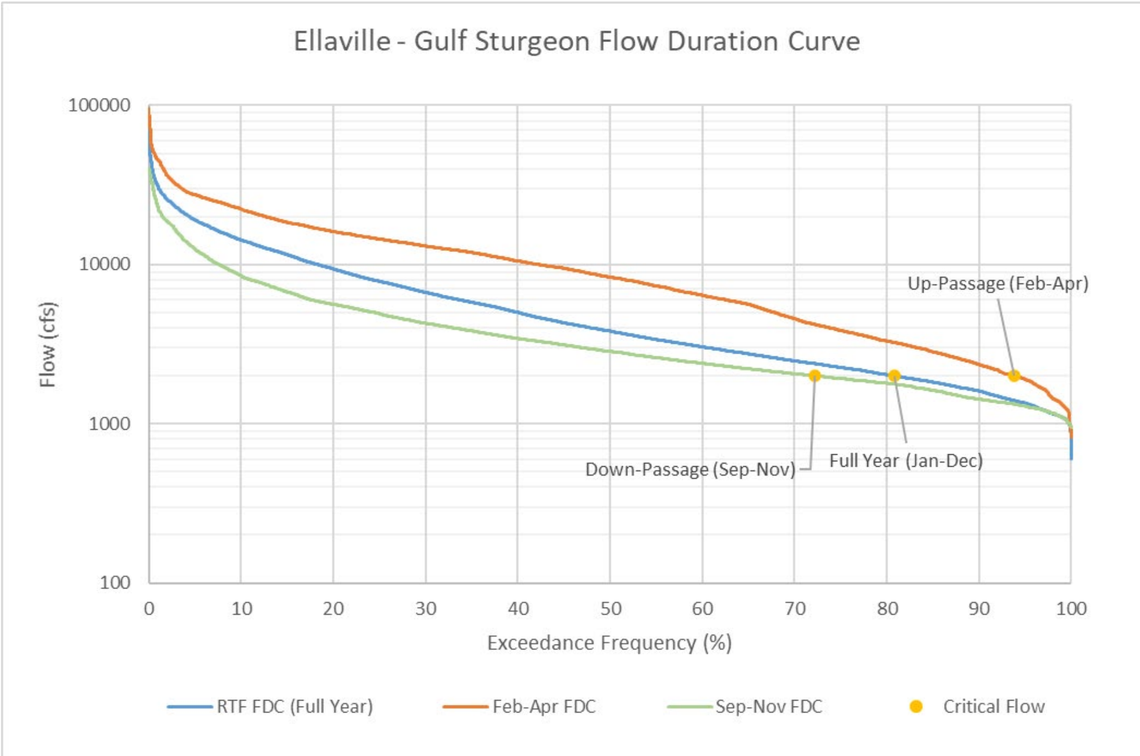
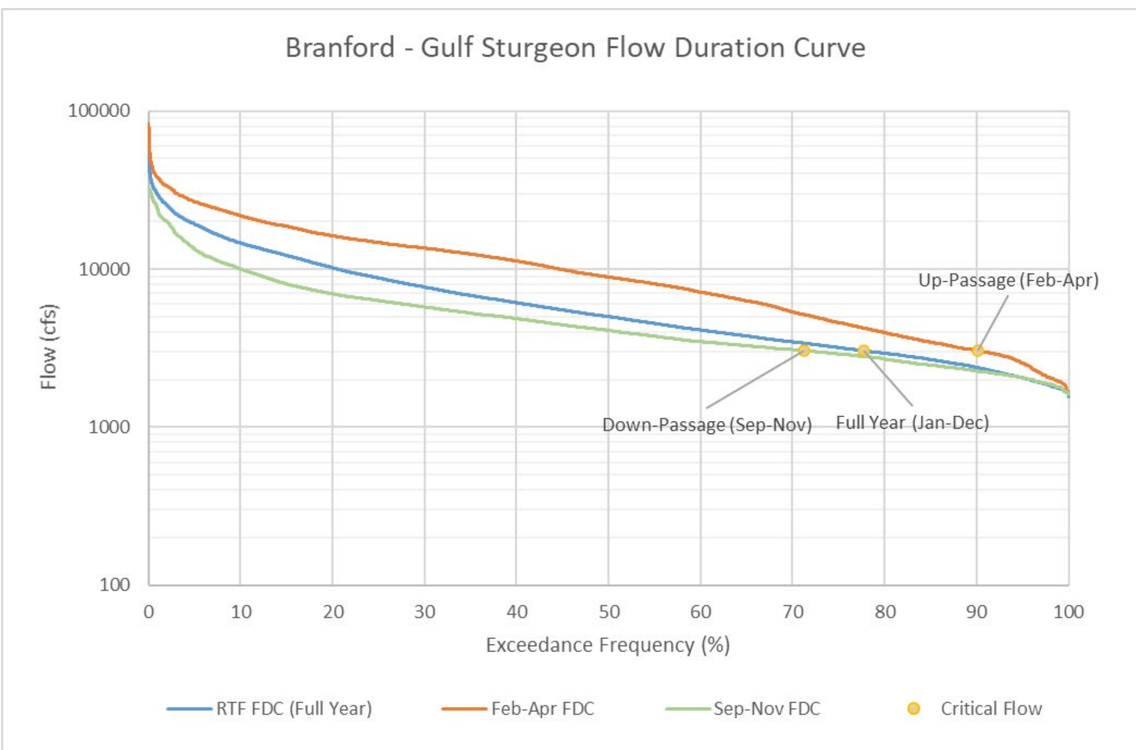


Figure 5-10. Example of water level allowing for at least 3 ft of water to cover 15 ft of the streambed

[8] These parameters follow the approach used for Gulf sturgeon passage in the Lower Santa Fe and Ichetucknee Rivers MFL Re-evaluation Report, citing personal communication with Michael Randall (USGS), 2013 (HSW, 2021).



a)



b)

Figure 5-11. Flow duration curves: full RTF daily flow record (blue), RTF daily flows for Gulf sturgeon spring migration months (orange), RTF daily flows for Gulf sturgeon fall migration months (green). a) Ellaville; b) Branford

For sturgeon passage within the portion of the river above RM 90, station 102.59 was the limiting shoal with a critical flow of 1,998 cfs at the Ellaville gage (**Figure 5-6**). This shoal is located slightly less than one river mile downstream of Lafayette Blue Spring. During the wetter February-April upstream migration, this critical flow was exceeded 6,952 days or an average of 84 passable days per season for the 83-year record. A no greater than 15% reduction in the number of passable days corresponds with a 40% allowable flow reduction at the Ellaville gage during this migration, which results in an RTF flow of 3,339 cfs and a hydrologic shift of 1,341 cfs. This allowable flow reduction would result in 5,906 passable days for the 83-year record or an average of 72 passable days per season. During the drier September-November downstream migration, the critical flow was exceeded 5,362 days for the 83-year record or an average of 65 passable days per season. A no greater than 15% reduction in the number of passable days corresponds with a 15% allowable flow reduction at the Ellaville gage during this migration, which results in an RTF flow of 2,344 cfs and a hydrologic shift of 346 cfs. This allowable flow reduction would result in 4,541 passable days for the 83-year record or 55 passable days per season on average. Graphic representations of these results are provided in **Figure 5-13** and **Figure 5-14**. The hydrologic shift of 346 cfs derived from the seasonal analysis will be applied year-round to prevent withdrawals from causing significant harm during the drier fall migration season.

For the portion of the river below RM 90, station 88.38 was the critical shoal with a critical flow of 3,044 cfs at the Branford gage (**Figure 5-12**). This shoal is located approximately 0.3 river miles downstream of Ravine Spring (Suwannee County). During the wetter spring migration up-river, this critical flow was exceeded 6,672 days or 81 passable days per season on average for the 83-year record. A no greater than 15% reduction in the number of passable days corresponds with a 31% allowable flow reduction at the Branford gage during this migration, which results in an RTF flow of 4,381 cfs and a hydrologic shift of 1,337 cfs. This allowable flow reduction would result in 5,673 passable days for the 83-year record or 69 passable days per season on average. During the drier fall migration down-river, the critical flow was exceeded 5,295 days or 64 passable days per season on average. A no greater than 15% reduction in the number of passable days corresponds with a 12% allowable flow reduction at the Branford gage during this migration, which results in an RTF flow of 3,444 cfs and a hydrologic shift of 400 cfs. This allowable flow reduction would result in 4,487 days for the 83-year record or 54 passable days per season on average. Graphic representations of these results are provided in **Figure 5-15** and **Figure 5-16**. The hydrologic shift of 400 cfs derived from the seasonal analysis will be applied year-round to prevent withdrawals from causing significant harm during the drier fall migration season.

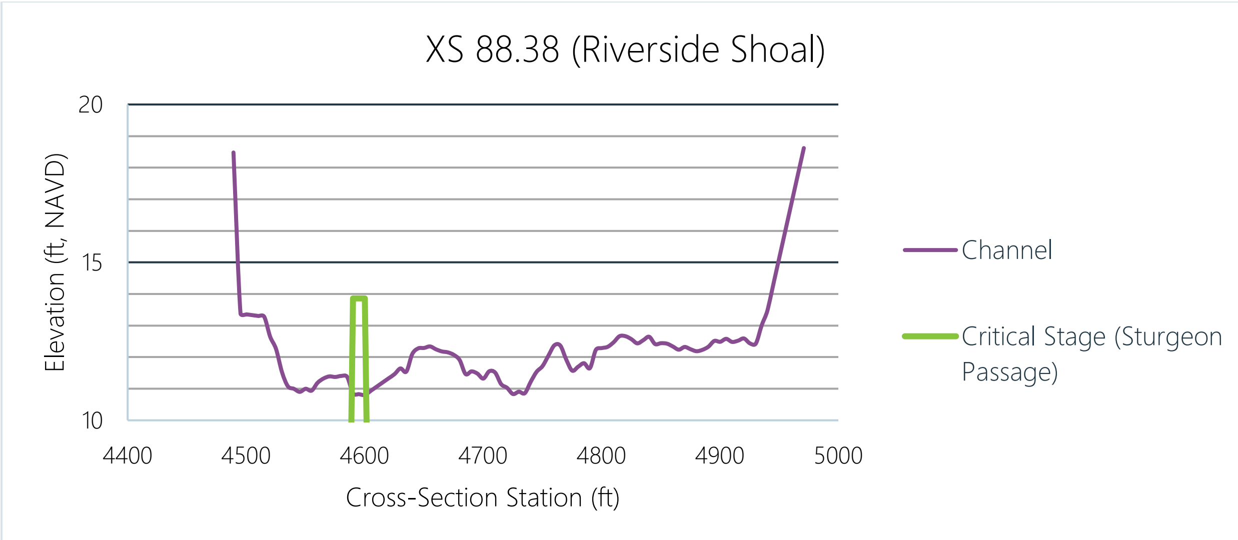
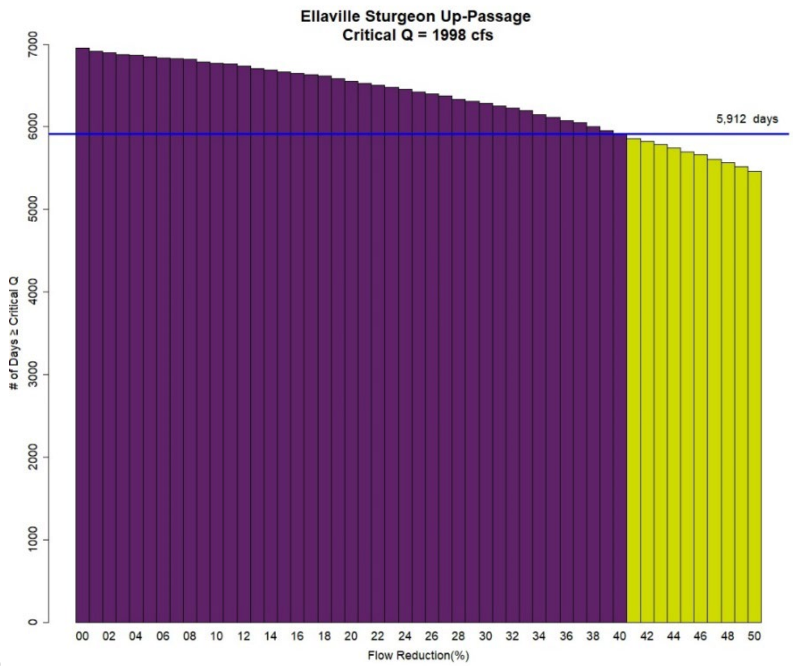
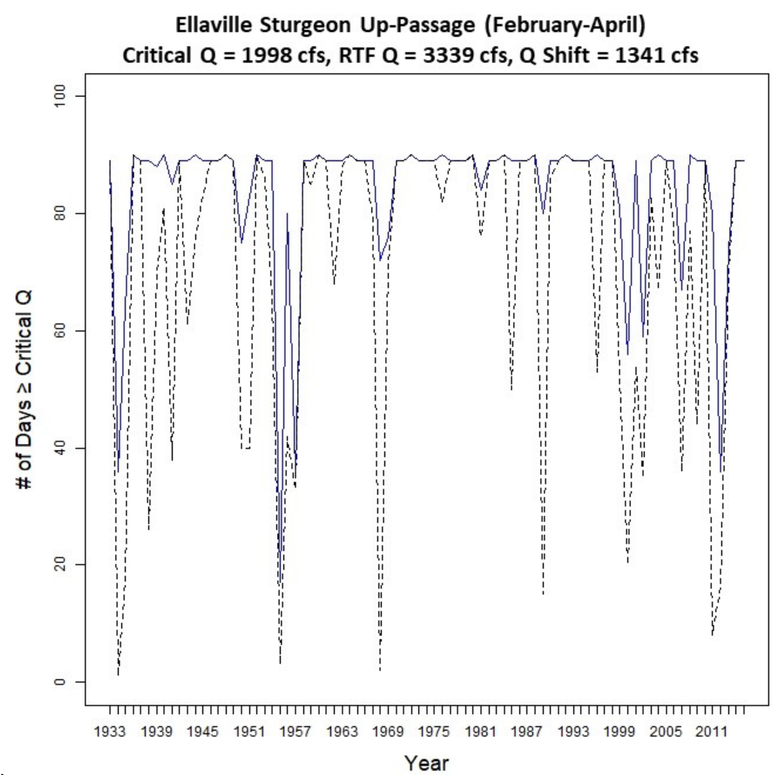


Figure 5-12. Critical shoal for Gulf sturgeon passage for portion of river below RM 90.

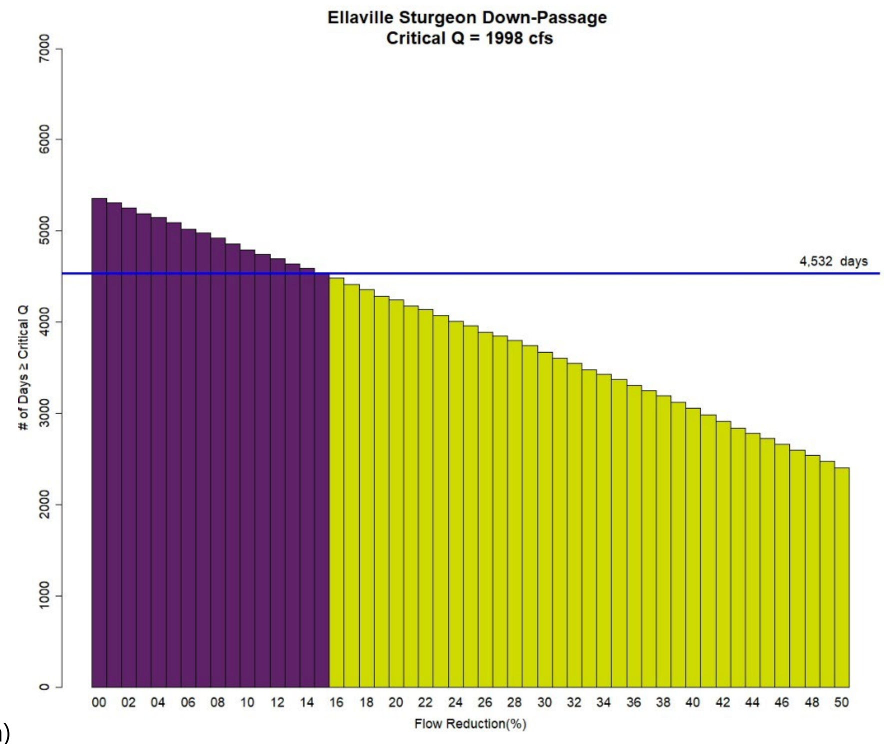


a)

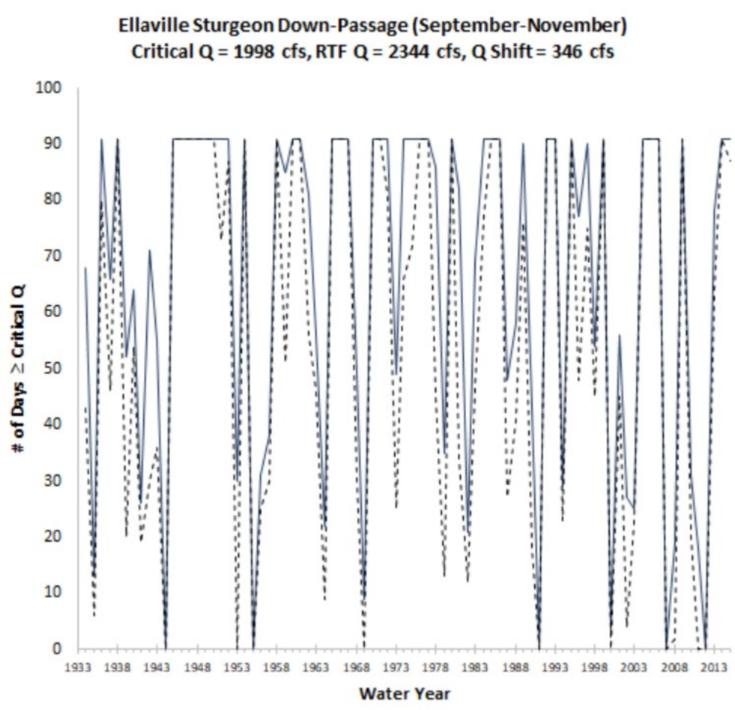


b)

Figure 5-13. Ellaville Gulf sturgeon spring migration passage results: a) iterative reduction graph; b) days per season above critical flow for RTF flow (solid line) and RTF flow reduced by 1341 cfs (dashed line)

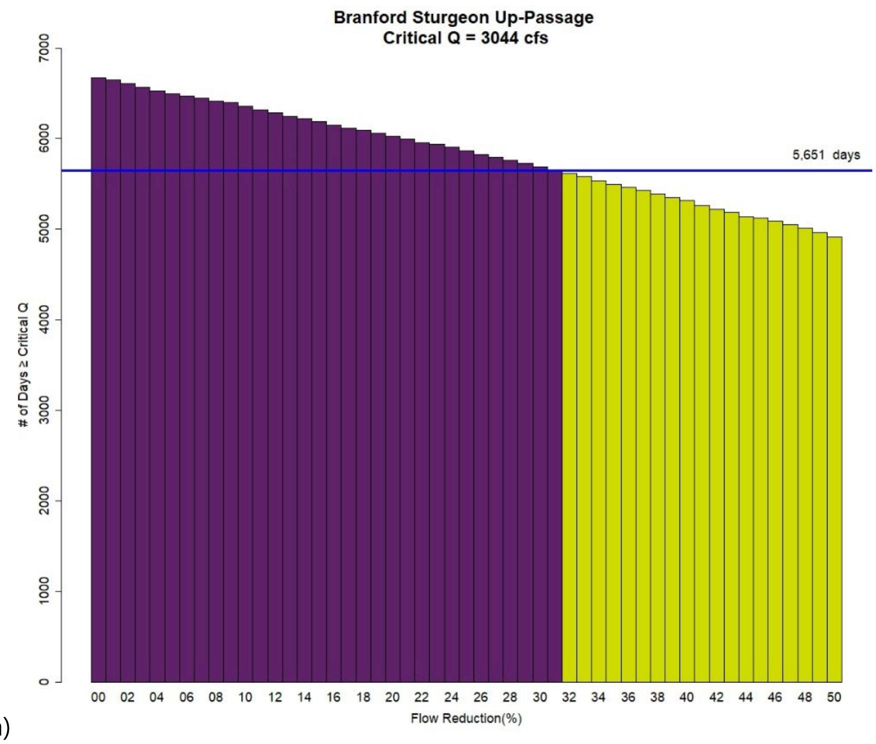


a)



b)

Figure 5-14. Ellaville Gulf sturgeon fall migration passage results: a) iterative reduction graph; b) days per season above critical flow for RTF flow (solid line) and RTF flow reduced by 346 cfs (dashed line)



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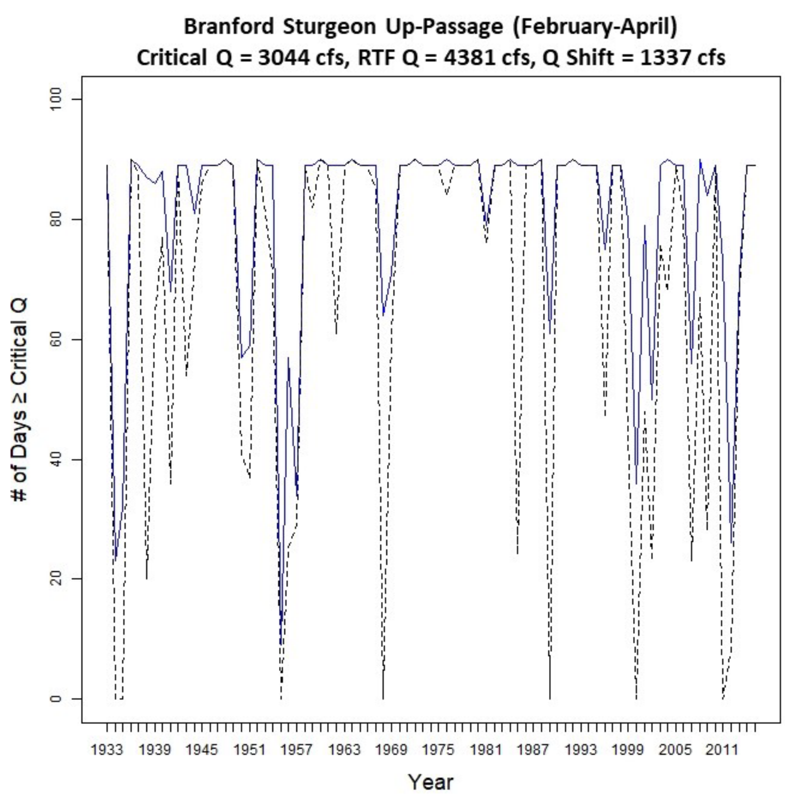
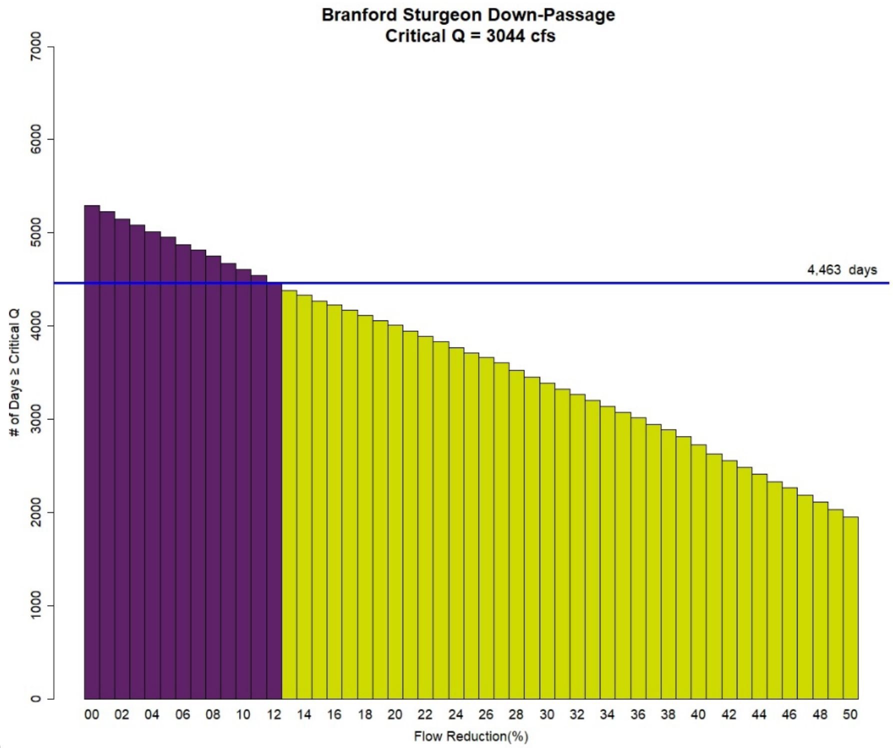


b)

Figure 5-15. Branford Gulf sturgeon spring migration passage results: a) iterative reduction graph; b) days per season above critical flow for RTF flow (solid line) and RTF flow reduced by 1337 cfs (dashed line)



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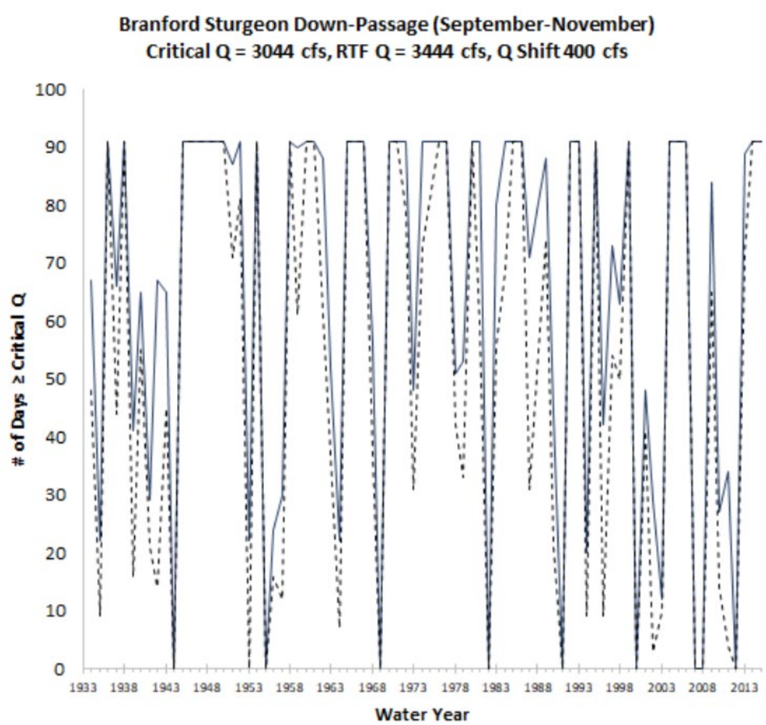


b)

Figure 5-16. Branford Gulf sturgeon fall migration passage results: a) iterative reduction graph; b) days per season above critical flow for RTF flow (solid line) and RTF flow reduced by 400 cfs (dashed line)

River to Spring Run Passage

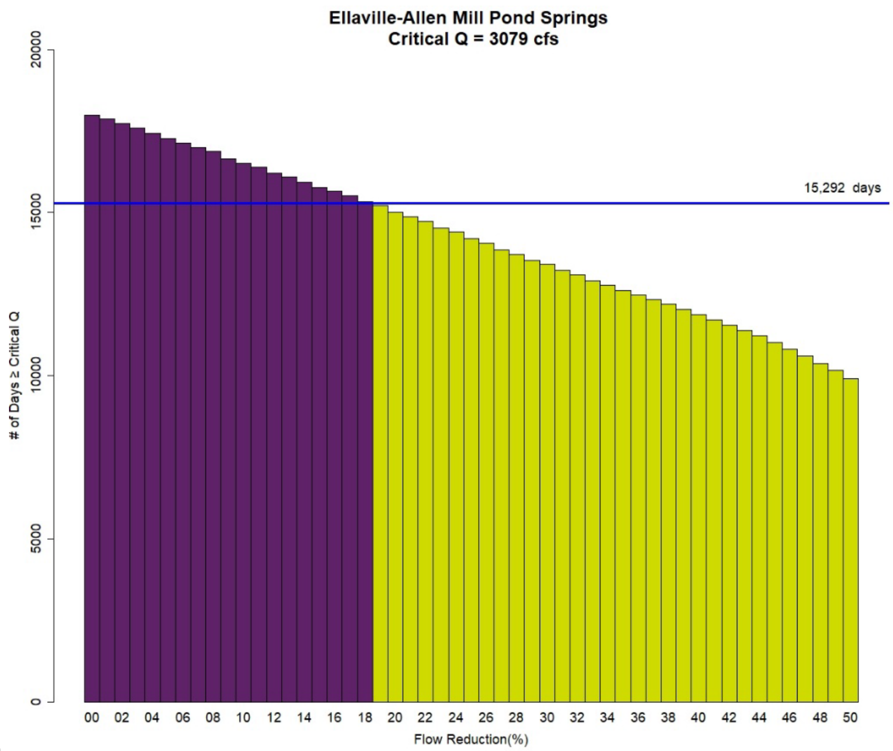
While a spring run's perennial flow maintains an opening to the Suwannee River for the exchange of flow and fish, the river does not continuously reach levels at which fish can travel from the main river channel into the spring run via the opening and ultimately providing access to MSR floodplain habitats (**Figure 5-17**). Fish passage statistics were estimated at the openings of three select spring runs (Allen Mill Pond, Otter, Peacock) using available cross-sectional survey data near the spring outlet and the previously described criteria and methods for general fish passage (0.8-foot depth over 25% of the channel width with no single width increment less than 10%). The critical stage determined for each spring run was then assessed at the closest HEC-RAS cross-section in the main river channel to determine the flow associated with that elevation. The river flow associated with river passage at each spring run was then corresponded with the contemporaneous flow at the appropriate compliance gage (Ellaville when above RM 90 or Branford when below RM 90) to determine a spring run entry/exit fish passage MFL.

Figure 5-17. Example of opening in bank of the Suwannee River maintained by perennial spring flow: view from river to spring run (top photo) and view from spring run to river (bottom photo)

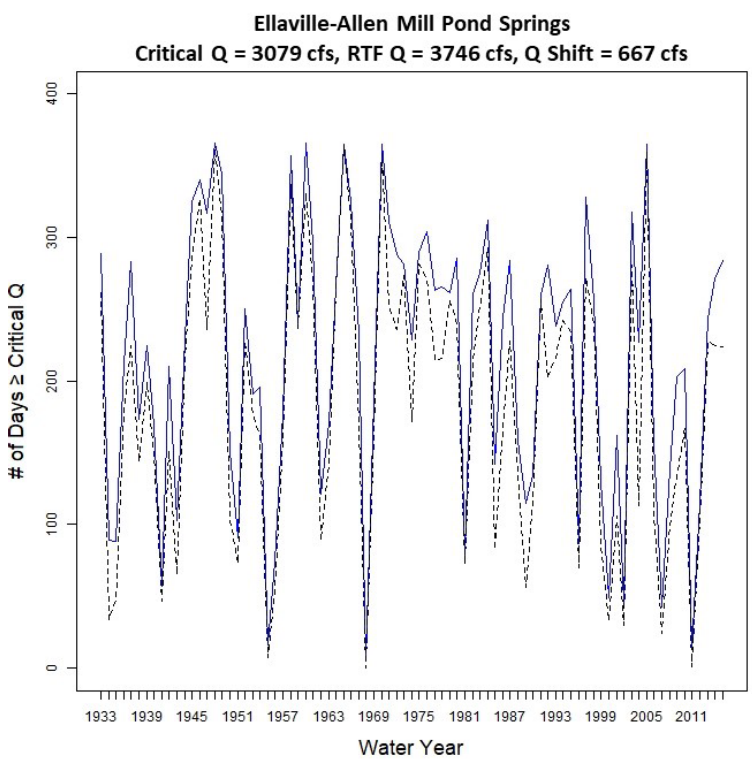
For fish passage into/out of the Allen Mill Pond spring run, a critical flow of 3,079 cfs at the Ellaville gage was determined. For the 83-year RTF flow record assessed, this critical flow was equalled or exceeded about 60% of the time: 17,991 days or 217 passable days per year on average. A no greater than 15% reduction in the number of passable days corresponds with an 18% allowable flow reduction at the Ellaville gage, which results in an RTF flow of 3,746 cfs and a hydrologic shift of 667 cfs. This allowable flow reduction would result in 15,292 passable days for the 83-year record or 185 passable days per year on average. Graphic representations of these results are provided in **Figure 5-18**.

For fish passage into/out of the Peacock spring run, a critical flow of 7,453 cfs at the Ellaville gage was determined. For the 83-year RTF flow record assessed, this critical flow was equalled or exceeded about 27% of the time: 8,076 days or 97 passable days per year on average. A no greater than 15% reduction in the number of passable days corresponds with a 12% allowable flow reduction at the Ellaville gage, which results in an RTF flow of 8,474 cfs and a hydrologic shift of 1,021 cfs. This allowable flow reduction would result in 6,863 passable days for the 83-year record or 83 passable days per year on average. Graphic representations of these results are provided in **Figure 5-19**.

For fish passage into/out of the Otter spring run, a critical flow of 1,320 cfs at the Branford gage was determined. For the 83-year RTF flow record assessed, this critical flow was always equalled or exceeded: 30,315 days or 365 passable days per year on average. A no greater than 15% reduction in the number of passable days corresponds with a 51% allowable flow reduction at the Branford gage, which results in an RTF flow of 2,678 cfs and a hydrologic shift of 1,358 cfs. This allowable flow reduction would result in 25,767 passable days for the 83-year record or 310 passable days per year on average. Graphic representations of these results are provided in **Figure 5-20**. The Otter spring run fish passage metric will not be used in the final MFL because it would take a greater than 50% reduction in flow to reduce fish passage, which does not plot on the flow duration curve (FDC) because it is below the lowest recorded flow in the RTF POR.

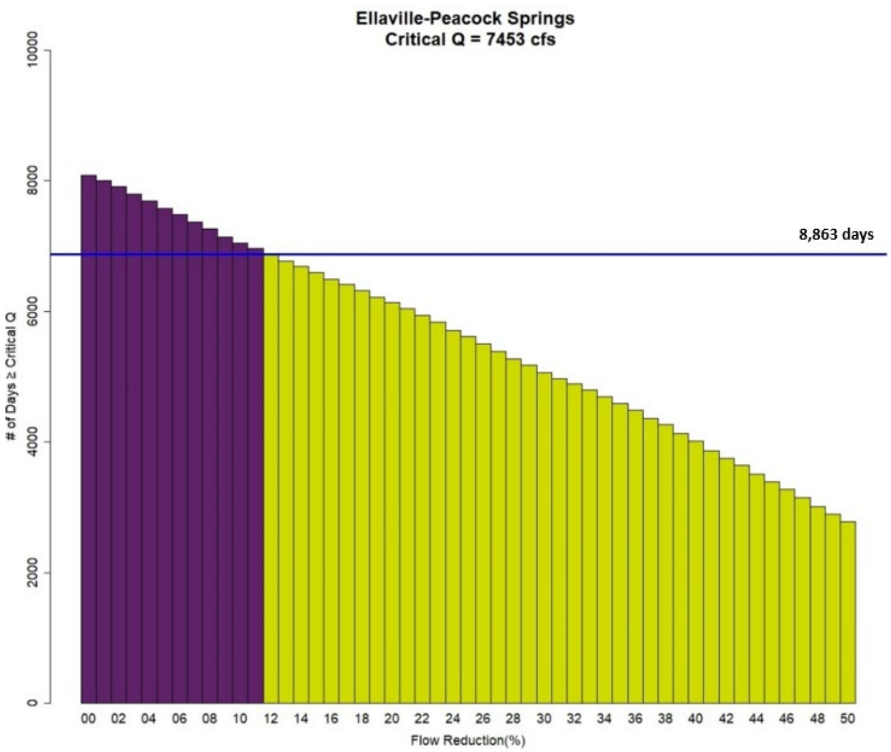


a)

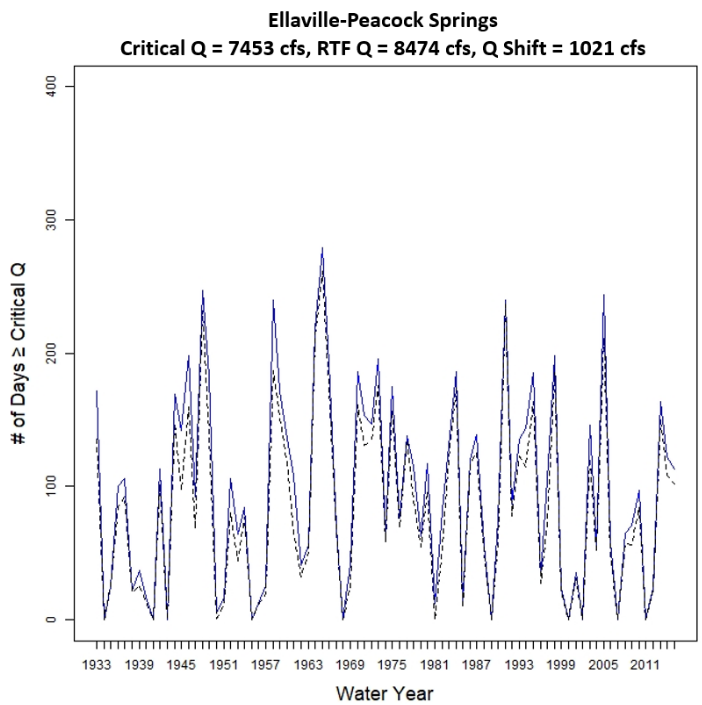


b)

Figure 5-18. Ellaville Allen Mill Pond Springs fish passage results: a) iterative reduction graph; b) days per year above critical flow for RTF flow (solid line) and RTF flow reduced by 667 cfs (dashed line)

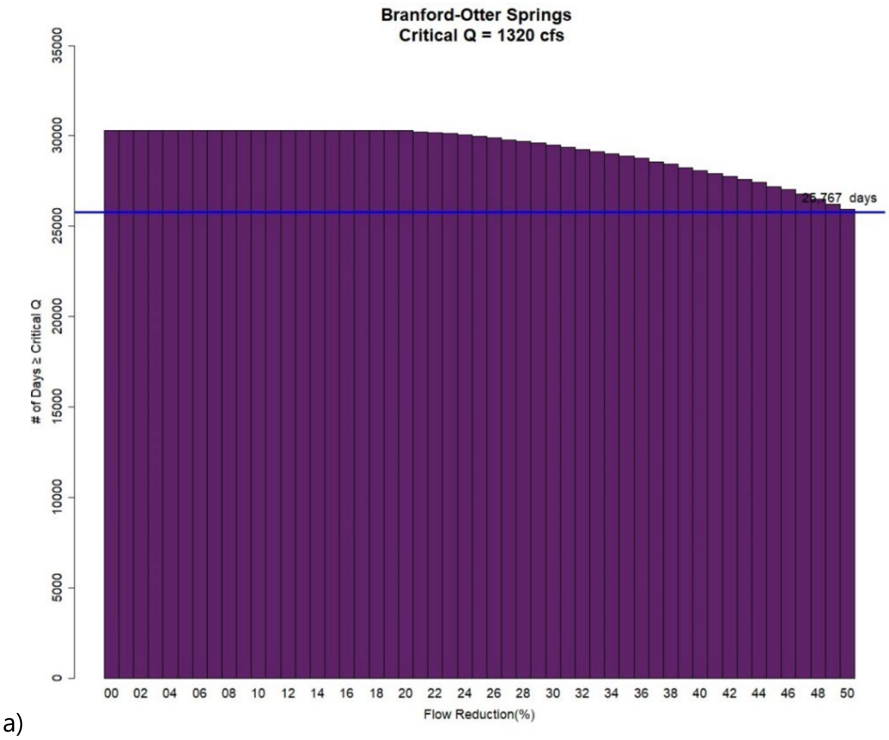


a)

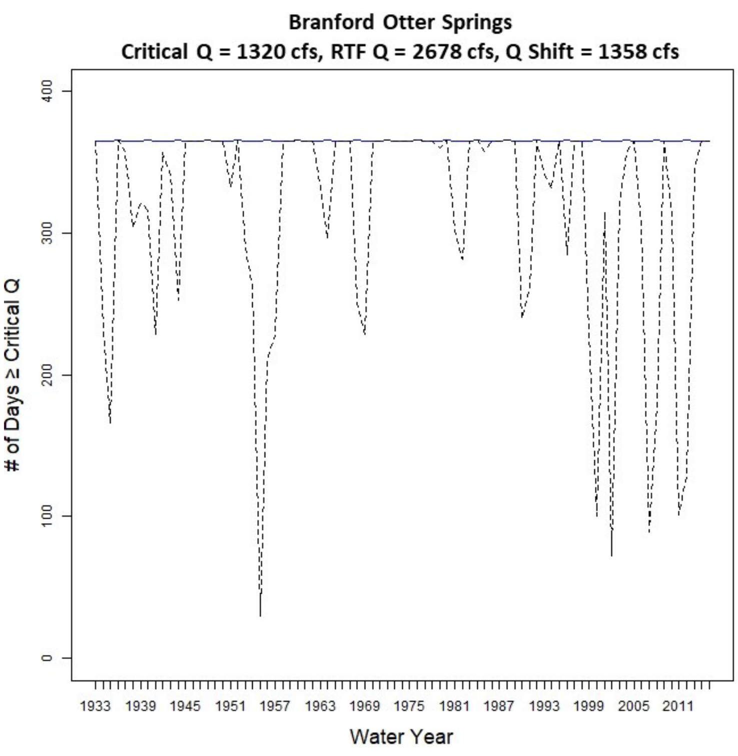


b)

Figure 5-19. Ellaville Peacock Springs fish passage results: a) iterative reduction graph; b) days per year above critical flow for RTF flow (solid line) and RTF flow reduced by 1021 cfs (dashed line)



a)



b)

Figure 5-20. Branford Otter Springs fish passage results: a) iterative reduction graph; b) days per year above critical flow for RTF flow (solid line) and RTF flow reduced by 1358 cfs (dashed line)

5.2.2 Wildlife Habitat

Wildlife habitat occurs instream in the main river channel, along the banks, and within the adjacent floodplain. The technical assessment of habitat relies on metrics for biological integrity or habitat suitability that can be related to flow and the associated stage and inundation of these primary flow-way features, as described in the following sections.

Instream Habitat

In-stream physical habitat modeling was performed for the MSR using SEFA software to characterize the relationship between instream habitat suitability and flow (**Appendix VIII**). Five sites were chosen for SEFA data collection in the MSR based on characteristic representation, accessibility, and diversity of habitat area (**Figure 5-21**). The District emphasized sites associated with major shoals, all of which occur upstream of Branford, under the assumption that these areas would likely present the most sensitive habitats to flow reductions. Project staff collected the necessary elevation, velocity, discharge, depth, and substrate data at five transects within each of the sites under three different flow/stage conditions ranging from 2,343 to 9,673 cfs between May and September 2013. Transects were established to assure the natural variability in habitat substrates and meso-habitats (pools, riffles, runs) would be sampled in each area. The river presents repeating sequences of deep (pool), transitional (run), and shallow (riffle, shoal) areas that are thus captured in the sample. So, although each sampling area is defined by the name of its dominant shoal, it is important to understand that the SEFA analysis covered a complete gamut of meso-habitats (not just shoals/riffles) at each area.

RTF flow records from WY 1933 to 2015 were derived for the closest HEC-RAS station to each shoal transect using HEC-RAS model output for the two compliance gages. The Ellaville gage (02319500) was used to translate flows to the Power Plant shoal and the Dowling Park shoal sites, and the Branford gage (02320500) was used to translate flows to the Lafayette Blue, Perry, and Riverside shoal sites based upon proximity to gage. Note that SEFA only includes flow values ranging from half the lowest flow collected during SEFA data collection to two times the highest flow collected per SEFA's convention (Jowett et al., 2014). This ranged from 1,324 to 16,370 cfs at the Ellaville gage and from 1,730 to 22,600 cfs at the Branford gage.

The model was run for 47 species/life stages to determine the change in average area weighted suitability (AWS) for the truncated RTF flow time-series and for various flow reduction scenarios from the RTF flows (5%, 10%, 15%, 20%, 25%). **Table 5-1** summarizes the species/life stages at each shoal that exhibited a 15% decrease in AWS associated with flow reductions. Note that seasonal runs were also conducted for the species/life stages referenced in **Table 3-3**.

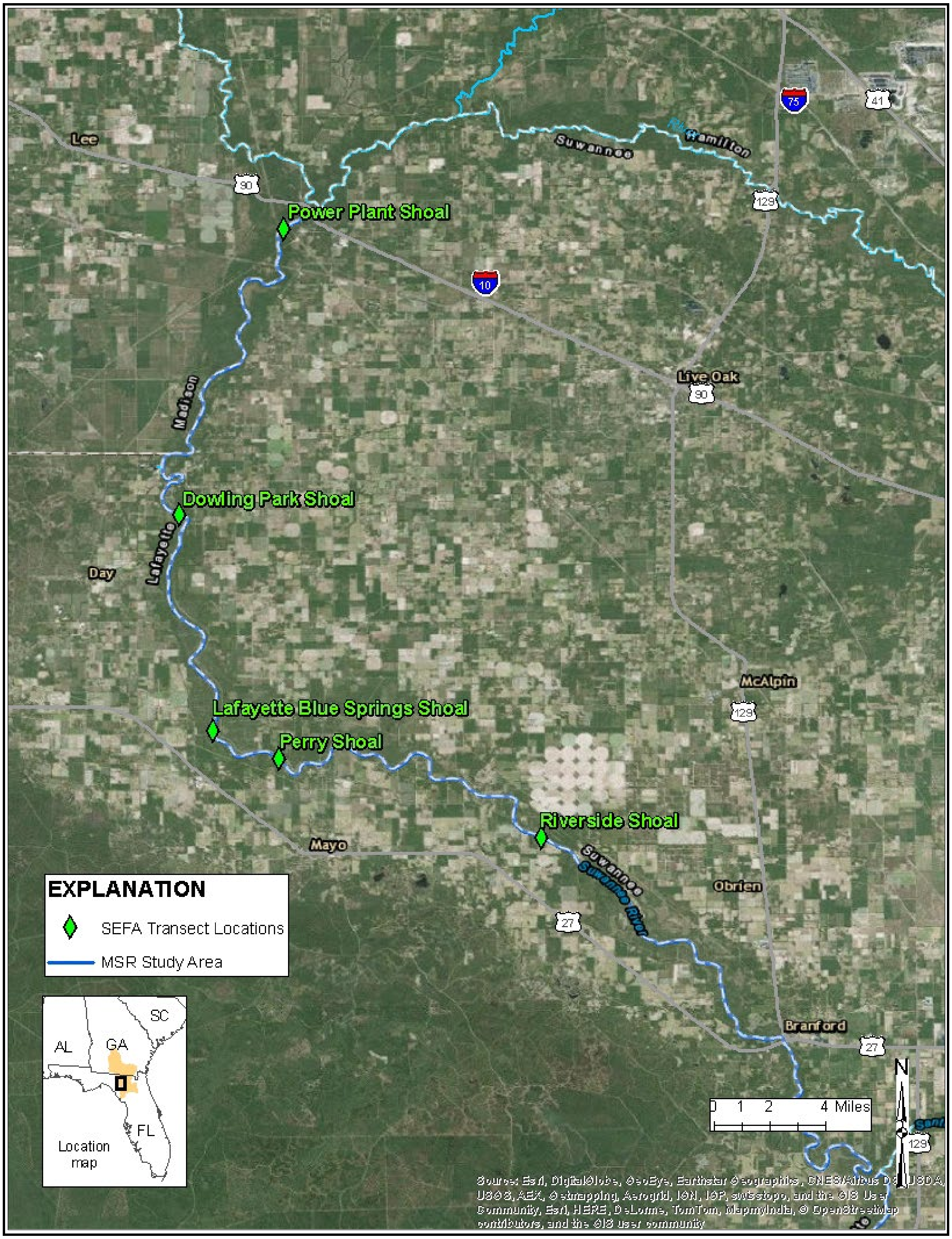


Figure 5-21. Map of selected sites for SEFA data collection in the Middle Suwannee River

Table 5-1. Percent flow reduction across the RTF period of record and associated percent reduction in the area weighted suitability (negative numbers) for representative species, guilds, and life stages

USGS Gage	Site	Species/Life Stage	% Change in AWS Resulting from Various Flow Reduction Scenarios: 5% Flow Reduction	10% Flow Reduction	15% Flow Reduction	20% Flow Reduction	25% Flow Reduction	RTF AWS Mean (ft^2/ft)	Reduced AWS Mean (ft^2/ft)	Allowable Percent Flow Reduction*	Hydrologic Shift (cfs)**
Ellaville	Power Plant	Habitat Guild Deep/Slow	-4.8	-9.6	-14.4	-19.1	-23.9	2.57	2.18	**15.7**	**600**
		Largemouth Bass Adult	-3.8	-7.9	-12.2	-16.7	-21.7	*0.58*	*0.5*	18.2	696
		Largemouth Bass Fry	-4.0	-7.5	-11.3	-16.2	-19.8	*0.07*	*0.06*	18.9	722
		Bluegill Fry	-2.7	-5.6	-9.1	-12.6	-15.8	*0.17*	*0.14*	23.9	914
	Dowling Park	Gulf Sturgeon Adult	-3.8	-7.7	-11.8	-16.0	-20.5	84.97	72.17	18.9	722
Branford	Lafayette Blue	Largemouth Bass Fry	-4.4	-10.1	-15.1	-20.0	-24.4	*0.04*	*0.03*	14.9	744
		Largemouth Bass Adult	-4.3	-9.0	-14.0	-19.3	-25.0	*0.49*	*0.42*	16.0	799
		Gulf Sturgeon Adult	-3.7	-7.6	-11.7	-16.0	-20.6	126.56	107.52	**18.9**	**944**
		Habitat Guild Deep/Slow	-3.1	-6.2	-9.5	-13.1	-17.0	3.95	3.36	22.6	1129
	Perry	*no limiting species*									
	Riverside	Largemouth Bass Adult	-3.3	-6.8	-10.5	-14.5	-18.7	2.15	1.83	20.7	1034
		Habitat Guild Deep/Slow	-3.3	-6.7	-10.3	-14.1	-18.0	4.55	3.86	21.3	1064

Notes:

- Purple denotes a violation in the 15% habitat reduction.
- **Bold** denotes limiting species for applicable compliance gage
- *Italics* denote species/life stages with less than 1 ft^2/ft of usable habitat; these species/life stages should not be used to determine MFLs
- *Based on linear interpolation to derive the relative flow reduction associated with a 15% reduction in RTF AWS
- **Derived by applying the allowable percent flow reduction to the median RTF flow.

Among the five sites sampled for this study, the Perry Shoal area did not have any species/life stages with more than 15% reduction in AWS upon reductions in the flow record. Bluegill, largemouth bass, Gulf sturgeon, and one habitat guild (deep/slow) had AWS reductions greater than 15% with flow reductions among the four remaining sites (**Table 5-1**). Of the species and life stages listed above, the largemouth bass fry at Lafayette Blue shoal is the most restrictive in terms of percent reduction of the flow record. However, since the site showed very little initial area weighted suitability (i.e., 0.04 ft^2/ft) for this species and life stage, the deep/slow guild at Power Plant shoal was selected as the most limiting species. This is applicable to the portion of the river above RM 90. A flow reduction of 15.7% for the deep/slow guild at Power Plant shoal showed a greater than 15% reduction in AWS. The use of linear interpolation on flow reductions between 15-20% at the Ellaville gage indicate that the most deleterious effects to habitat area begin to occur at 15.7%. Thus, any flow reduction greater than 15.7% would violate the habitat reduction threshold. As previously mentioned, the range of flows for which this percent reduction is applicable is from 1,324 to 16,370 cfs at the Ellaville gage. The hydrologic shift, determined by applying the percent reduction to the median Ellaville RTF flow of 3,822 cfs, is 600 cfs.

The critical species/life stage below RM 90 is the Gulf sturgeon adult at Lafayette Blue shoal. The use of linear interpolation on flow reductions between 15-20% at the Branford gage indicates that the most deleterious effects to Gulf sturgeon adult habitat area begin to occur at 18.9%. Thus, any flow reduction greater than 18.9% would cause a greater than 15% reduction in the species' habitat. As previously mentioned, the range of flows for which this percent reduction is applicable is from 1,730 to 22,600 cfs at the Branford gage. The hydrologic shift, determined by applying the percent reduction to the median Branford RTF flow of 4,993 cfs, is 944 cfs.

Riparian Bank Habitat

Snags and tree roots provide woody habitat along the banks of the Suwannee River. Rocky limestone outcroppings also provide habitat along the banks in some sections of the river. To distinguish between the open water channel and riparian bank habitat, the lower extent of woody plants was surveyed along selected locations of the river channel margins. This generally corresponded to the bottom elevation of the bald cypress (*Taxodium distichum*) treeline (**Figure 5-22**). Using survey data collected at 20 bank locations along the MSR during August and September 2014, an elevation profile was developed for the breakpoint between the open water channel and riparian bank habitat (**Figure 5-23**, **Appendix IV**). The following equations were used to determine the critical elevations for this breakpoint based on the regression equation between survey data and river mile.

Upstream of RM 90, EL = -12.232 + 0.3243*RM
Between RM 39.5 and 90, EL = -10.54 + 0.3055*RM
Downstream of RM 39.5, EL = 1.53

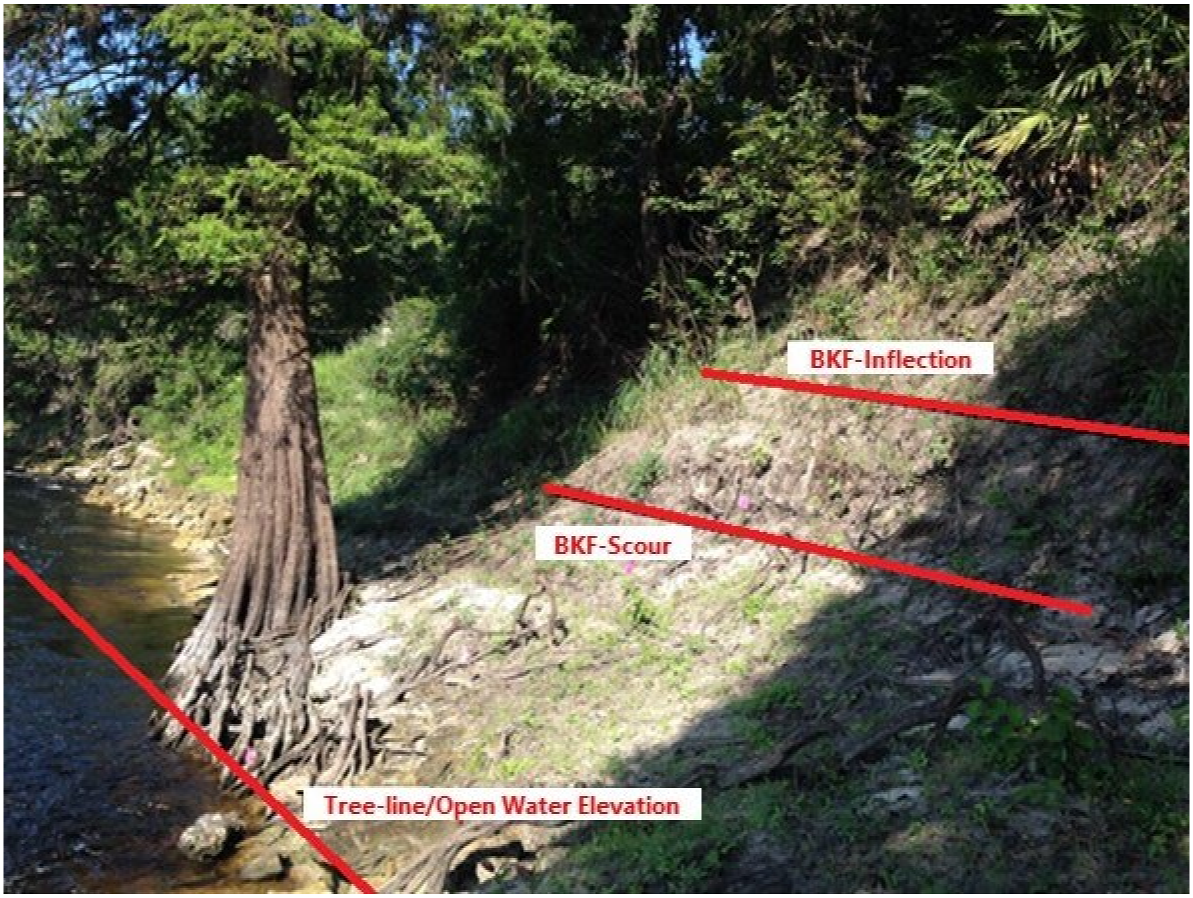


Figure 5-22. Riparian bank habitat

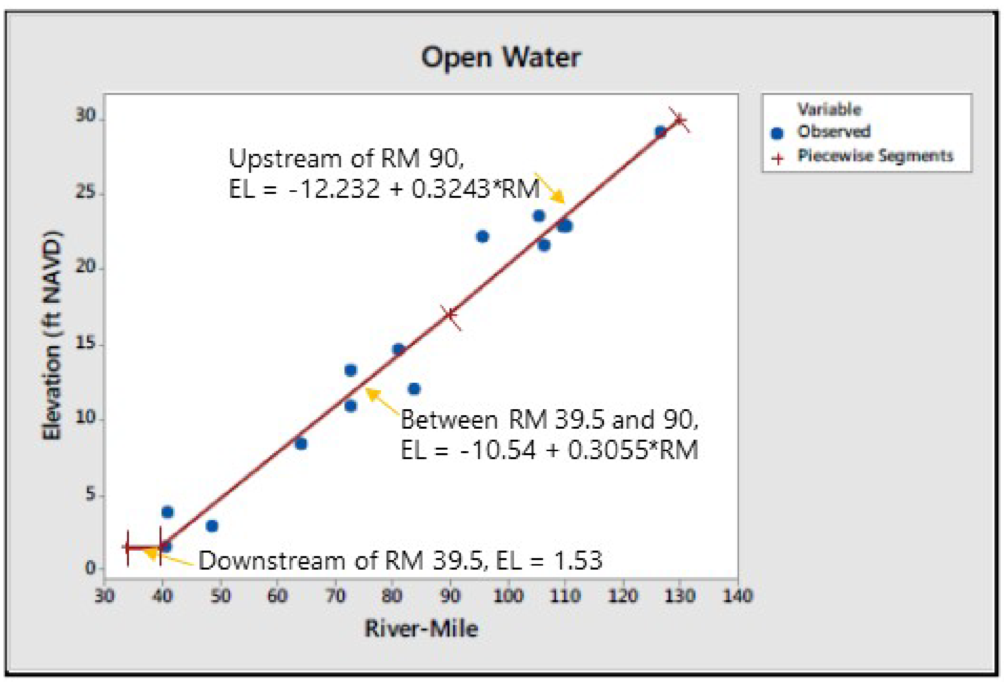
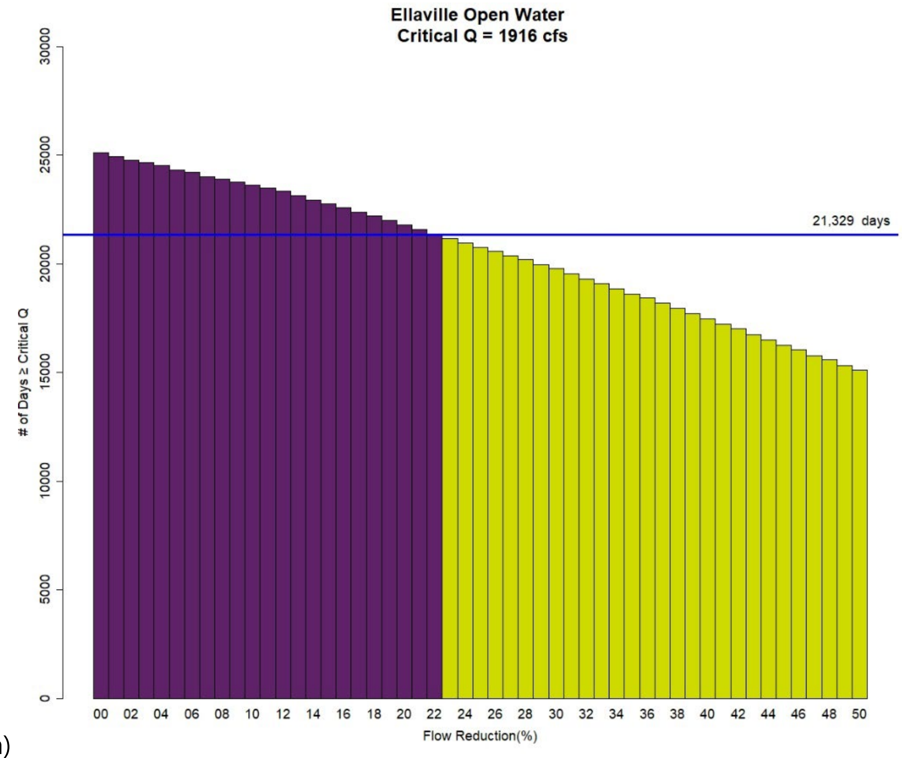


Figure 5-23. Regression for open water elevation vs river mile based on survey data

Once the critical elevations were determined for each gage, the HEC-RAS model was then used to determine the critical flow associated with that elevation. The critical flow for the breakpoint between the open water channel and the riparian bank habitat within the portion of the river above RM 90 is 1,916 cfs at the Ellaville gage. For the 83-year RTF flow record assessed, this critical flow was equalled or exceeded about 83% of the time: 25,094 days or 302 inundated days per year on average. A no greater than 15% reduction in the number of days inundated corresponds with a 22% allowable flow reduction at the Ellaville gage, which results in an RTF flow of 2,461 cfs and a hydrologic shift of 545 cfs. This allowable flow reduction would result in 21,329 inundated days for the 83-year record or 257 inundated days per year on average. Graphic representations of these results are provided in **Figure 5-24**.

For the portion of the river below RM 90, the critical flow for the breakpoint between the open water channel and the riparian bank habitat is 5,485 cfs at the Branford gage. For the 83-year RTF flow record assessed, this critical flow was equalled or exceeded about 45% of the time: 13,711 days or 165 days per year on average. A no greater than 15% reduction in the number of days inundated corresponds with a 13% allowable flow reduction at the Branford gage, which results in an RTF flow of 6,331 cfs and a hydrologic shift of 846 cfs. This allowable flow reduction would result in 11,654 inundated days for the 83-year record or 140 inundated days per year on average. Graphic representations of these results are provided in **Figure 5-25**.



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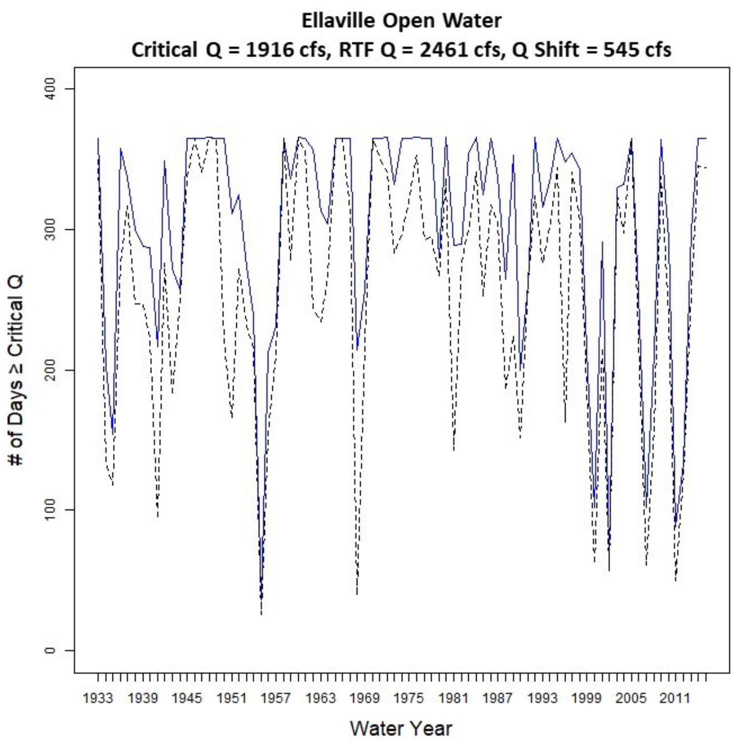
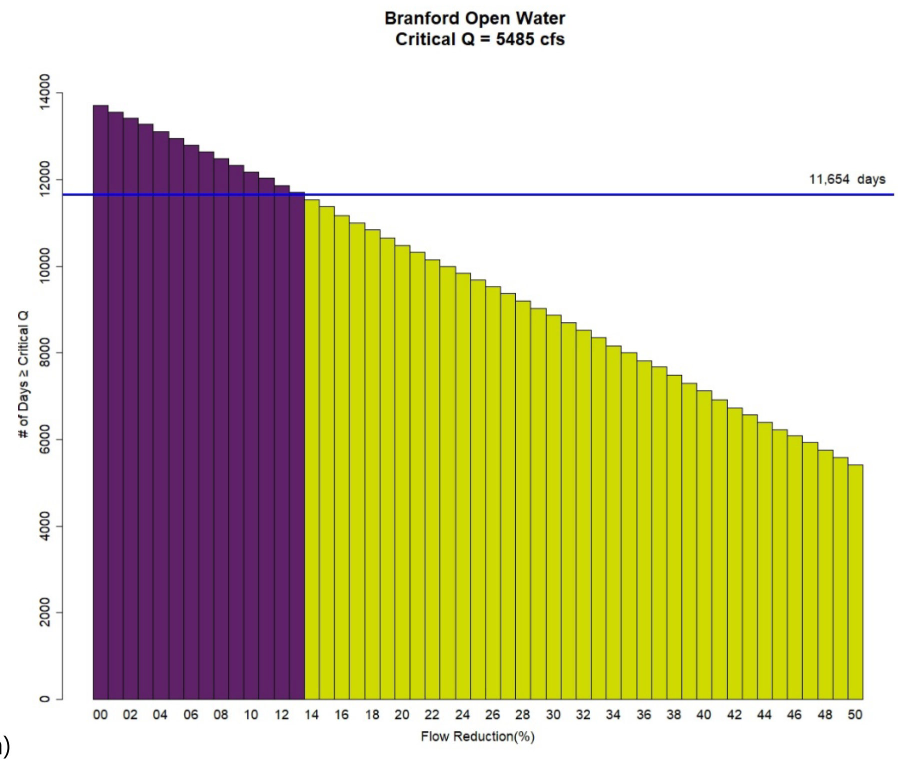


b)

Figure 5-24. Ellaville open water results: a) iterative reduction graph; b) days per year above critical flow for RTF flow (solid line) and RTF flow reduced by 545 cfs (dashed line)



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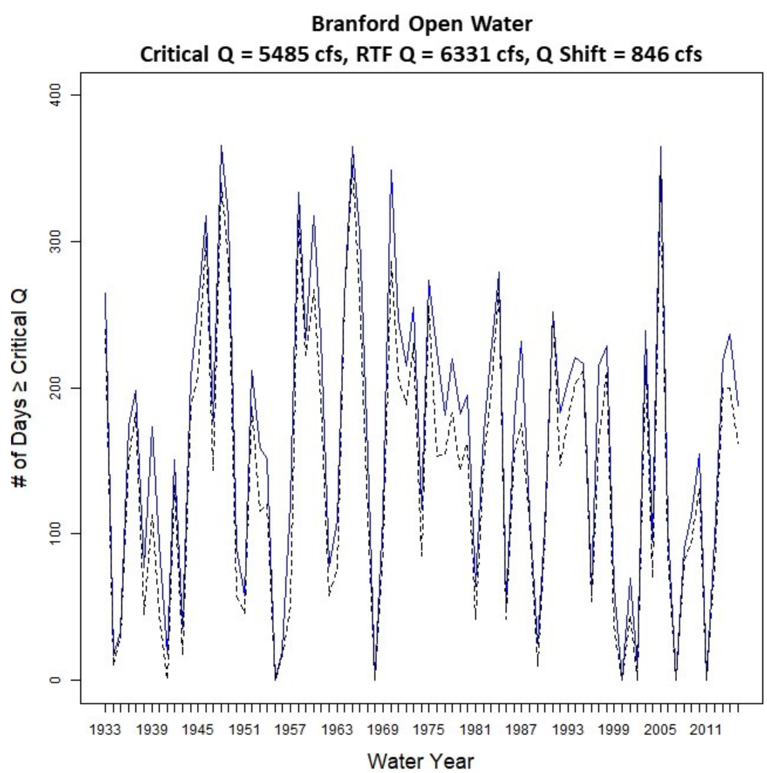


b)

Figure 5-25. Branford open water results: a) iterative reduction graph; b) days per year above critical flow for RTF flow (solid line) and RTF flow reduced by 846 cfs (dashed line)

Floodplain Habitat

Floodplains support riparian forests with plant species composition and canopy structure that vary to a considerable extent in the frequency, depth, and duration of river floods. These habitats include a diverse flora and provide valuable habitat for a wide variety of aquatic and terrestrial fauna. Many fish species use both instream and floodplain habitats. Utilization of habitats adjacent to the main river channel, and movement into the floodplain during high water varies by fish species (Toth 1991, 1993). Floodplains provide feeding and spawning habitats (Guillory 1979, Ross and Baker 1983) and a refuge for juveniles (Graff and Middleton 2001, Finger and Stewart 1987). For these reasons, floodplain habitat is usually carefully evaluated in Florida riverine MFL studies, typically forming a substantial basis for establishing the high-flow MFL criteria. Based on field assessments conducted in the MSR floodplain, two general wetland communities occur: Deep Swamp and Bottomland Swamp (see **Section 3.2** and **Appendix IV** for more detailed descriptions of these wetland communities). The critical flows for these communities were determined according to methods similar to that described for the open water breakpoint, and results are presented below.

Deep Swamp

Critical elevations for the deep swamp community were determined for each compliance gage (Ellaville and Branford) based upon the maximum surveyed plot elevation for the Deep Swamp versus their respective locations according to river-mile using the following equation:

$$EL = -5.39 + 0.3274*RM$$

The regression, which was developed using survey data, is shown in **Figure 5-26** and detailed in **Appendix IV**. Since there were no apparent inflections for the Deep Swamp community, only a simple linear regression was fit.

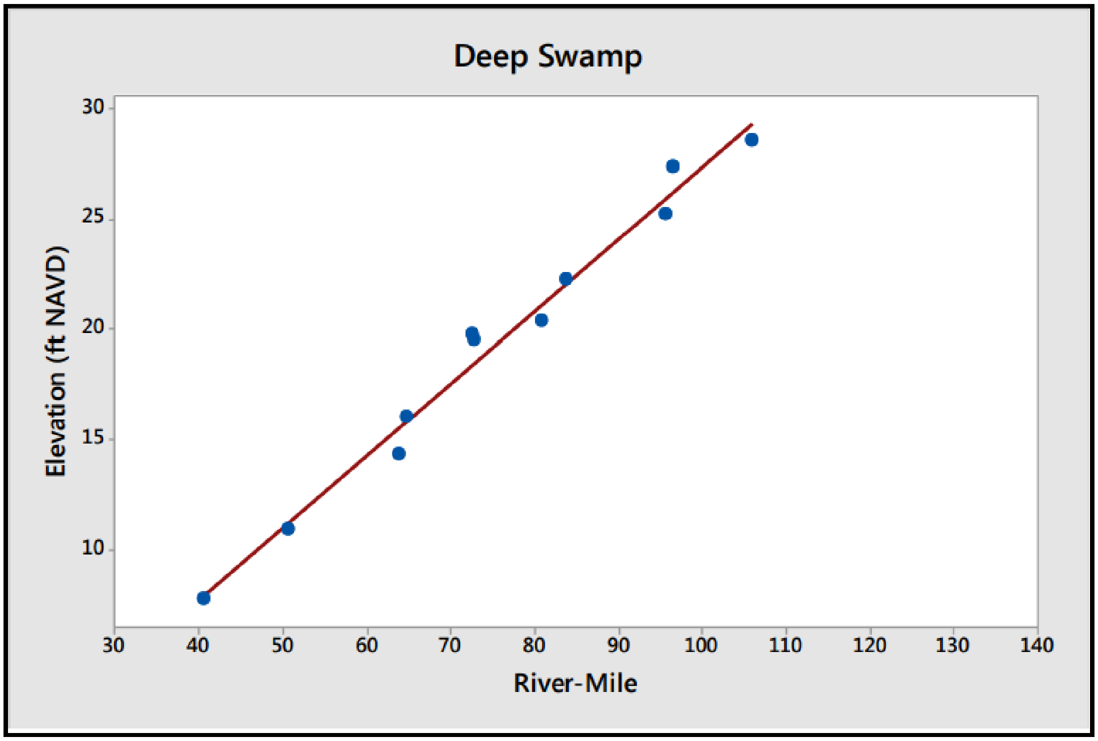
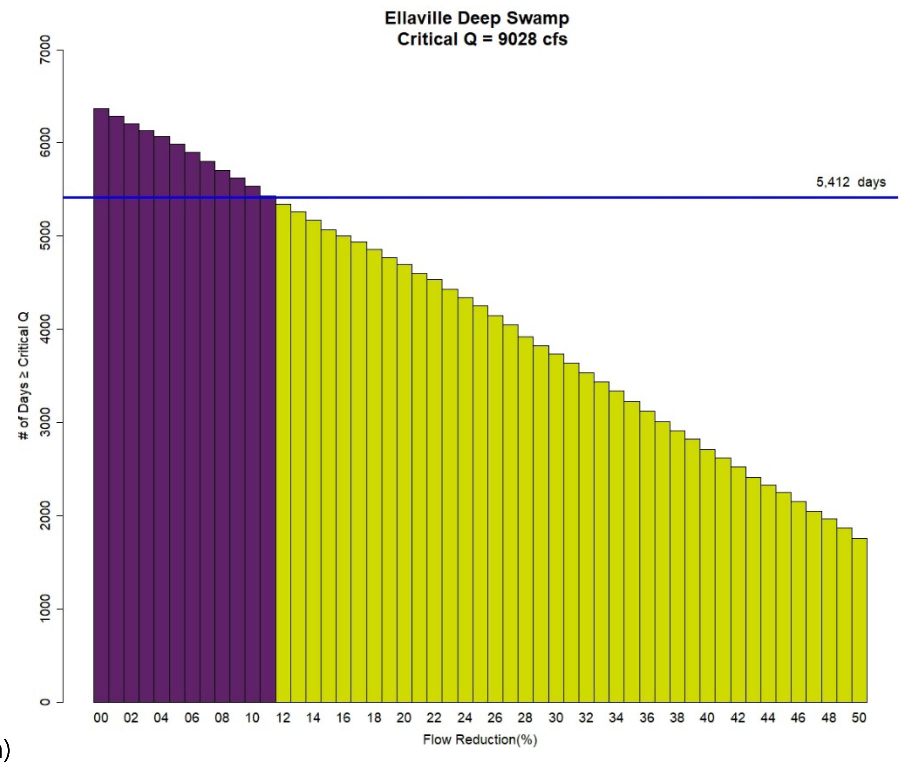


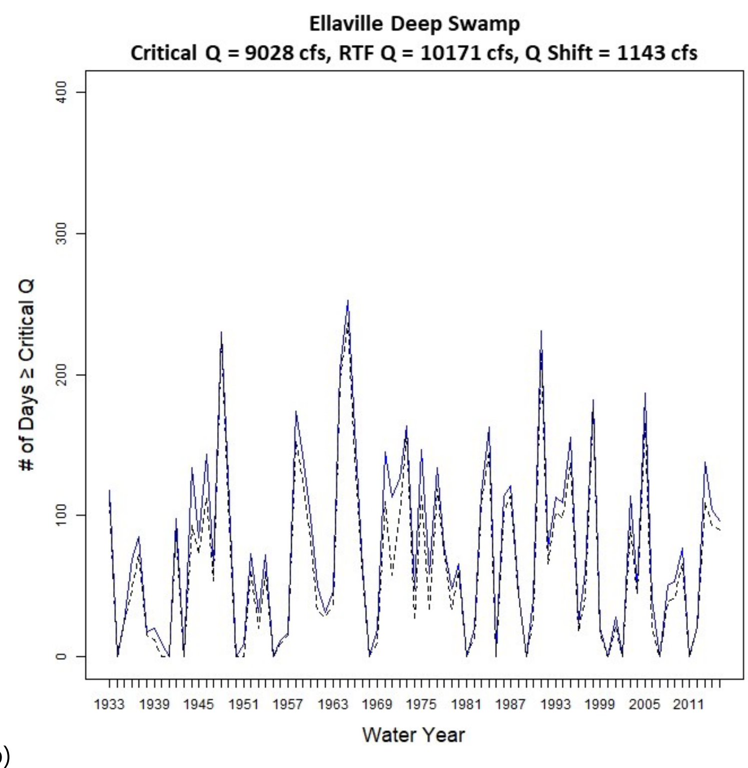
Figure 5-26. Regression for Deep Swamp elevation vs river mile based on survey data

The HEC-RAS model was then used to determine the critical flow associated with respective compliance gage elevations. The critical flow for maintaining a deep swamp community within the portion of the river above RM 90 is 9,028 cfs at the Ellaville gage. For the 83-year RTF flow record assessed, this critical flow was equalled or exceeded about 21% of the time: 6,368 days or 77 inundated days per year on average. A no greater than 15% reduction in the number of days inundated corresponds with a 11% flow allowable reduction at the Ellaville gage, which results in an RTF flow of 10,171 cfs and a hydrologic shift of 1,143 cfs. This allowable flow reduction would result in 5,412 inundated days for the 83-year record or 65 inundated days per year on average. Graphic representations of these results are provided in **Figure 5-27**. Note that deep swamps are not prevalent in this portion of the river and tend to be associated with karst features.

For the portion of the river below RM 90, the critical flow for maintaining a deep swamp community is 12,259 cfs at the Branford gage. For the 83-year RTF flow record assessed, this critical flow was equalled or exceeded about 15% of the time: 4,497 days or 54 inundated days per year on average. A no greater than 15% reduction in the number of days inundated corresponds with a 7% allowable flow reduction at the Branford gage, which results in an RTF flow of 13,243 cfs and a hydrologic shift of 984 cfs. This allowable flow reduction would result in 3,822 inundated days for the 83-year record or 46 inundated days per year on average. Graphic representations of these results are provided in **Figure 5-28**.

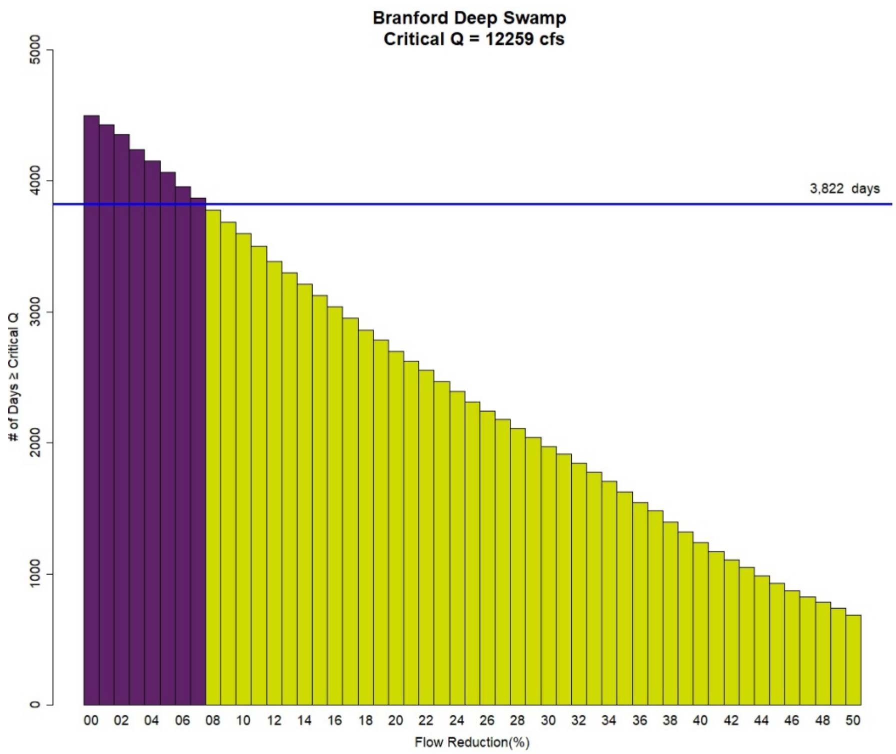


a)

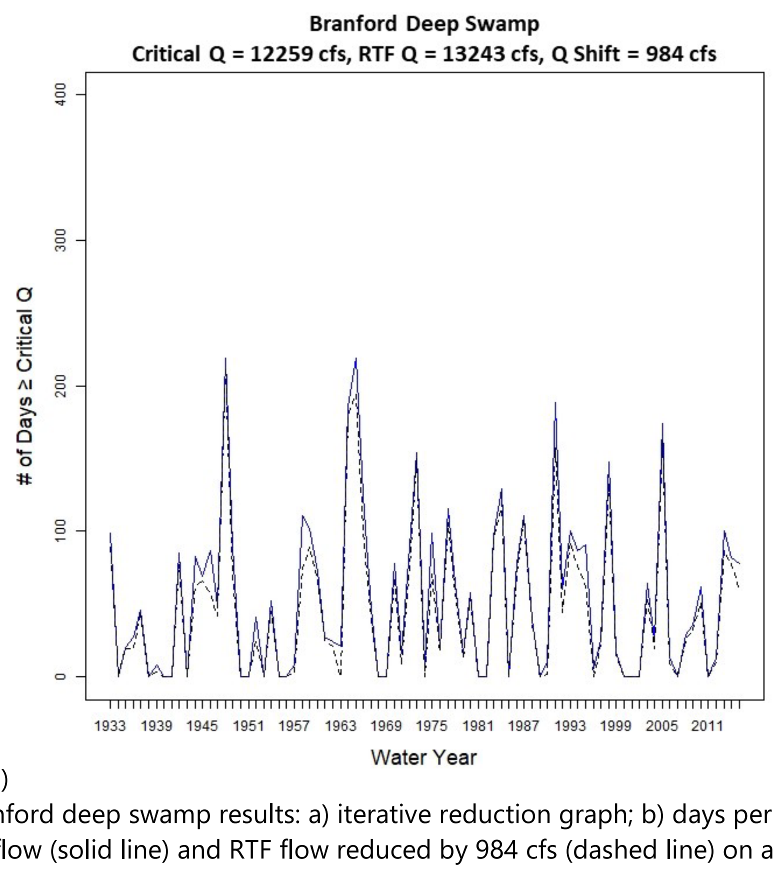


b)

Figure 5-27. Ellaville deep swamp results: a) iterative reduction graph; b) days per year above critical flow for RTF flow (solid line) and RTF flow reduced by 1143 cfs (dashed line)



a)



b)

Figure 5-28. Branford deep swamp results: a) iterative reduction graph; b) days per year above critical flow for RTF flow (solid line) and RTF flow reduced by 984 cfs (dashed line) on an annual basis

Bottomland Swamp

Critical elevations for the bottomland swamp community were determined for each compliance gage (Ellaville and Branford) using the following equations:

Upstream of RM 90, EL = -11.19 + 0.4365*RM
Downstream of RM 90, EL = -3.99 + 0.3565*RM

The regressions, which were developed using survey data, are provided in **Figure 5-29** and detailed in **Appendix IV**. An implied scatter at river-mile 90 resulted in a piecewise regression fit for the Bottomland Swamp community.

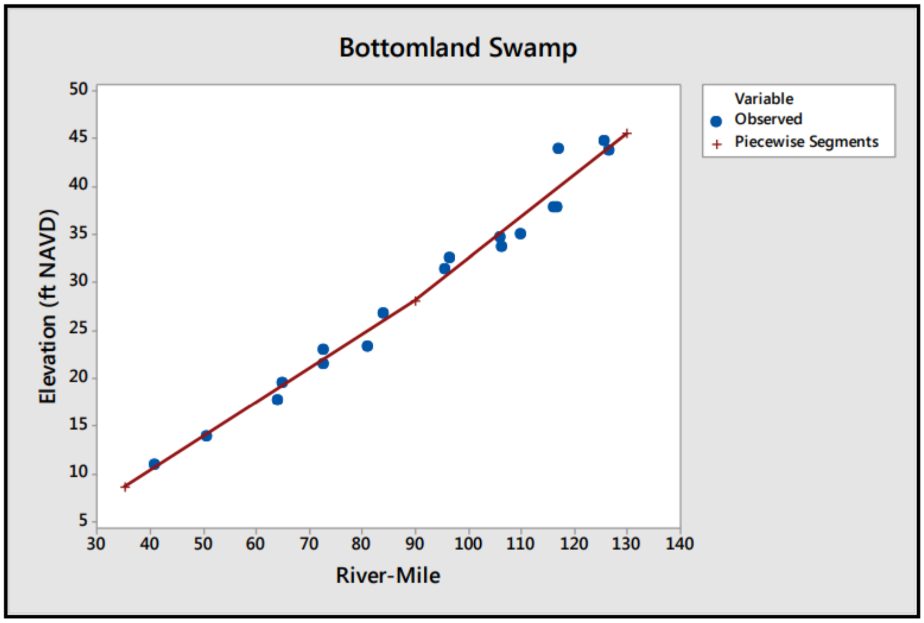


Figure 5-29. Regression for Bottomland Swamp elevation vs river mile based on survey data

The HEC-RAS model was then used to determine the critical flow associated with that elevation. The critical flow for maintaining a bottomland swamp community within the portion of the river above RM 90 is 17,776 cfs at the Ellaville gage. For the 83-year RTF flow record assessed, this critical flow was equalled or exceeded about 6% of the time: 1,858 days or 22 inundated days per year on average. A no greater than 15% reduction in the number of days inundated corresponds with a 5% allowable flow reduction at the Ellaville gage, which results in an RTF flow of 18,759 cfs and a hydrologic shift of 983 cfs. This allowable flow reduction would result in 1,579 inundated days for the 83-year record or 19 inundated days per year on average. Graphic representations of these results are provided in **Figure 5-30**.

For the portion of the river below RM 90, the critical flow for maintaining a bottomland swamp community is 17,149 cfs at the Branford gage. For the 83-year RTF flow record assessed, this critical flow was equalled or exceeded about 7% of the time: 2,073 days or 25 inundated days per year on average. A no greater than 15% reduction in the number of days inundated corresponds with a 6% allowable flow reduction at the Branford gage, which results in an RTF flow of 18,328 cfs and a hydrologic shift of 1,179 cfs. This allowable flow reduction would result in 1,762 inundated days for the 83-year record or 21 inundated days per year on average. Graphic representations of these results are provided in **Figure 5-31**.

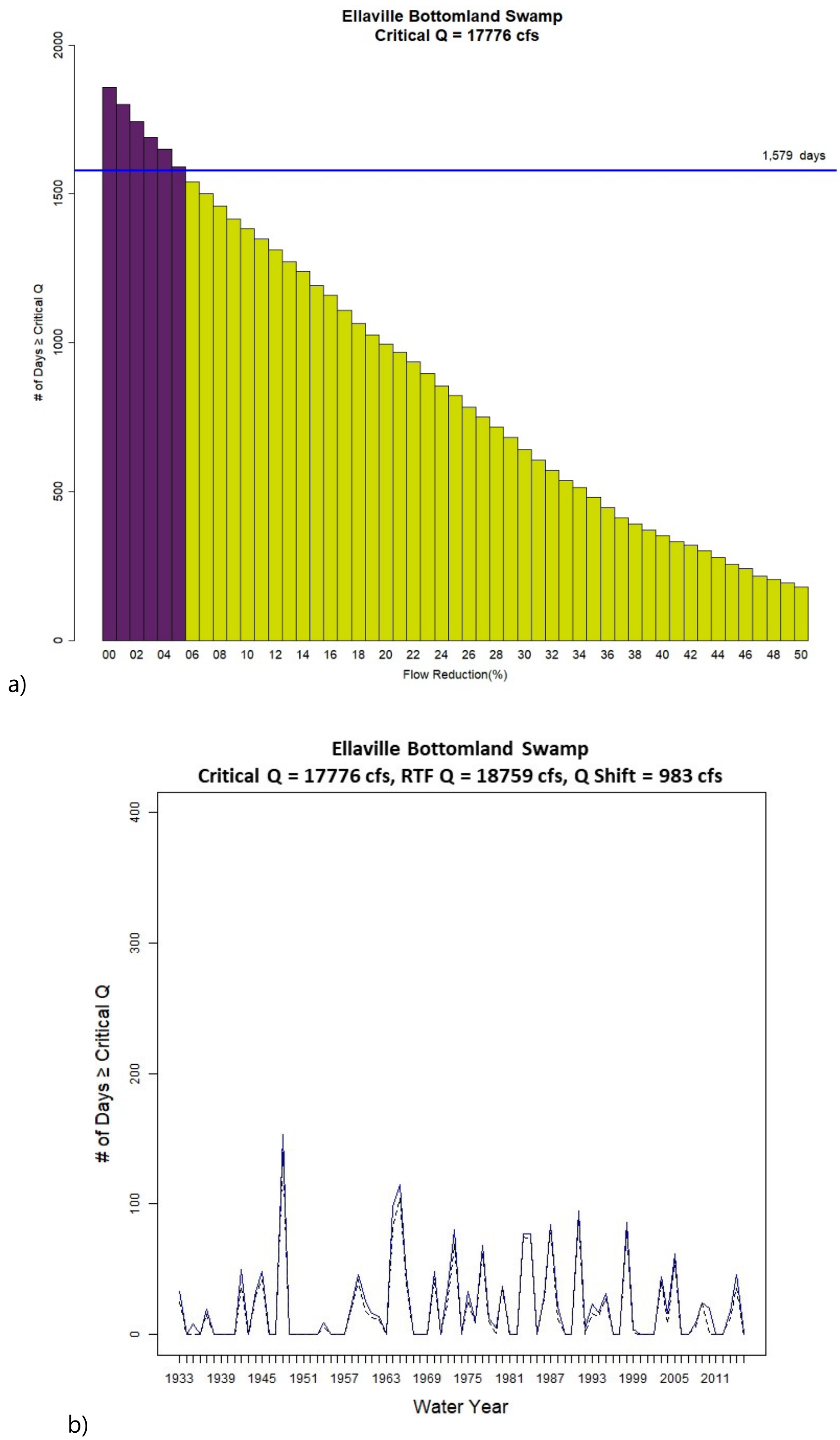
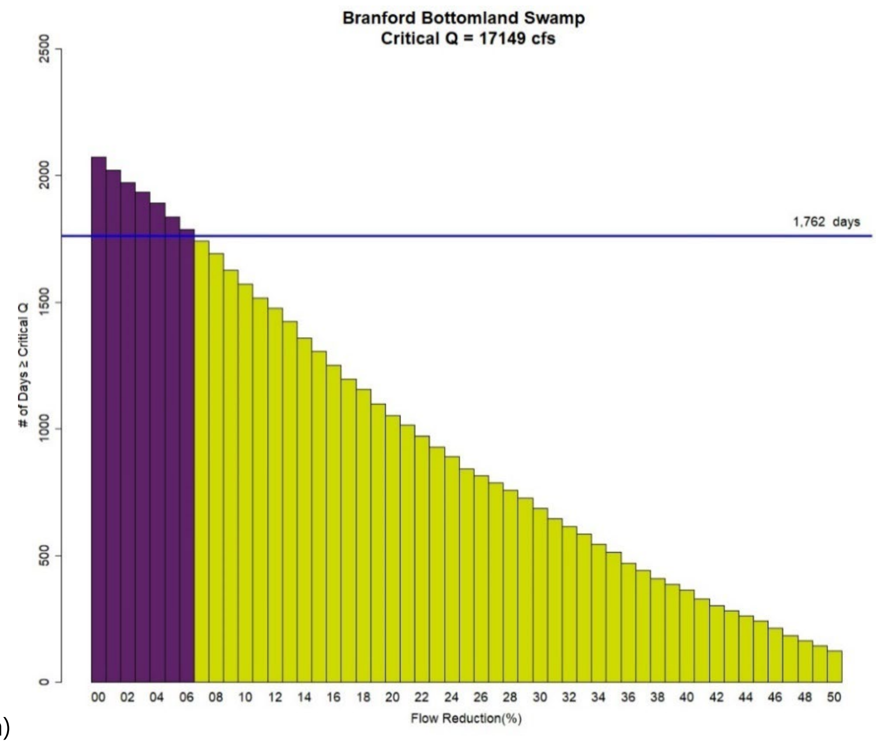
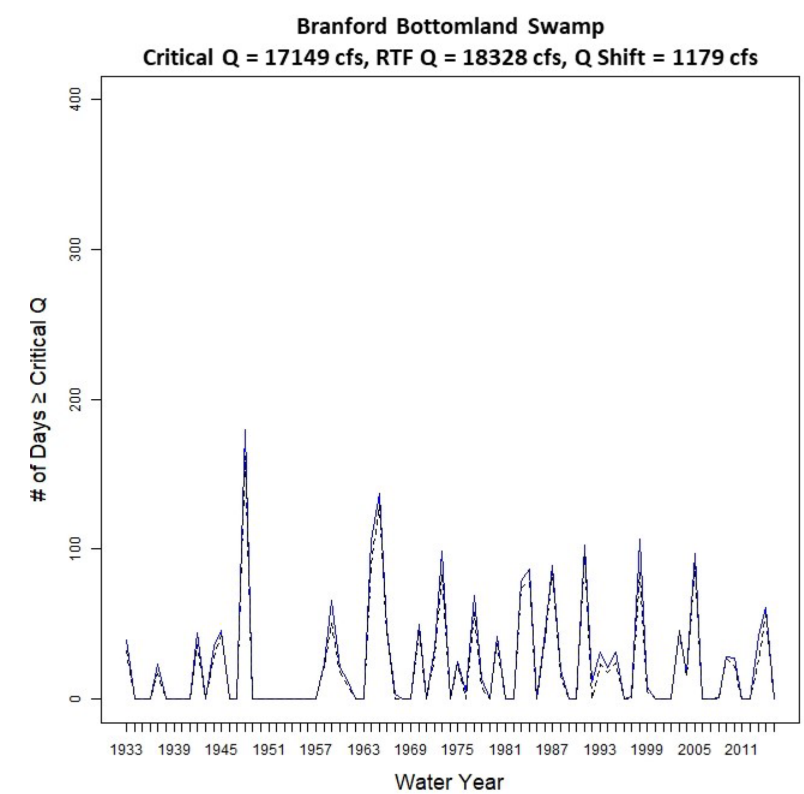


Figure 5-30. Ellaville bottomland swamp results: a) iterative reduction graph; b) days per year above critical flow for RTF flow (solid line) and RTF flow reduced by 983 cfs (dashed line)



a)



b)

Figure 5-31. Branford bottomland swamp results: a) iterative reduction graph; b) days per year above critical flow for RTF flow (solid line) and RTF flow reduced by 1179 cfs (dashed line)

5.3 SEDIMENT LOADS

Rivers are conduits for water and sediment. To assess sediment transport in the MSR, two fluvial geomorphic profiles were linearly regressed against river-mile: bankfull stage and alluvial ridge crests, as described in the following sections.

5.3.1 Bankfull

Bankfull stage occurs at or near a hydraulic break where stream channel carving processes begin to give way to floodplain building. Bankfull stage thus provides a process-oriented way to characterize the boundary between the river channel and floodplain. The bankfull profile was identified by fitting a piecewise regression through the average of the two most reliable field indicators of bankfull stage. The field indicators were the rooted scour line (BKF-Scour) and the upper convex inflection (BKF-Inflection) along the bank (**Figure 5-22**). These two indicators tended to straddle the prevailing floodplain surface elevations behind the alluvial ridge where surveyed. The piecewise linear regression of the bankfull profile most closely corresponded to the HEC-RAS river profile of the 20% exceedance discharge for the study area (**Appendix IV**), which is well within the normal range of bankfull flow of large Florida rivers and perennial streams, which average 24% exceedance (Kiefer et al. 2015). The bankfull profile represents the part of the flow regime that does the most overall work to maintain the open channel and its alluvial habitat features such as bend pools, sandy shoals, and point bars. It can also contribute sediment to the lowest parts of the floodplain with river access, and the potential for such contribution is supported by the hydrologic record with exceedances ranging from 15% to 21% for the deep swamp habitat in the study reach.

Critical elevations for maintaining the bankfull channel were determined for each compliance gage using the following equations:

Upstream of RM 90, EL = -10.354 + 0.3600*RM
Downstream of RM 90, EL = -3.55 + 0.2844*RM

The regressions, which were developed using survey data, are provided in **Figure 5-32** and detailed in **Appendix IV**.

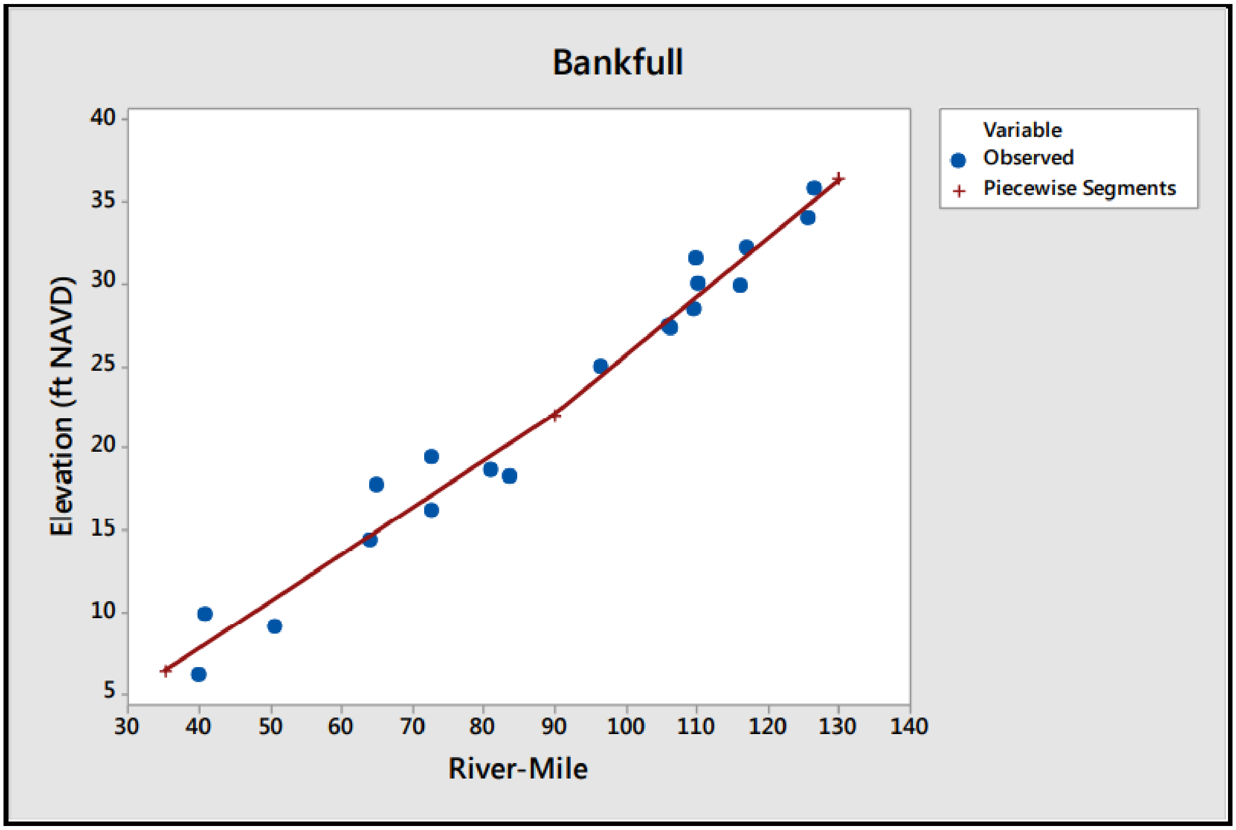
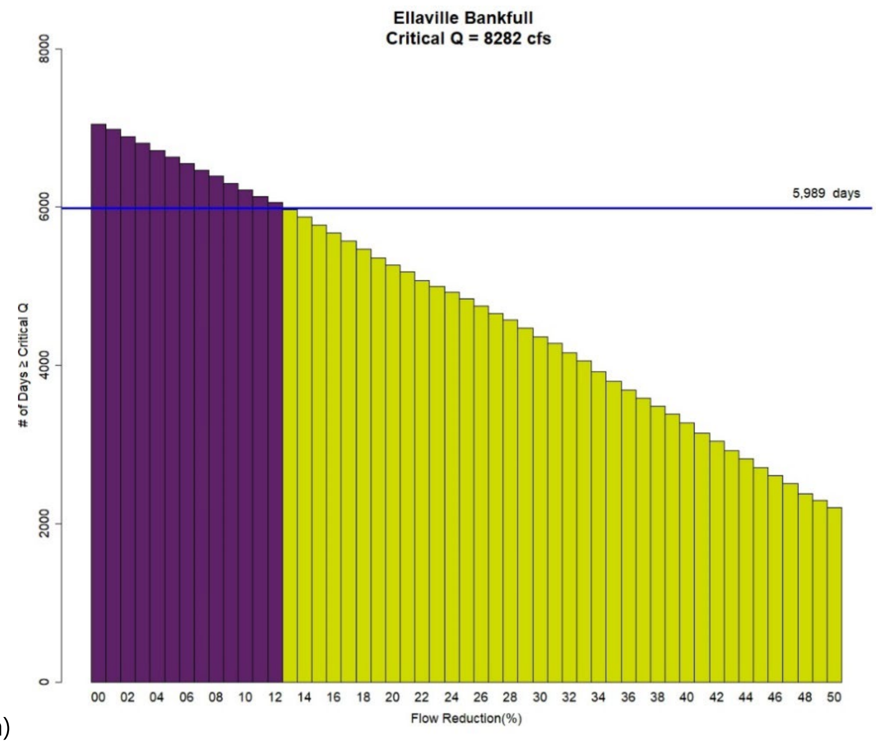


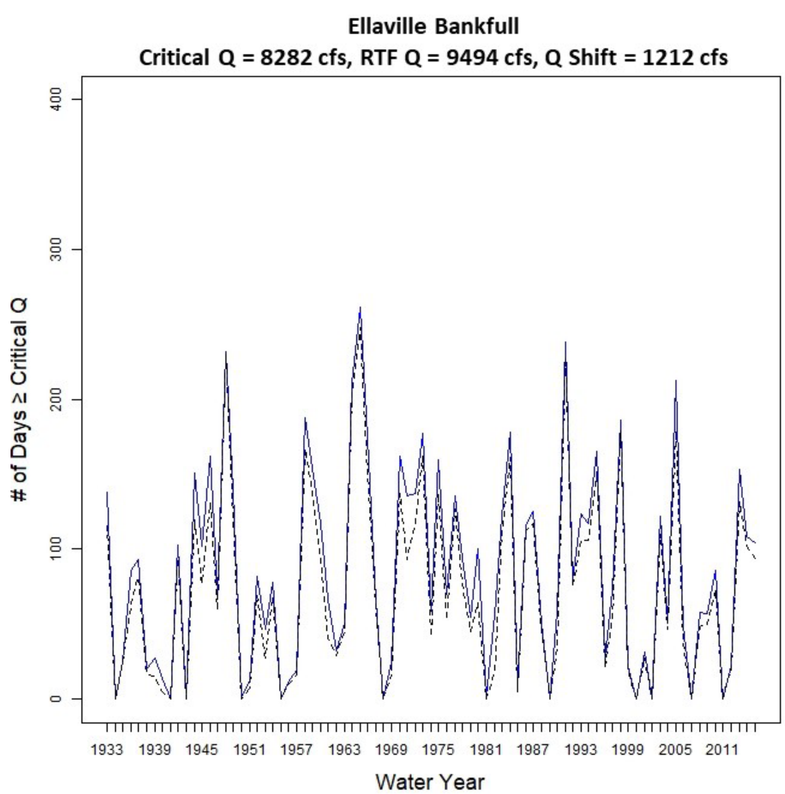
Figure 5-32. Regression for bankfull elevation vs river mile based on survey data

The HEC-RAS model was then used to determine the critical flow associated with that elevation. The critical flow for maintaining the bankfull channel within the portion of the river above RM 90 is 8,282 cfs at the Ellaville gage. For the 83-year RTF flow record assessed, this critical flow was equalled or exceeded about 23% of the time: 7,047 days or 85 inundated days per year on average. A no greater than 15% reduction in the number of days inundated corresponds with a 13% allowable flow reduction at the Ellaville gage, which results in an RTF flow of 9,494 cfs and a hydrologic shift of 1,212 cfs. This allowable flow reduction would result in 5,989 inundated days for the 83-year record or 72 inundated days per year on average. Graphic representations of these results are provided in **Figure 5-33**.

For the portion of the river below RM 90, the critical flow for maintaining the bankfull channel is 10,553 cfs at the Branford gage. For the 83-year RTF flow record assessed, this critical flow was equalled or exceeded about 19% of the time: 5,763 days or 69 inundated days per year on average. A no greater than 15% reduction in the number of days inundated corresponds with a 10% allowable flow reduction at the Branford gage, which results in an RTF flow of 11,671 cfs and a hydrologic shift of 1,118 cfs. This allowable flow reduction would result in 4,898 inundated days for the 83-year record or 59 inundated days per year on average. Graphic representations of these results are provided in **Figure 5-34**.

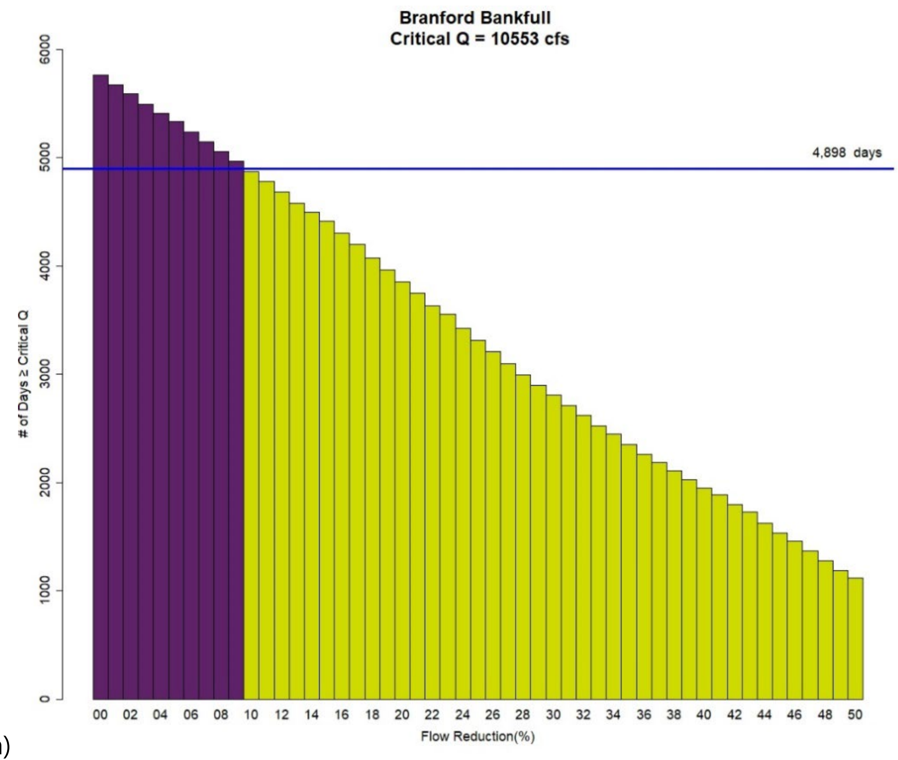


a)

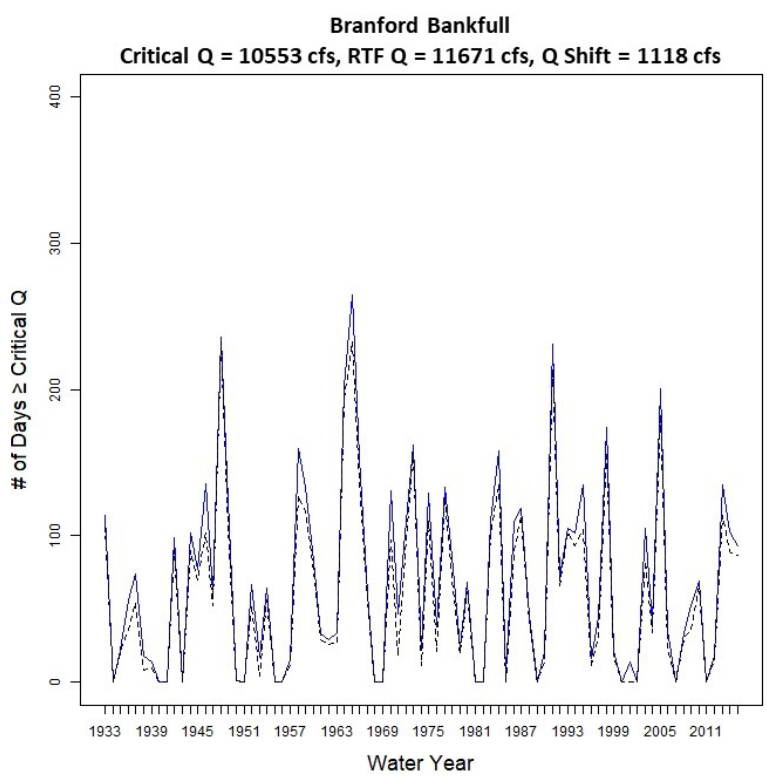


b)

Figure 5-33. Ellaville bankfull results: a) iterative reduction graph; b) days per year above critical flow for RTF flow (solid line) and RTF flow reduced by 1212 cfs (dashed line)



a)



b)

Figure 5-34. Branford bankfull results: a) iterative reduction graph; b) days per year above critical flow for RTF flow (solid line) and RTF flow reduced by 1118 cfs (dashed line)

5.3.2 Alluvial Ridge Crest

The alluvial ridge represents an upper surface that is actively maintained by sporadic floods, generally occurring at close to a five-year return interval on the lower Suwannee River (Light et al. 2002). During the 2014 MSR field study, an approximate 5-year flood occurred, and it crested the alluvial ridge in many places, depositing a veneer of fresh sand. The alluvial ridges in the study area are typically formed by sand depositing close to the river margins as flood waters rise. It is the first place the river can drop the heavier sediments it is carrying during a flood, and most alluvial rivers have such ridges. Alluvial ridge elevations are highly variable. The ridge can pinch down to lower crest elevations around bends and as it approaches natural breaches near floodplain swale inlets. Therefore, ridge elevation data was selected only from surveyed locations deemed to be representative of the local ridge crest. Local low areas near breaches and pinch-down areas were excluded. The alluvial ridge crest profile was defined by fitting a piecewise regression of the elevations of the selected sample areas versus the HEC-RAS river mile designations (**Appendix IV**). The profile falls between the 2% and 5% HEC-RAS exceedance profiles downstream of Luraville. This is within the range of floodplain-forming flows estimated for Florida perennial blackwater streams, with a mean exceedance of 2% (Kiefer et al. 2015). The alluvial ridge is crested for an even shorter period upstream of Luraville, with discharge exceedances ranging between 1% and 2%. The elevation of the alluvial ridge crest is a reasonable surrogate for the deposition of sediments across the MSR floodplain, which maintains the diversity and extent of floodplain surfaces (**Figure 5-35**). Its inclusion, along with bankfull flow, assures the gamut of routine floodplain building processes are covered from high to low surfaces.

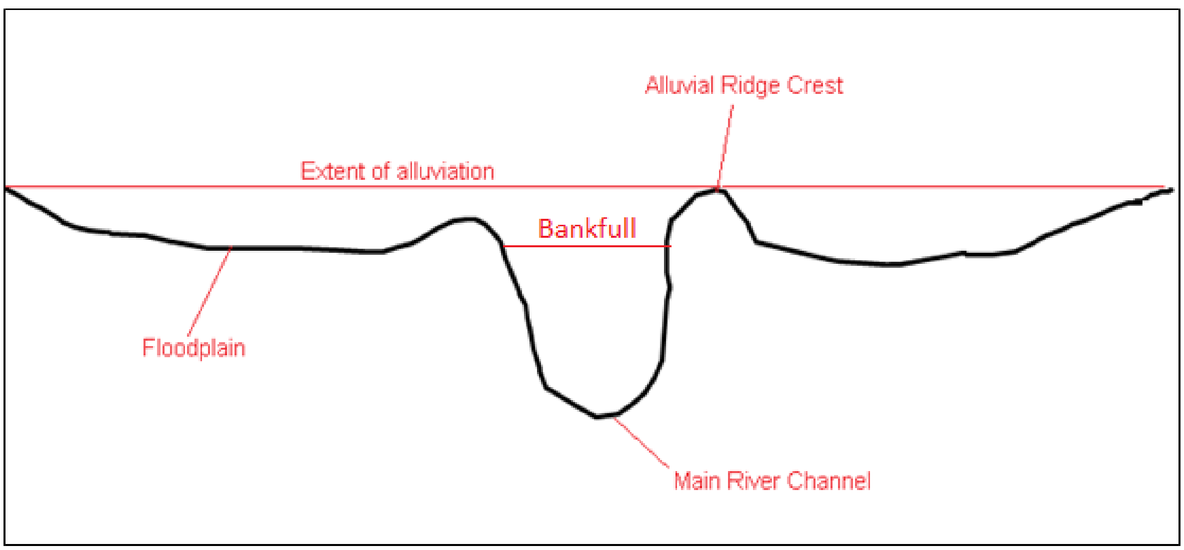


Figure 5-35. Extent of alluviation during the ARC flow

Critical elevations for maintaining an alluvial floodplain were determined using the following equations:

Upstream of RM 90, EL = -19.153 + 0.5940*RM
Downstream of RM 90, EL = -6.22 + 0.4503*RM

The regressions, which were developed using survey data, are provided in **Figure 5-36** and detailed in **Appendix IV**.

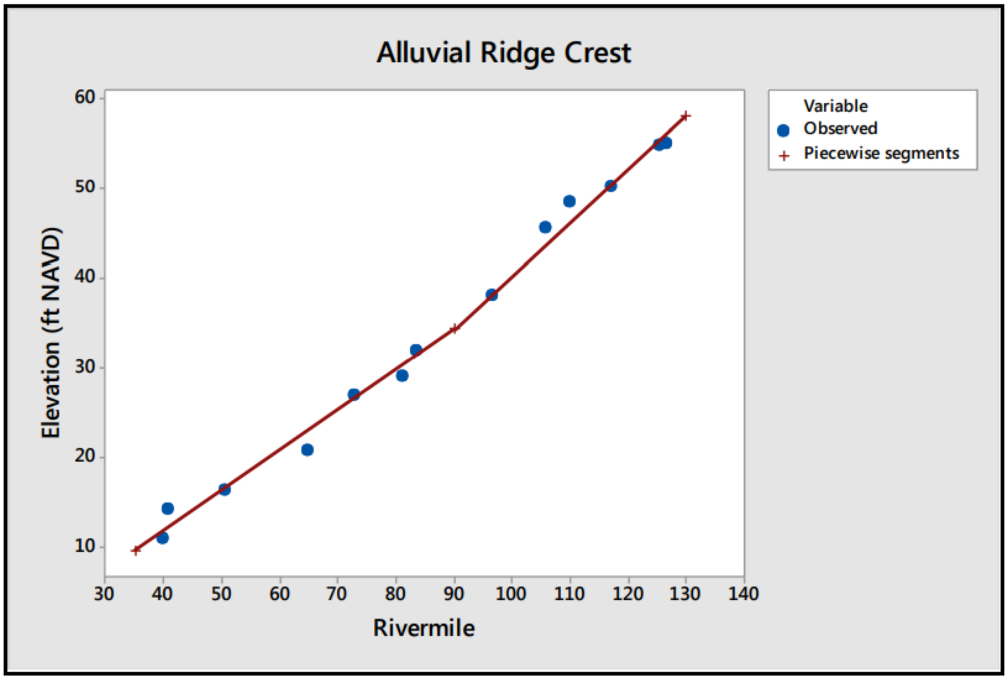
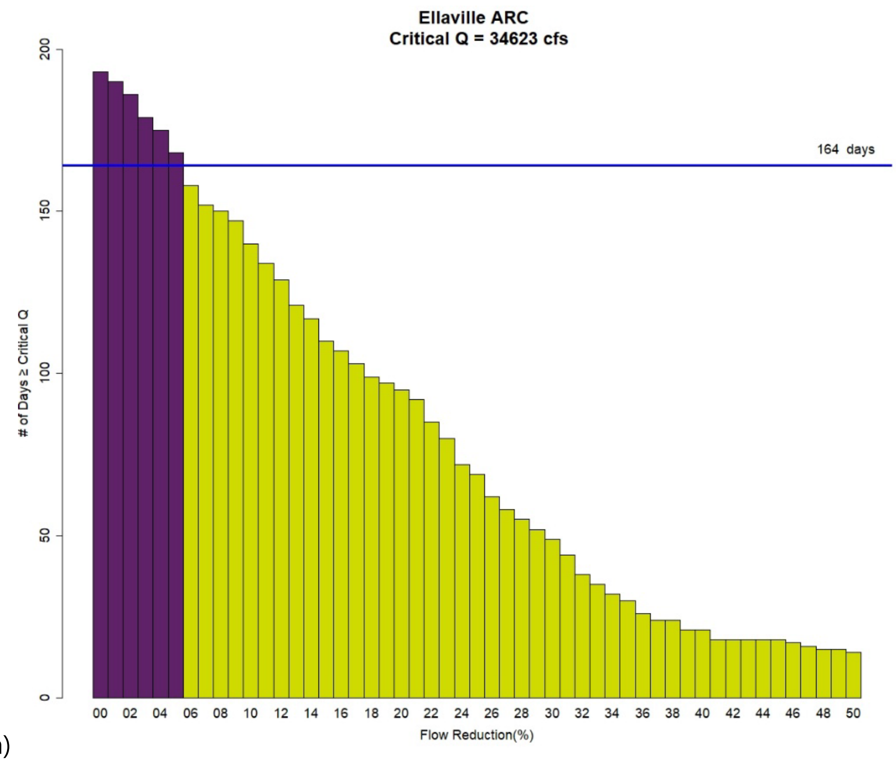


Figure 5-36. Regression for Alluvial Ridge Crest based on survey data

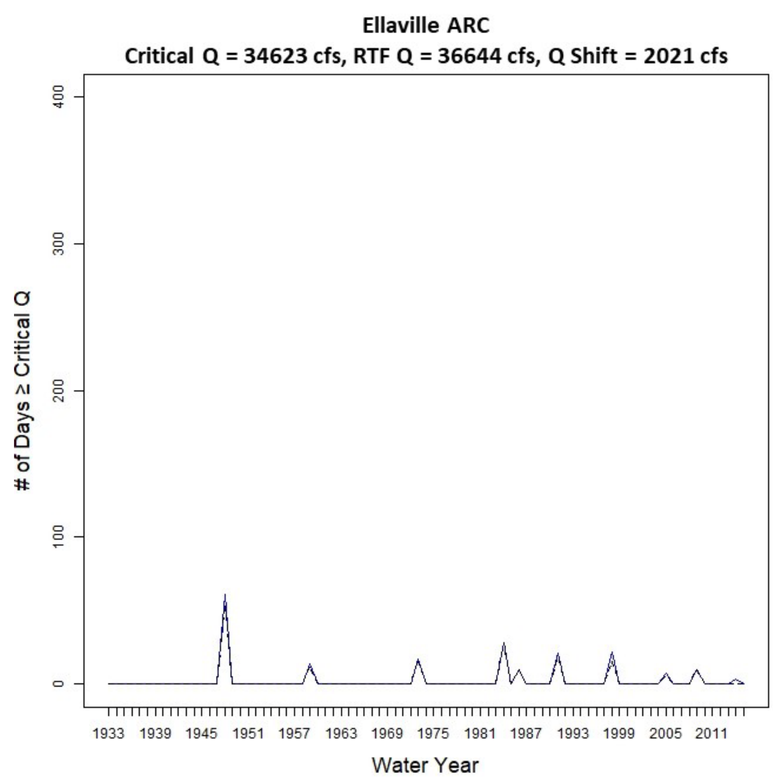
The HEC-RAS model was then used to determine the critical flow associated with that elevation. The critical flow for maintaining an alluvial floodplain within the portion of the river above RM 90 is 34,623 cfs at the Ellaville gage. For the 83-year RTF flow record assessed, this critical flow was equalled or exceeded 1% of the time: 193 days or 2 inundated days per year on average. A no greater than 15% reduction in the number of days inundated corresponds with a 6% allowable flow reduction at the Ellaville gage, which results in an RTF flow of 36,644 cfs and a hydrologic shift of 2,021 cfs. This allowable flow reduction would result in 164 inundated days for the 83-year record or 2 inundated days per year on average. Graphic representations of these results are provided in **Figure 5-37**.

For the portion of the river below RM 90, the critical flow for maintaining an alluvial floodplain is 24,996 cfs at the Branford gage. For the 83-year RTF flow record assessed, this critical flow was equalled or exceeded about 2% of the time: 635 days or 8 inundated days per year on average. A no greater than 15% reduction in the number of days inundated corresponds with a 4% allowable flow reduction at the Branford gage, which results in an RTF flow of 26,026 cfs and a hydrologic shift of 1,030 cfs. This allowable flow reduction would result in 539 inundated days for the 83-year record or 6 days per year on average. Graphic representations of these results are provided in **Figure 5-38**.

The development process for the linear models presented for riparian and floodplain habitat(s), and fluvial benchmarks is presented in detail in **Appendix IV**. During the process, an interaction term representing piecewise effects was developed for river mile-elevation regressions to determine if piecewise regression made a statistically significant improvement versus simple linear regression. A valid piecewise regression should support the use of separate slope profiles up- and downstream of RM90. In all cases the overall model was statistically significant ($p < 0.0001$), but the piecewise approach did not appear to add a statistically significant interaction. However, a good physical rationale exists for the piecewise approach, and it was retained because it did not harm the overall model significance or fit (r^2). Furthermore, no single model had an r^2 less than 96.9%, and this is attributed to the effort in obtaining defensible empirical field data, as reported in **Appendix V** of this study.

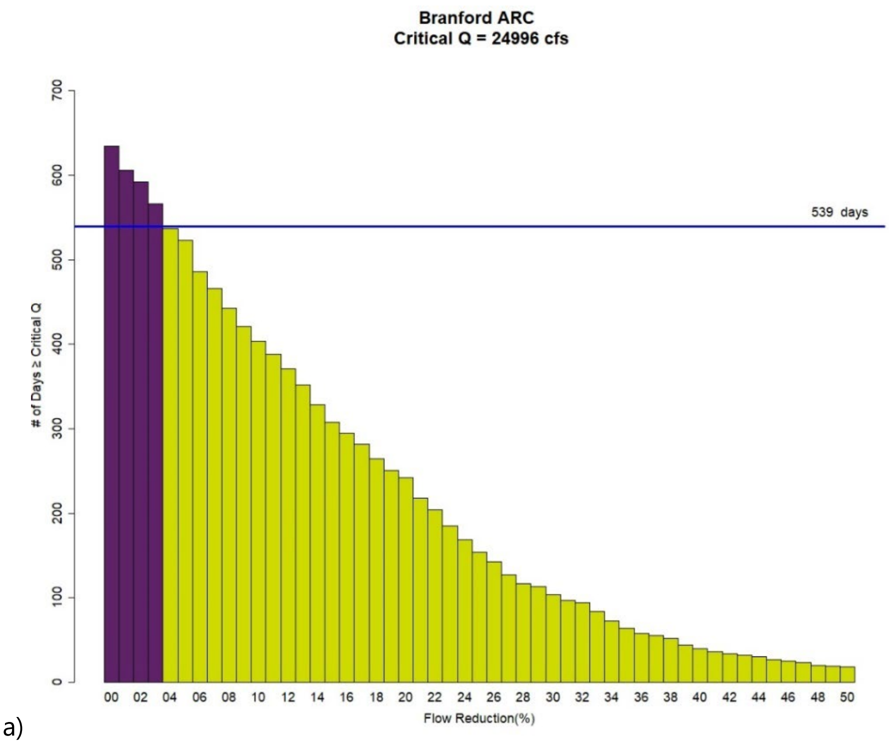


a)

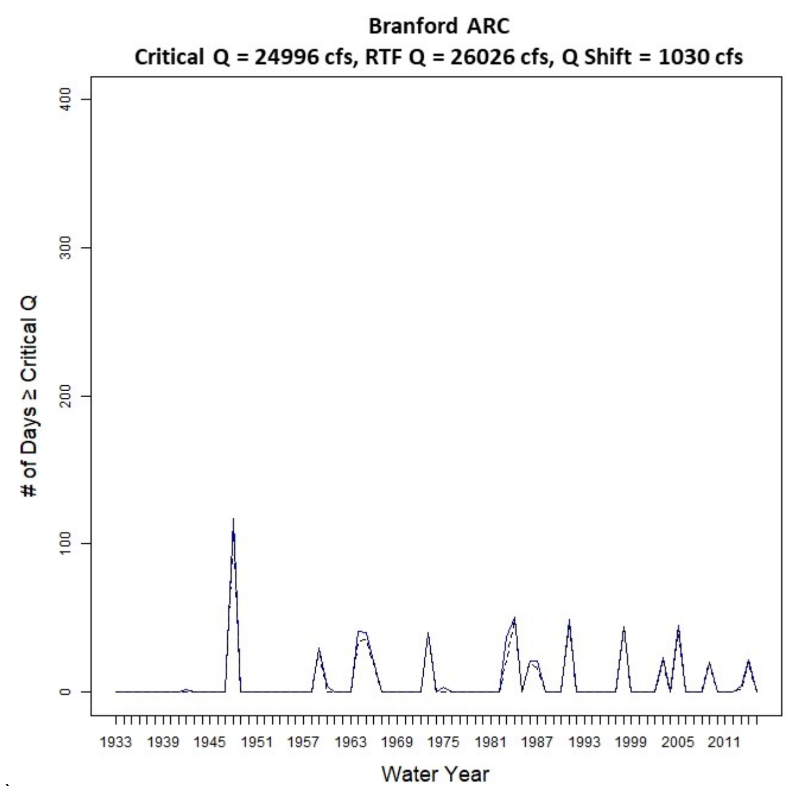


b)

Figure 5-37. Ellaville alluvial ridge crest results: a) iterative reduction graph; b) days per above critical flow for RTF flow (solid line) and RTF flow reduced by 2021 cfs (dashed line)



a)



b)

Figure 5-38. Branford alluvial ridge crest results: a) iterative reduction graph; b) days per year above critical flow for RTF flow (solid line) and RTF flow reduced by 1030 cfs (dashed line)

5.4 WRV EVALUATION SUMMARY

Relevant values derived for each assessed WRV are summarized in **Table 5-2** and **Table 5-3** below and include critical flow, reduced flow, and MFL variables. For the Ellaville gage, Gulf sturgeon passage during the fall is the limiting WRV, with a 15% allowable flow reduction resulting in a 346 cfs hydrologic shift (**Table 5-2**). Gulf sturgeon fall migration passage is also the most limiting WRV for the Branford gage, with a 12% allowable flow reduction resulting in a hydrologic shift of 400 cfs (**Table 5-3**).

Table 5-2. Flow reductions associated with decreases in time critical flows are exceeded at the Ellaville gage.

WRV	Critical Flow Variables			Reduced Flow Variables			MFL Variables		
	Critical Flow (cfs)	Associated Percent Exceedance (%)	Average Days per Year Critical Flow Exceeded	Percent Exceedance Resulting from a 15% Decrease in Time Exceeded (%)	Average Days per Year Critical Flow Exceeded in Reduced Flow	RTF Flow Resulting from a 15% Decrease in Time Exceeded (cfs)	Change in Average Days per Year Critical Flow Exceeded	Hydrologic Shift (cfs)	Percent Flow Reduction Resulting in 15% Decrease in Average Days per Year Critical Flow Exceeded (%)
Index	A	B	C	D	E	F	G	H	I
General Fish Passage	1,045	100	364	85	309	1,840	55	795	43
Gulf Sturgeon Passage (February-April)	1,998	94	84	80	72	3,339	13	1,341	40
Gulf Sturgeon Passage (September-November)	1,998	72	65	61	55	2,344	10	**346**	15
Recreational Boating	1,908	83	303	70	257	2,457	45	549	22
In-stream Habitat: Deep/Slow Guild	3,822[9]	50	--	--	--	--	--	600	16
Riparian Bank Habitat/Open Water	1,916	83	302	70	257	2,461	45	545	22
Fish Passage in/out Allen Mill Pond Spring	3,079	60	217	51	185	3,746	33	667	18
Fish Passage in/out Peacock Springs	7,453	27	97	23	83	8,474	15	1,021	12
Bankfull	8,282	23	85	20	72	9,494	13	1,212	13
Deep Swamp	9,028	21	77	18	65	10,171	12	1,143	11
Bottomland Swamp	17,776	6	22	5	19	18,759	3	983	5
Alluvial Ridge Crest	34,623	1	2	1	2	36,644	0	2,021	6

Blue shading indicates limiting WRV

[9] This represents the Median RTF flow. SEFA modeling applies to flows ranging from 1,324 to 16,370 cfs.

Table 5-3. Flow reductions associated with decreases in time critical flows are exceeded at the Branford gage.

WRV	Critical Flow Variables			Reduced Flow Variables			MFL Variables		
	Critical Flow (cfs)	Associated Percent Exceedance (%)	Average Days per Year Critical Flow Exceeded	Percent Exceedance Resulting from a 15% Decrease in Time Exceeded (%)	Average Days per Year Critical Flow Exceeded in Reduced Flow	RTF Flow Resulting from a 15% Decrease in Time Exceeded (cfs)	Change in Average Days per Year Critical Flow Exceeded	Hydrologic Shift (cfs)	Percent Flow Reduction Resulting in 15% Decrease in Average Days per Year Critical Flow Exceeded (%)
Index	A	B	C	D	E	F	G	H	I
General Fish Passage	2,042	95	347	81	295	2,898	52	856	30
Gulf Sturgeon Passage (February-April)	3,044	90	81	77	69	4,381	12	1,337	31
Gulf Sturgeon Passage (September-November)	3,044	71	64	61	55	3,444	10	**400**	12
Recreational Boating	1,778	99	360	84	306	2,738	54	960	35
In-stream Habitat: Gulf Sturgeon Adult	4,993[10]	50	--	--	--	--	--	944	19
Riparian Bank Habitat/Open Water	5,485	45	165	38	140	6,331	25	846	13
Bankfull	10,553	19	69	16	59	11,671	10	1,118	10
Deep Swamp	12,259	15	54	13	46	13,243	8	984	7
Bottomland Swamp	17,149	7	25	6	21	18,328	4	1,179	6
Alluvial Ridge Crest	24,996	2	8	2	6	26,026	1	1,030	4

Blue shading indicates limiting WRV

[10] This represents the Median RTF flow. SEFA modeling applies to flows ranging from 1,730 to 22,600 cfs

6.0 RIVER MFLS

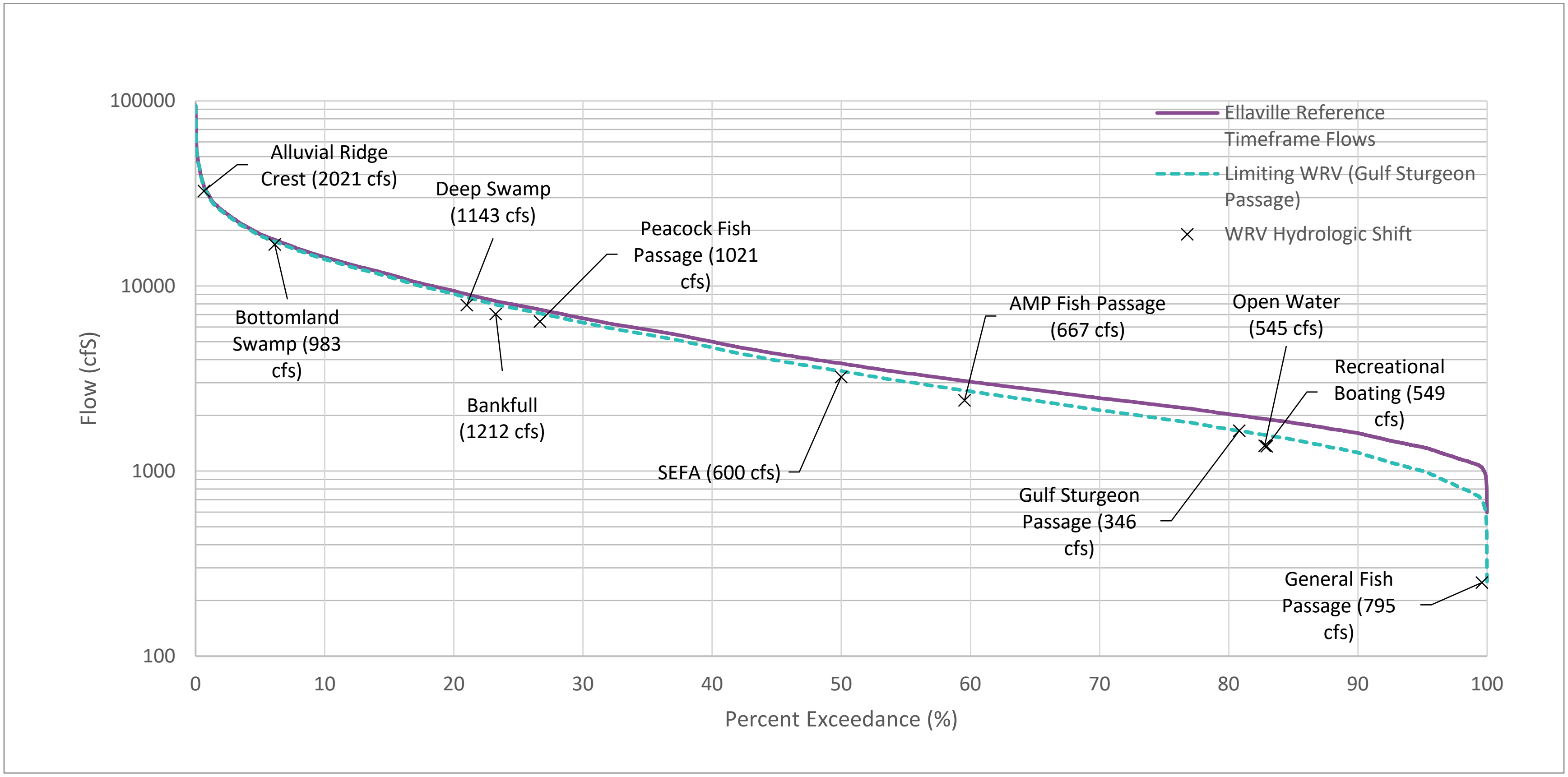
6.1 Discussion and Summary

The Middle Suwannee River was evaluated to determine flow regimes protective of various water resource values (WRVs), including recreation, fish passage, fish and wildlife habitat, and sediment loads. Best available information was used to identify specific metrics for evaluating flow reduction scenarios that would protect the resources. Allowable flow reductions for each metric were determined by an iterative approach in which flow could not be reduced below a point that would cause greater than 15% reduction in either usable area or inundation time (as described in **Section 5**). **Table 5-2** and **Table 5-3** summarize the critical flows and allowable flow reductions (or hydrologic shifts) determined for various WRV metrics at the two compliance gages (Ellaville and Branford). Allowable flow reductions ranged from 5% to 43% at the Ellaville gage and from 4% to 35% at the Branford gage.

WRV metrics were then plotted with the RTF flow duration curve (FDC) for each gage, covering an 83-year period of record (WY1933-2015) (**Figure 6-1** and **Figure 6-2**). Based on these figures, the metrics assessed were found to cover the entire FDC with floodplain habitats and sediment loads covering the high flows, instream habitat (SEFA) covering the middle flows, and fish passage and boat passage covering the low flows. Gulf sturgeon passage was found to be the limiting WRV at both the Ellaville and Branford gages, with an allowable flow reduction of 15% and 12% from the RTF flow for that WRV, respectively (**Table 5-2** and **Table 5-3**, **Figure 6-1** and **Figure 6-2**).

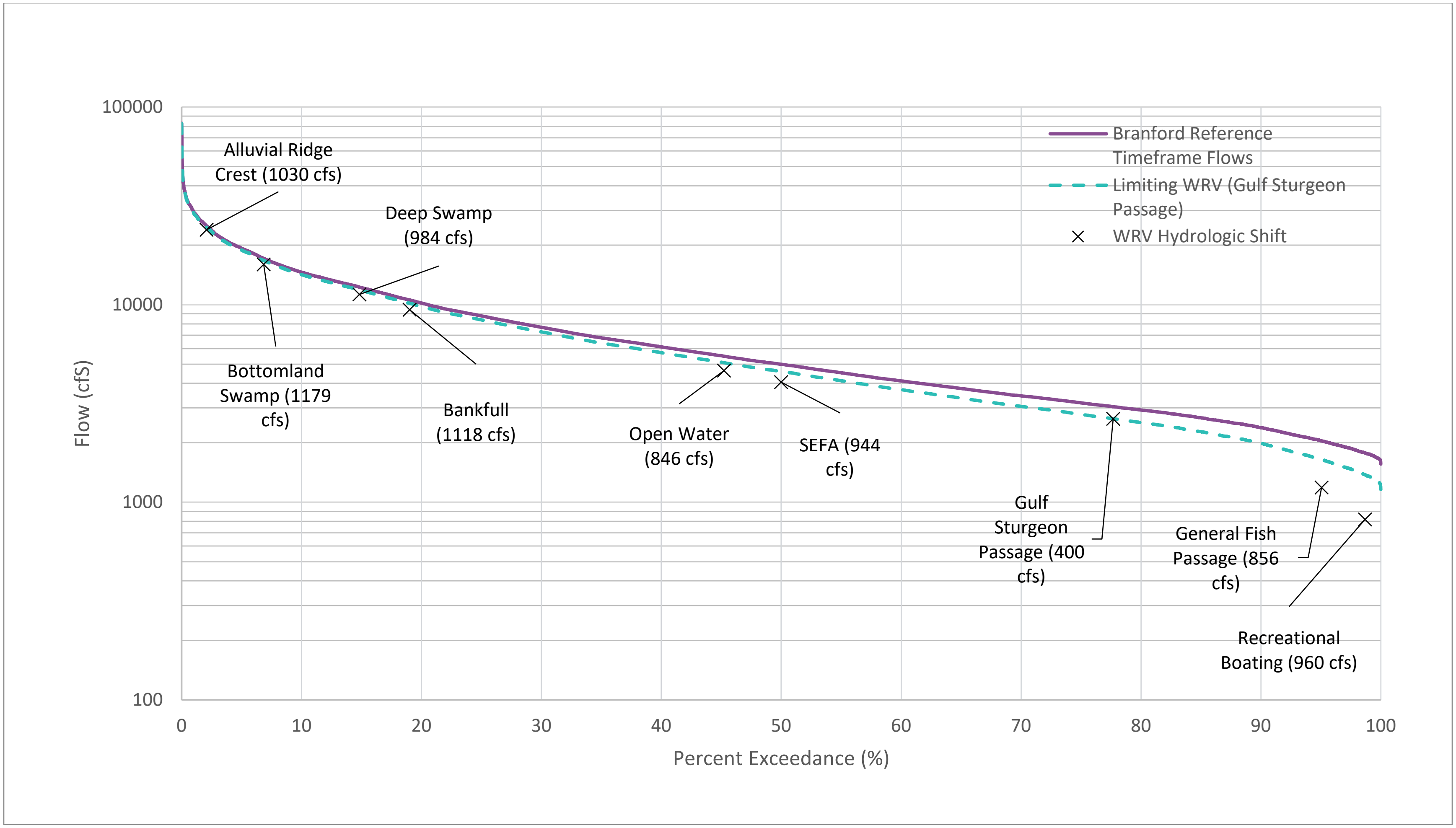
The amount of available flow or hydrologic shift (derived by subtracting critical flow from RTF flow) was plotted against the corresponding critical flow values to assess the availability of water across the RTF flow range, and the resulting available flow graphs for Ellaville and Branford were subsequently used to determine the potential allowable withdrawal schedule and determine comprehensive MFL criteria (**Figure 6-3** and **Figure 6-4**). It was determined that a single value flow reduction approach would be taken, using the most restrictive or limiting critical flows. In the case of both Ellaville and Branford, this corresponds with Gulf sturgeon fall passage and results in a reduction of 346 cfs across the flow duration curve for Ellaville and 400 cfs for Branford (**Figure 6-5** and **Figure 6-6**). The underlying premise of applying a single-value flow reduction below median flows is the assumption that regional withdrawals are from groundwater pumping. If surface water diversions are proposed in the future, then larger volumes of water would be available without causing significant harm when flows are above median conditions.

Appendix X provides critical flow day plots corresponding to single value flow reductions of 346 cfs for Ellaville and 400 cfs for Branford. These plots reflect the reality that some metrics in certain areas of the FDC were more limiting to withdrawals than others. Thus many of the critical flow day plots in **Section 5** do not reflect the results based on the proposed MFL criteria, which are more protective since they are based on the most limiting WRV.



*Gulf sturgeon passage represents the more protective fall migration MFL flow. It is the most limiting WRV and is applied year-round.

Figure 6-1. Ellaville flow duration curve and WRV metrics



*Gulf sturgeon passage represents the more protective fall migration MFL flow. It is the most limiting WRV and is applied year-round.

Figure 6-2. Branford flow duration curve and WRV metrics

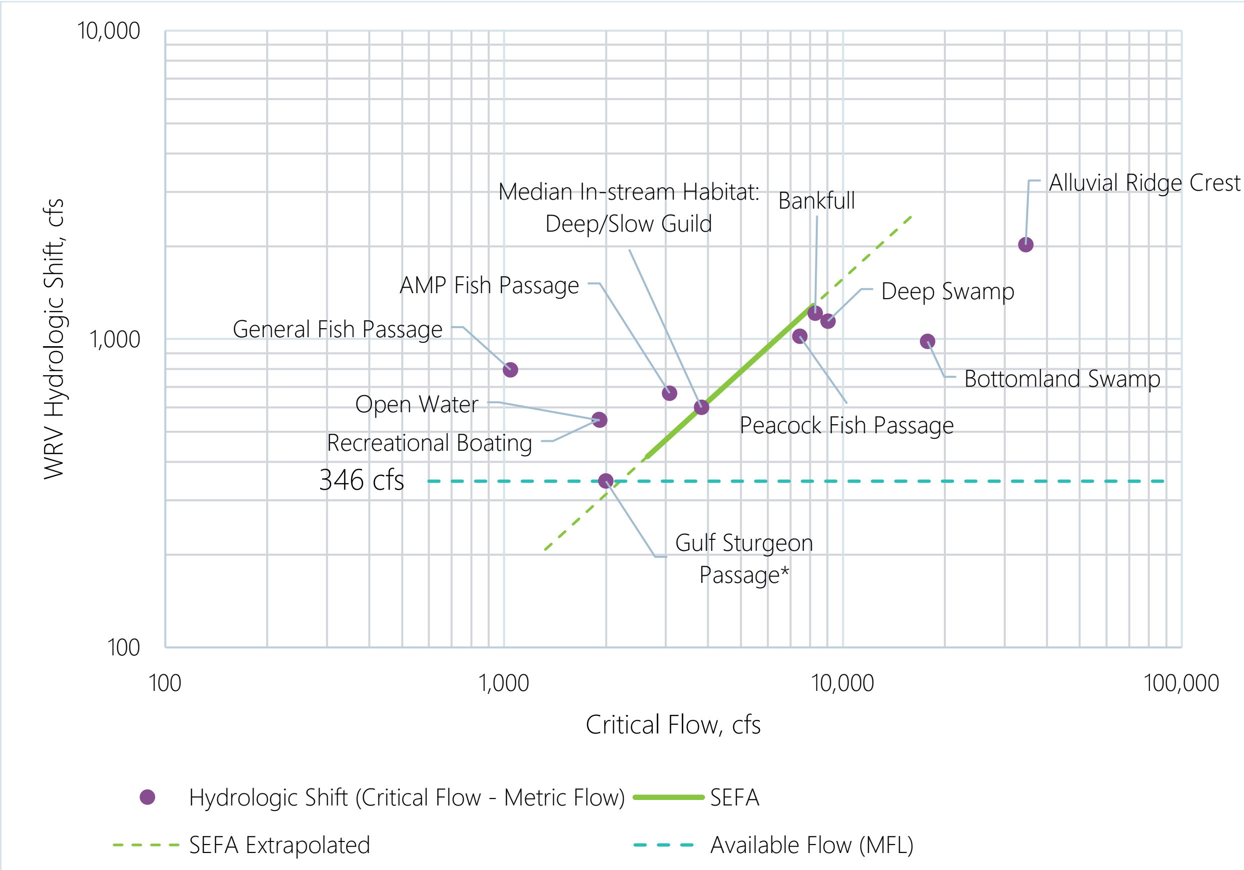


Figure 6-3. Available flow versus critical flow for WRVs and MFL conditions at Ellaville

Asterisk denotes most limiting WRV

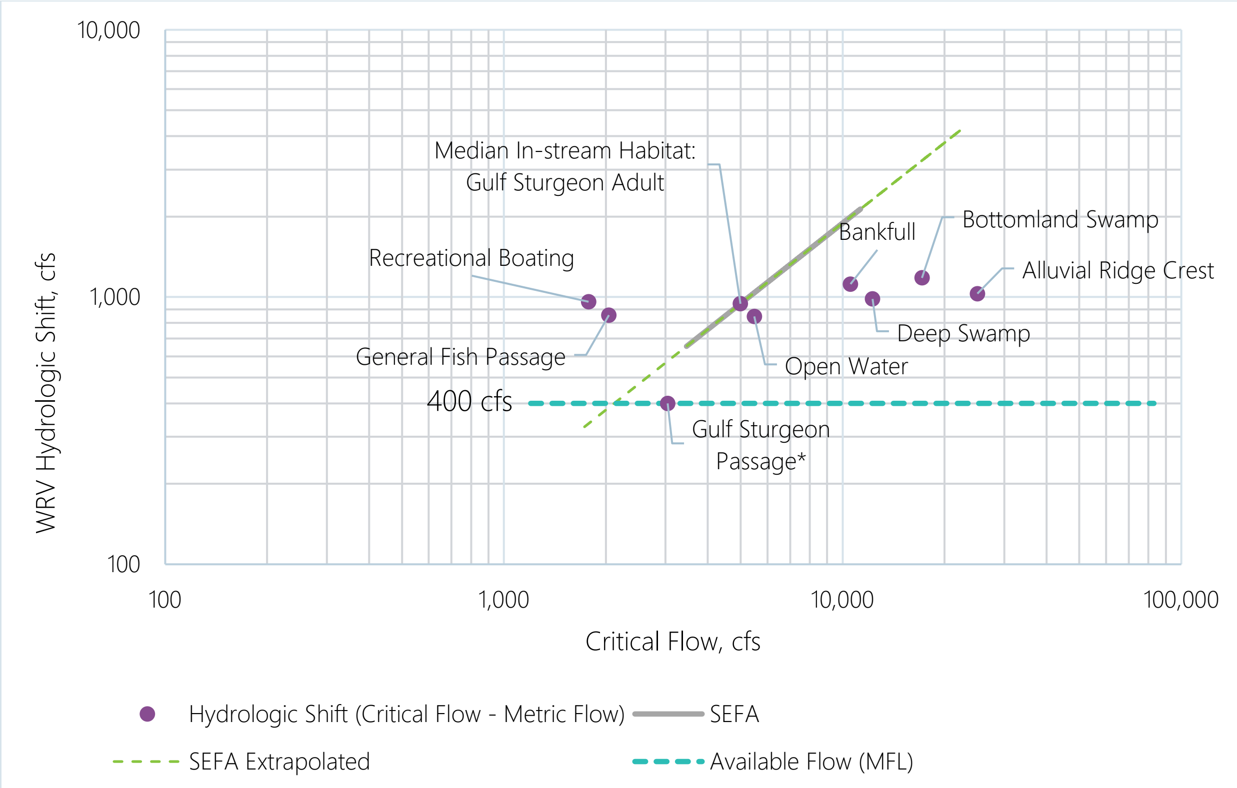


Figure 6-4. Available flow versus critical flow for WRVs and MFL conditions at Branford

Asterisk denotes most limiting WRV

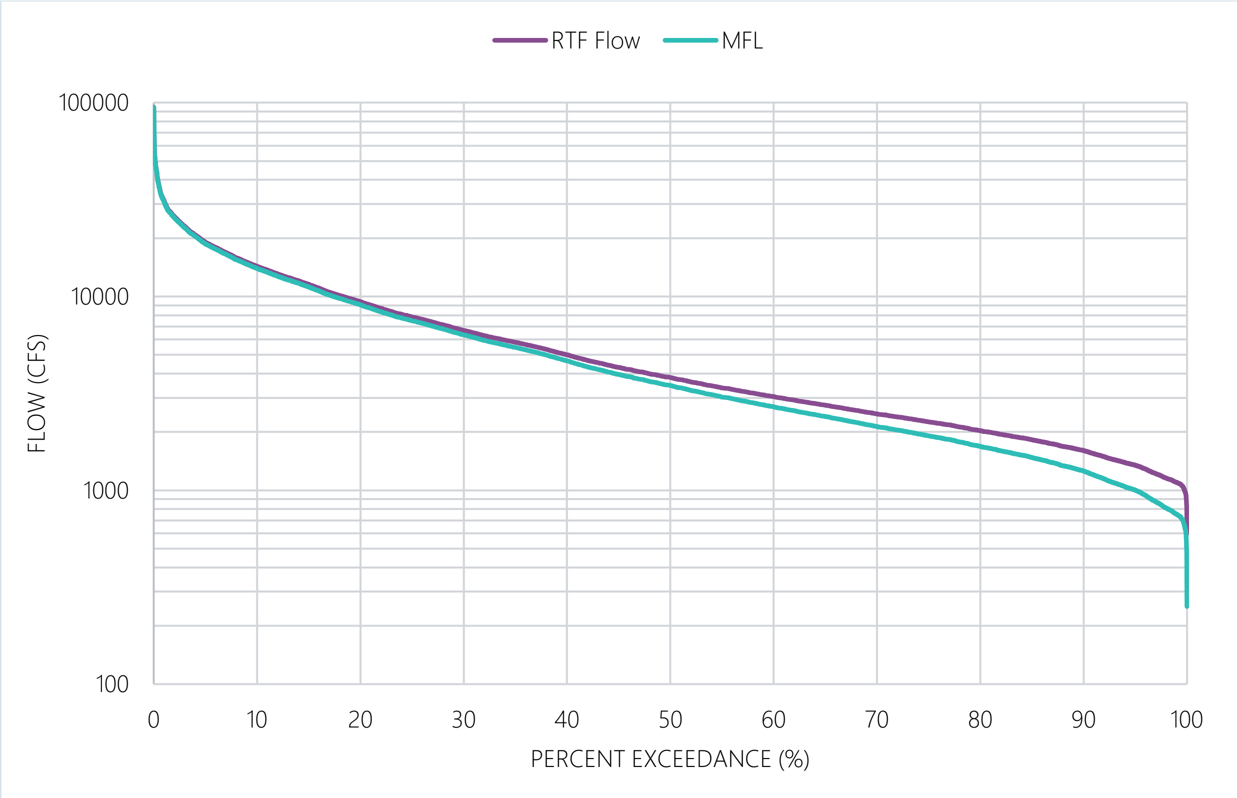


Figure 6-5. Ellaville RTF and proposed MFL flow duration curves

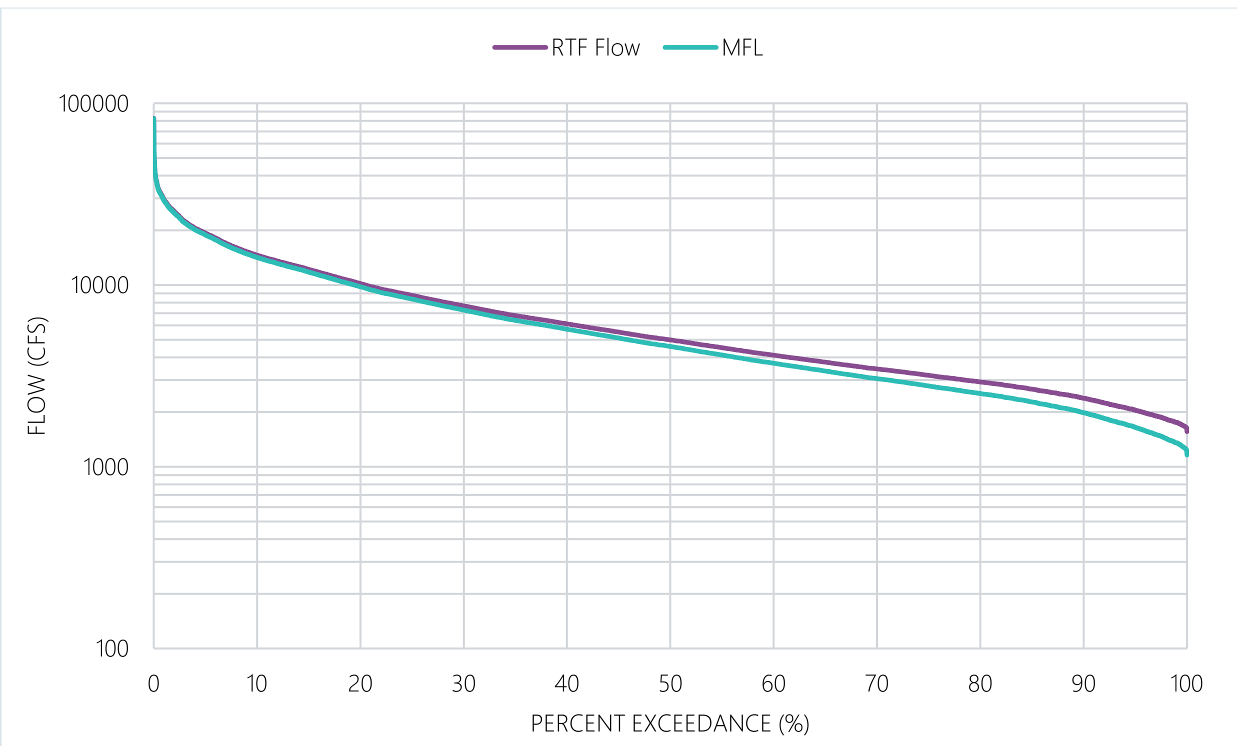


Figure 6-6. Branford RTF and proposed MFL flow duration curves

6.2 Proposed MFLs

The MFLs recommended for the Middle Suwannee River are based on analyses of flow reductions that protect multiple WRV metrics across the entire range of natural flow conditions. MFLs are represented as single value flow reductions. While it is possible to designate MFLs for multiple flow conditions for a particular gage, prescribing a single MFL flow condition at a gage provides efficacy from a water management perspective.

6.2.1 Proposed River MFLs

The MFL proposed for a gaging station is based on a restrictive hydrologic shift developed from the WRVs evaluated and is applied at the median flow (**Table 6-1**).

- Ellaville gage – at median flow of 3,822 cfs the change is 346 cfs, or a reduction of 9.1%.
- Branford gage – at median flow of 4,993 cfs the change is 400 cfs, or a reduction of 8.0%.

The difference between the RTF and MFL flows represents a potential maximum allowable shift in the hydrology of the MSR due to withdrawals as measured at the Ellaville and Branford gages.

Table 6-1. MFL criteria for Ellaville and Branford gages

Parameter	Ellaville	Branford
RTF median flow (cfs)	3,822	4,993
Hydrologic shift (cfs)	346	400
MFL at median (cfs)	3,476	4,593
Relative flow reduction at median flow (%)	9.1%	8.0%

The differences between the RTF and MFL flow duration curves (**Figure 6-5** and **Figure 6-6**) represent a single value flow reduction for the MSR at the Ellaville and Branford gage, respectively. Applying a single value flow reduction means that the relative percent flow reduction changes at varying exceedance frequencies, increasing at lower flows. **Table 6-2** and **Table 6-3** provide the relative percent flow reduction at select exceedance frequencies, ranging from 5% to 95%, for the Ellaville and Branford gages, respectively. The relative differences between the RTF and MFL median flows at both gages on the MSR are less than 10% (**Table 6-1**). Such flow reductions would provide adequate protection under the paradigm proposed by Richter et al (2011) for which a reduction of less than 10% of daily flows provides a high level of protection and lower risk to the ecosystem. A high-level of protection means that the natural structure and function of the riverine ecosystem will be maintained with minimal change (Richter et al, 2011). Other levels include 10-20% - moderate level of protection and moderate risk and >20% - low protection and high risk. The proposed MFL is implemented as a constant withdrawal, thus the hydrologic alteration is most apparent in the low to moderately low flow ranges. The proposed MFL is implemented as a constant withdrawal to be consistent with how groundwater withdrawals are regulated in the region.

Table 6-2. RTF and MFLs flow values for select exceedance frequencies at Ellaville gage

Condition	Exceedance Frequency						
	5%	10%	25%	50%	75%	90%	95%
RTF (cfs)	19,034	14,294	7,840	3,822	2,255	1,605	1,347
MFLs (cfs)	18,688	13,948	7,494	3,476	1,909	1,259	1,001
Relative Flow Reduction (%)	1.8	2.4	4.4	9.1	15.3	21.6	25.7

Table 6-3. RTF and MFLs flow values for select exceedance frequencies at Branford gage

Condition	Exceedance Frequency						
	5%	10%	25%	50%	75%	90%	95%
RTF (cfs)	19,270	14,618	8,780	4,993	3,185	2,383	2,049
MFLs (cfs)	18,870	14,218	8,380	4,593	2,785	1,983	1,649
Relative Flow Reduction (%)	2.1	2.7	4.6	8.0	12.6	16.8	19.5

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