Minimum Flows and Levels for the Aucilla River, Wacissa River and Priority Springs

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EXECUTIVE SUMMARY

The Aucilla and Wacissa Rivers, including priority springs, were evaluated to determine flow regimes that would be protective of fish and wildlife habitats and recreational activities. Both rivers are classified by the FDEP as Outstanding Florida Water (OFW), and “special waters” within the OFW designation.

The Aucilla River originates from artesian springs in central Georgia and flows south approximately 89 miles to the Gulf of Mexico. Along its path it traverses marshes and lakes in northern Florida, karst limestone east of Tallahassee, and sinks and resurgences below the Cody Scarp before finally rising at Nutall Rise and flowing into the Gulf of Mexico. The river picks up tannins from decaying vegetation and acquires a black tint as it flows south. The Wacissa River is a major tributary to the Aucilla River and provides a substantial portion of the total Aucilla flow, particularly at low flows. More than 12 springs feed the Wacissa River as it flows through swampy lowlands in the Aucilla Wildlife Management Area. The Wacissa River diffuses into numerous braids for several miles before flowing into the Aucilla River.

An essential element in establishing MFLs is identifying or developing a baseline flow record that reflects unimpacted or minimally-impacted historical conditions over representative long term hydrometeorological cycles. Anthropogenic impacts, if they exist, should be minimal. The USGS gaging station 02326500, Aucilla River near Lamont, is most useful for characterizing regional trends because it has a long period of record (POR) that extends from October 1951 to present and is centrally located within the study area. It is the index gage for the Aucilla River MFLs. Based on the analysis of a relationship between rainfall and flow at Lamont, there is no evidence of persistent anthropogenic impacts on the streamflow at the Lamont gage during the historic period of water years (WYs) 1951-2014. Hence, baseline condition, which is an estimate of unimpaired flow conditions, is defined as the POR at Lamont (WYs 1951-2014).

Flow data reported for the USGS gaging station 02326526, Wacissa River near Wacissa, are used as a surrogate for the combined flow from the springs upstream of the Wacissa gage. The station is the index gage for the Wacissa River MFLs, although its period of record is relatively short (2001 to present) and not sufficient to gage anthropogenic impacts. A spring-flow rating was developed and uses groundwater level as the explanatory variable.

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 environmental water resource values (WRVs). Three WRVs are relevant to the two rivers and springs and have sufficient available information to develop relationships between the WRVs and system hydrology. These include (1) Recreation In and On the Water, (2) Fish and Wildlife Habitats and the Passage of Fish, and (3) Estuarine Resources.

Recreation was evaluated in terms of paddling on both rivers, and motorized boating on the

Wacissa. Salinity regimes in the Aucilla River estuary were evaluated using a calibrated hydrodynamic model. Instream freshwater habitat was evaluated using habitat simulation models developed for one segment of the Aucilla River and two segments of the Wacissa River. Riparian bank and floodplain habitats were evaluated using a combination of HEC-RAS flow profile modeling and ArcGIS mapping of wetland vegetation communities.

Three MFLs are recommended for the Aucilla River for successively higher flow regimes referenced to the index gage at Lamont.

- A 6.5% flow reduction during low to moderate flows would remain protective of the oligohaline salinity regime of the Aucilla River estuary. The 0-2 ppt (parts per thousand) and 0-5 ppt oligohaline regimes are the most sensitive to reductions in freshwater flow of the metrics evaluated for the Aucilla River**.** This estuarine flow reduction limitation applies over about 72% of the baseline flow duration curve (0 to 355 cfs). The allowable flow reductions would range from zero to 23 cfs when flow at the Lamont gage is less than or equal to 355 cfs.
- A 13% flow reduction would remain protective of bank habitat for increasingly higher flows of up to 558 cfs, which is associated with the average top-of-bank stage within the middle reach of the Aucilla River. Between 46 and 73 cfs would be available during this flow range that occurred about 8% of the time during the baseline period.
- A flow reduction of up to 17% would remain protective of floodplain habitat, various portions of which were inundated by overbank flow about 20% of the time during baseline conditions. Beginning with 95 cfs of available water at a top-of-bank flow of 558 cfs in the middle Aucilla River, increasing amounts of water could be available as limited to 17% of flow.

The three Aucilla River MFLs referenced to the Lamont gage can be translated downstream to the Scanlon and Aucilla Acoustic Doppler Velocity Meter (ADVM) gages.

Two MFLs are recommended for the Wacissa River for successively higher flow regimes referenced to the index gage near Wacissa.

- A 5.1% reduction in flow during moderate to low flows less than 376 cfs would be protective of recreation activities associated with motor boating. Up to 19 cfs would be available as limited to 5.1% of flow.
- A 7.3% flow reduction of Wacissa River flows greater than 376 would remain protective of instream habitat. The most limiting metric is the area weighted suitability for largemouth bass fry. Collectively, the recommended Wacissa River MFLs would be protective of the Aucilla River estuary.

The MFLs recommended for the priority springs are based on baseline river hydrology and the index streamflow gages for the respective rivers.

- Nutall Rise is a resurgence, primarily of the Aucilla River, and its discharge is nearly all of the freshwater surface inflow to the upper portions of the Aucilla River estuary. When applied to Nutall Rise, the 6.5%, 8%, and 17% flow reduction thresholds developed for the Aucilla River at Lamont gage would be protective of recreation and freshwater habitats on the Aucilla River and the estuarine habitat downstream from the rise.
- The Wacissa Springs Group is a collection of at least 12 springs that give rise to the Wacissa River (Rosenau et al. 1977), and the Wacissa gage is considered an index for the combined flows of the Wacissa Springs Group. The 5.1% and 7.3% flow reduction thresholds developed for the Wacissa River gage would be protective of recreation on the Wacissa, its riverine habitat, and the habitat in the Aucilla River estuary.

1 Introduction and Relevant Water Resource Values

The Suwannee River Management District (SRWMD) is currently establishing and implementing minimum flows and levels (MFLs) for certain priority water bodies/courses within the District by assessing whether the current long-term hydrologic regime and any flow reduction from the baseline long-term hydrologic regime will cause significant harm to the water resources or ecology of the system. The Aucilla River, the Wacissa River, and priority springs system (AWSS) are on the MFLs priority List and Schedule (SRWMD 2015). 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 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

The objective of this document is to present the data and analyses that provide technical support for establishing and adopting Minimum Flows and Levels (MFLs) for the AWSS. A brief description of the AWSS is provided in this section, along with a screening of the WRVs with respect to the relevance of the river system. Sections 2 and 3 include descriptions of the hydrology and biology of the river system. Section 4 includes the approach to setting MFLs, and Section 5 includes the MFLs analyses. Section 6 is a summary of the work effort.

1.1 Watershed and River Descriptions

The Aucilla River Basin covers an area of almost 610,000 acres, with swamps and forests dominating the land cover types. Approximately 77% of the watershed resides within Florida and the remaining 23% is in Georgia (FWC 2011b). Total river length has been reported to be somewhere between 69 and 75 miles, with all but roughly 20 miles residing within Florida (Lenz 2006). The Aucilla River Watershed is one of the four watersheds that define the Ochlockonee

River Basin, which is one of Georgia's 14 major river basins (GADNR 2002). In the Aucilla Watershed, there are several first-magnitude springs, including Wacissa Spring, which gives rise to the Wacissa River.

The Wacissa River is the main tributary of the Aucilla. Adding to Wacissa River are about 20 other springs found in the first 1.5 miles of the Wacissa's headwaters. The Wacissa flows southward until it disappears into a group of small streams and river swamps known as "The Warriors" or "Western Sloughs" located west of the Aucilla River (Lenz 2006). Near the same area, the Aucilla goes underground through sinks and reappears as many as 30 times as rises (also referred as resurgences), most notably Nutall Rise (Figure 1).

The Aucilla is characterized as a blackwater river. This type of river is named for its dark brown, tannin-stained waters that originate in acidic swamps and flatwoods. Blackwater streams have highly acidic (low pH) water from decaying plant materials and support biological diversity. The Wacissa is a clear, spring-fed river.

About 20 miles south of Lamont and 12 miles north of Apalachee Bay in an area called the Aucilla Sinks, the Aucilla plunges underground. For the next eight miles or so, the river flows underground in a network of caverns, connected to the surface by a series of limestone sinks and river rises, some of which are 100 feet deep. The Wacissa River joins the Aucilla downstream of the Aucilla Sinks in a densely vegetated area of multiple channels about four miles above the mouth of the Aucilla River (Figure 1).

1.2 Screening and Identification of Relevant WRVs

A qualitative evaluation of risk and value was performed for each of the ten WRVs to identify those WRVs most relevant to the Aucilla and Wacissa Rivers. This evaluation was based on review of available information and assessment of outcomes that potentially could result under a flow-reduction scenario. The ten WRVs were scored on a nine-point scale for relevance from low (1 point) to high (9 points) by considering three factors: the risk of adverse consequence attributable to a flow reduction, the intrinsic value of the WRV, and the existence of legislated protection. A WRV that would be adversely impacted by a flow reduction is scored higher than one that would be impacted to a lesser degree or not at all (in the latter case, a score of zero would be applied). Intrinsic value is a measure of how essential the WRV is perceived to be to the public and to water managers. The legislated protection factor is a measure of a WRV's perceived value as evidenced by special legislation that protects the water resource.

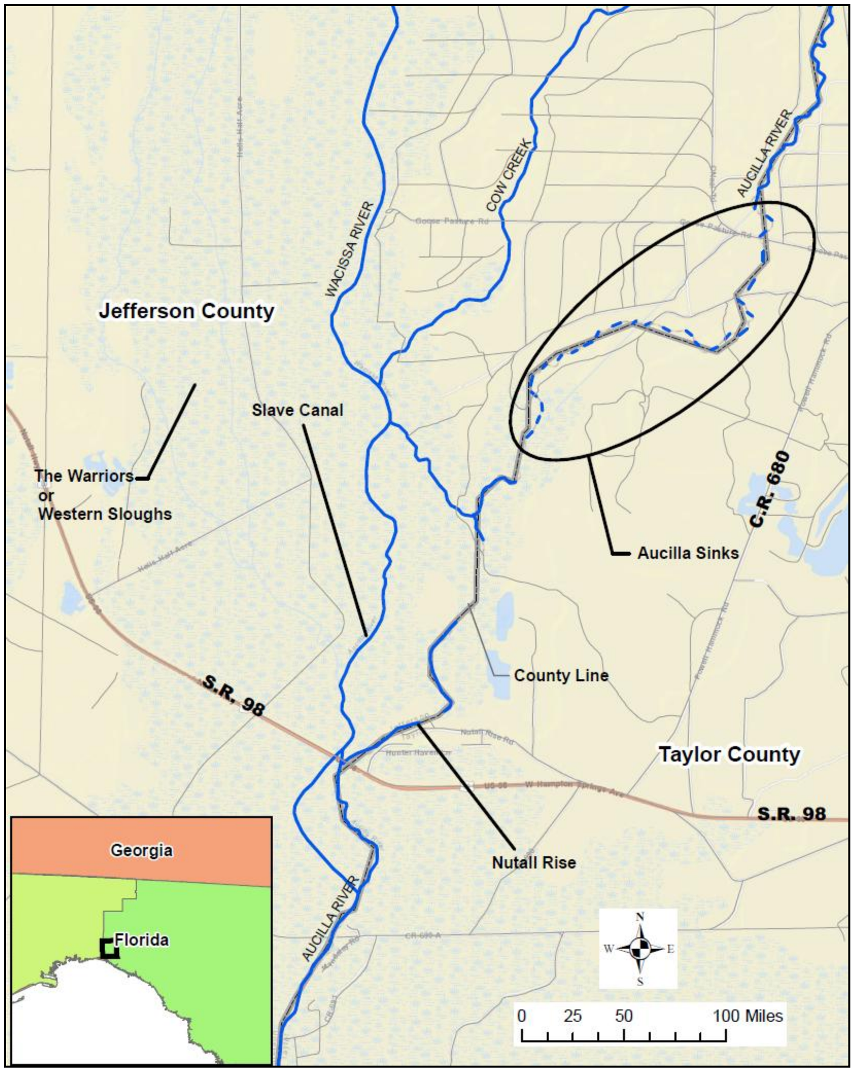


Figure 1. Channels and features near the confluence of the Aucilla and Wacissa Rivers

Nine of the ten WRVs are deemed potentially relevant to the Aucilla and Wacissa, with total scores of 6 points or higher (Table 1). The highest-ranked WRVs are Fish/Wildlife Habitat and Fish Passage and Estuarine Resources (9 points each), followed by Recreation (8 points). The availability of general and site-specific information relative to a specific WRV is indicated using similar scoring (Table 1).

Table 1. Aucilla and Wacissa River water resource values screening summary
[Scoring factors for relevance are 0 for none, 1 for low, 2 for medium, and 3 for high]

Water Resource Value		Function Risk to Flow Reduction (1)	Overall Intrinsic Value (2)	Legislated Environmental Protection (3)	Total Score	Available Data (4)
1	Recreation in/on water	2	3	3	8	2
2	Fish/wildlife habitat and fish passage	3	3	3	9	3
3	Estuarine resources	3	3	3	9	3
4	Transfer of detrital material	2	1	3	6	2
5	Maintain freshwater storage	2	1	3	6	1
6	Aesthetic/scenic attributes	2	3	2	7	1
7	Filtration/absorption of nutrients/other pollutants	2	2	3	7	1
8	Sediment loads	3	2	2	7	2
9	Water quality	2	2	3	7	2
10	Navigation	0	1	1	2	1

Notes:

(1) Relevance of the WRVs risk to flow reduction; i.e., whether there is a functional relationship to flow and, if so, how strong.
(2) The perceived relevance of a value to the general public and water managers.
(3) The relevance of legislated protection, if any, associated with a specific WRV.
(4) Availability of data in literature to define functional relationships and flow impacts.

1. Recreation In and On the Water

Recreation along the Aucilla and Wacissa Rivers is an important WRV, with many recreational activities involving boat access to the river. The Aucilla is classified by the FDEP as an Outstanding Florida Water (OFW), and the Aucilla Wildlife Management Area (AWMA) reflects conscious efforts to maintain and enhance the experience of visiting the river. The Aucilla is part of Florida's Statewide System of Greenways and Trails, where boaters and kayakers can observe a variety of wetland communities. It also offers unique karst formations that create rapids enjoyed by kayakers. From the point at which the blackwater of the Aucilla meet the clear, spring-fed waters of the Wacissa, boaters can navigate their way through the Slave canal, a human-engineered waterway (Figure 1). The Aucilla also is a part of the Great Florida Birding and Wildlife Trail (GFBWT), a Florida Fish and Wildlife Conservation Commission (FWC) program that connects 2,000 miles of self-guided trails and unifies 515 birding and wildlife viewing sites throughout Florida (Lenz 2006).

The Aucilla and Wacissa Rivers are "special waters" within the OFW designation. For a body of water to be designated 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.*).

2. Fish and Wildlife Habitats and the Passage of Fish

The importance of fish and wildlife habitats is evidenced by the special waters designation awarded by the ERC. Different 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 Aucilla and Wacissa Rivers are an important source of these habitats for a variety of wildlife, including many rare, threatened and endangered species (Lenz 2006). More than 20 species of animals and plants are assigned by Florida Natural Areas Inventory (FNAI 2010, FNAI 2015*a*, FNAI 2015*b*, FNAI 2015*c*) or noted by Lenz (2006) as rare, imperiled or critically imperiled (Table 2). In terms of federal classifications, the wood stork (*Mycteria americana*) and Mexican tear-thumb (*Polygonum meisnerianum* var. *beyrichianum*) are listed as threatened and Kemp's ridley sea turtle (*Lepidochelys kempii*) as endangered. The U.S. Fish and Wildlife Service reclassified the wood stork from endangered to threatened in June 2014. Area 11, in the lower Aucilla River watershed, is one of five areas along the north side of St. Marks National Wildlife Refuge that are identified as having the "best habitat for wood storks among the expansion lands" (USFWS 2010). Area 11 includes generally about 4 miles of the Aucilla River between US 98 and the Wacissa River mouth.

Table 2. Rare, imperiled, or critically imperiled species listed for the Aucilla and Wacissa rivers [State rank designed as Species of Special Concern (SSC), State Threatened (ST), Critically Imperiled (S1), Imperiled (S2), Very rare and local throughout its range (S3); Federal rank designated by Threatened (T), Proposed Threatened (PT), and Endangered (E)]

Species	Common Name	Florida State Rank	Federal Rank
Birds			
Aramus guarauna	Limpkin	SSC, S3	---
Egretta caerulea	Little blue heron	SSC	---
Egretta thula	Snowy egret	SSC	---
Egretta tricolor	Tricolored heron	SSC	---
Eudocimus albus	White ibis	SSC	---
Grus canadensis pratensis	Florida sandhill crane	ST S2 S3	---
Mycteria americana	Wood stork	S2	T
Bivalves			
Medionidus walkeri	Suwannee moccasinshell [2]	S1	PT
Decapods			
Procambarus horsti	Big Blue Spring Cave crayfish [3]	S1	---
Fish			
Enneacanthus chaetodon	Blackbanded sunfish	S3	---
Micropterus notius	Suwannee bass	S3	---
Isopods			
Remasellus parvus	Swimming Little Florida Cave isopod [3]	S1 S2	---

Species	Common Name	Florida State Rank	Federal Rank
Mayflies			
Asioplax dolani	A Mayfly	S1 S2	---
Odonates			
Macromia alleghaniensis	Allegheny River Cruiser	S1	---
Nannothemis bella	Elfin skimmer	S1 S2	---
Neurocordulia molesta	Smoky shadowfly	S1	---
Plants			
Eleocharis rostella	Beaked spikerush [1]	S1	---
Carex chapmanii	Chapman's sedge	S3	---
Leitneria floridana	Corkwood	S3	---
Lilium iridollae	Turk's cap lily [1]	S1	---
Minuartia godfreyi	Godfrey's sandwort [1 2]	S1	---
Najas filifolia	Narrowleaf naiad [2]	S1 S2	---
Phyllanthus liebmannianus ssp. *Platylepis*	Pinewoods dainties	S2	---
Polygonum meisnerianum var. *beyrichianum*	Mexican tear-thumb [1]	S1	---
Ribes echinellum	Miccosukee gooseberry [1 2]	S1	T
Stachys hyssopifolia var. *lythroides*	Tallahassee hedge-nettle	S1	---
Reptiles		---	---
Lepidochelys kempii	Kemp's ridley sea turtle [1 2]	S1	E

Species	Common Name	Florida State Rank	Federal Rank

1. Also listed as LE: Endangered species, subspecies, or isolated population so few or depleted in number or so restricted in range that it is in imminent danger of extinction.

2. Also listed as G1: Critically imperiled globally because of extreme rarity (five or fewer occurrences or fewer than 1,000 individuals) or because of extreme vulnerability.

S1: Critically imperiled in Florida because of extreme rarity (five or fewer occurrences or fewer than 1,000 individuals) or because of extreme vulnerability to extinction due to some natural or man-made factor.

S2: Imperiled in Florida because of rarity (six to 20 occurrences or fewer than 3,000 individuals) or because of vulnerability to extinction due to some natural or man-made factor.

S3: Either very rare and local throughout its range (21-100 occurrences or fewer than 10,000 individuals) or found locally in a restricted range or vulnerable to extinction from other factors.

PT: Proposed threatened (Federal Register Vol. 80 (No. 193): 60335-60348).

Sources: FWC 2015a, FNAI 2010, FNAI 2015a, FNAI 2015b, FNAI 2015c, Lenz 2006

3. Lives in aquatic caves.

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). Salinity reflects a blend of freshwater (<0.5 ppt) with a saline (>30 ppt) source such as the Gulf of Mexico. A salinity regime refers to an area (or volume) of water in the estuary at a particular location in which flora and fauna have acclimated to the normal range of salinities that occur throughout the year. The salinity at a particular location is dynamic, tidally influenced, and inversely proportional to freshwater flow such that higher salinity is associated with lower freshwater flow and high tide.

The habitat available for biota is critical to the maintenance of ecosystem function in the estuarine portions of waterbodies, and diminished freshwater flows can result in an isohaline movement up-river that places stress on established ecological communities. Beaked spikerush (*Eleocharis rostella*) is a moderately salt-tolerant, obligate wetland plant that is known to occur in oligohaline (0.5 to 5.0 ppt) marshes and alkaline waters. In addition, commercial and public interests are integrally associated with sports fishing and scalloping near the coast. Therefore, consideration of estuarine resources is essential to the establishment of MFLs for this coastal river system.

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. An ample supply of such organic matter typically is present in surface runoff. Flow reduction could reduce downstream transfer of this organic energy source.

5. **Maintenance of Freshwater Storage**

Maintaining freshwater storage involves the protection of an amount of freshwater supply for permitted users at the time of MFLs determination. The direct withdrawal of surface water or an indirect flow reduction associated with groundwater withdrawals will reduce streamflow to one degree or another. The risk to existing uses generally is mitigated by the State-wide regulation of water use and provisions for reviewing water use permit applications.

6. **Aesthetic and Scenic Attributes**

WRV 6 refers to features of a natural or modified waterscape usually associated with passive uses, such as sightseeing, hiking, photography, contemplation, and other forms of relaxation. The aesthetic and scenic attributes of the Aucilla River are defining features of this river as it transforms itself from swamp to creek to river, disappearing into sinks and reappearing as rises before making its final above-ground appearance at Nutall Rise and flowing into the estuary. South of Lamont, Florida, the river hosts some of Florida's whitewater rapids. The contrast of the blackwater of the Aucilla where it meets the clear, spring-fed waters of the Wacissa also adds to the river's unique aesthetic appeal. The natural, old-Florida setting of Florida's Big Bend area is appealing to nature-lovers and economically important to the growing eco-tourism industry. This WRV thus is considered relevant, with its importance a logical consequence of the designation of both rivers as special waters within the OFW classification.

7. **Filtration and Absorption of Nutrients and Other Pollutants**

WRV 7 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. The FDEP performed a Total Maximum Daily Load (TMDL) evaluation of fecal coliform in 2001 for the Aucilla River watershed, with the results indicating that nonpoint sources related to agricultural and urban activities have a significant impact on fecal coliform bacteria loading in the watershed (USEPA 2001). Subsequent evaluations have shown that the river also has been adversely impacted by nutrients and mercury and that introduced, undesirable plant species such as elodea (*Elodea canadensis michx*.), hydrilla (*Hydrilla verticillata*), and water hyacinth (*Eichhornia crassipes*) are out-competing the native eelgrass (*Vallisneria americana*) (Lenz 2006).

While the negative effects of nonpoint source loading may be increased to some degree by reductions in flow, this WRV is likely to be protected more effectively by implementation of best-management practices and other means of reducing the nutrient loads to the watershed than by maintaining the current flow regime. This WRV also will be protected as a consequence of protecting other WRVs. Thus, this WRV is given a lower screening score and concluded to be less relevant in setting MFLs for the Aucilla and Wacissa Rivers.

8. Sediment Loads

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 Aucilla River is the only site in Florida that yields radiocarbon dates from a Paleo-Indian era. The river is renowned for the prehistoric artifacts and fossils that are present. The lower Aucilla River, particularly the Half Mile Rise section, has an entrenched limestone channel that carries very little sediment load, thus allowing artifacts to be easily obtained (Dunbar 2007). Lower flows as might occur under a reduced-flow scenario will allow some sediment to settle out, which could diminish or otherwise impact the archeological attraction of the river. As preemptive measures, systems have been put in place that divert stormwater from the river, and parking lots used by visitors or local businesses have been supplemented or replaced with native vegetation to prevent further erosion and sediment loading into the river (SRWMD 2012). Notwithstanding these improvements and, given the archeological importance of the river, this WRV is relevant to the development of MFLs but a limited amount of sediment data are available.

9. Water Quality

Water quality refers to the chemical and physical properties of water not included in WRV 7. The main reason for an OFW designation is to protect ambient water quality. Healthy scallop beds and fish populations depend on sufficient levels of dissolved oxygen and an absence of elevated levels of pollutants. The OFW designation pursuant to Section 403.061(27), F.S., provides protection to the river against any projects that would lower water quality from its condition at the time the designation was made. The high legal protection afforded by this designation makes water quality an important WRV for the Aucilla and Wacissa Rivers. Similar to WRV 7, this WRV is likely to be protected more effectively by implementing best-management practices and other means of reducing the loads to the watershed than by merely maintaining the current flow regime. Thus, this WRV is given a lower screening score and concluded to be of lesser importance in setting MFLs for the Aucilla and Wacissa Rivers.

10. Navigation

While navigation is directly related to flow, it is not a relevant WRV for the Aucilla and Wacissa Rivers because no commercial barges or other large commercial vessels utilize the rivers. Small boat traffic and commercial guide operations will be protected under WRV 1 (Recreation In and On the Water).

1.3 Priority WRVs

Based on the screening (Table 1), primarily on the availability of data and literature to quantitatively define the relationship between flow and impacts to WRVs, the following WRVs were investigated to identify the threshold hydrologic conditions for developing MFLs.

WRV 1 Recreation In and On the Water

WRV 2 Fish and Wildlife Habitats and the Passage of Fish

WRV 3 Estuarine Resources

2 Hydrology

The hydrology of the Aucilla and Wacissa Rivers, including regional characteristics of the watershed and the locations and extent of hydrometeorological records, is described in this section. Gaging stations important to the MFLs assessment are identified and their streamflow characteristics discussed. A hydrologic analysis of long-term hydrometeorological records to characterize period of record conditions and to identify a baseline time period also was performed and is presented in this section.

2.1 Physiography and River Description

The Aucilla Basin is part of the Aucilla-Suwannee-Ochlockonee Basin (Torak et al. 2010), and most of the Florida portion of Aucilla is within the SRWMD boundary (Figure 2). There are three major physiographic regions within the Aucilla Basin-Tifton Upland in Georgia, Tallahassee Hills and Gulf Coastal Lowlands in Florida (Figure 3). The Tifton Upland and Tallahassee Hills are parts of a nearly continuous series of topographically high uplands containing gently rolling hills with broad rounded summits situated between the low-lying Dougherty Plain to the northwest, Gulf Coastal Lowlands to the south, and Okefenokee Basin to the east (Torak et al. 2010). The Tifton Upland and Tallahassee Hills contain the 927-mi^2 Red Hills region, which encompasses the Aucilla and Ochlockonee River Basins in Florida and Georgia and is bounded on the south by a persistent topographic break (i.e., an escarpment) referred to as the Cody Scarp (Figure 3).

The Tallahassee Hills is a subdivision of the Northern Highlands that is characterized by red clay hills. The Floridan aquifer is thinly confined in this region, and streams are often intermittent or in parts flow underground in the karst landscape. The Cody Scarp denotes a transition between the Tallahassee Hills and Northern Highlands and the relatively flat coastal region of the Gulf Coastal Lowlands.

The Gulf Coastal Lowlands 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 4). The Upper Floridan aquifer (UFA) is unconfined and is the only aquifer present at the surface. The Lowlands in the south and the west are characterized by land surface elevations that range from 0 MSL to 100 feet (Ceryak 2005).

The Aucilla River is approximately 89 miles long and has a drainage basin of 954 square miles (Torak et al. 2010). The river rises from artesian springs in central Thomas County, Ga., and drains marshes and lakes before flowing over karst limestone east of Tallahassee, Florida. The Aucilla flows on the surface through northern Jefferson County until 4.5 miles north of US Highway 98, where the river dives underground; closely spaced sinks define its underground

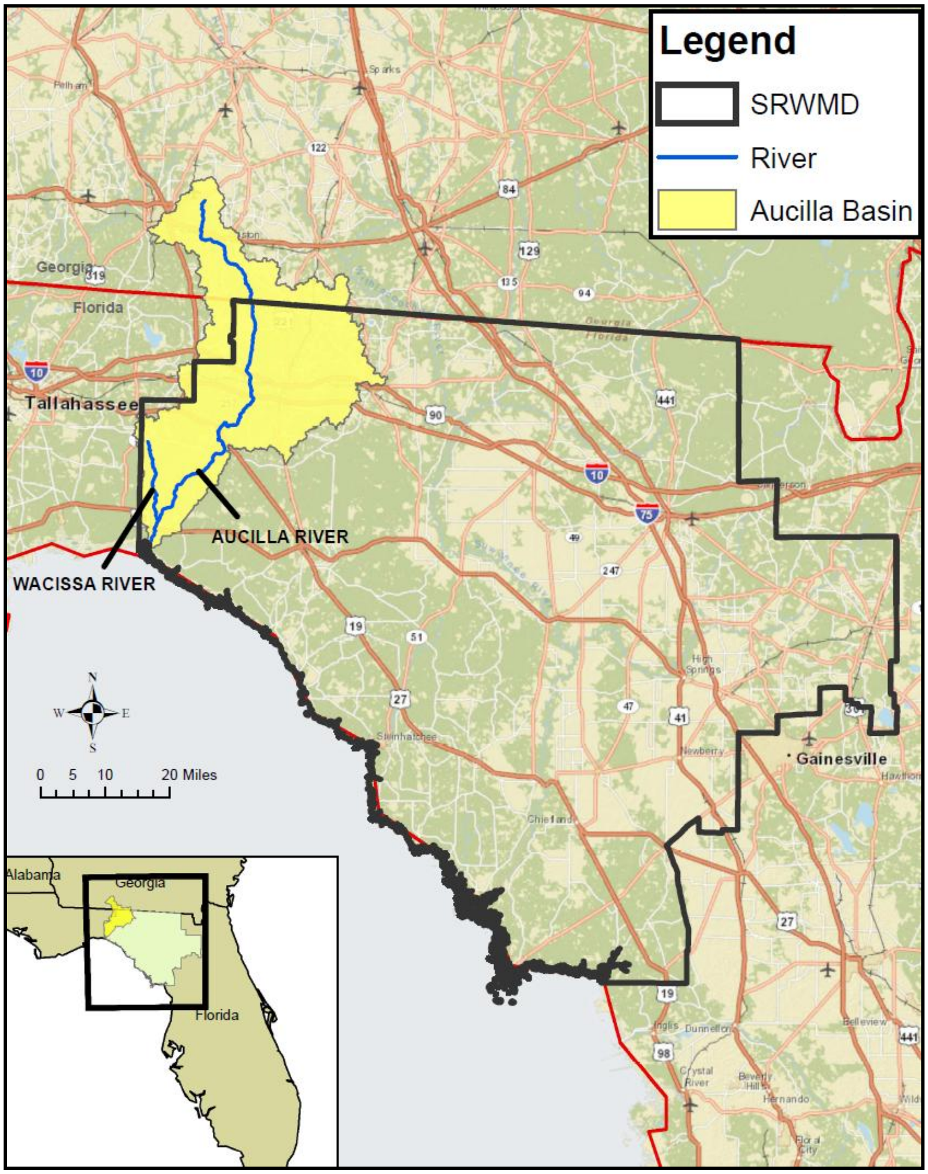


Figure 2. Aucilla Basin and SRWMD boundary

path until its re-emergence nearly 1.8 miles further south (Webb 2006). The Aucilla sinks again at the foot of next segment of the river, called Half Mile Rise, and rises twice more before flowing into the Gulf of Mexico. The penultimate 0.6 miles segment, called Little River, begins approximately 1.5 miles downstream of Half Mile Rise (Figure 5). The river sinks at the confluence with the Little River and emerges again 160 ft downstream at Nutall Rise, and then flows 4.3 miles to the Gulf of Mexico. A series of large and small sinks provide views of the river's underground path between Half Mile Rise and Little River.

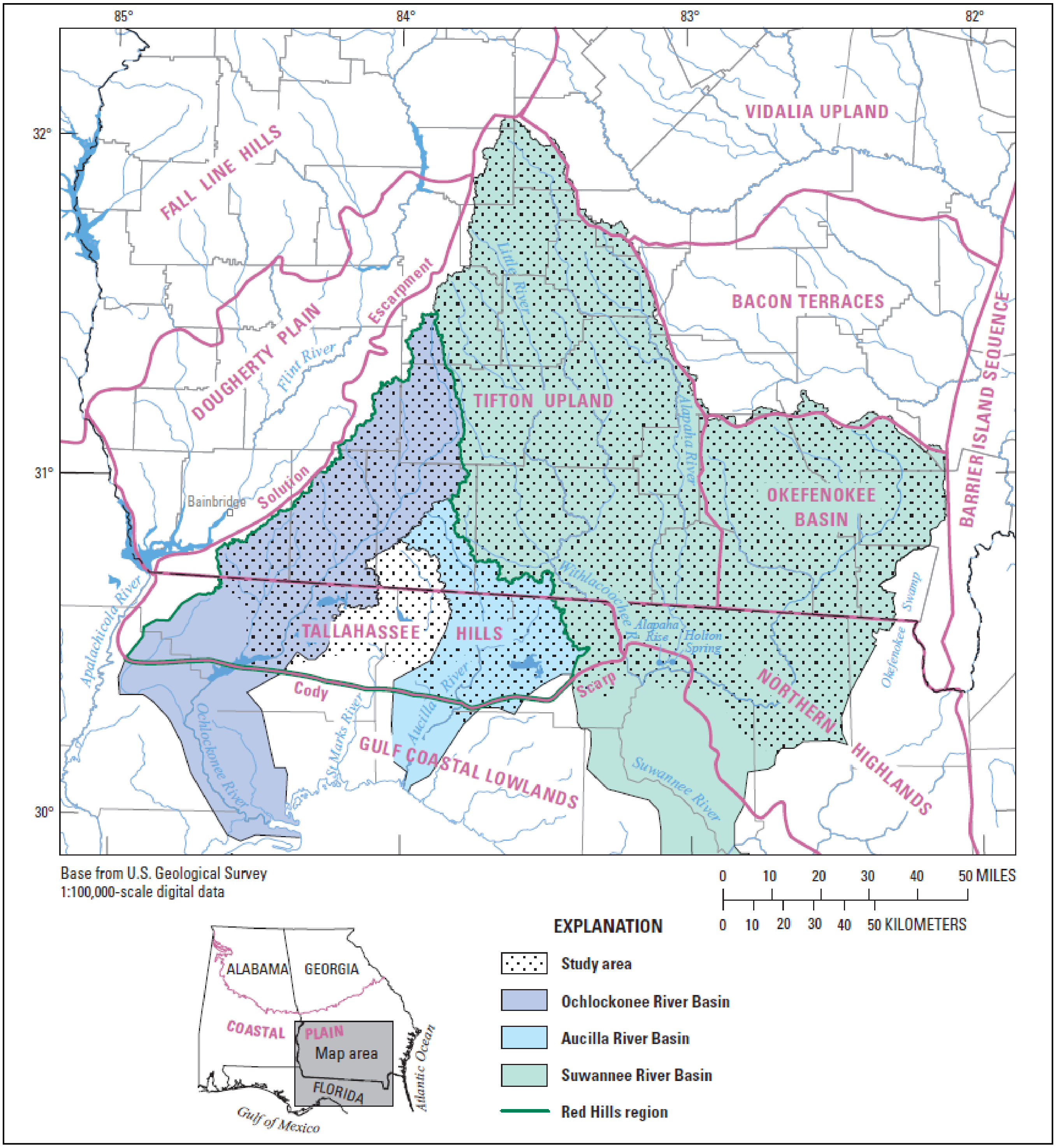


Figure 3. Physiographic divisions in the Aucilla-Suwannee-Ochlockonee River Basin [Source: Torak et al. 2010]

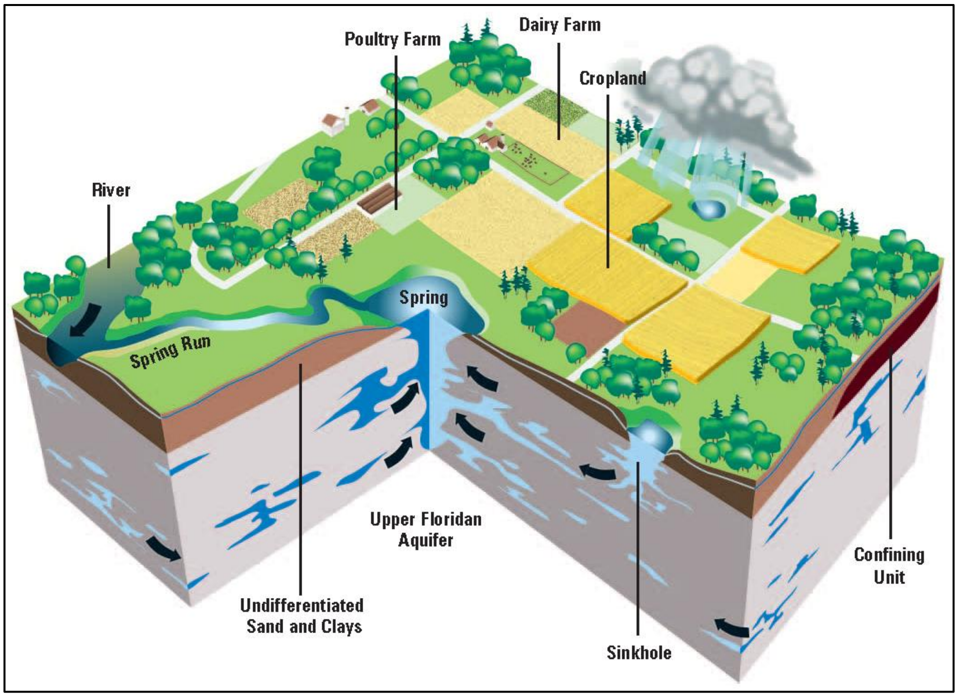


Figure 4. General cross-section and surface features in the Gulf Coastal Lowlands [Source: FDEP 2001]

The Wacissa River is a tributary to the Aucilla River and provides a substantial portion of the total flow, particularly at low total flow. Sixteen springs feed the Wacissa River as it flows through swampy lowlands in the Aucilla Wildlife Management Area. The head springs are located at the Wacissa Spring County Park. About 1.5 miles downstream of Goose Pasture, the historic man-made five mile long Slave Canal was constructed during the 1850s in an attempt to join the Wacissa and Aucilla Rivers (Figure 5). After its passage through the Slave Canal, the clear Wacissa waters merge with the Aucilla's "blackwater" (NRT 2012). For several miles below Goose Pasture, the Wacissa River diffuses into several braids and re-forms again just before flowing into a stretch of sinkholes known as Half Mile Rise, part of the Aucilla River Sinks segment (FDEP 2013a).

2.2 Monitoring Locations and Period of Record

2.2.1 Streamflow

A number of stream gaging stations have been maintained on the rivers and creeks within and adjacent to the Aucilla River watershed (Figure 6, Table 3). Four gauging stations are located on the Aucilla River. The Lamont gage has the longest period of continuous flow record, dating back to the 1950 (Figure 7). Four stream-gaging stations also have been maintained on the Wacissa River (Figure 6, Table 3) and Wacissa River near Wacissa has the longest period of continuous flow record, dating back to 2001. Two stream-gaging stations are present on Little Aucilla River, a small creek joining the main Aucilla River. The Econfina River lies east of the Aucilla and runs to the Gulf of Mexico almost parallel to Aucilla River. One gaging station is maintained on the Econfina River and has continuous flow record dating back to 1950, similar to the Lamont gage, that is useful for comparing with Aucilla River flow data.

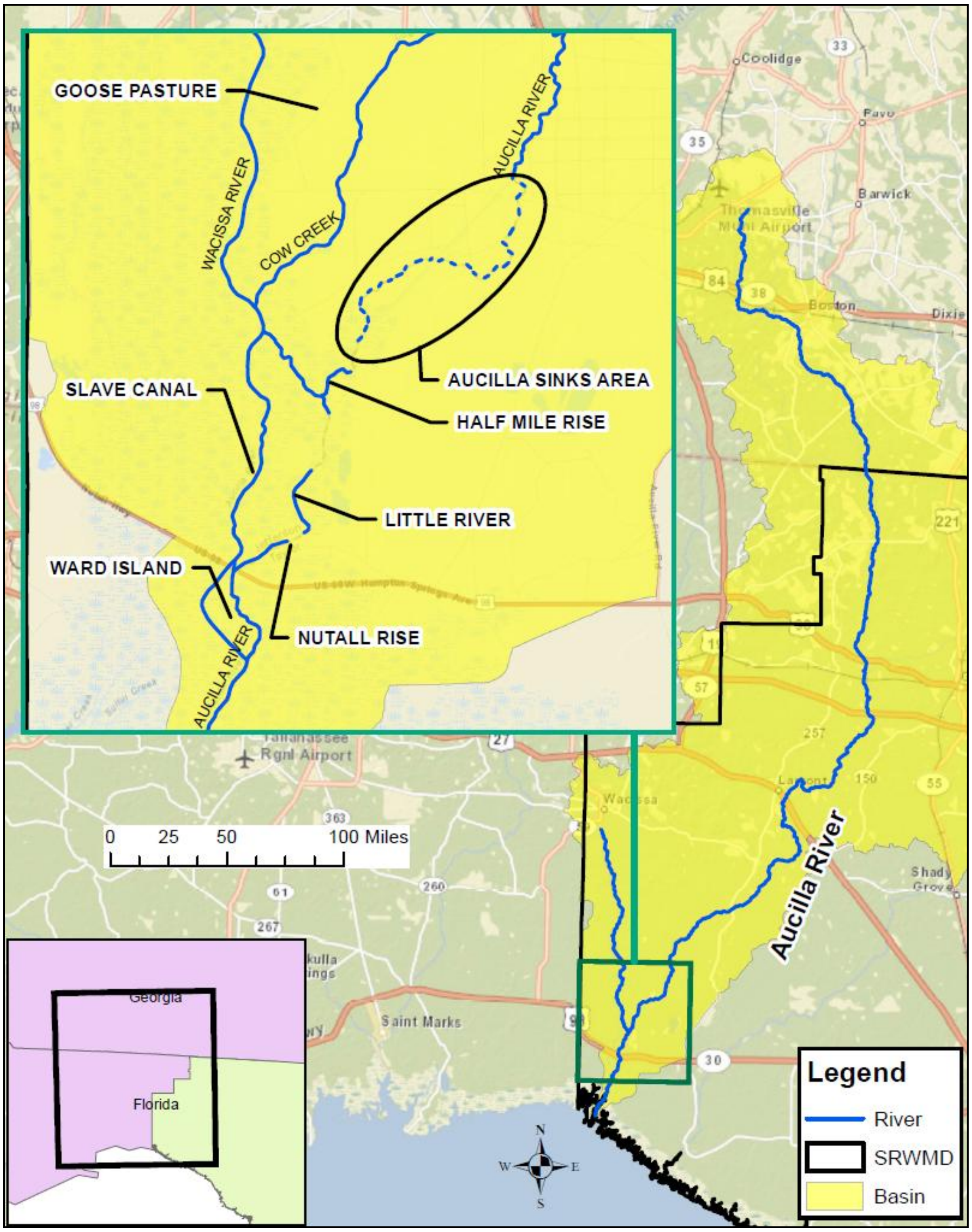


Figure 5. Features on the Aucilla and Wacissa Rivers

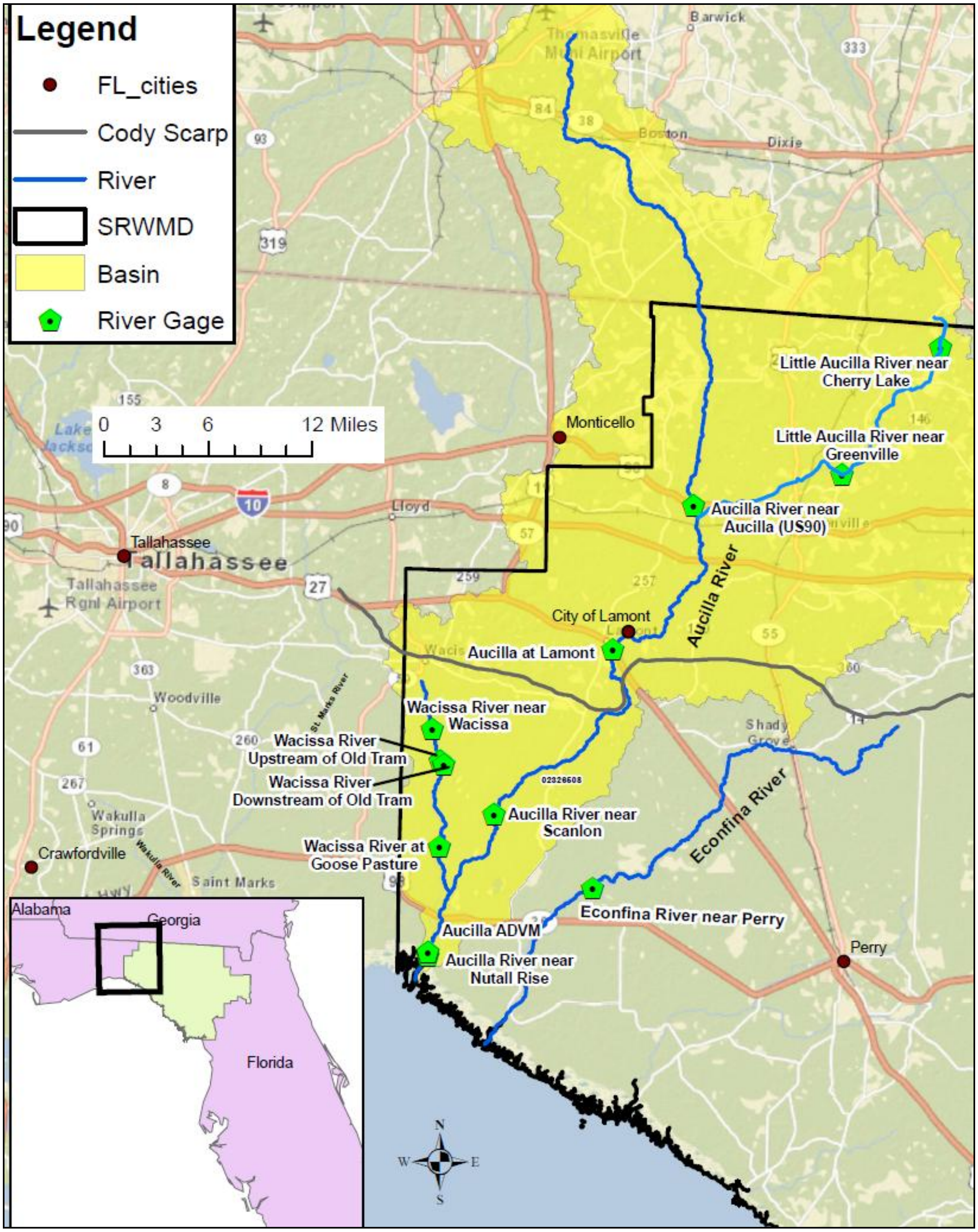


Figure 6. Location of stream gaging stations within the Aucilla and Econfina watersheds

Table 3. Select stream gaging stations in the Aucilla and Econfina River watersheds
[Source: USGS NWIS 2015, SRWMD 2015]

USGS Site No.	Name	Drainage Area (square miles)	Parameter	Period of Record[1]
02326250	Aucilla River near Aucilla (US90)	345	Flow	03/09/1956-10/04/1990 (Miscellaneous)
			Stage	03/09/1956-present (Miscellaneous)
02326500	Aucilla River near Lamont	780	Flow	03/01/1950-present
			Stage	02/09/1950-present
02326512	Aucilla River near Scanlon	805	Flow	08/30/1976-10/07/1997
			Stage	08/30/1976-08/25/1996
02326550	Aucilla River near Nutall Rise	938.6	Flow	05/04/2001-10/04/2010
			Stage	05/04/2001-present
-	Aucilla Acoustic Doppler Velocity Meter (ADVM)	-	Flow	2/13/2015-6/8/2015
			Stage	2/13/2015-6/8/2015
02326261	Little Aucilla River near Cherry Lake	13.9	Flow	01/09/1970-06/04/1996 (Miscellaneous)
			Stage	01/09/1970-06/04/1996 (Miscellaneous)
02326300	Little Aucilla River near Greenville	90.7	Flow	02/12/1964-06/04/1996 (Miscellaneous)
			Stage	02/12/1964-06/04/1996 (Miscellaneous)
02326526	Wacissa River near Wacissa	30	Flow	02/10/2001-present
			Stage	04/18/2013-present
02326528	Wacissa River Upstream of Old Tram	-	Stage	09/26/2013-present
02326529	Wacissa River Downstream of Old Tram	-	Stage	09/26/2013-present
02326536	Wacissa River at Goose Pasture	-	Stage	04/18/2013-present

USGS Site No.	Name	Drainage Area (square miles)	Parameter	Period of Record[1]
02326000	Econfina River near Perry	198	Flow	02/01/1950-present
			Stage	02/01/1950-present

1. Short periods of missing record exist for many gages.

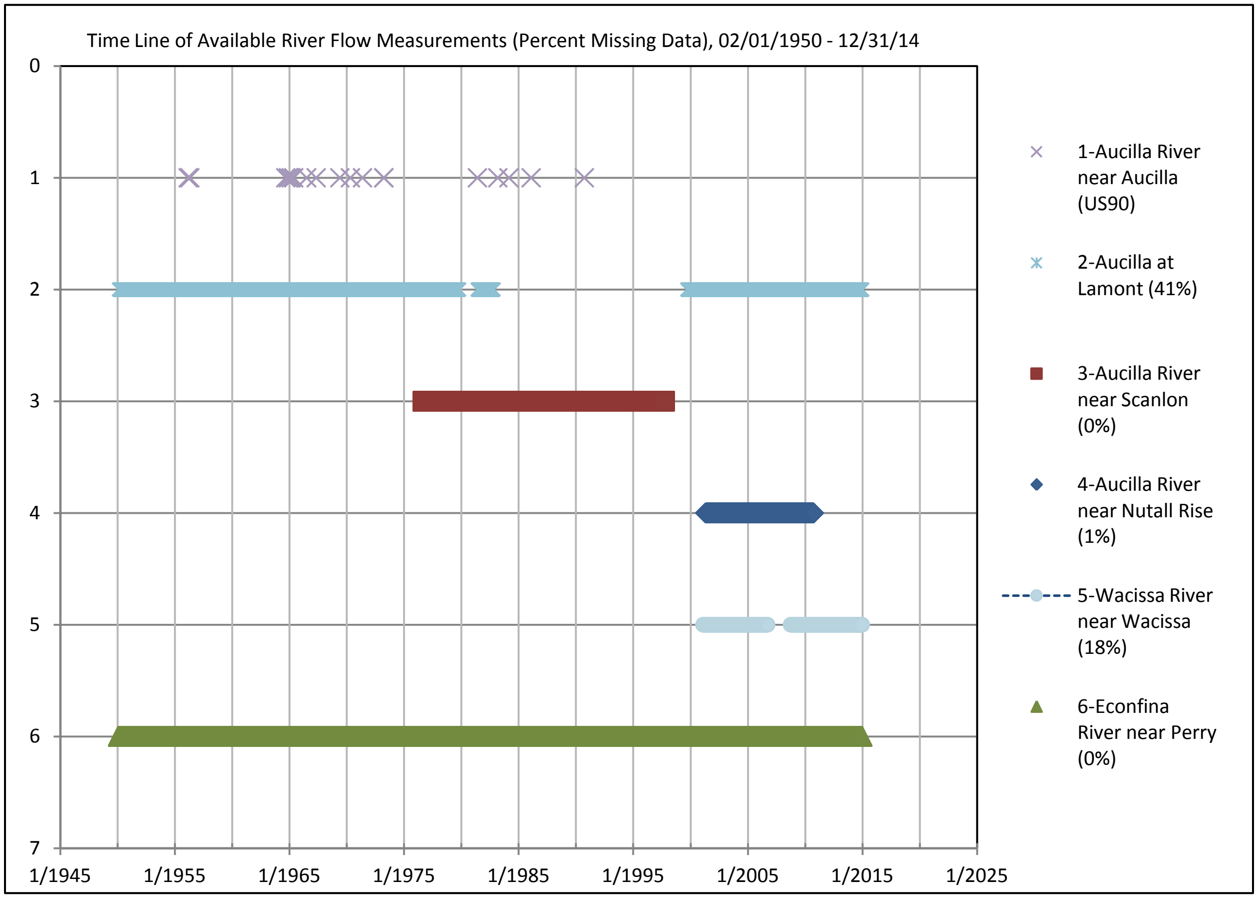


Figure 7. Timeline of streamflow data available for gaging stations within the Aucilla and Econfina watersheds

2.2.2 Springs

A total of 16 springs have been reported on the Wacissa River (SRWMD 1998) with the majority located along the upper two miles of Wacissa River (Figure 8 and Table 4). Nutall Rise is the only major spring reported on the Aucilla River (Figure 8) and is a first magnitude resurgence. Nutall Rise and the Wacissa Springs Group are designated MFLs priority water bodies in the SRWMD 2015-2018 MFLs Priority List.

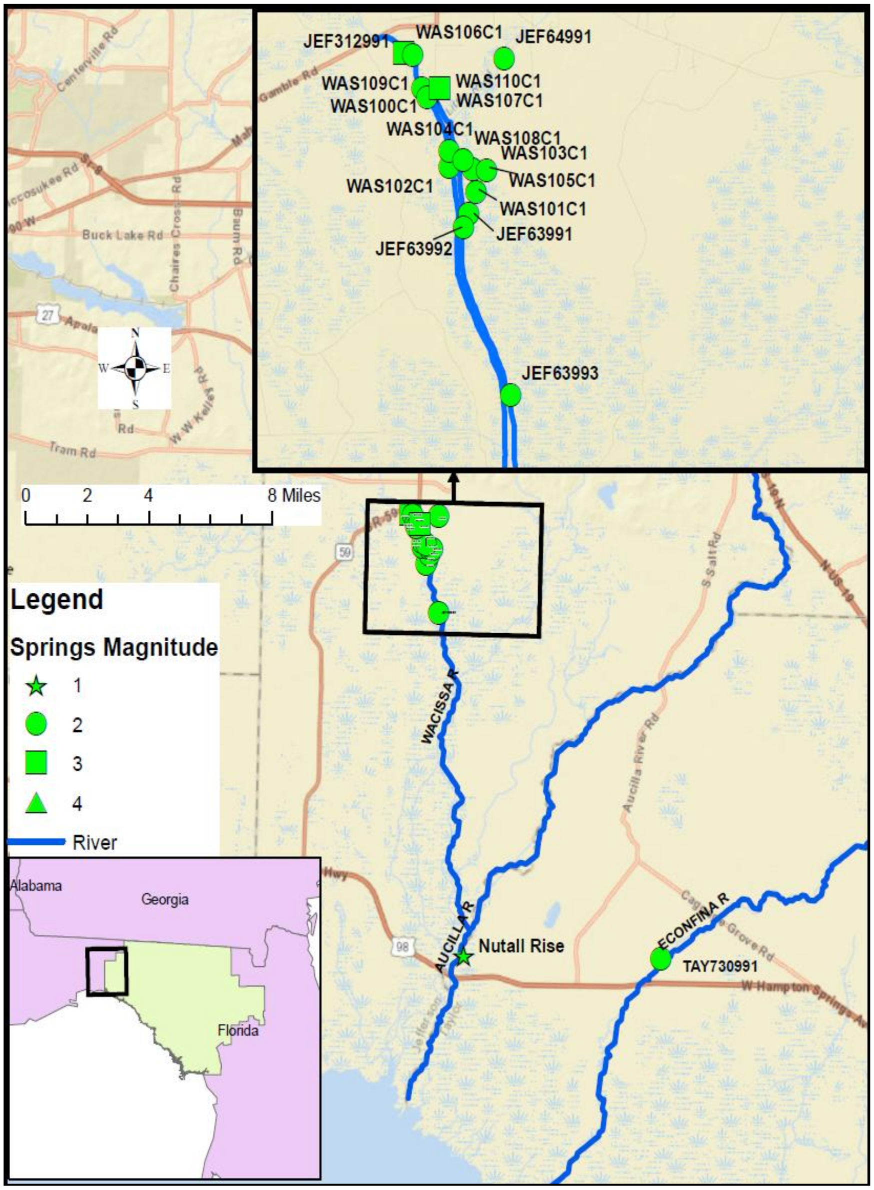


Figure 8. Spring locations within the Aucilla and Econfina watersheds

Table 4. Springs in the Aucilla watershed
[Source: USGS NWIS, SRWMD Water Data Portal]

Name	Station ID	USGS ID	Magnitude	No. of Flow Measurements	Period of Record
Springs Located on Aucilla River					
Nutall Rise	AUC100C1		1	1	06/10/1998
Springs Located on Wacissa River					
Horsehead Springs	WAS106C1		2	1	03/12/1999
Allen Spring	JEF64991		2	1	06/04/1999
Log Spring	WAS107C1		2	1	03/19/1999
Thomas Spring	WAS109C1		2	1	03/19/1999
Wacissa Headspring	WAS100C1		1	1	06/04/1999
Aucilla Spring	WAS110C1		3	1	06/04/1999
Cassidy Springs	WAS104C1	301996083593401	2	13	08/23/2007-04/23/2014
Minnow Springs	WAS108C1		2	2	06/03/1999-04/23/2014
Blue Springs	WAS102C1	301949083591800	2	3	07/16/1942-04/24/2014
Buzzard Log Springs	WAS103C1		2	2	03/19/1999-04/23/2014
Garner Springs	WAS105C1		2	2	03/19/1999-04/24/2014
Un-named Spring	JEF63991		2	1	06/03/1999
Big Blue Spring	WAS101C1	02326523	2	46	07/16/1942-04/22/2014
Un-named Spring	JEF63992		2	1	06/03/1999
Un-named Spring	JEF63993		2	1	06/03/1999
Un-named Spring	JEF312991		3	1	03/12/1999

2.2.3 Rainfall

PRISM (Parameter-elevation Relationships on Independent Slopes Model) monthly time series rainfall data (AN81m) near the Lamont gage were provided by the SRWMD. The time series was obtained by aggregating and averaging the monthly rainfall data within the drainage area of the Lamont Gage (780 sq miles) using a grid containing standard PRISM 4km (2.48 miles) grid cells (Figure 9). The AN81m time series datasets were modeled by the PRISM Climate Group using an interpolation method (PCG 2014).

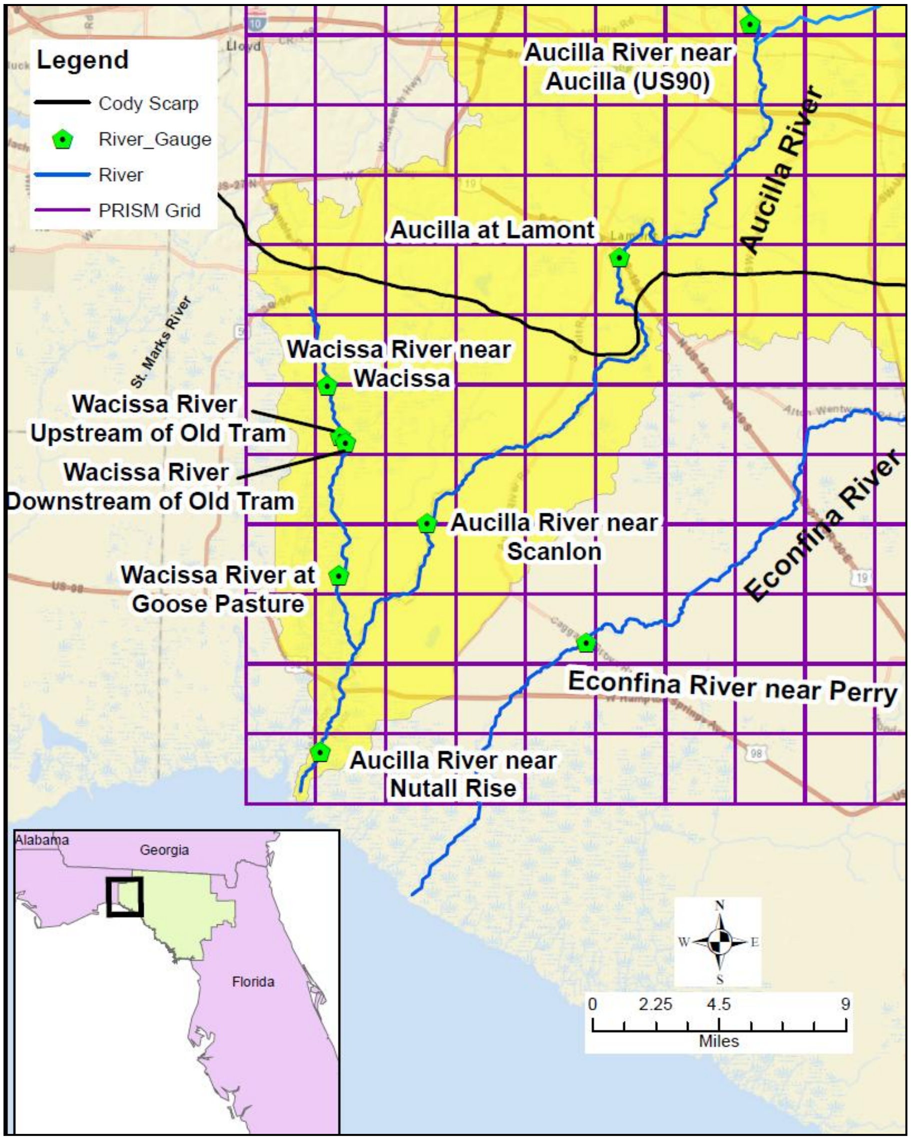


Figure 9. PRISM 4km grid
[Source: PCG 2014]

2.2.4 Groundwater Level

Based on data retrieved from SRWMD and USGS data portals, of the 48 wells located in the three Florida counties closest to the Aucilla watershed, about 90% of the wells are completed in the Floridan aquifer system (Table 5). The wells are widely distributed throughout the Aucilla watershed in Florida (Figure 10). Monitoring wells with long periods of record, such as the Upper Floridan Aquifer monitoring wells N010719001 and N030727001, can be useful for characterizing trends over time. Non-continuous water level data are available at monitoring well N010719001 since 1961 and continuous data are available at monitoring well N030727001 from 1984 to present (Table 6). At monitoring well N010719001, water level data were recorded during March 1961, quarterly from 1976 through 1985 and then monthly thereafter.

Table 5. Groundwater monitoring wells in north Florida

County	No. of Wells	Aquifer Monitored			
		Floridan	Inter-mediate	Surficial	Undesig-nated
Jefferson	6	6	0	0	0
Taylor	20	16	0	4	0
Madison	22	21	0	1	0
Total	48	43	0	5	0

Table 6. Select Upper Floridan Aquifer groundwater monitoring wells in the Aucilla watershed

I.D.	Depth (ft)	Non-continuous Data			Continuous Data		
		Period of Record		Count	Period of Record		Count
S040407001	12	1977	2013	364	2013	Present	535
S030424003	40	2009	2013	46	2013	Present	523
S020433001	30	1989	2012	240	2012	Present	902
S010430002	NA	NA	NA	NA	2013	Present	502
N030524001	122	1988	2012	287	2012	Present	1006
N020611002	137	2002	2012	68	2012	Present	1009
N030727001	181	1977	1984	31	1984	Present	11040
N010719001	229	1961	Present	389	NA	NA	NA

2.3 Period of Analysis and Flow Characteristics

USGS gages with long-term data, located on the Aucilla and Wacissa rivers, were selected for hydrologic analysis. Associations between the flows at different gages were used for infilling missing data and the resulting data series were used to characterize the flow of the Aucilla and Wacissa Rivers.

2.3.1 Period of Analysis

Aucilla at Lamont (02326500) gages a drainage area of 780 mi^2, about 82% of the Aucilla's watershed area (954 mi^2). It was selected as the primary gage for hydrologic analysis (Figure 6) because it has a continuous period of record extending from water year (WY) 1951 through WY 2014 (Table 3), except for WYs 1980 through 1999, and 2007.

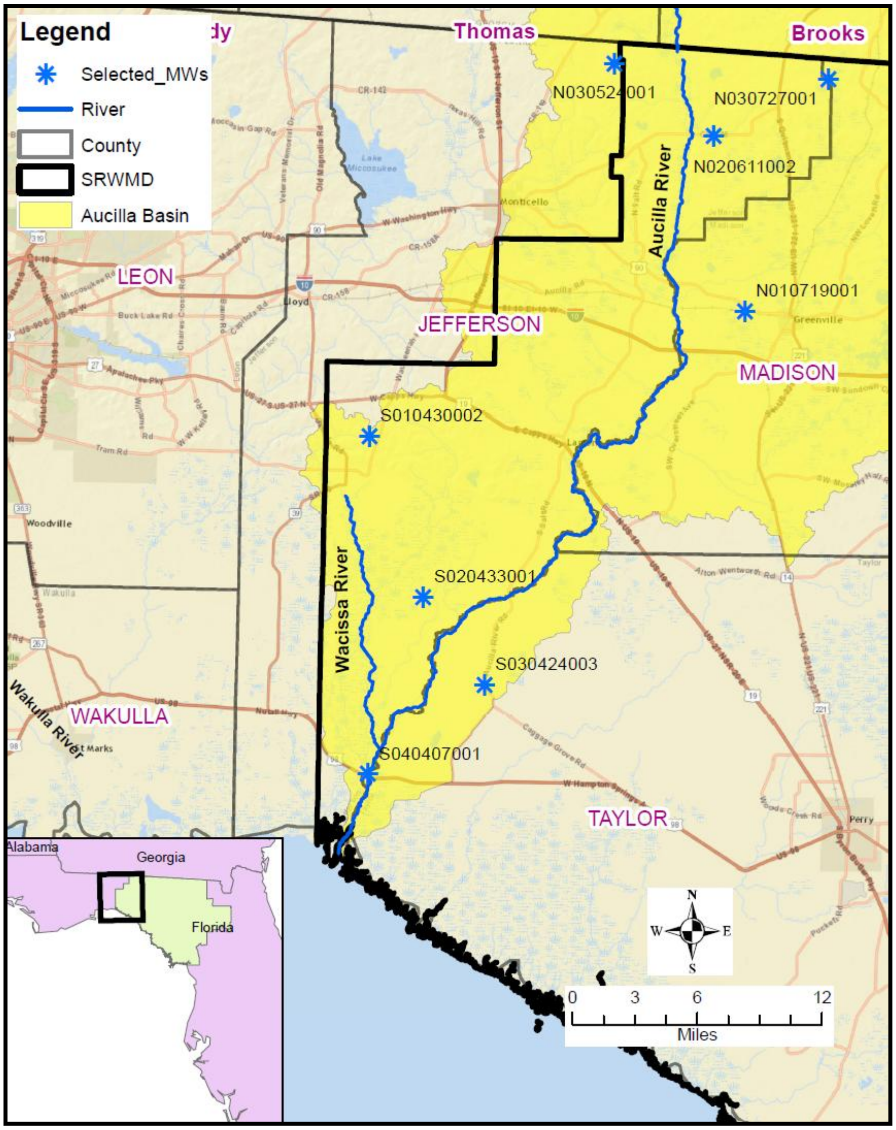


Figure 10. Location of select groundwater-level monitoring wells within Aucilla watershed

Water years 1951 through 2014 (i.e., October 1950 through September 2014) were selected as the period with best available data for hydrologic analysis. The period encompasses the longest period of streamflow record and ancillary data, such as rainfall, that can be evaluated to characterize streamflow conditions.

2.3.2 Missing Record and Record Extension

The equipment used to monitor streamflow and other environmental variables malfunctions at times or may be damaged by natural events or vandalism. Also, monitoring programs can change. Such occurrences may result in gaps in a particular time series. In addition, not all of the monitored environmental variables have the same period of record. Infilling of missing records and record-extensions were completed using regression techniques (Appendix F) and exceedance duration curves were used to allow comparison of data sets for different gages.

Infilling missing streamflow data at Lamont was accomplished using linear regression analysis developed for the association between Lamont and Scanlon for the common POR (8/30/1976-10/7/1997), and between Lamont and Econfina near Perry (02326000) for WYs 1998 and 1999. Equations used for estimating flows at Scanlon and Lamont and infilling missing periods of flow data at Lamont are as follows:

$$Q_{Scanlon} = 34.5 + (1.48\ Q_{Lamont}) - (0.000121\ Q^2_{Lamont}) \quad (1)$$

$$Q_{Lamont} = 3.0923 * Q_{Econfina} - 38.968 \quad (2)$$

2.3.3 Flow Characteristics

The annual average flow of the Aucilla River near Lamont has been fairly steady over time, except perhaps prior to 1957 (Figure 11). A non-parametric regression model, LOESS (LOcal RegrESSion), is fitted to depict the variation in flow data. The smoothing parameter is the proportion of data used to fit the non-parametric regression model and a range of 0.25 to 0.5 is used for most applications (Figure 11). Daily flows at the USGS gages on the Aucilla River (Figure 12) vary over a wide range compared to the primary gage on the Wacissa River (02326526) over the common period of analysis (WYs 2003-2006). The daily average flow at Lamont for the common POR ranges from 5 cfs to 6,490 cfs, whereas the flow range at Wacissa gage is from 242 cfs to 532 cfs. The sustained greater low flows at Wacissa reflect groundwater input to the river even during periods of little surface water runoff and are in sharp contrast to the low-flow characteristics at the Lamont gage.

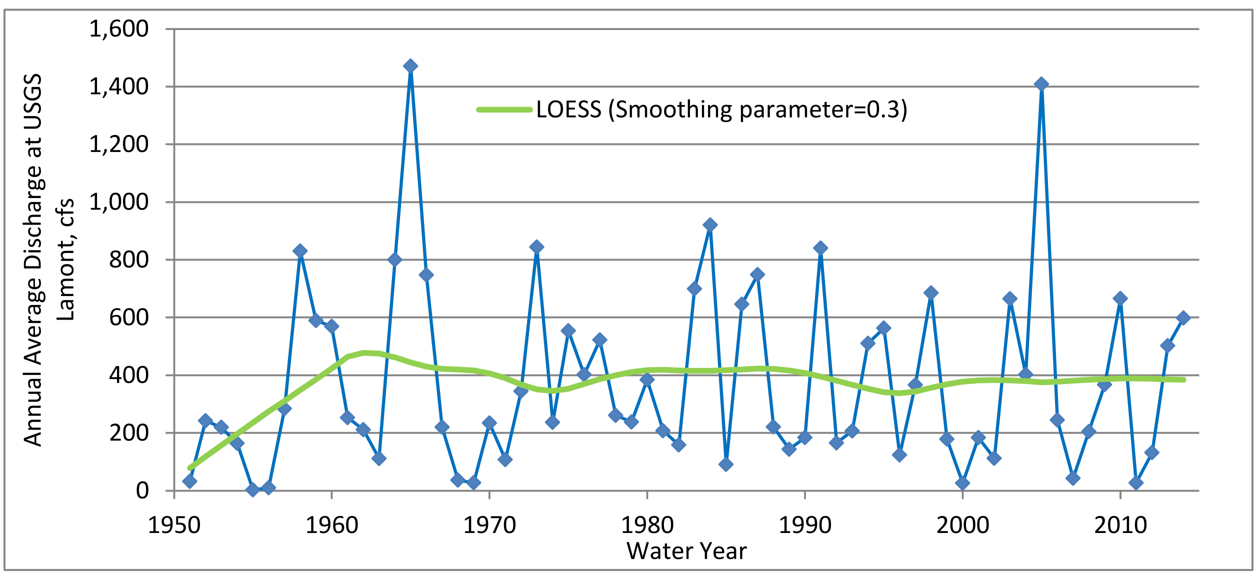


Figure 11. Annual average flow at the USGS Lamont gage

Daily estimates of flow at Scanlon were calculated using equation 1. The influence of spring flows in the Wacissa River are evident in the flow duration curves for the Lamont and Wacissa gages (Figure 12) and the combined Scanlon and Wacissa flows (Figure 13). The relative proportion of the Aucilla River flow near Nutall Rise that may be attributable to the Wacissa River was determined by calculating a time series of the ratio of daily Wacissa flow and the combined daily flows at the Wacissa and Scanlon gages. The relative portion of Wacissa flow corresponding to the combined Wacissa and Scanlon flow is plotted on the same graph as the percent exceedance for flows at various gages using a secondary x-axis of the daily Wacissa flow ratio (Figure 13). The exponential equation could be used to estimate flow at the Wacissa gage as a function of flow at Scanlon.

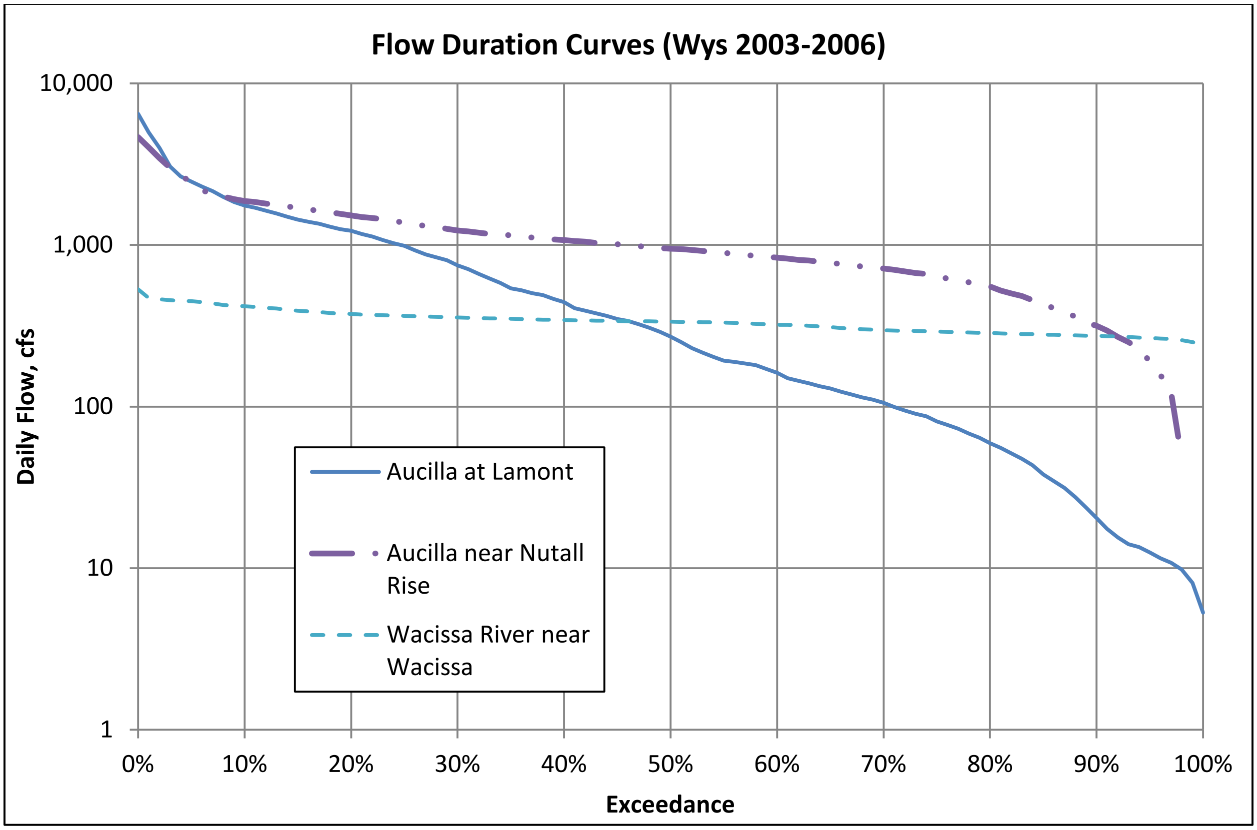


Figure 12. Flow duration curves for the Aucilla and Wacissa gages, WYs 2003 – 2006

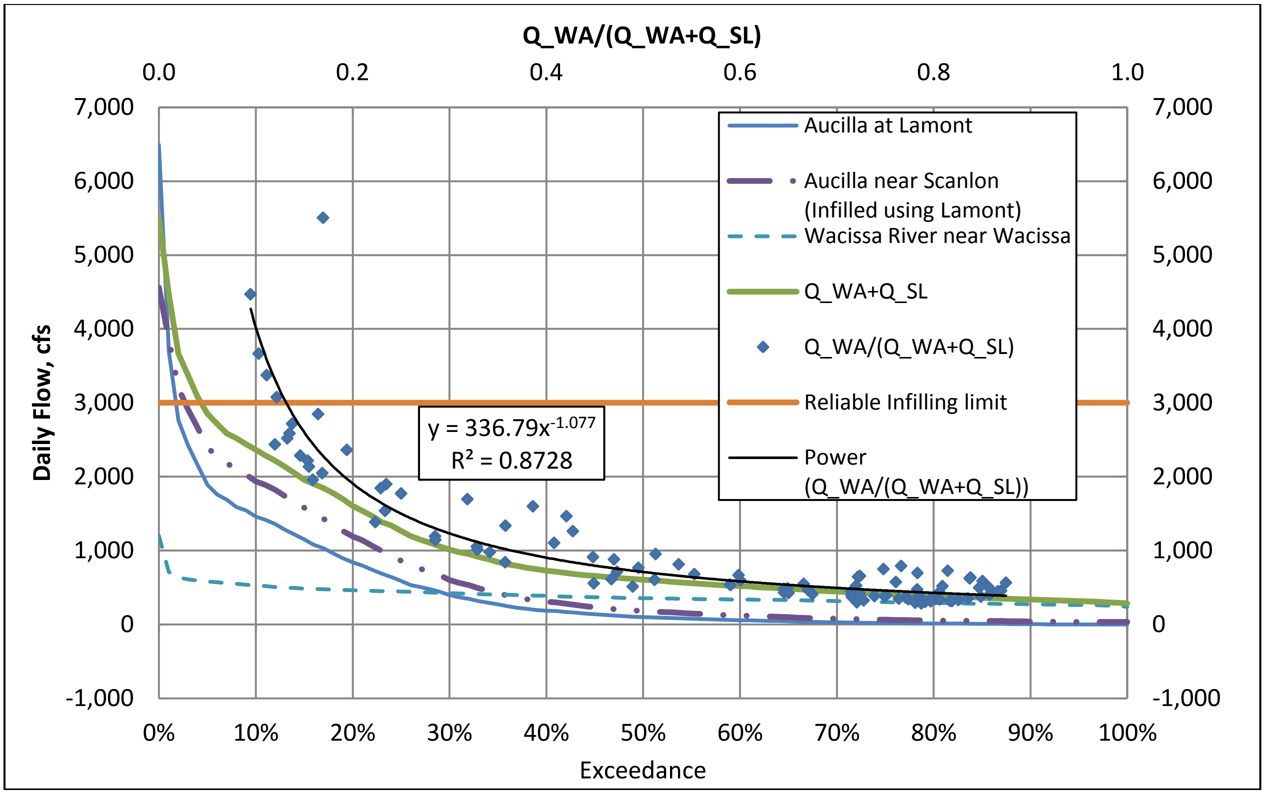


Figure 13. Flow duration curves and flow proportioning, WYs 2002 – 2014, excl. 2007-2008 [Q_SL and Q_WA designate daily flows of Aucilla near Scanlon and Wacissa near Wacissa]

2.3.4 Seasonality

Historical, daily flows are distributed seasonally with a steady rise in discharges beginning in November and rising to a maximum in late February to early March (Figure 14). Monthly average flow for the period of analysis increase from a minimum in November to a peak in March of the following year (Figure 15). The average flows historically remained relatively steady from May through September and then declined to the late-year minimum, and the pattern is similar for monthly average flow.

2.4 Historical Rainfall Characteristics

Annual rainfall was calculated using PRISM data as described in section 2.2.3. Average annual rainfall within the drainage area of the Lamont gage during WYs 1951-2014 ranged between 37 and 76 inches and averaged 54 inches (Figure 16). No distinct pattern is apparent in the five-year moving averages, although the 5-year moving average declined about 3 inches from 55 to 52 inches beginning in 2000.

One method for graphically examining trends in annual hydrometeorological variables such as flow and rainfall is to plot the cumulative deviations of a variable from its mean value over a POR. From WY 1953 until 1956, annual rainfall was less than the long-term average and a deficit of about 30 inches had accumulated (Figure 17). The deficit was eliminated during a short period of above-average rainfall from 1956 to 1960. Between 1993 and 1998 above-average rainfall was recorded resulting in a surplus of 47 inches. From 1998 through 2012, rainfall then decreased substantially below the long-term average resulting in a cumulative rainfall deficit of about 55 inches over that period of time.

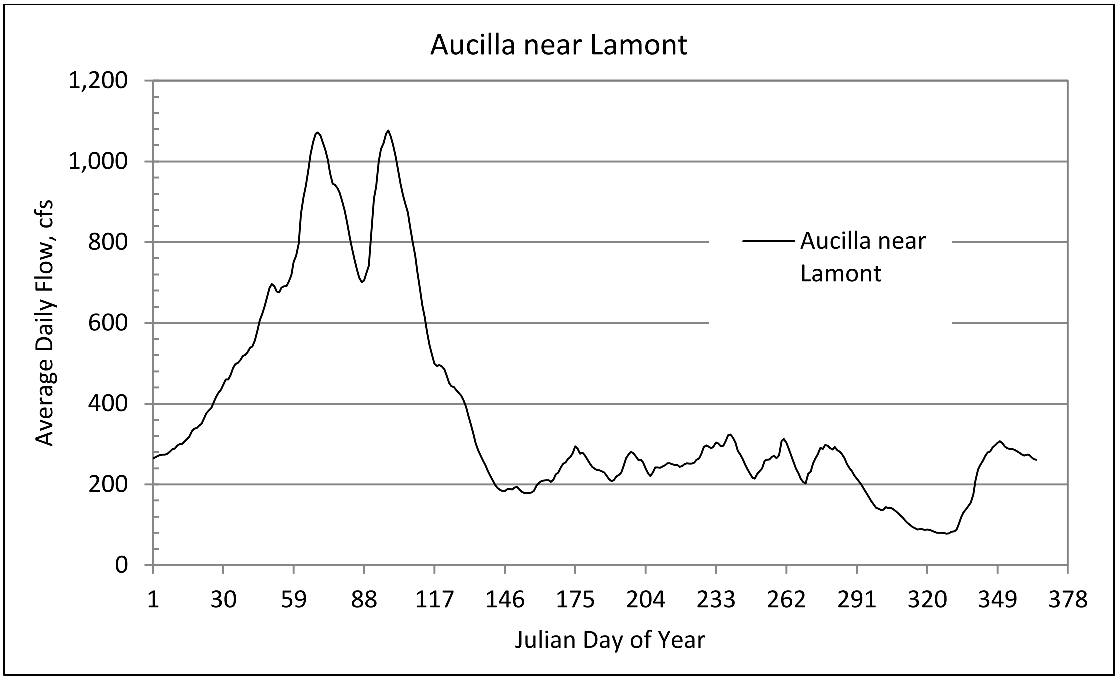


Figure 14. Daily average historical flow for the Aucilla River near Lamont, WYs 1951-2014.

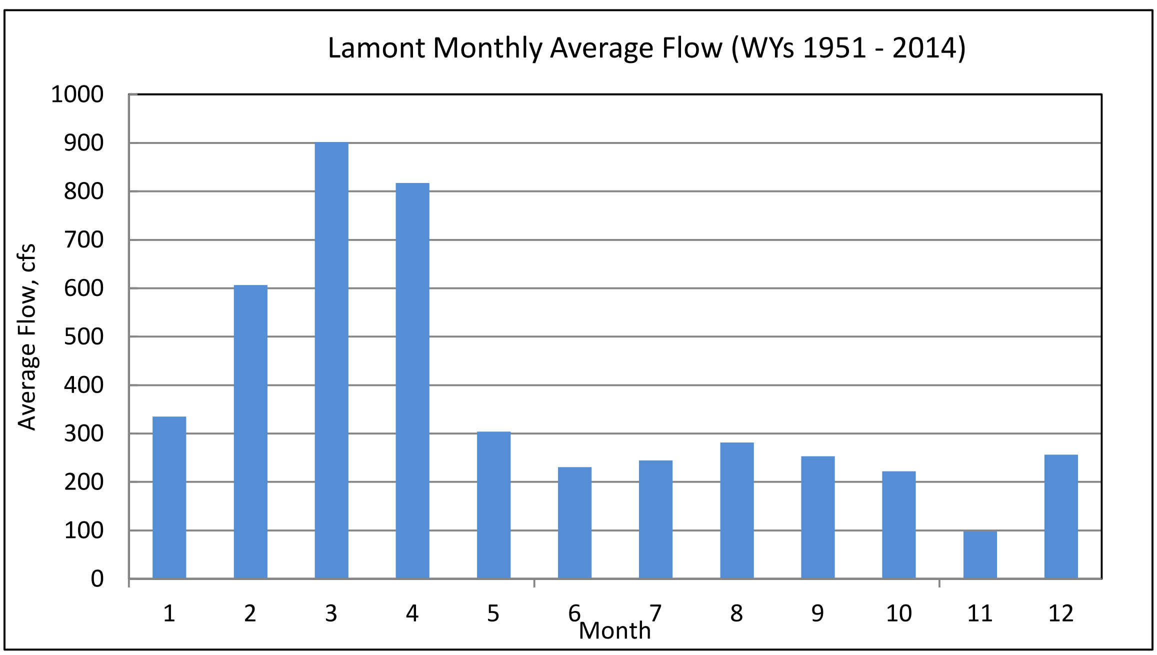


Figure 15. Monthly average historical flow for the Aucilla River near Lamont, WYs 1951 – 2014

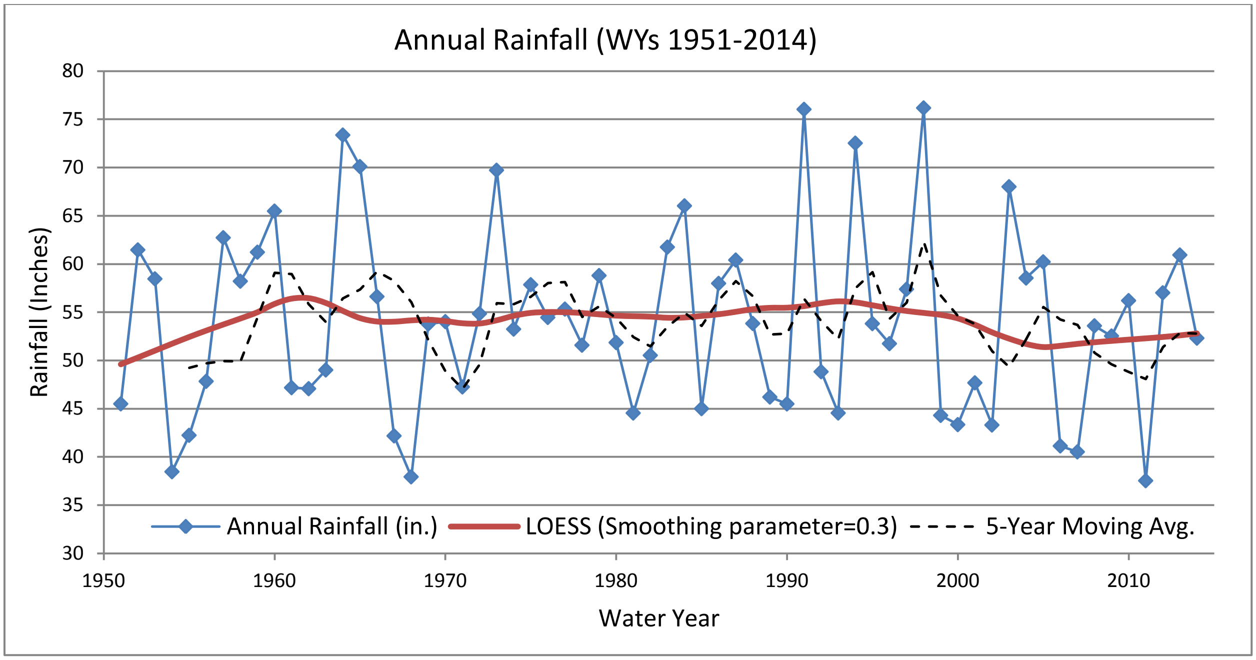


Figure 16. Historical average annual rainfall within drainage area of Lamont, WYs 1951-2014

2.5 Historical Groundwater Use and Water Levels

Groundwater in Florida is withdrawn for public, industrial, agricultural, and recreational uses (Marella 2009). Some of the increase in groundwater use is attributable to a population increase in a five-county area (Brooks and Thomas Counties, Georgia, and Jefferson, Taylor, and Madison Counties, Florida) that was relatively stable at about 86,000 between 1900 and 1970 and then began to increase rapidly. The population of this five-county area increased to 117,518 by 2010 (USCB 2015). Taylor County Florida has experienced the greatest proportional increase in population, increasing from 12% of the region's population in 1950 to 19% in 2010 (USCB 2015).

From 1980 through 2010, Taylor County withdrew approximately 50% of combined groundwater use within the five-county area. Mining, which is one of the base industries in Taylor County, along with the pulp mill (WUP 2-123-217887-1), is responsible for a high percentage of groundwater use.

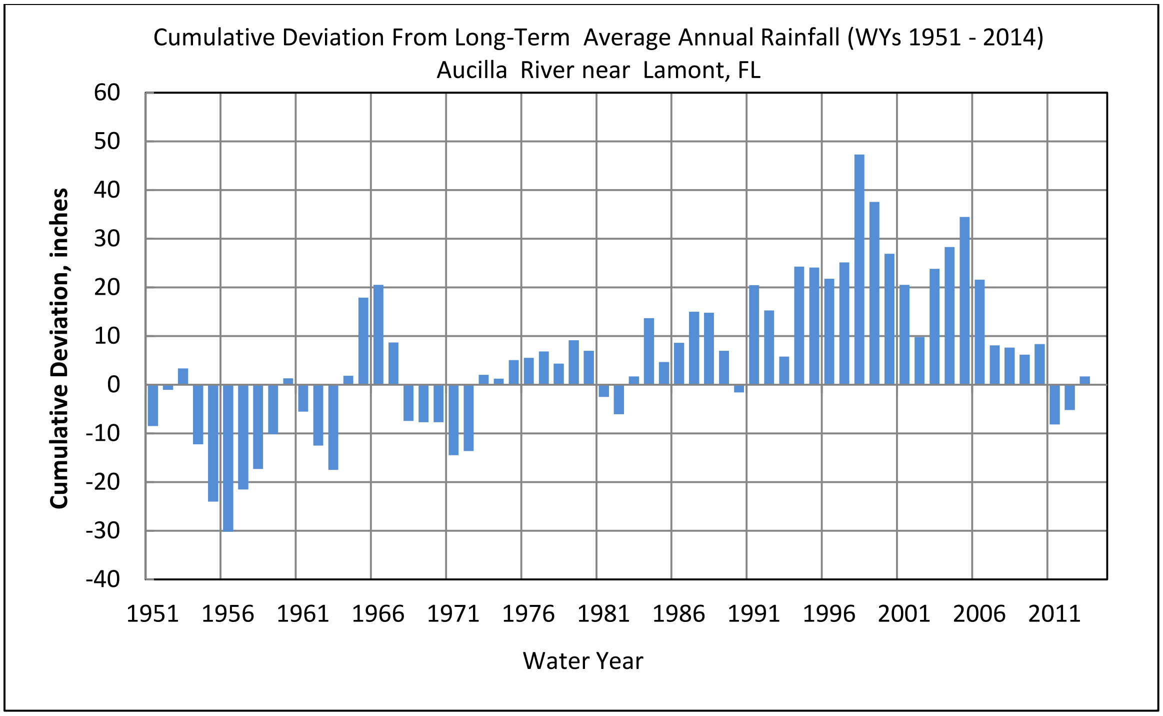


Figure 17. Cumulative deviation of annual basin-wide average rainfall from long-term average, WYs 1951-2014

The UFA potentiometric surface elevation within Florida ranges from 90 ft at the state line where the aquifer is confined to 0 ft near the Gulf coast where the aquifer is unconfined (Figure 18). The potentiometric surface has declined regionally from levels estimated using computer modeling for predevelopment conditions circa 1880 (DePaul et al. 2008). The decline in the potentiometric surface from predevelopment to 1980 within the Aucilla River watershed is estimated to be less than 10 feet (Figure 19). However, substantial local groundwater-level declines have been observed within the 8,000 square-mile Aucilla-Suwannee-Ochlockonee (ASO) River Basin in south-central Georgia (Figure 20). The observed decline was attributed to increased withdrawals from the Upper Floridan Aquifer for agricultural use since the mid-1970s, and by drought conditions during the 1980s and from 1998 to 2002 (Marella 2009). A decline in annual minimum seven-day average streamflow was observed since the late 1970s at a stream gaging station on the Ochlockonee River near Thomasville, GA (02327500), which is located west of the northern part of Aucilla watershed (Figure 20).

Records of historical UFA groundwater levels dating back to 1961 are available to characterize long-term patterns within the Aucilla watershed (Table 5 and Figure 10). Of the 8 wells monitored within the Florida portion of the Aucilla Watershed, the Jerry Hall monitoring well (N010719001) has the longest period of record, which has one measured value in 1961 and then from 1976 to current year. Groundwater levels have varied considerably over short periods of time; an annual variation of four feet or more is common (Figure 21).

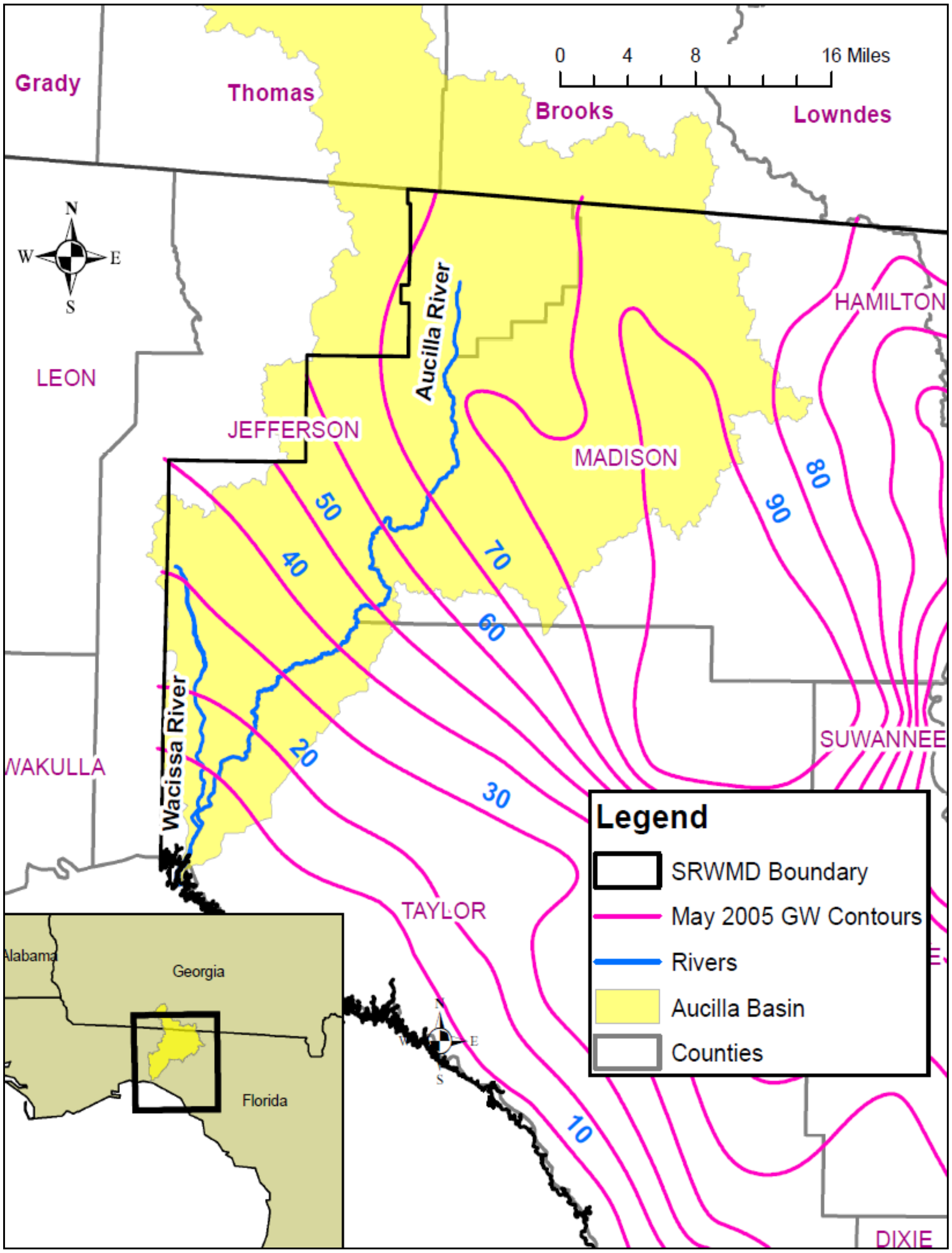


Figure 18. UFA potentiometric surface within the SRWMD

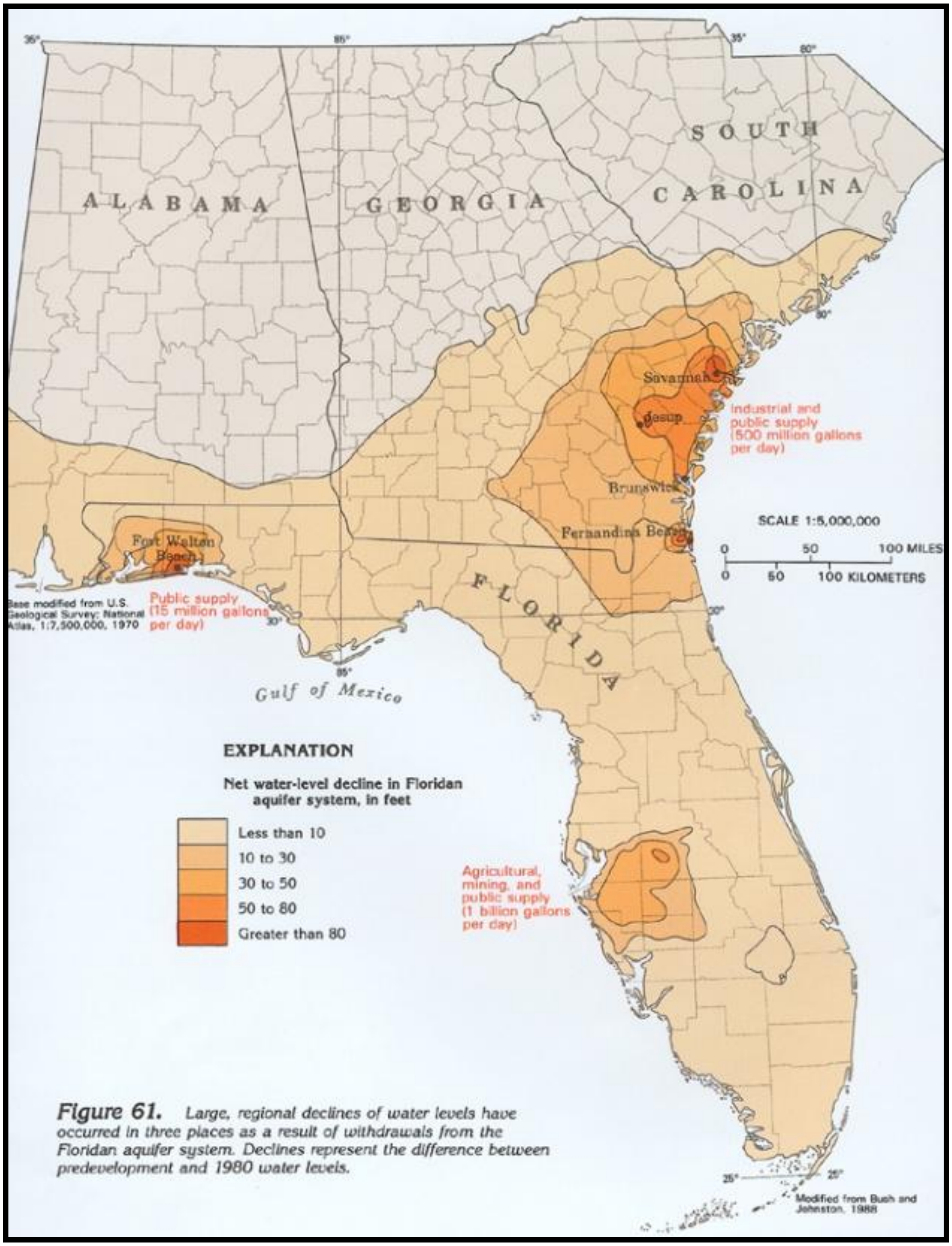


Figure 19. Estimated decline in the UFA potentiometric surface, predevelopment to 1980 [Source: Miller 1986]

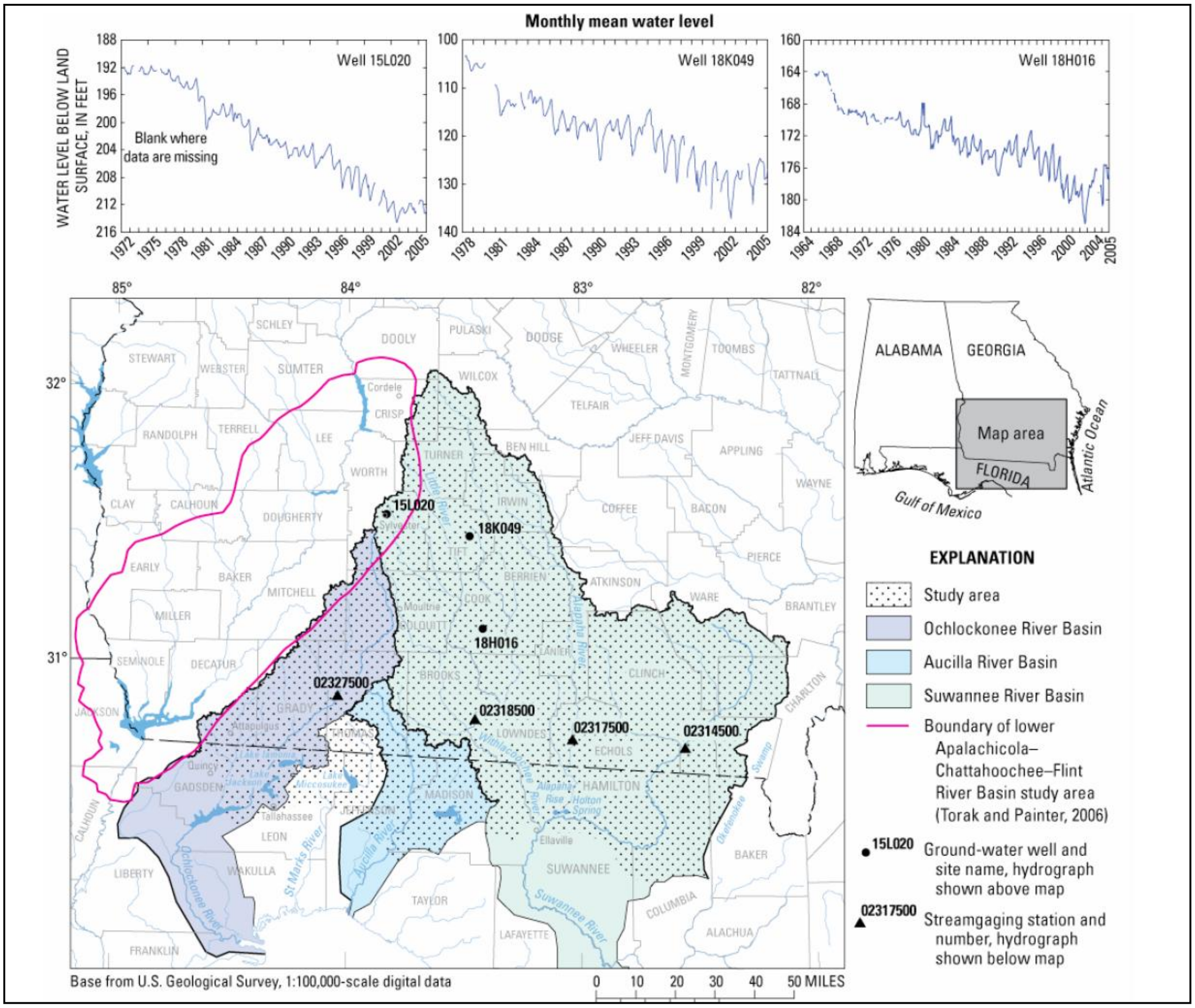


Figure 20. Groundwater hydrographs for selected observation wells in ASO Basin [Source: Torak et al. 2010]

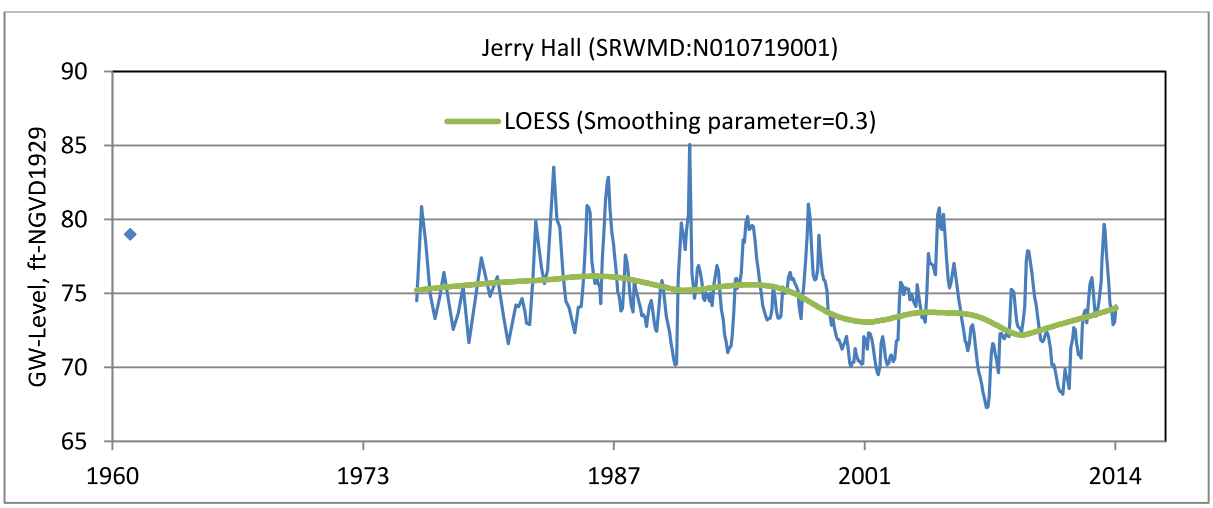


Figure 21. Historical groundwater levels in the UFA at Jerry Hall near Greenville, Florida

The potentiometric surface at this location and Carolyn Philips well (S040407001; Figure 21) has not declined nearly as much since 1976, when compared to the groundwater decline further north in south-central Georgia.

Groundwater levels in UFA have been measured continuously at Blackwater Plantation well (N030727001) located in Jefferson county, FL. Annual average water levels were calculated at Blackwater Plantation well have declined over the POR (Figure 23) but substantially less compared to the groundwater level decline in south-central Georgia (Figure 20Figure 23).

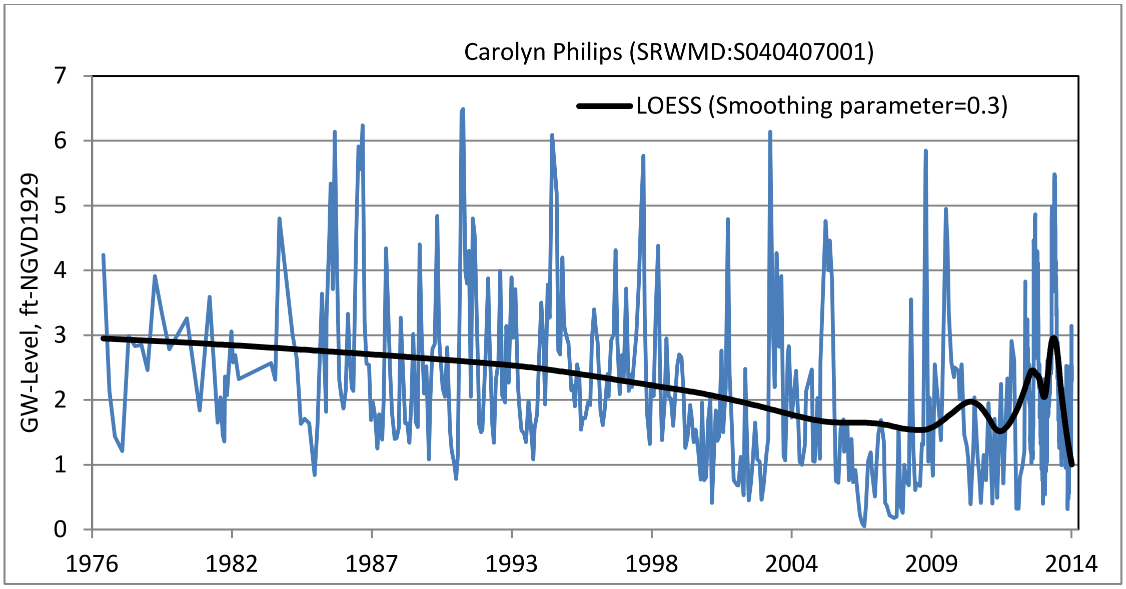


Figure 22. Historical groundwater levels in the UFA at Carolyn Phillips in Taylor County, Florida

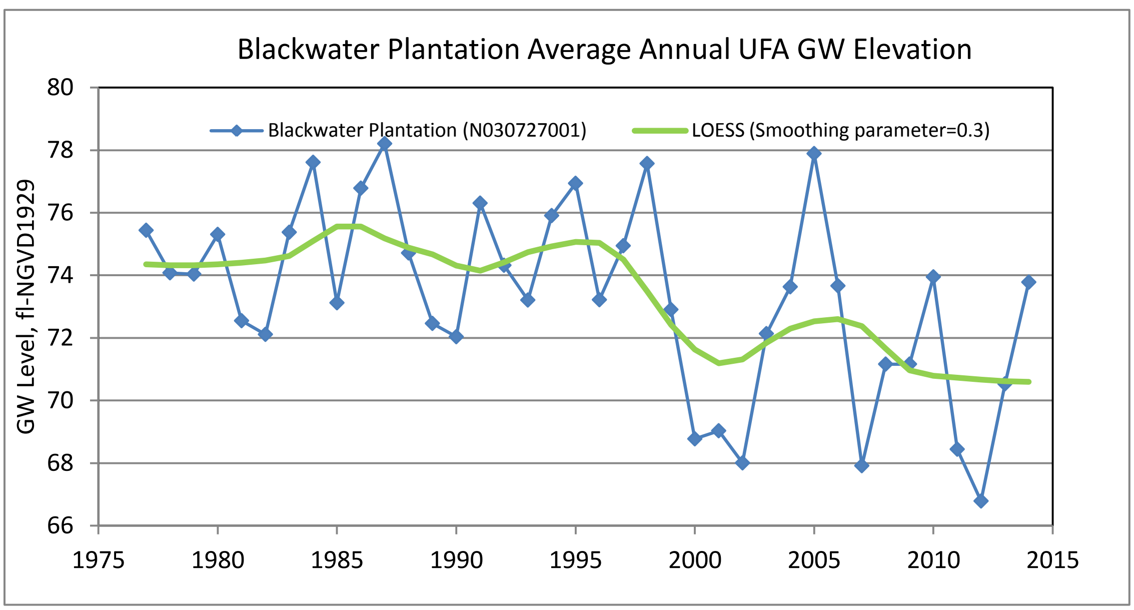


Figure 23. Historical groundwater levels in the UFA at Blackwater Plantation in Jefferson County, Florida

2.6 Spring Flow

The MFLs assessment considers priority springs on the Wacissa and Aucilla Rivers. Nutall Rise is a resurgence and is located on the Aucilla River near US98 (Figure 8). Springs on the Wacissa River are located near the town of Wacissa in Jefferson County. Several springs are located at the head of the river near the county park. The remaining springs are scattered along the upper 2 miles of the river. SRWMD (2000) listed 16 springs in this group (Figure 8).

Time series of daily streamflow data at the Wacissa gage near Wacissa (02326526) were used as a surrogate to the combined spring flow upstream of Wacissa gage. Associations between measured streamflow at Wacissa gage and groundwater level were evaluated to characterize a spring-flow rating.

A spring-flow rating is defined as the relationship between spring flow and one or more explanatory variables. The minimum flow recorded at Wacissa gage is a positive flow of 240 cfs. Positive spring flow occurs when the groundwater level exceeds both the Point of Zero Flow (PZF) and the river stage. Spring flow will increase as groundwater level increases and be relatively unaffected by river conditions when the river stage is less than the PZF.

The USGS has standard methods for charactering stage-flow ratings, relationships between turbulent streamflow and water level (Rantz 1992). A relationship that plots as a straight line on logarithmic paper is represented by a power function with three fitting parameters (equation 3).

$$Q = K(G - C)^n \quad (3)$$

in which

Q is flow;

(G – C) is the head, or depth of water, on a hydraulic control;

G is the gage height of the water surface at the stream gage;

C is the offset or gage height of zero flow, also referred to as the PZF, determined by measurement or fitting analysis; and

K and n are fitting parameters determined through analysis

The parameter "C" is an offset that centers the explanatory variable in a multiple linear regression (MLR) application (Helsel and Hirsch 2000). Thus, the offset can be interpreted in several ways when the power function is used to evaluate spring flow using groundwater level as the explanatory variable. If groundwater level is being monitored relatively near the spring, the offset may represent the elevation of the spring sill. However, if groundwater level is being monitored at some distant location, the regression analysis may result in an offset that is substantially higher than the sill. In this case, the offset is interpreted as a data centering parameter.

Groundwater levels at eight (8) monitoring wells located within the Florida portion of Aucilla watershed (Figure 10) along with stage at Wacissa gage were evaluated as explanatory variables. A rating is developed by using regression analysis to evaluate regression parameters (K, C and n) that minimize the sum of the squared differences between measured and calculated streamflows at the Wacissa gage. Continuous groundwater levels measured at well S010430002 explained more of the variance in streamflow at the Wacissa gage (R^2 = 0.678) than any other explanatory variables (Figure 24). The relatively poor fit to high flows may indicate a lagged response of aquifer water levels to extreme rainfall events.

Some seasonality is evident in the time series of residuals for the spring flow rating ($Q = 47.19(G-26.0)^{1.087}$) possibly due to seasonal variations in the density of submerged aquatic vegetation (Figure 25). The river stage near Wacissa also was tested as a predictor but did not result in removal of the autocorrelation.

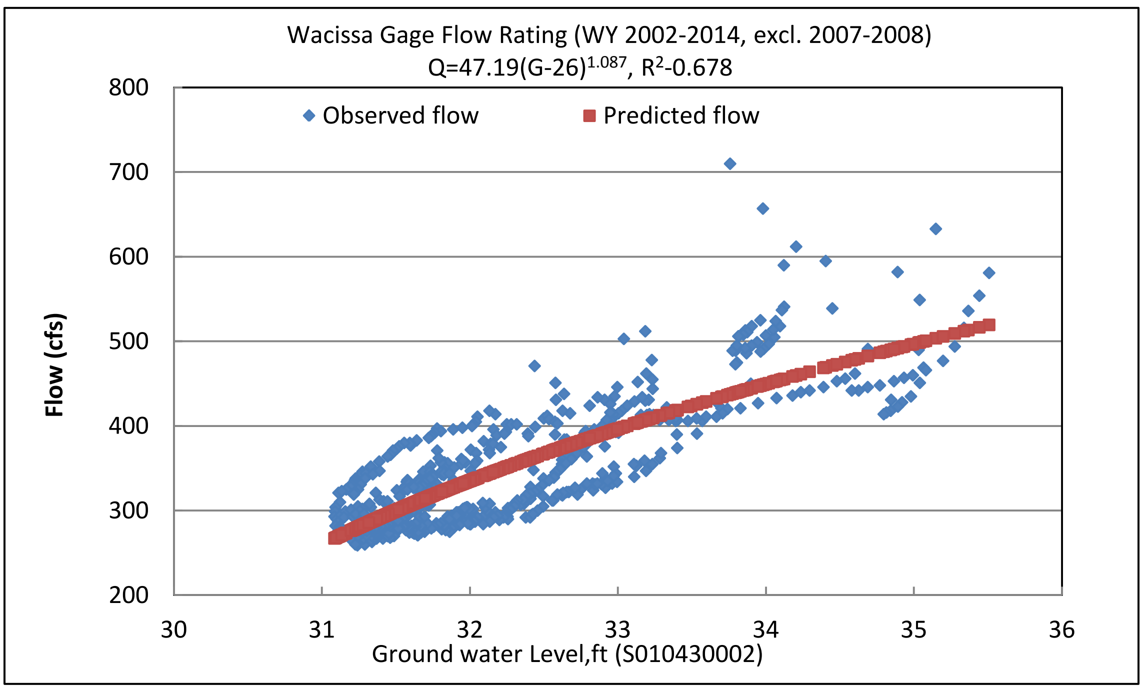


Figure 24. Spring-flow rating for Wacissa gage

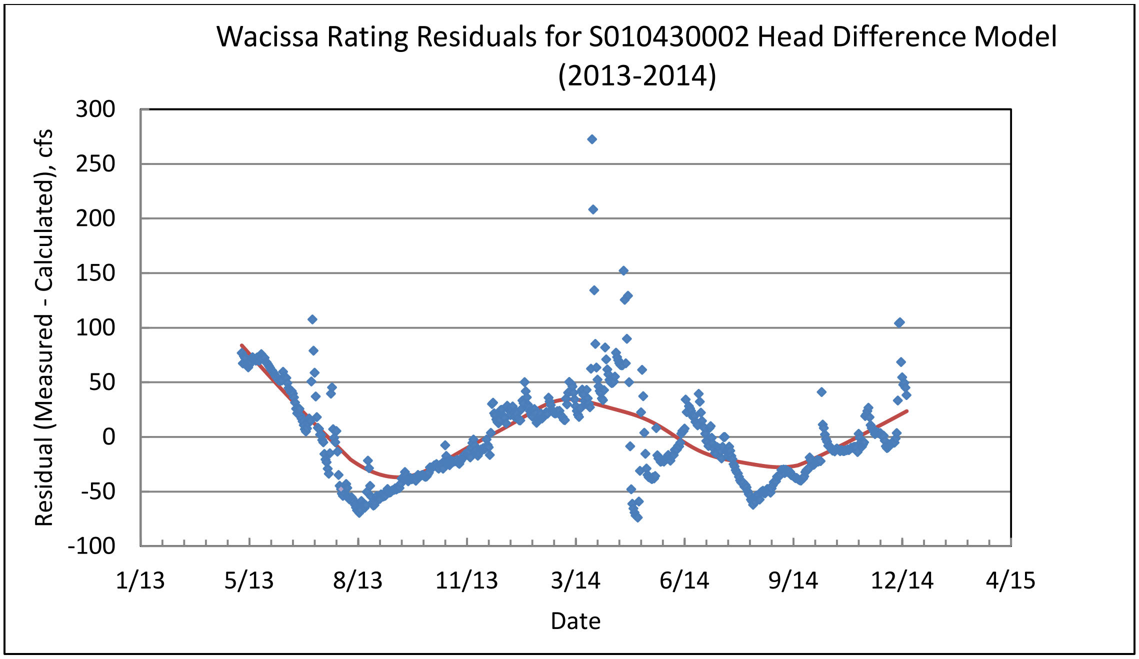


Figure 25. Residual vs. Time for Wacissa Rating

2.7 Hydrologic Analysis

The conceptual model of Aucilla and Wacissa River system along with rainfall and flow trends and associations are discussed in this section.

2.7.1 Conceptual Model

A conceptual model is a descriptive representation of a hydrologic system that characterizes the relevant physical and hydrologic conditions. Watershed yield calculations were performed to determine the groundwater and surface water exchange as an initial step toward conceptualizing the stream-aquifer interaction. Regional factors such as geology, topography, local groundwater use, and temporary or permanent diversions of runoff typically influence the watershed yield.

The upper portion of the Aucilla watershed above the Cody Scarp is dominated by the interaction of the surficial aquifer and the Aucilla River and small streams that drain into the Aucilla river. Upgradient of the Cody Scarp, surficial drainage systems have developed, while below the Cody Scarp, internal drainage dominates. In the vicinity of the Cody Scarp, the Floridan aquifer is considered semi-confined to unconfined (Figure 26). Streams crossing the Cody Scarp become losing streams, to the extent that some cease flowing altogether as they sink completely into the subsurface. River flow is dominated by groundwater inputs downgradient of the Cody Scarp, particularly under low flow conditions (Lenz 2006).

Yield calculations were performed to determine gains and losses occurring in various reaches of Aucilla River (Table 7). Yield gain was calculated using the flow gain and gain in watershed area. The substantial yield gain between Lamont and Scanlon compared to the yield gain between other gages suggests that the river reach downstream of Lamont is gaining a substantial amount of groundwater. The top elevations of UFA and May 2005 UFA potentiometric elevations evince groundwater recharge to the Aucilla river downstream of the Lamont gage (Figure 27). The substantial yield gain on the Wacissa is due to the large contribution of groundwater flow relative to the watershed area.

A geologic section along the river thalweg was prepared using geology maps and channel thalweg elevations measured during HEC-RAS cross section field surveys (Figure 27). The top elevation of the Floridan Aquifer system coincides with the surface elevation at about river mile 30 and the Wacissa River confluence occurs at about river mile 7. Downstream from river mile 30, the river is directly connected to the UFA and the rate of gains and losses from the river to the UFA are a function of the difference in the hydraulic head associated with river stage and the UFA potentiometric surface.

Table 7. Yield and Yield Gain

	Yield Calculations (WY 2002-2010 excl. 2007-2008)						
USGS Gage	USGS I.D.	Watershed Area (sq miles)	Flow (cfs)	Watershed Area Gain (sq miles)	Flow Gain (cfs)	Yield (in/yr)	Yield Gain (in/yr)
Aucilla (US90)	02326250	345	150	345	150	5.90	5.90
Lamont	02326500	780	552	435	402	9.61	12.5
Scanlon	02326512	805	720	25	168	12.1	91.2
Wacissa	02326526	30	380	30	380	172	172
Nutall Rise	02326550	939	1097	104	-3	15.8	-0.39

Notes:

Aucilla average flow was generated using relationship with Lamont

Scanlon average flow was generated using relationship with Lamont

Wacissa average flow was generated using measured data

Nutall Rise average flow was generated using measured data

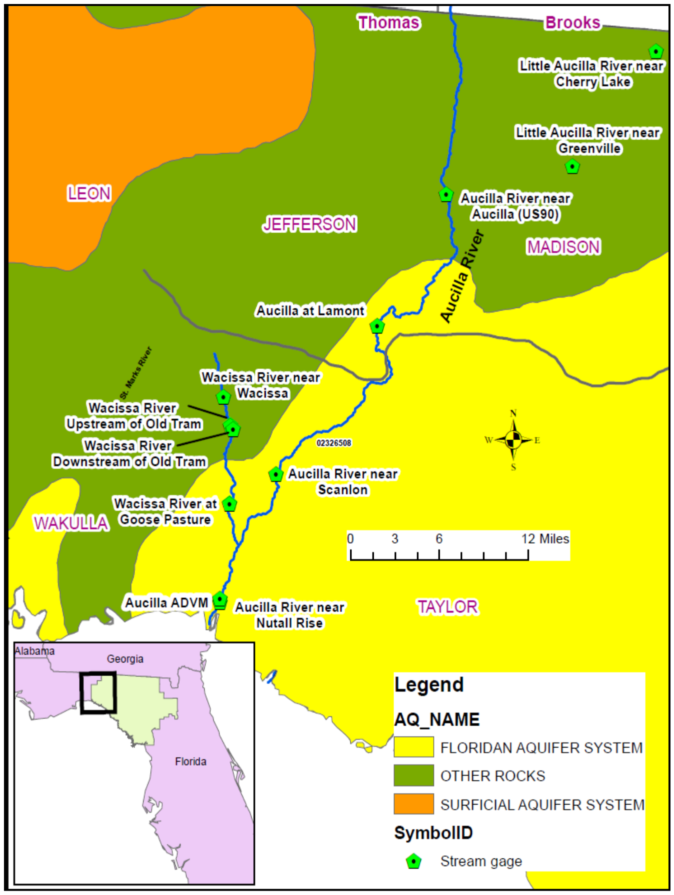


Figure 26. Top aquifers within the Aucilla watershed

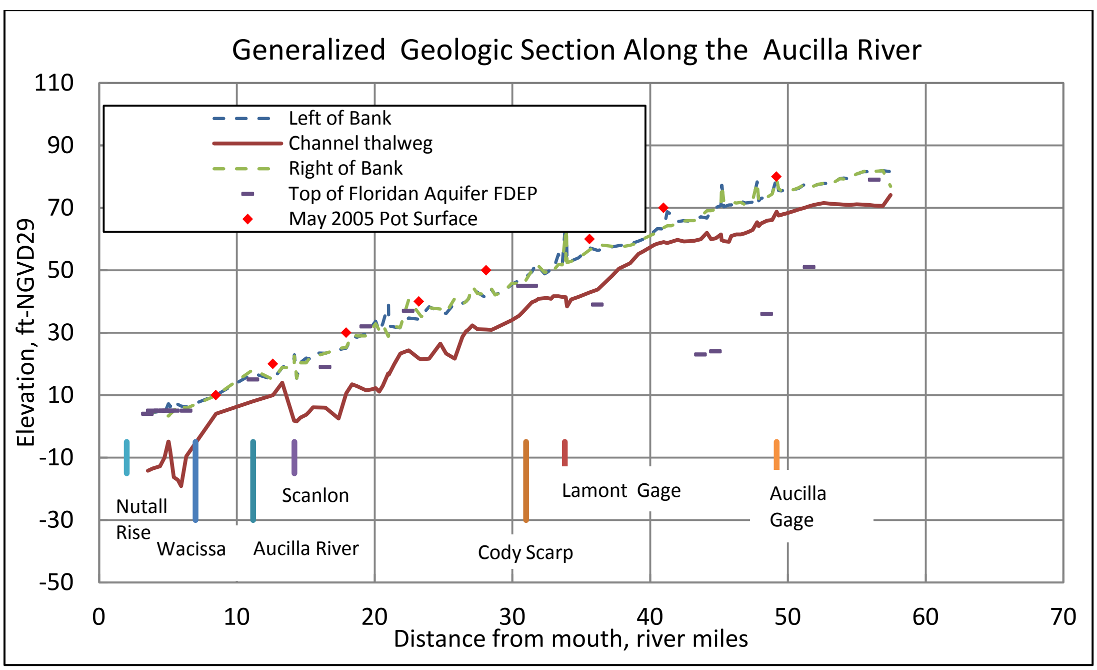


Figure 27. Generalized geologic section along the Aucilla River

2.7.2 Trends in Long-term Hydrologic and Meteorological Data

The assessment of MFLs for the Aucilla River is supported by long-term hydrologic records. The data are evaluated to characterize historic, current, and baseline conditions. A historic condition reflects the broader period of primary hydrometeorological records available for analysis and current condition reflects recent anthropogenic impacts and climate conditions. Trends and relationships between observed hydrologic and meteorological variables are important in MFLs determinations to assist with identifying a baseline flow record and for distinguishing between anthropogenic and climatic influences on flow. A baseline flow record is one that reflects unimpacted or minimally-impacted historical conditions over representative long term hydrometeorological cycles. The USGS gage at Lamont is most useful for characterizing regional trends because it has a long period of record (POR) and is centrally located within the study area.

A rainfall surplus of 41 inches and 25 inches occurred for the periods 1993-1998 and 2002-2005 respectively (Figure 17) and a similar trend in flow is evident at Lamont (Figure 28). Similarly, a rainfall deficit of 37 inches and 43 inches occurred for the periods 1998-2002 and 2005-2012, respectively, and a similar trend of flow deficit is evident at Lamont.

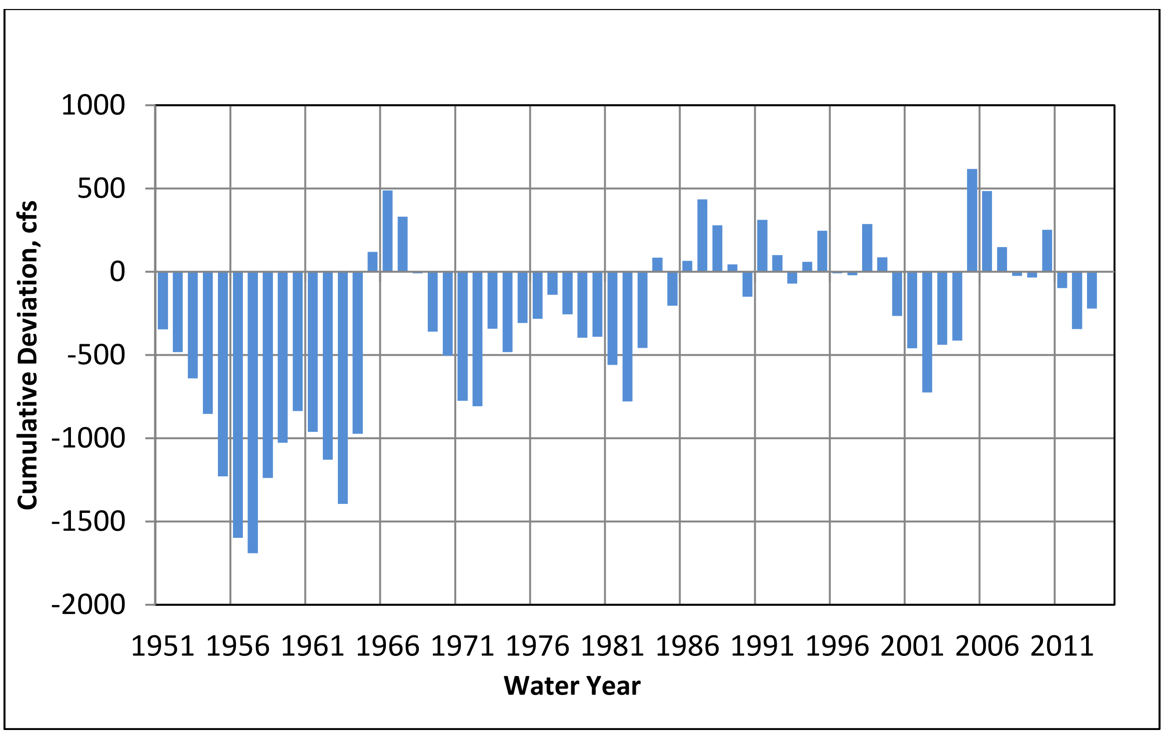


Figure 28. Cumulative deviation of annual average flow for USGS gage Aucilla River near Lamont, FL for WYs 1951-2014

Seasonal flow and rainfall patterns also are similar but with some seasonal relative magnitude differences. Flow peaks are highest in the spring, and there is a small secondary peak in the late summer (Figure 15). The monthly average of weighted rainfall also has two peaks, with the highest in summer and a secondary peak in the spring (Figure 29). The earlier peak in flow reflects both winter rainfall and lower evapotranspiration (ET).

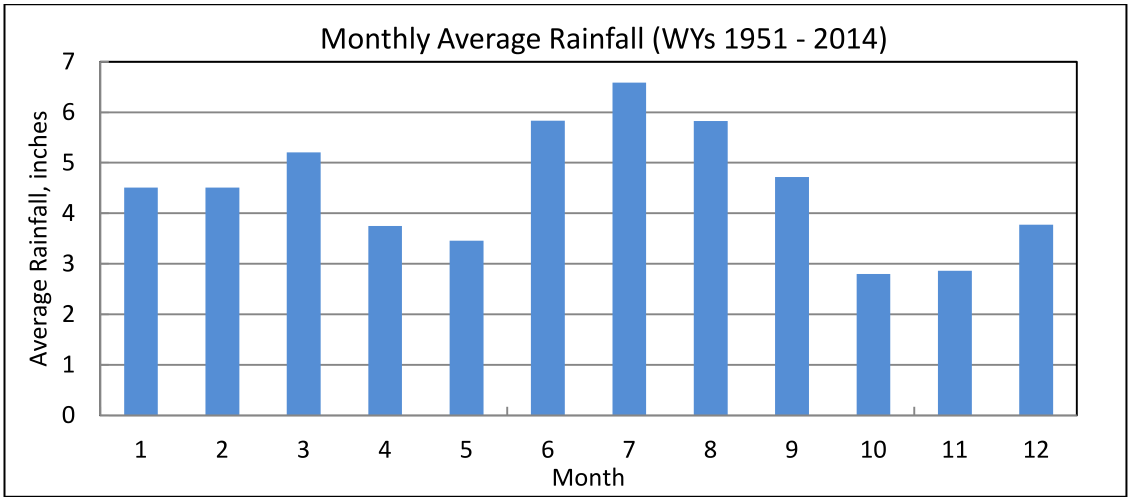


Figure 29. Monthly average of rainfall data for WYs 1951 – 2014

2.7.3 Rainfall-Flow Association

Further analysis was performed to determine if a temporal flow deviation exists that is not explained by precipitation or other climatological variables. Flow records for the long-term USGS gage at Lamont and associated weighted rainfall were analyzed to determine if the watershed yield may have changed over time and, if so, to quantify the magnitude of the changes over the period of interest. A linear association between the annual flow and rainfall is given by:

$$Q = b0 + b1 * R_i + b2 * R_{i-1} + b3 * R_{i-2} \quad (4)$$

in which

Q is the estimated annual average flow at Lamont, in cfs;

R_i = rainfall in the current (i) WY, in inches;

R_{i-1} = rainfall in the preceding (i-1) WY;

R_{i-2} = rainfall in the second preceding (i-2) WY; and

b0, b1, b2 and b3 are fitting parameters.

Another more useful form of equation (4) is derived by rearranging variables and is given by

$$Q = A * (R_w - E) \quad (5)$$

in which

R_w = Weighted annual precipitation ($R_w = b1' * R_i + b2' * R_{i-1} + b3' * R_{i-2}$);

A is a unit-conversion term and fixed parameter for each gaged area of a watershed, in cfs/(inches/year); and

E is an intercept term related to annual water losses other than runoff (e.g., primarily evapotranspiration, but also other water losses or gains), in inches.

Using the linear regression module in SPSS and period of record data (i.e., WYs 1951 – 2014), associations between weighted annual rainfall and flow were developed for the Lamont gage with good agreement between predicted and measured flows (i.e., R^2 value of 64%, and residuals evenly distributed about the predicted flow) (Figure 30, Figure 31, and Figure 32).

Table 8. Summary of derived hydrologic variables for equation (4)

Gage	b1'	b2'	b3'	A	E	R^2	Number of observations
Aucilla River near Lamont	0.629	0.221	0.150	41.28	44.80	0.64	64

There is no primary point of inflection in the double mass curves of the cumulative predicted flow versus cumulative measured flow after which the curve continues to depart from the 1-1 reference line (Figure 33). However, the regression model consistently under predicts from WY 1990 to WY 2000 and then over predicts from WY 2000 to WY 2014 (Figure 34) when rainfall is used as the explanatory variable. Data gaps from November 1983 through October 1998 were infilled using an association with flow data for the Scanlon gage.

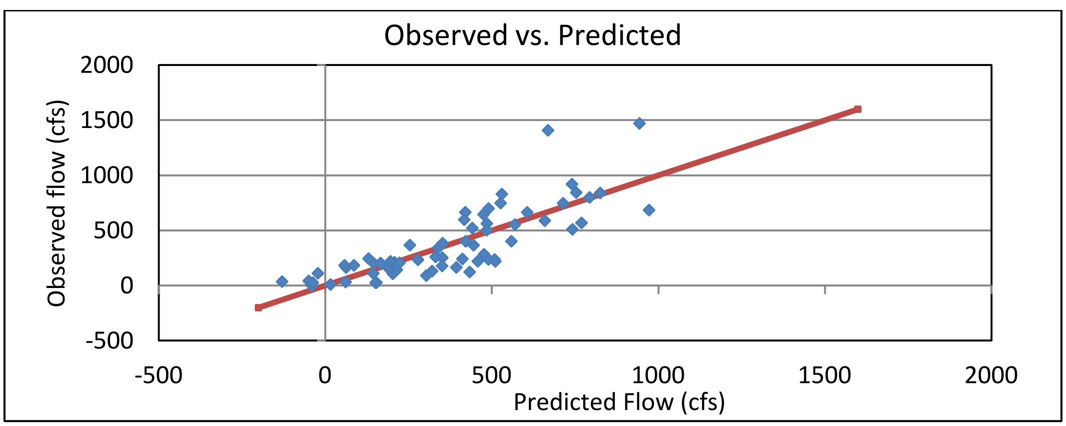


Figure 30. Predicted versus measured annual flow (top) for the USGS gage at Lamont for WYs 1951 - 2014
[1-1 reference line]

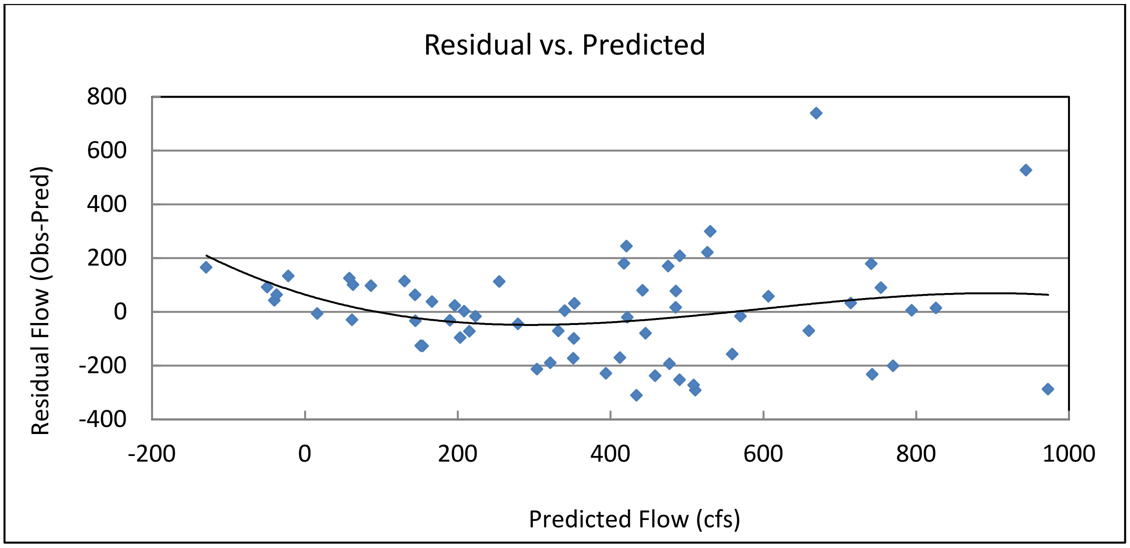


Figure 31. Residual versus predicted annual flow (bottom) for the USGS gage at Lamont for WYs 1951 - 2014
[Cubic reference line]

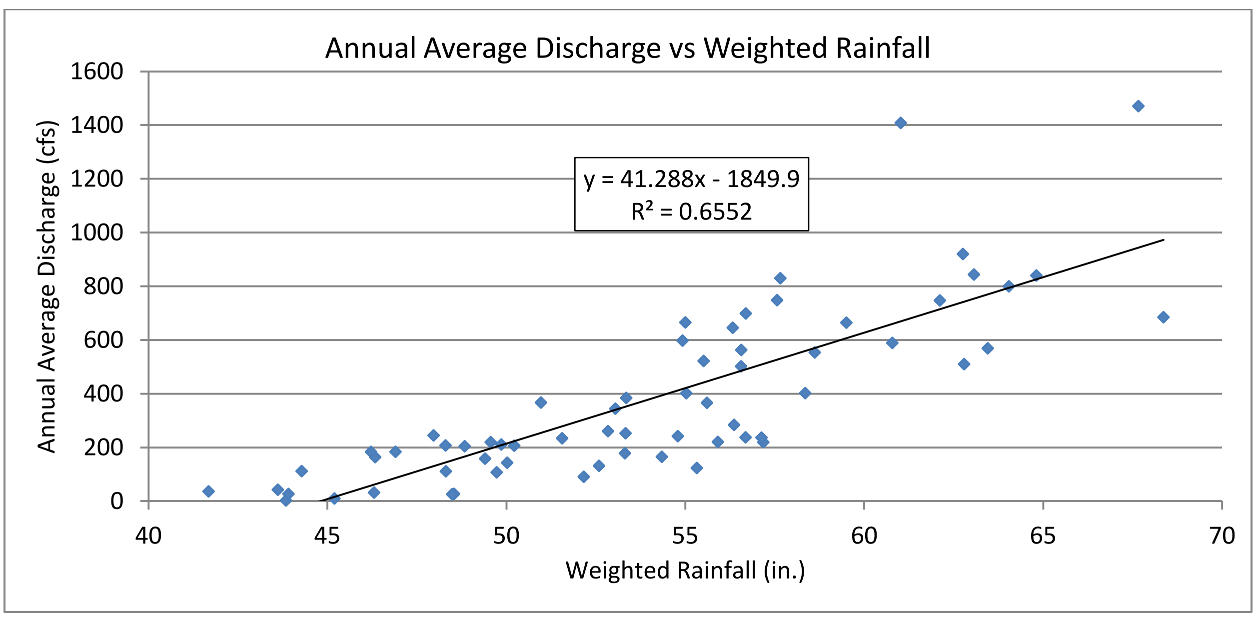


Figure 32. Annual average discharge vs weighted rainfall for the USGS gage at Lamont for WYs 1951 - 2014

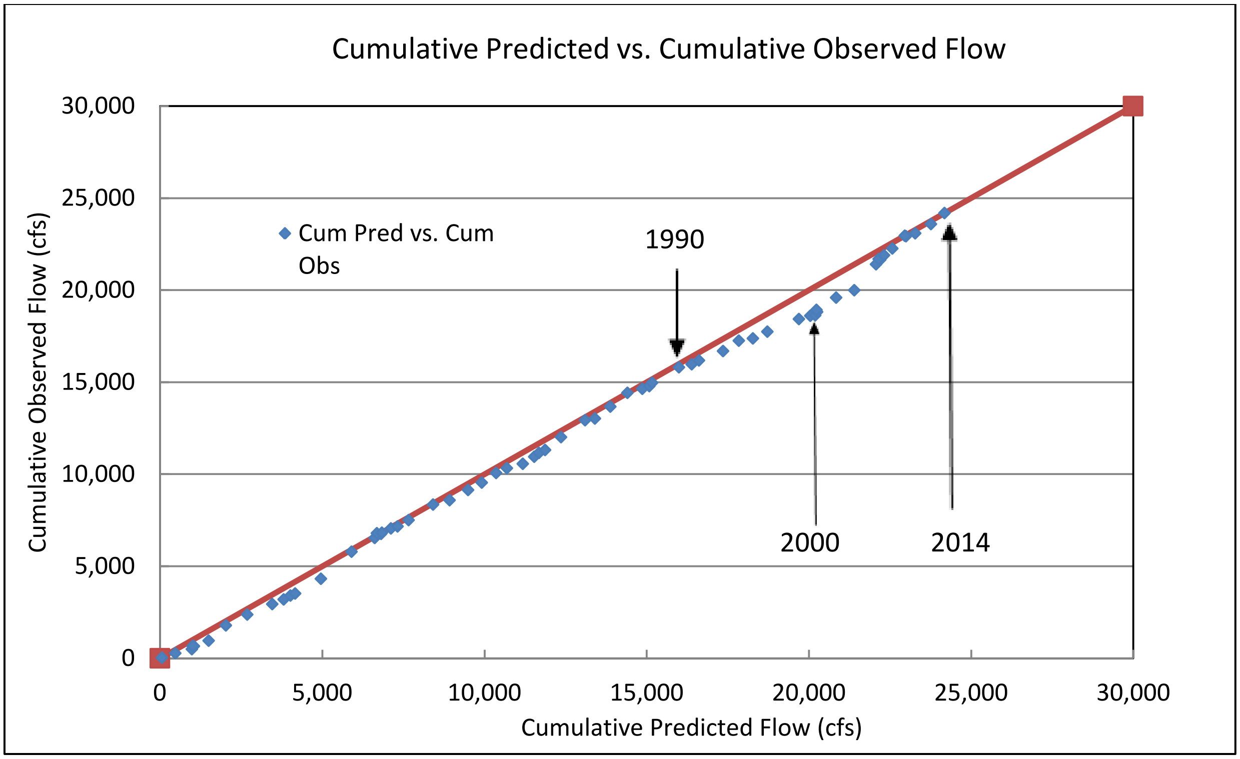


Figure 33. Double mass curve of cumulative measured and predicted annual flows for the Lamont USGS gage
[1-1 reference line]

Variations in the double mass relationship are magnified by plotting the cumulative residuals (i.e., observed minus predicted flows) versus time (Figure 34). This relationship more clearly shows the consistent over prediction between WY 1990 and WY 2000, and under prediction between WY 2000 and WY 2014. A persistent decrease in cumulative residuals followed by a persistent increase indicates that the model under predicts flow in the pre-period and over predicts during the post-period. No similarly persistent trend in cumulative residuals is evident over the POR at Lamont between WY 1951 and WY 2014 (Figure 34).

Based on local groundwater level trends, water use data and regression analysis (section 2.5 and section 2.7.3), there is no persistent evidence of anthropogenic impacts on the streamflow at the Lamont gage for the POR (WY 1951-2014).

To understand the dynamic nature of climate patterns and its effect on hydrology, it is useful to characterize current conditions in the context of long-term historical conditions. Daily flow duration curves (Figure 35) were prepared for the Lamont gage on the Aucilla River for two periods of time (1951-1990 and 1991-2014). The difference in flow duration curves for the two periods of time is negligible. At very low flows (exceeded between 80 and 100% of the time), the flows during a period that included a recent drought (1991-2014) were about 5-10 cfs lower than the low flows prior to 1991.

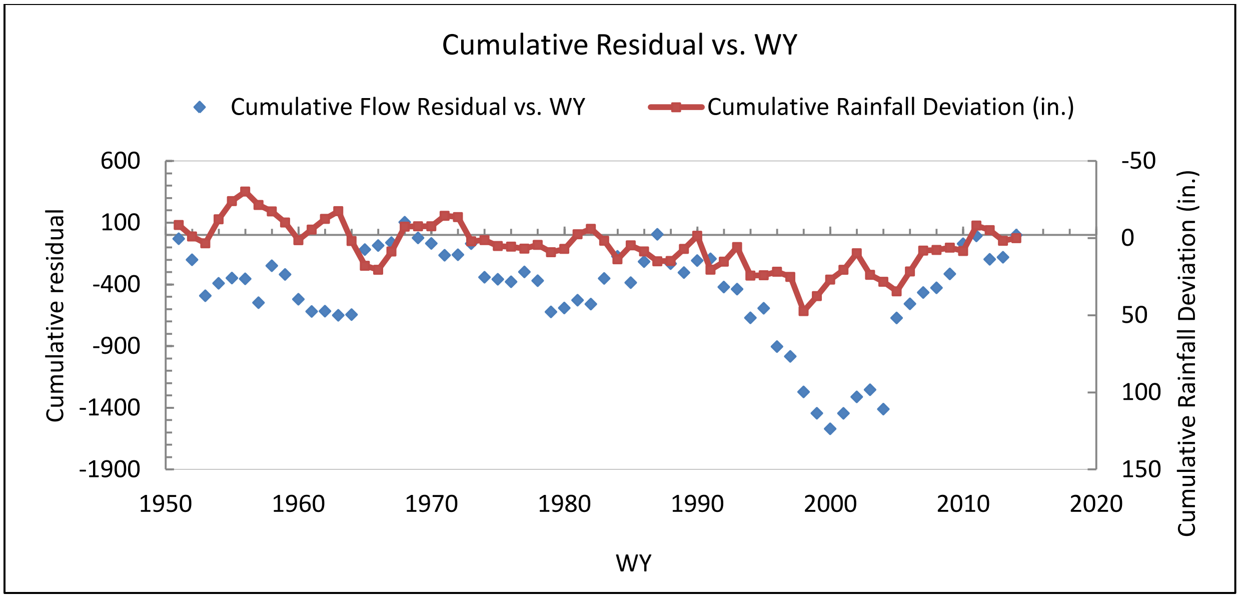


Figure 34. Cumulative residuals for annual average flow model (equation 4) based on all data for the USGS gage at Lamont for WYs 1951 – 2014

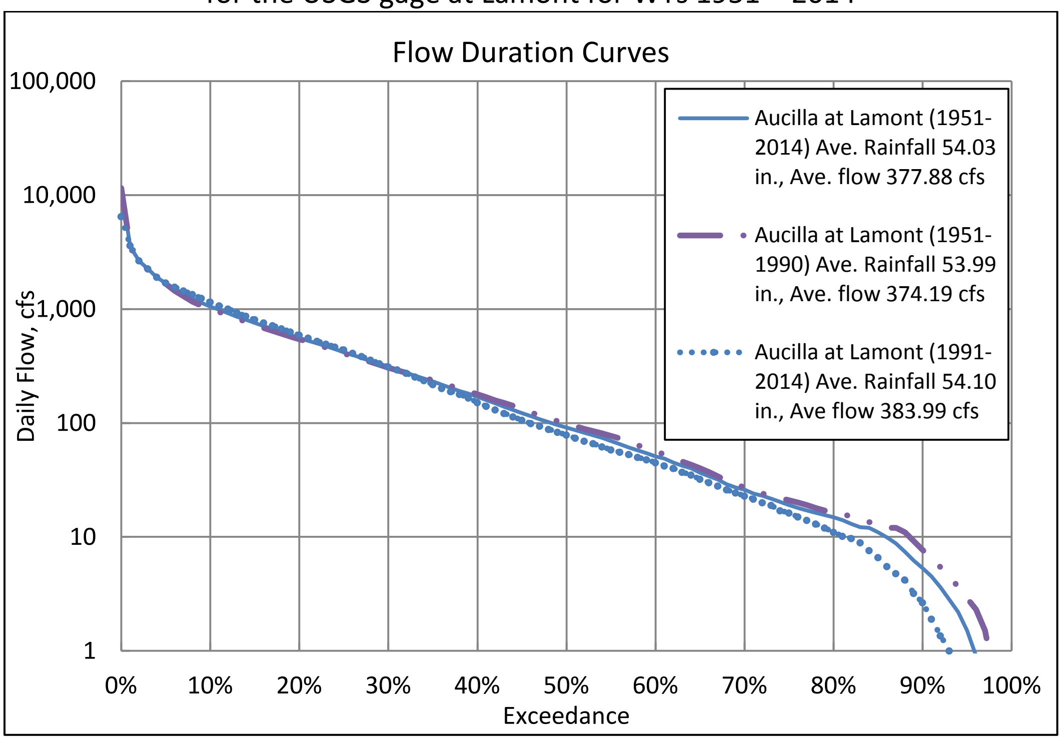


Figure 35. Flow duration curves for WYs 1951-1990 and recent conditions WYs 1991-2014 at Lamont gage

2.7.4 Stage-Flow Relations

Stage-flow relationships are needed for the MFLs assessment at both gaged and ungaged locations along the length of the rivers. These relationships can be used to determine the inundation characteristics of the river channel and floodplain.

2.7.4.1 Gaged Locations

The relationship between flow and simultaneous stage measurements (rating) near Lamont gage (02326500) shows a steepening of the slope around stage 52 ft NGVD (Figure 36), indicating a substantial increase in top width of the cross-section. This elevation of 52 ft matches the top of bank elevation prescribed in the HEC-RAS model near the Lamont gage at river mile 33.813 (Figure 37).

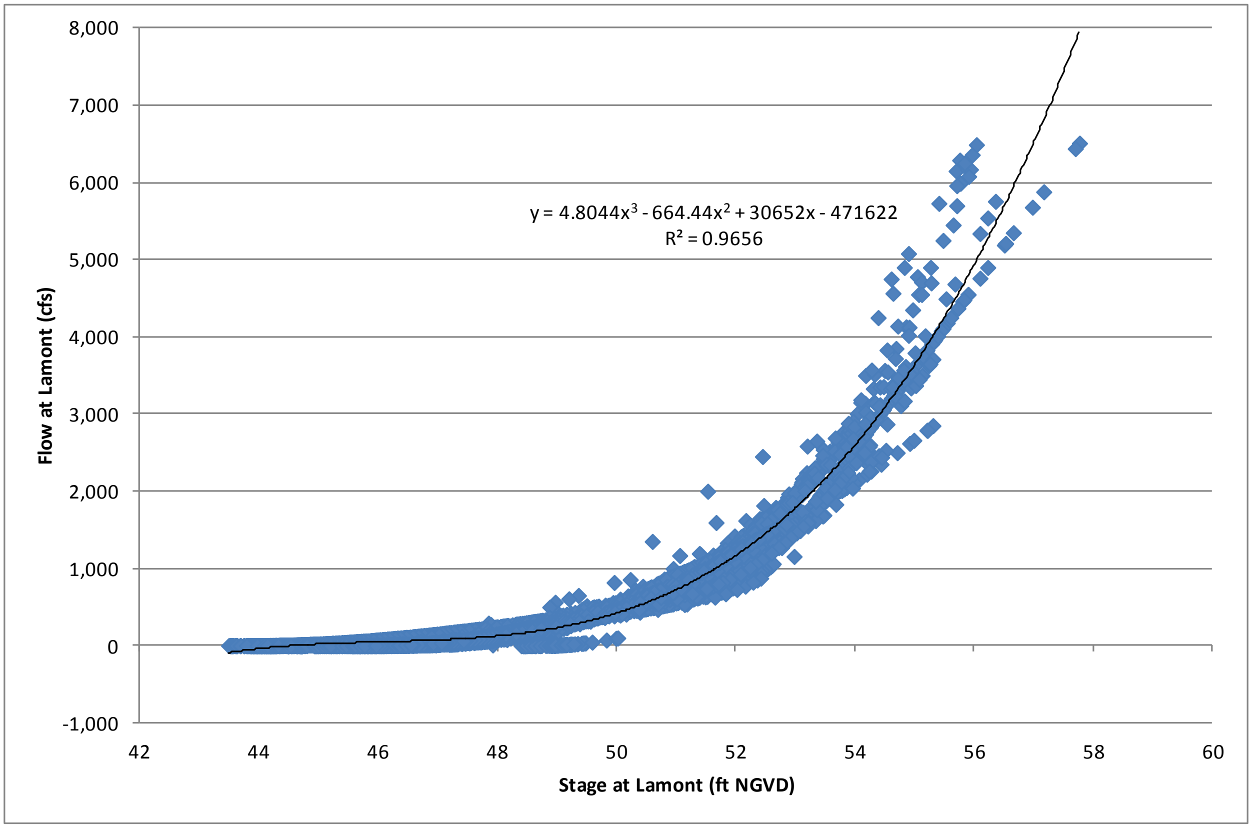


Figure 36. Rating curve for Aucilla River near Lamont gage (02326500)

2.7.4.2 Ungaged Locations

Stage-flow relations at ungaged locations can be characterized using hydraulic computer models. HEC-RAS is a computer program used to model the hydraulics of water flowing through natural rivers and other channels during steady and unsteady flow conditions (Brunner 2008). The HEC-RAS software supersedes the HEC-2 river hydraulics package which is a one-dimensional, steady flow, water-surface profiles program. HEC-RAS is quasi two-dimensional in that it can calculate the lateral distribution of flow and velocity within user-defined subareas of the main channel and overbank areas based on subarea conveyance. Primary inputs to HEC-RAS are channel geometry, channel roughness coefficient, and boundary conditions for stage and flow. Although HEC-RAS calculates more than 50 hydraulic characteristics, the primary model output of interest includes water-surface elevation, depth, water velocity, bottom shear stress, and flow area for both in-channel and overbank areas.

2.7.4.2.1 HEC-RAS Models

In 2002, the District contracted with Taylor Engineering to convert the original FEMA HEC-2 model of the Aucilla River into a HEC-RAS format (Taylor Engineering 2002). The model represents about 54 river miles and extends from the Gulf of Mexico to about the Florida-Georgia state line (Figure 37). The model input dataset includes 145 cross sections of the main channel and floodplain (i.e., an average interval of about 0.4 miles per section) and 10 cross sections at bridges. None of the cross-sections were geo-referenced. Spatially varied flows were prescribed for 15 river reaches to represent the 10-, 50-, 100-, and 500-year floods. The water surface profiles calculated for the four floods exceed the top of bank. The flow distributions used in the Taylor model represent the river as a losing system with flow decreasing in the downstream direction beginning at river mile 36.98. The river upstream from that location is represented as a gaining system. HSW subsequently refined the Taylor Engineering model for this MFLs assessment (see Section 2.7.4.2.2).

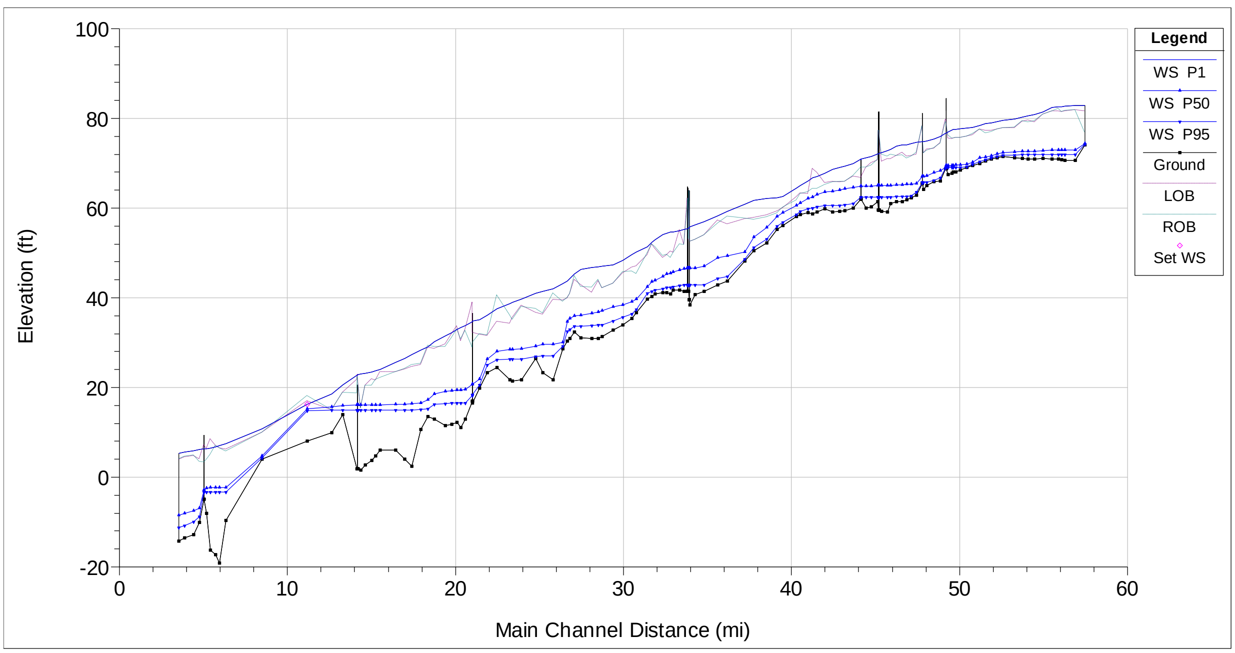


Figure 37. Extent of the HEC-RAS model of the Aucilla River
[Elevation is referenced to NGVD29]

In the summer of 2013, the District and Florida Fish and Wildlife Commission (FWC) initiated a project to characterize the hydraulics of the Wacissa River (Simpson and Coarsey 2014). A HEC-RAS model was prepared to represent a 7.5-mile reach of the Wacissa River extending from the USGS gage near Wacissa, FL (No. 02326526) to a downstream gage at Goose Pasture (No. 02326536) located about 2.5 miles upstream from the confluence with the Aucilla River (Figure 38). In May 2015, the SRWMD made refinements to the Wacissa HEC-RAS model for its use with the System for Environmental Flow Analysis (SEFA) software. The refined model and results were used for this MFLs analysis. The model output tables are included in Appendix G.

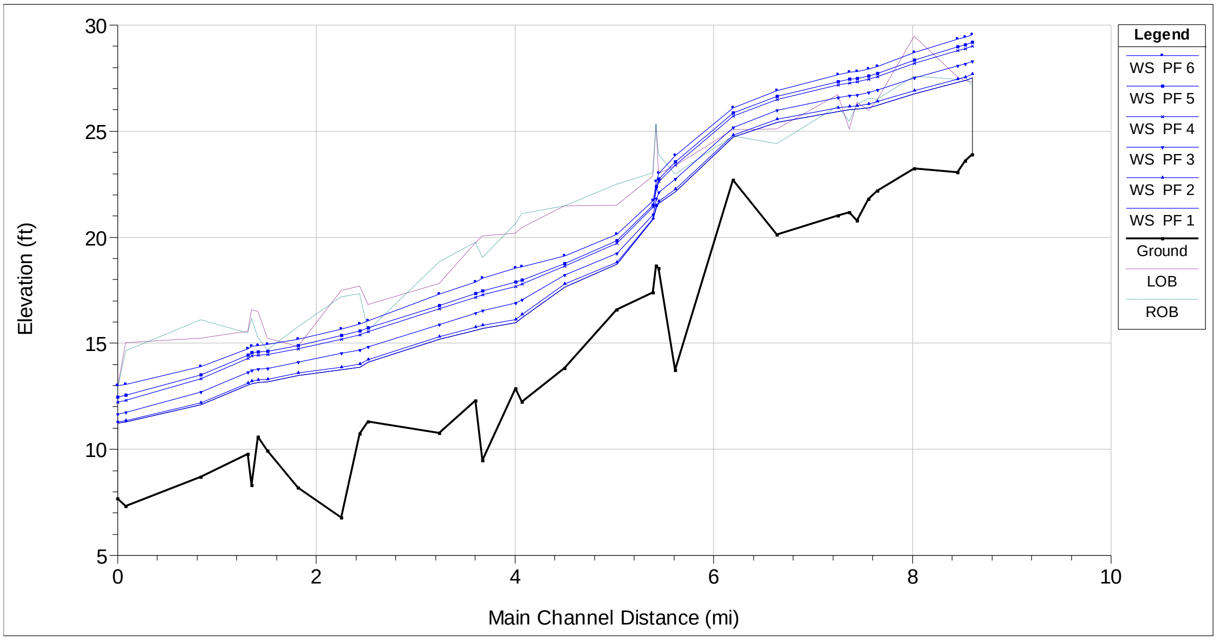


Figure 38. Extent of the HEC-RAS model of the Wacissa River
[PF 1, PF 2, PF 3, PF 4, PF 5 and PF 6 designate profiles associated with flows of 233, 254, 357, 518, 563 and 670 cfs, respectively, at the USGS gage near Wacissa, FL; elevation referenced to NGVD29]

2.7.4.2.2 Model Refinements

HSW geo-referenced the cross sections of the Aucilla HEC-RAS model by assigning real-world coordinates using HEC-GeoRAS. Geo-referencing allows the model to have a common coordinate system with GIS layers and helps in visualizing the limits of the model and its results using background data (Figure 39), and in post processing applications. Based on the watershed yield analysis (Section 2.7.1), flow inputs represent the river as a gaining system between Lamont and Scanlon (Table 9). Flows at gages for various exceedances were calculated using Lamont data and the corresponding gage flow association with Lamont flow data. Flow inputs for cross sections between the gages were calculated using linear interpolation. Negative values generated by infilling were replaced with 0.1 cfs flow to be consistent with the conceptual model of the Aucilla River and for HEC-RAS model stability (Section 2.7.1).

Table 9. Flow proportioning for Aucilla HEC-RAS model for select cross-sections

River Station	River Gage	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95
57.449	Ashville	832.7	386.1	233.7	113.9	53.6	20.3	1.1	0.1	0.1	0.1	0.1	0.1
49.184	Aucilla (US90)	1110.2	514.8	311.6	151.9	71.4	27.0	1.5	0.1	0.1	0.1	0.1	0.1
33.813	Lamont	3534.0	1685.0	1054.0	558.0	308.0	170.0	91.0	51.0	26.0	15.0	5.0	2.0

River Station	River Gage	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95
14.169	Scanlon	3753.6	2184.8	1460.0	822.7	478.9	282.6	168.2	109.7	72.9	56.7	41.9	37.5
3.53	Nutall Rise	4137.6	2568.8	1844.0	1206.7	862.9	666.6	552.2	493.7	456.9	440.7	425.9	421.5

Notes:

All values in cfs

PX denotes X percent exceedance for WYs 1951-2014

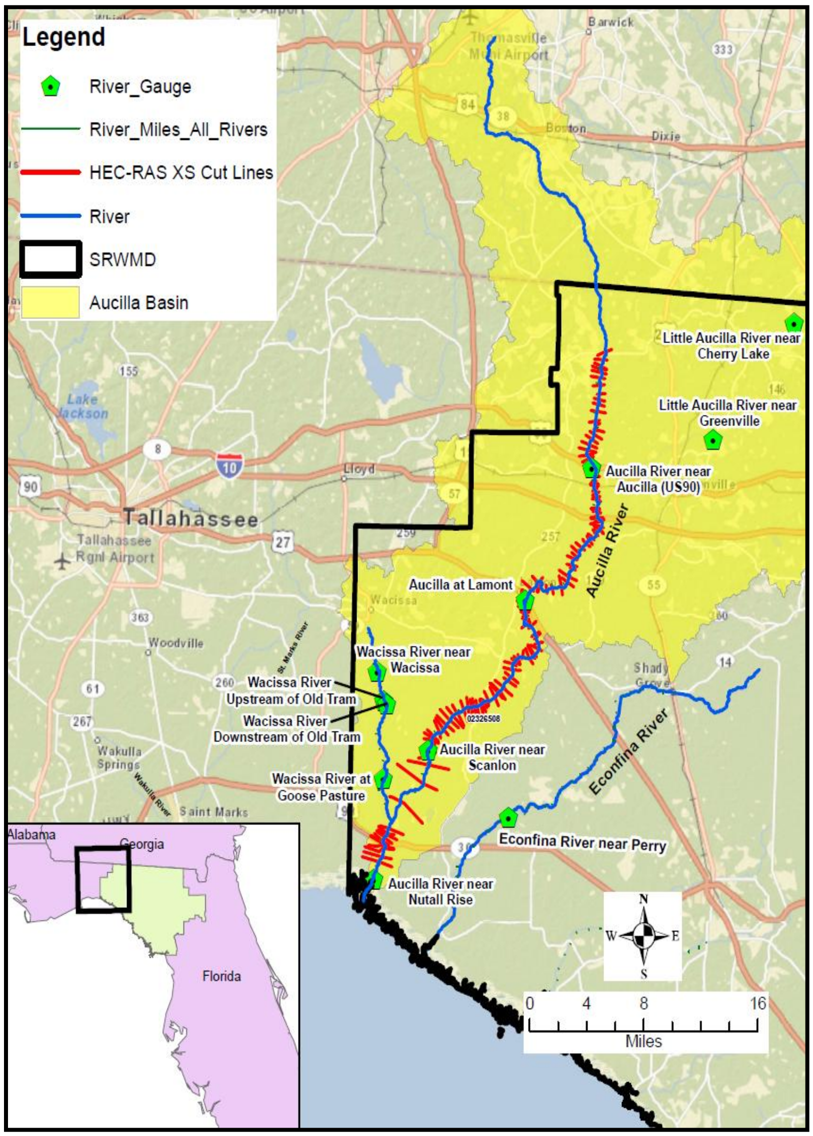


Figure 39. Geo-referenced HEC-RAS model cross sections of the Aucilla River

2.8 Hydrology Summary and Relevance to the MFLs Assessment

Best available data were used to characterize hydrologic conditions of the over the period of

WYs 1951-2014. The conceptual model and statistical analysis formed the basis for characterizing the baseline condition. Based on the analysis of relationship between rainfall and flow at Lamont (Section 2.7.3), there is no evidence of persistent anthropogenic impacts on the streamflow at Lamont gage during the historic period of record (WYs 1951-2014). Hence, the baseline condition, which is an estimate of unimpaired flow conditions is defined as the POR at Lamont (WYs 1951-2014).

The hydrologic characteristics of the Aucilla and Wacissa Rivers are distinctly different and can be assessed separately. Based on watershed yield analysis (Section 2.7.1), the Aucilla River is a gaining river until Scanlon and flow inputs for the HEC-RAS models were determined using the conceptual model and flow associations between various gages. A measurable gain in flow along the Wacissa river could not be assessed based on the available data at the existing gage locations.

Flow data at Wacissa gage near Wacissa are used as a surrogate for the combined flow from the springs upstream of the Wacissa gage. The baseline condition for Wacissa River is the entire POR data available at Wacissa gage near Wacissa (2001 to 2014). A spring-flow rating was developed and uses groundwater level as the explanatory variable (Section 2.6).

Based on the relative flows at gages on the Wacissa and Aucilla Rivers, flow proportioning was estimated between the Wacissa and Aucilla as a function of total flow. Hydrologic analysis was used to set the framework for the Aucilla-Wacissa River system MFLs assessment and provided the following information that is needed for developing MFLs.

- Infilled periods of missing record at Lamont using flows for nearby gages
- Defined a baseline condition, which is the entire POR at Lamont
- Defined the apportionment of flow of Wacissa River from the combined flows of the Aucilla and Rivers to transfer estuarine based MFLs to each of the rivers.
- Defined rating curves over the length of existing HEC-RAS models for the Aucilla and Wacissa Rivers.

3 Biology

Regionally significant riverine and floodplain ecological communities occur in and around the Aucilla and Wacissa Rivers. Flow reductions in the AWSS have the potential to alter the hydrology of wetland habitats and instream aquatic habitats (Darst et al. 2002). These alterations could potentially

- decrease the number and extent of semi-permanently inundated ponds;
- decrease the free-floating aquatic plants that grow only in riverine floodplain ponds;
- promote a shift to more upland species within the different riverine vegetative communities (and upper tidal bottomland hardwood communities) along the river;
- alter the percentage and cover of invasive species;
- reduce the type(s) of aquatic habitats preferred/required by select invertebrate and vertebrate species;
- modify the salinity regime within the estuary to the detriment of select species; and
- increase residence time of water within locations of slower flow rates (potentially altering dissolved oxygen and temperature regimes).

The MFLs assessment of fish and wildlife habitat was performed within the context of a Conceptual Ecological System (CES) model that is representative of the Aucilla/Wacissa Rivers system. The CES model is described in the next section, followed by descriptions of regional ecosystems and species of interest more sensitive to potential reductions in flows and/or levels.

3.1 Conceptual Ecological System Model

One goal of an MFLs assessment is to evaluate an allowable change in hydrology that would remain protective of the ecosystem and its component communities. A simple Conceptual Ecological System Model (CESM) was developed to help identify the primary components of ecosystems, the major natural processes that drive or stress the river ecosystems, the ecological effects of these processes, and biological attributes or indicators of these ecological responses.

The CESM (Figure 40) is the framework for characterizing the primary eco-regions and trophic levels along the study reach and quantitative, flow-related indicators of biological integrity or the extent of selected habitats. The climate of northern Florida and resulting hydrology influence the geometry of the Aucilla and Wacissa River channels and floodplains; the resulting topoedaphic conditions influence the surrounding vegetation communities, which are the habitats for the regional wildlife community.

Figure 40. Conceptual ecological system model variables

The primary CESM variables are as follows.

Hydrology — the volume and periodicity of water moving through the Aucilla-Wacissa system that is characterized frequently by a flow-duration curve.

Climate — the combined effects of precipitation, temperature, and other climatic factors that influence system hydrology.

Channel Geometry — geomorphological features such as the channel dimension, slope, and substrate which influence the association between hydraulic variables (i.e., stage-flow relation, stage-top width, etc.).

Vegetation Community — a group of plant populations that coexist in space and time within a defined area and interact directly or indirectly; vegetation communities are distributed along a continuum, influenced by topography, soils, the amount and periodicity of water, and climate. In the study area, vegetative communities are grouped categorically by position relative to the main river channel (Figure 41):

riverine – the Aucilla and Wacissa Rivers within the boundaries of Florida are 'perennial streams', meaning they flow throughout the year (except in the Aucilla' s upper reaches in years of excessive drought) and, although water levels vary, there are many plants that are highly water dependent and grow within the channel.

riparian zone – borders the river shorelines and plants receive a constant supply of water at average flows, and obligate wetland trees and shrubs such as bald cypress, tupelo, coastal plain willow and pop ash are found. Rising above the river shoreline to the river top of bank are plant associations that vary in the amount of water they require and receive water from the river when water levels are high, or from precipitation.

floodplain – above the top of bank along much of the river, the floodway widens across the landscape and periodic flooding supports forested and emergent types of freshwater wetlands.

Habitat — places where an organism or a biological population normally lives or occurs (i. e., the location or environment where an organism is most likely to be found). For this MFLs assessment, habitat is grouped similarly to vegetation community by position relative to the river channel (Figure 41).

Wildlife Community — various species of invertebrate and vertebrate animal populations that coexist in space and time within a defined area and interact directly or indirectly. Because most species can move, the composition of the community can vary, often seasonally during migration, nesting, or spawning runs, or depending on forage availability. Wildlife species need space, shelter, and food, and are influenced by the habitats (topography, soils, and water), climate, and forage available to them.

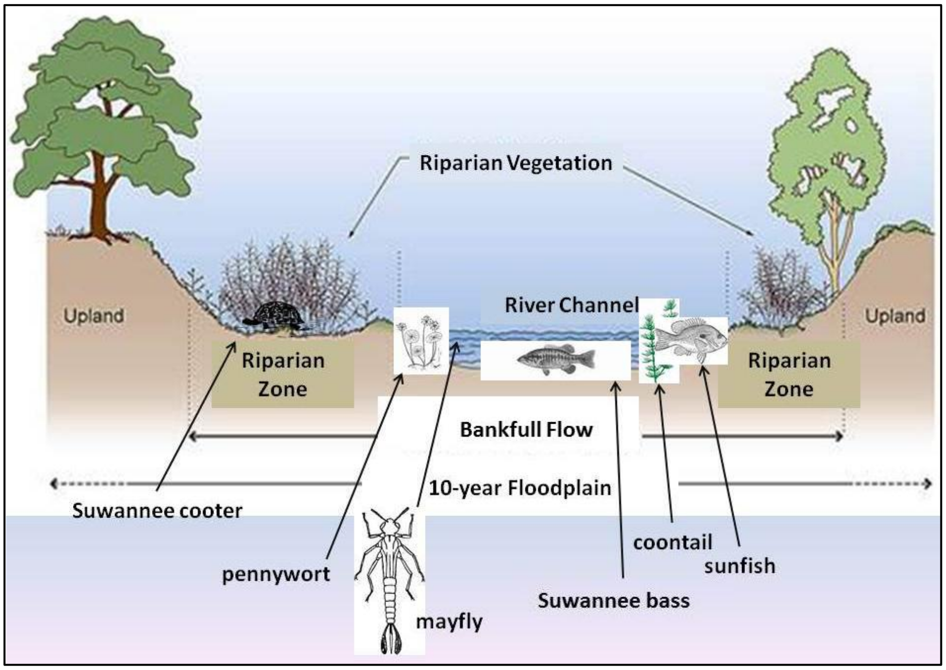


Figure 41. Conceptual cross-section of wetted perimeter, vegetation community, and habitat availability in the Aucilla-Wacissa ecosystem

A simple conceptual model of the trophic relationships in the Aucilla-Wacissa study area characterizes the roles of the aquatic organisms in the river and relevance as forage for consumers (Figure 42). At the lowest level, plants and algae are producers that photosynthesize using the dissolved nutrients (nitrogen, phosphorus, etc.) in the water. At the next level, mussels, and insects appear as primary consumers that consume bacteria, algae, and plants and produce detritus, while carnivorous (predatory) fish appear at the next level, the secondary consumers. The tertiary consumers are the top-level predaceous fish and turtles in the river. Organic matter produced by the decomposition of organisms at all four levels is recycled back to producers by detritivores and decomposers.

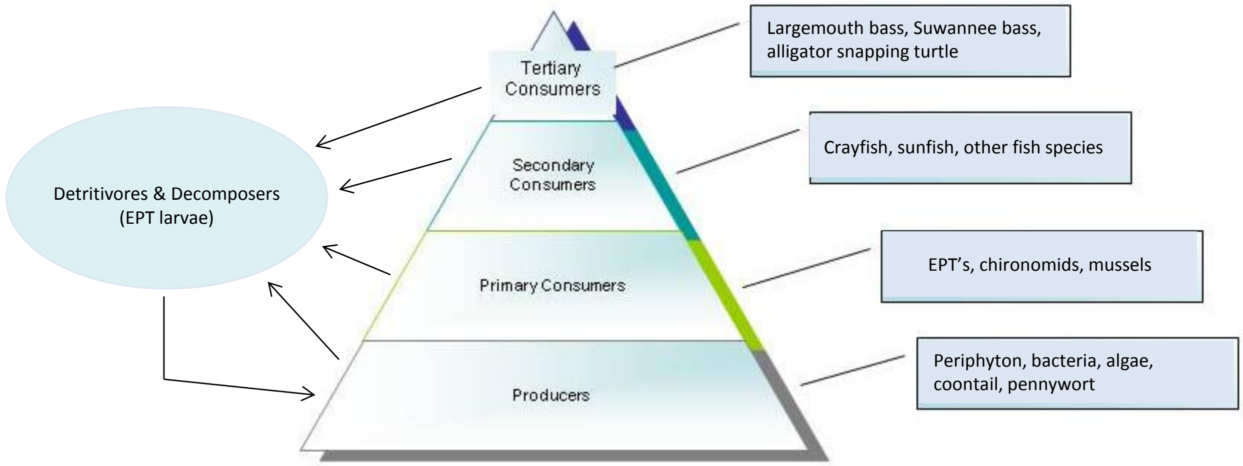


Figure 42. Conceptual trophic model for the Aucilla-Wacissa riverine ecosystem. [EPT designates the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)]

General fish assemblages can be categorized using a four-way matrix of water velocity and water depth to encompass groups of fish in ecological guilds; i.e. species that exploit similar habitat (Table 10). The species guild identifiers are designated using a 4-letter sequence that denotes water velocity and water depth best suited for the species. For example, the identifier "VSDS" designates a preference for slow velocity, shallow depth environment.

Table 10. Generalized ecological guilds and identifiers for fishes in the Aucilla and Wacissa rivers

	Water Velocity (V)	
Water Depth (D)	Slow (S)	Fast (F)
Shallow (S)	Species Guild VSDS	Species Guild VFDS
Deep (D)	Species Guild VSDD	Species Guild VFDD

Four flow regimes should be considered when examining river flow requirements for instream and out-of-bank floodplain habitats: 1) flood flows that determine the boundaries of and shape floodplain and valley features; 2) overbank or near overbank flows that maintain riparian habitats; 3) in-channel flows that keep immediate stream banks and channels functioning; and 4) instream flows that meet critical biota requirements such as fish passage and reproduction. Thus, broad ecological functions, as well as species-specific needs, are considered in the establishment of MFLs (Hill et al. 1991).

In a typical floodplain forest of north Florida (Figure 43), riparian habitats border the river channel, and associations of trees grouped into vegetative communities extend across the floodplain. The topoedaphic setting varies across the floodplain, creating an irregular distribution of wetland communities based on soils and water requirements. Trees common to the hydrology of the low and upper terraces may be found also within sloughs and swamps behind the confining levees of the river channel.

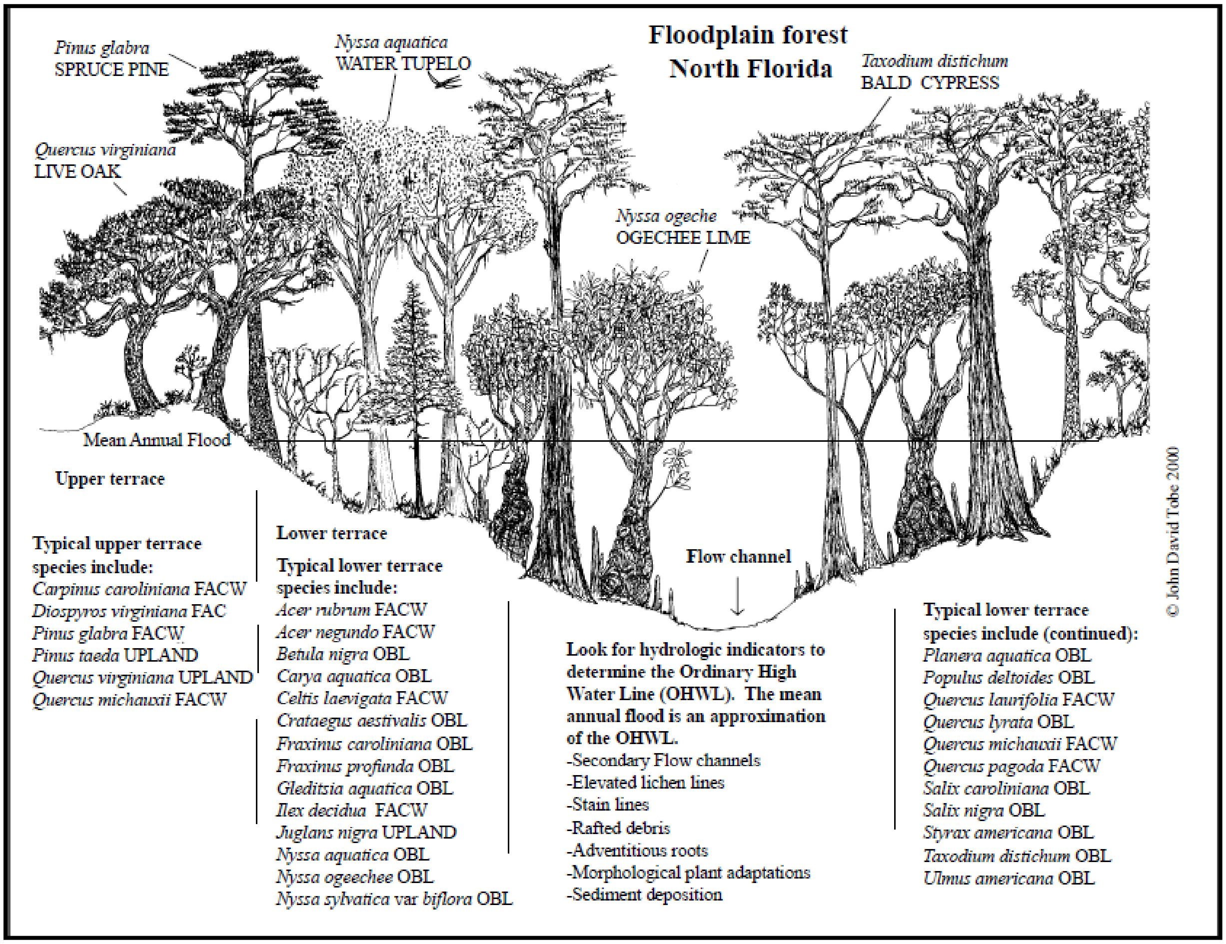


Figure 43.Conceptual diagram of a floodplain forest in north Florida
[Source: FDEP 2012; Cowardin et al. 1979]

3.2 Ecoregions and Natural Communities

Ecoregions were designed to serve as a spatial framework for environmental resource management and denote areas within which ecosystems and the type, quality, and quantity of environmental resources are generally similar (USEPA 2013). The ecoregions have been used to develop regional biological criteria and water quality standards and to set management goals for nonpoint source pollution, among other applications. The Wacissa River is entirely within the Gulf Coast Flatwoods ecoregion.

The Aucilla River begins in the Tallahassee Hills/Valdosta Limesink ecoregion in south Georgia and then drops down the Cody Scarp to the Gulf Coast Flatwoods ecoregion, before emptying into the broad marshes of Apalachee Bay in the Gulf of Mexico (Figure 44).

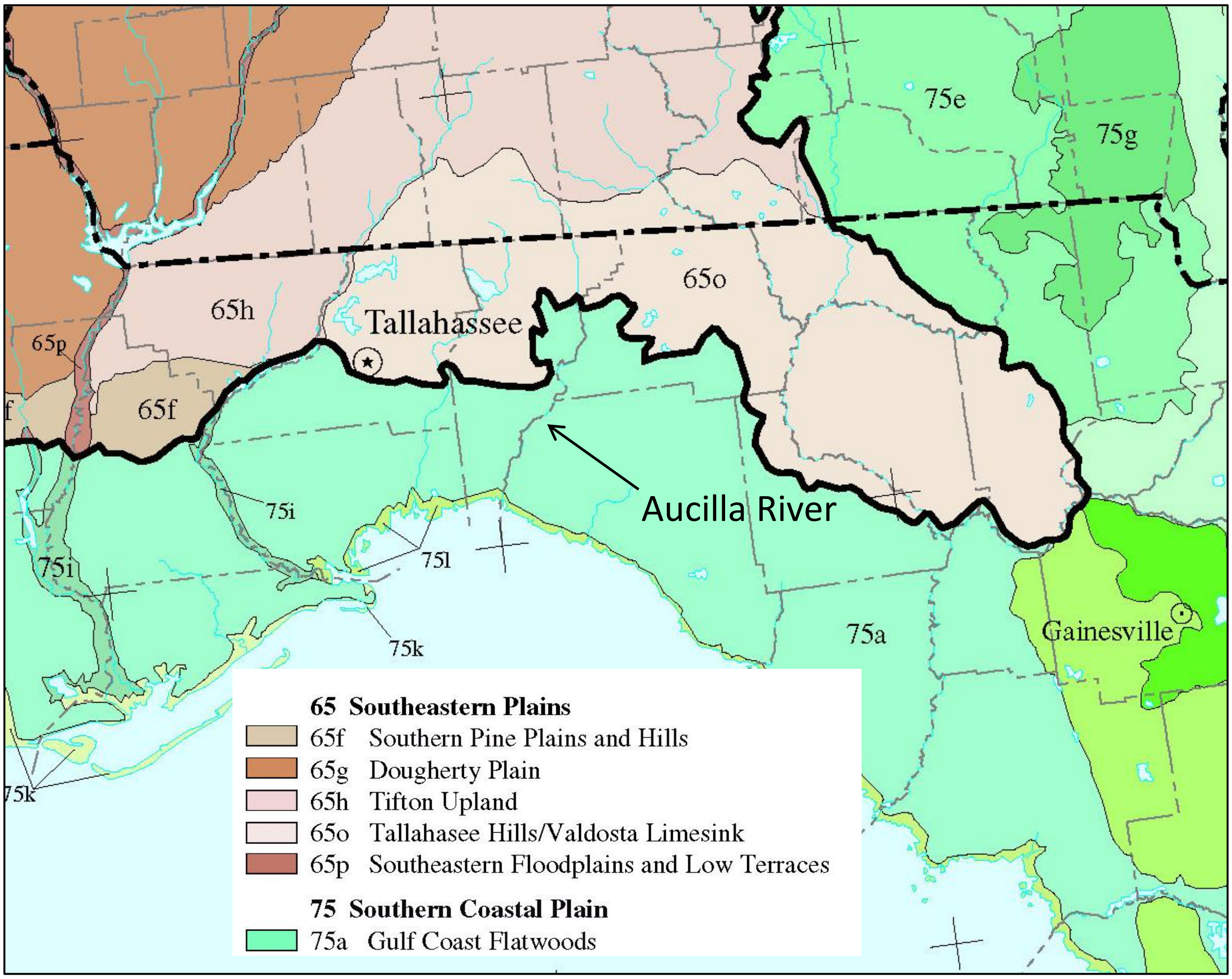


Figure 44. Level IV ecoregions in the vicinity of the Aucilla River
[Wacissa River (not shown) is entirely within ecoregion 75a. Source: USEPA 2013]

The Tallahassee Hills/Valdosta Limesink sub-ecoregion combines two slightly different areas, both influenced by underlying limestone (GADNR 2001).

> "The Floridan aquifer is thinly confined in this region, and streams are often intermittent or in parts flow underground in the karst landscape. In the west, the Tallahassee Hills portion has rolling, hilly topography that is more forested than 65h. Clayey sands weathered to a thick red residual soil are typical. Relief decreases towards the east, and the Valdosta Limesink area has more solution basins with ponds, lakes, and swampy depressions, as well as areas with more cropland. The soils are typically brownish. Mixed hardwoods and pine are found on the clayhill upland soils, while longleaf

pine/xerophytic oak types occur on the sandy, well-drained areas.”

The Gulf Coast Flatwoods sub-ecoregion stretches from coastal Mississippi into western Pasco County, Florida (USEPA 1994).

> “There are heterogeneous areas and habitats within the sub-region, including coastal lagoons and mangrove; swamp and marsh; the clastic, non-karst terraces and deltas of the Apalachicola; limestone plains and rock lands; and paleo sand dune areas. Along the coast, the coastal strand and pine scrub vegetation found on dunes, spits and barrier islands of the Panhandle, changes to mangrove and coastal marshes from Wakulla to Pasco counties. In general, pine flatwoods mixed with some hardwood forest and swamp vegetation characterize the inland region. The Apalachicola National Forest and private pine plantations cover a large part of this sub-region in Florida.”

The AWSS comprises a watershed with diverse rivers and floodplains. Within Florida, the Aucilla River has been characterized by three reaches with distinctly different channel and riparian zone characteristics and ecosystems (Lenz 2006; Figure 45). A synopsis of May 2015 field observations made along the three Aucilla reaches and the Wacissa follows.

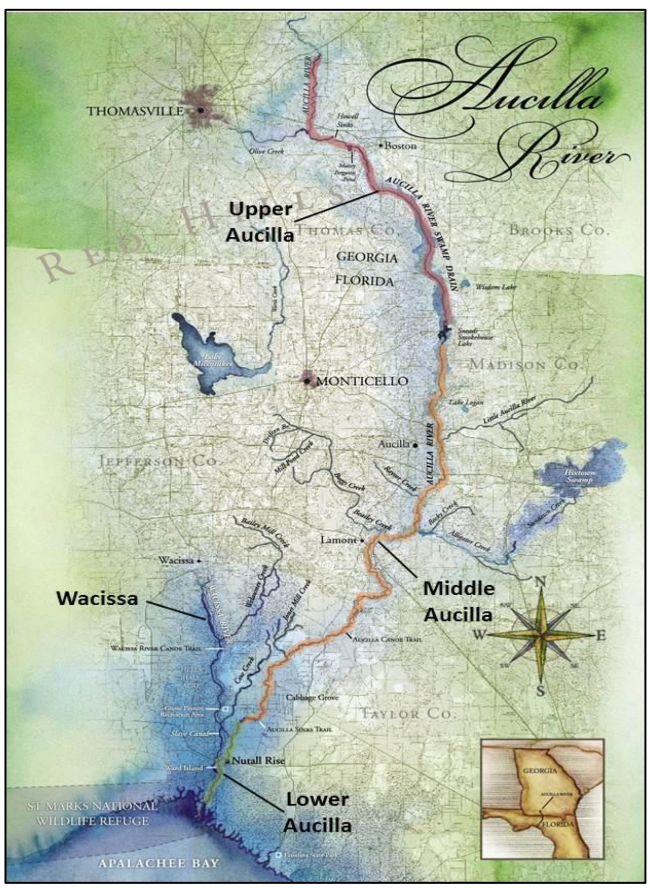


Figure 45. Primary reaches of the Aucilla and Wacissa Rivers
[Modified from Lenz 2006]

Upper Aucilla River

The upper Aucilla is part of the Tallahassee Hills/Valdosta Limesink ecoregion (Figure 44). Upon crossing the Georgia line and entering into Florida, the Aucilla River is sometimes referred to as the Aucilla River Drain/Swamp (Lenz 2006). This area between the State line and US Route 90 (Figure 45) is dominated by tree species tolerant of extended inundation, such as cypress (*Taxodium* spp.*)*, swamp tupelo (*Nyssa sylvatica* var. *biflora.*), ash (*Fraxinus* spp.), and red maple (*Acer rubrum*). Within this stretch, the river channel is poorly defined in many places, and the river flows slowly southward toward the US90 bridge.

The floodplain within the Upper Aucilla is wide. It is largely an extensive swamp system, Sneads Smokehouse Lake being a notable feature (Figure 46). Erosional features are minimal because of the low flow velocity, and finer-grained sediments are common within the regularly inundated portions of the riparian areas and floodplain.

Figure 46. View of the upper Aucilla River at Sneads Smokehouse Lake
[Note the large cypress and open water. Photograph taken by HSW on March 20, 2015.]

Given that the river has ill-defined or absent banks along this stretch, some of the river floodplain appears to be inundated frequently. Cypress, tupelo, ash, red maple, with some river birch are commonly found closest to the river proper (Figure 47). At slightly higher elevations with respect to the river, these tree species are joined by a large number of hardwood species such as (but certainly not limited to): sweet bay magnolia (*Magnolia* *virginiana*), swamp bay (*Persea palustris*), laurel oak (*Quercus laurifolia*) and the closely related diamond leaf oak (*Q. obtusa*), water oak (*Q. nigra*), sweetgum (*Liquidambar styraciflua*), hackberry (*Celtis laevigata*), American elm (*Ulmus americanus*), and American hornbeam (*Carpinus caroliniana*).

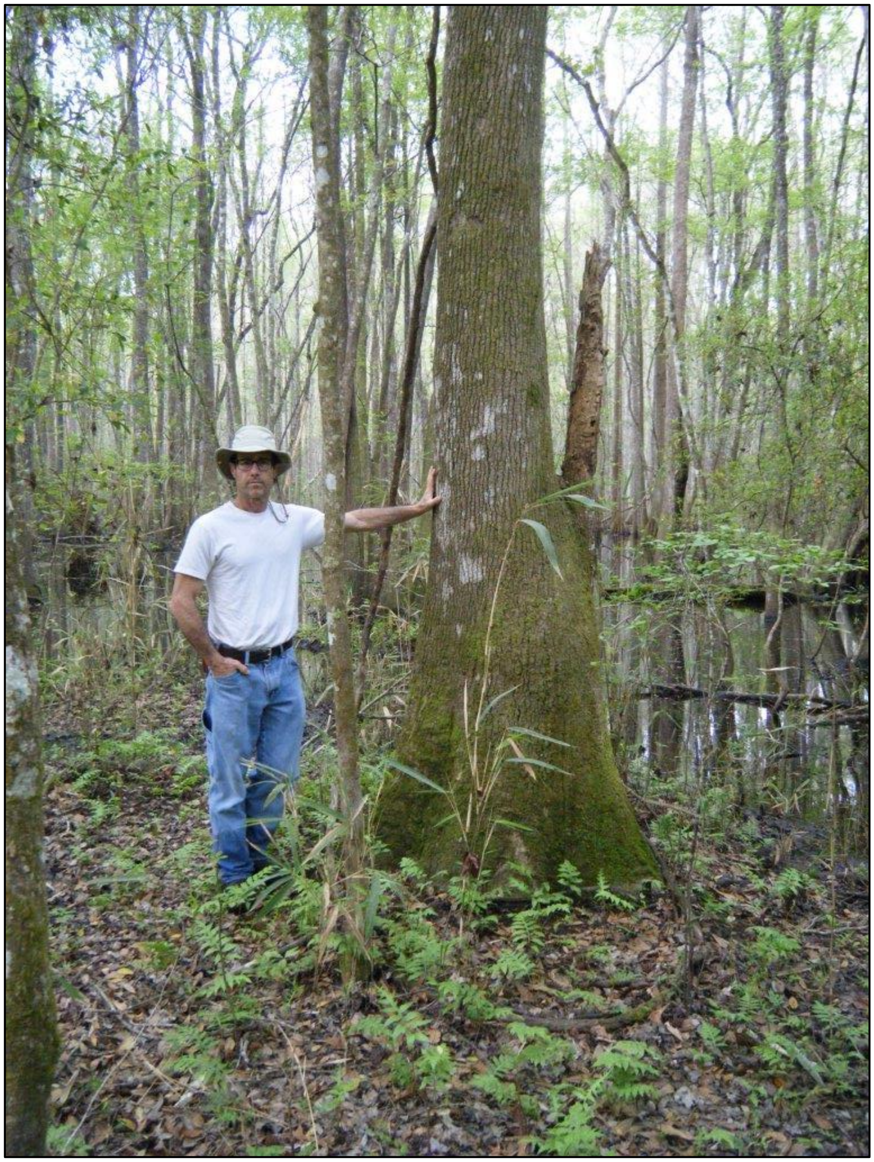


Figure 47. View of large tupelo at edge of water on the upper Aucilla River
[Photograph taken by HSW on March 20, 2015]

<u>Middle Aucilla River</u>

Downstream of the US90 bridge, the river develops a defined channel with stream banks and noticeable water flow. This segment of the Aucilla River is sometimes called the Middle Aucilla. This segment of the river receives runoff from a 15.5 square mile swamp system to the east called the Hixtown Swamp (Lenz 2006). The hydric portion of the watershed of the Middle

Aucilla becomes more narrow in this stretch as the river channel becomes deeper and better defined, with steep banks that restrict average and below average flows to the river channel proper. During a March 2015 field inspection, river birch (*Betula nigra*) were observed to be relatively common along the banks within the Middle Aucilla (Figure 48).

The Middle Aucilla maintains its continuity as it begins to drop rapidly (for a Florida river) in elevation between US90 and Dead Man's Sink near the head of Aucilla Sinks Trail (Figure 45) where the river disappears underground for the first time. Upstream of the trail the river is characterized by a significant current (Figure 49), shoals and rocky and/or sandy bottom as it carves its bed deeper into the limestone bed, so that, as one moves down-river from US90 to Dead Man's Sink, the banks of the river become increasingly steep and higher above the water surface (Lenz 2006). This results in the adjacent wetland communities becoming more isolated from the river channel than is the case within the Upper Aucilla.

Between Dead Man's Sink and Nuttall Rise, there are many rises and sinks. Beginning at Dead Man's Sink, the next 8 miles of the river as it continues toward the Gulf of Mexico becomes a string of caverns, many of which are open to the surface. Hydric vegetative communities are located within a narrow zone in this section of the river compared with the Upper Aucilla (Figure 50). In this 8 mile stretch, the interconnections of these hydric communities at land surface with the river itself (below land surface for the most part) are indirect under all but the highest flow regimes.

Along the Middle Aucilla, as the river becomes more deeply-incised, the lower-lying hydric communities become more and more limited. Cypress, tupelo and river birch are found mostly along the narrow portions next to the channel. Mixed Wetland Hardwoods and Bottomland Forests become the dominant types of hydric communities.

<u>Lower Aucilla River</u>

The Lower Aucilla is part of the Gulf Coastal Lowlands. It is within this section that the Aucilla is joined by the Wacissa River. These two rivers come together at several locations close to the Nuttall Rise. The hydric community portion of the freshwater segment of the Lower Aucilla is also composed largely of floodplain swamp and hydric hammock. Nuttall Rise is the final Aucilla River resurgence and becomes tidal shortly downstream (Lenz 2006).

Figure 48. Typical view of the middle Aucilla River and river birch
[Photograph taken by HSW on March 20, 2015.]

Figure 49. Typical view of the middle Aucilla River
[Note the steep banks, swift current, riparian vegetation, and snags. Photograph taken by HSW on March 20, 2015]

Figure 50. View of a rise on the Aucilla River between Dead Man's Sink and Nuttall Rise [Note distance from the water to top of bank. Photograph taken by HSW on March 21, 2015]

The topography in this lower segment of the river is relatively flat. Once emerging at Nuttall Rise, a short section of the river is freshwater tidal. The effects of the saline Gulf of Mexico begin to become visually evident about 2 miles downstream from Nutall Rise at the downstream end of Ward's Island about 1 mile downstream from the US98 bridge (Figure 45). The river maintains a defined channel with low shoreline almost all the way to the coast (Figure 51). At the mouth, an extensive network of salt marshes is present, along with submerged seagrass beds and oyster bars. Most of the lower Aucilla is within the St. Marks National Wildlife Refuge (Figure 45).

Along the Lower Aucilla, hydric hammocks become a more dominant part of the hydric community landscape. Four, equally abundant tree species are found in the lowlands along the Wacissa River (FWC 2005) – sweetbay (*Magnolia virginiana*), red maple (*Acer rubrum*), sweetgum (*Liquidamba*r styraciflua), and laurel oak (*Quercus laurifolia*). These tree species can be joined by red cedar (*Juniperus virginiana*) and cabbage palm (*Sabal palmetto*). The hydric hammocks are often associated with limestone close to land surface. This is consistent with the coastal segment of the Aucilla River and the spring-fed nature plus Gulf Coastal Lowlands location of the Wacissa River.

Downstream of US98 where saltwater begins to exert an influence, hydric hammocks dominate the shoreline, with red cedar and cabbage palm becoming more dominant in the canopy of this community type. Slightly salt-tolerant herbaceous plants such as sawgrass (*Cladium jamaicense*) and bulrush (*Scirpus* sp.) become evident along the shoreline as the system changes from freshwater tidal to estuarine (Figure 52). Cypress along the shoreline become fewer as salinity increases. Near the river mouth, salt marsh becomes the dominant vegetation community type, with black needle rush (*Juncus roemerianus*), and salt-meadow cord grass (*Spartina patens*) as the most obvious species.

Figure 51. Typical view of the lower Aucilla River
[Note water level nearly up to top of bank. Photograph taken by HSW on March 21, 2015.]

Figure 52. Typical view of the lower Aucilla River and sawgrass
[Note the large solitary cypress surrounded by sawgrass along shore. Photograph taken by HSW on March 21, 2015.]

Wacissa River

Because the Wacissa River emerges fully formed from several large-volume springs, it remains a perennial river from start to finish. It resides entirely within the Gulf Coastal Lowlands. Consequently, for most of its entire length, the Wacissa is bordered by a relatively wide expanse of hydric vegetative communities. Because it is a perennial, spring-fed stream, the Wacissa River is classified in the Florida Fish and Wildlife Conservation Commission-Florida Natural Areas Inventory (FWC/FNAI) Florida Cooperative Land Cover (CLC) Map version 3.0 as a "Spring-run Stream", a perennial watercourse with deep aquifer headwaters, clear, circum-neutral pH, and often a solid limestone bottom (FWC 2014).

Along much of the banks of the Wacissa River, the dominant landscape is hydric hammock.

Even though this vegetative community type is not usually the dominant one at low elevations relative to a river, minimal water level fluctuations on the Wacissa means that these systems are not often inundated for extended periods of time, hence the ability for a wide variety of species associated with a hydric hammock to grow.

Figure 53. Typical view of the Wacissa River from the wetland shoreline
[Photograph taken by HSW on March 21, 2015.]

3.3 Floodplain Vegetation and Soils

In the Upper Aucilla, much of the forested wetlands are saturated or inundated primarily from precipitation after heavy prolonged rains that pond over the poorly draining soils or from stormwater inflow from the surrounding watershed. In areas where wetlands lie above the intermediate confining unit (clayey sands) and the potentiometric surface is high, surficial waters are unable to infiltrate into the ground, and wetland conditions thus are sustained. Karst features are a predominant factor in the hydrology of much of the Middle and Lower Aucilla and Wacissa Rivers that are linked through complex aquifer connections to the river (Beck et al. 1985).

Historical reports from FWC (2004, 2005, and 2012) and the St. Marks National Wildlife Refuge

(USFWS 2015b) were examined and compared with the CLC map digital inventory of land use and cover obtained from the District GIS database as an ARC-GIS shapefile for use in examining and mapping floodplain habitats. A field reconnaissance effort was undertaken from March 20-22, 2015, along much of the length of the Aucilla and Wacissa Rivers to support and verify the vegetative community maps, general plant species compositions, and verification of SSURGO hydric soils maps where hydric soils end and non-hydric soils begin.

Based on the CLC Map at least 18 major freshwater natural communities are documented to occur within the Aucilla/Wacissa River system watershed (FWC 2014). Of these, 11 are palustrine wetland communities with areas exceeding 1% of the total area inventoried within a 2,000-foot wide corridor that may be altered by flow and associated stage reductions within the rivers themselves due to their proximity to the rivers (Table 11).

The floodplain vegetation communities include: Mixed Wetland Hardwoods, Floodplain Swamp, Bottomland Forest, Cypress, Hydric Hammock, Gum Pond, other Wetland Forested Mixed, Wet Flatwoods, Mixed Scrub-shrub Wetland, Bottomland Forest, and Baygall (Table 11). One additional estuarine natural community (salt marsh) is mapped within the study area by the FWC/FNAI and exists near the mouth of the river. The freshwater systems are categorized as natural rivers, streams and spring-run streams (Table 11).

The Aucilla River corridor totals 13,093 acres of which nearly 50% is categorized as palustrine wetlands comprised of Mixed Wetland Hardwoods (18.4%), Bottomland Forest (6.9%; a sub-category of Mixed Wetland Hardwoods), Floodplain Swamp (13.0%), Cypress (6.9%) and Hydric Hammock (3.6%) (Table 11). Of these, the Floodplain Swamp and Cypress community types are associated with longer durations and depths of inundation than are the other three types. The Wacissa River corridor totals 3,437 acres of which over 60% of the vegetative community consists of Hydric Hammock (60.5%) (Table 11). The second and third most common community types are the Upland Hardwood Hammock, at 10.2%, and Spring-run Stream, at 6.3% (Table 11).

Soil surveys produced by the USDA Natural Resources Conservation Service (NRCS) are the standard for soil classification and include information on numerous soil properties that are important to hydrologic and ecologic processes. Because soil functioning can vary at a regional level based on local soil morphology, county-specific lists of hydric soils (i.e., soils that are inundated or saturated long enough to support wetland plant communities, typically with poor drainage and a shallow seasonal high groundwater table) were obtained to confirm the presence of hydric soils in the study area. The NRCS digital Soil Survey Geographic Database (SSURGO) was utilized to determine presence of hydric soils in the study area and was obtained from the District GIS database as an ARC-GIS shapefile for this purpose. The SURGO data are based on detailed county surveys (Allen 1989, Howell and Williams 19990, and Watts et al. 2000).

Table 11. Predominant land covers within a 2,000-foot wide corridor centered on each river [Land cover with areas exceeding 1% of a river total; **Bold** denotes a palustrine wetland community]

Aucilla River			
Land Cover Code	Description	Area (acres)	Relative Amount
2233	**Mixed Wetland Hardwoods**	**2410**	**18.4%**
183332	Coniferous Plantations	1863	14.2%
2215	**Floodplain Swamp**	**1707**	**13.0%**
22331	**Bottomland Forest**	**903**	**6.9%**
2211	**Cypress**	**901**	**6.9%**
1400	Mixed Hardwood-Coniferous	795	6.1%
1110	Upland Hardwood Forest	728	5.6%
2232	**Hydric Hammock**	**470**	**3.6%**
221312	**Gum Pond**	**409**	**3.1%**
4100	Natural River and Streams	372	2.8%
1840	Transportation	261	2.0%
2240	**Other Wetland Forested Mixed**	**251**	**1.9%**
1311	Mesic Flatwoods	231	1.8%
5240	Salt Marsh	220	1.7%
2221	**Wet Flatwoods**	**175**	**1.3%**
1120	Mesic Hammock	167	1.3%
2112	**Mixed Scrub-Shrub Wetland**	**162**	**1.2%**

Wacissa River			
Land Cover Code	Description	Area (acres)	Relative Amount
2232	**Hydric Hammock**	**2079**	**60.5%**
1110	Upland Hardwood Forest	351	10.2%
4130	Spring-run Stream	218	6.3%
183332	Coniferous Plantations	192	5.6%
2233	**Mixed Wetland Hardwoods**	**190**	**5.5%**
2240	**Other Wetland Forested Mixed**	**89**	**2.6%**
4100	Natural Rivers and Streams	69	2.0%
2215	**Floodplain Swamp**	**63**	**1.8%**
2231	**Baygall**	**58**	**1.7%**
22331	**Bottomland Forest**	**40**	**1.2%**
1400	Mixed hardwood-Coniferous	38	1.1%

About 53% of the 13,095 acres of the soils series categorized within a 2,000 foot wide corridor centered on the Aucilla River main channel are classified as hydric. The Surrency, Plummer, and Cantey Frequently Flooded soils series are the most frequently occurring soil series, accounting for 12.7% of the corridor area (Table 12). The soils that comprise the series are characterized as fine sand and loamy sands that are frequently flooded. Accounting for 6.9% of the corridor, the Pamlico-Dorovan Mucks series represents the most widely distributed soil with high organic content.

About 76% of the 3,437 acres of soils categorized within a 2,000 foot wide corridor centered on the Wacissa River main channel are classified as hydric. The Nutall-Tooles Fine Sands soils series is the most frequently occurring soil series, accounting for 71.7% of the corridor area (Table 12). All three of the hydric soil series mapped within the Wacissa River corridor are characterized as fine sand; no muck soils are identified.

3.4 Riverine and Riparian Habitat

Riverine, or instream, habitats provide protective cover and sources of food within an aquatic environment used by many benthic macroinvertebrates, fish, and other aquatic wildlife. Benthic substrates in the rivers vary widely, ranging from fine grained muck sediments to generally sand, limestone shelves with pebbly gravel and exposed large rock, and bedrock. Aquatic vegetation varies widely depending upon river velocities, substrate, and water chemistry.

Within the Wacissa River where water clarity facilitates the dense growth of rooted aquatic plants, species such as spring tape grass (*Sagittaria kurziana*), tape grass (*Vallisneria americana*), and pondweed (*Potamogeton illinoensis*) are common, along with infestation by such invasives as *Hydrilla verticillata*. A substantial amount of wild rice (*Zizania aquatica*) borders the edge of the Wacissa River.

In the Upper Aucilla, patches of rooted or floating aquatic vegetation such as lily pads like *Nuphar lutea* and *Nymphaea odorata,* pickerelweed (*Pontederia cordata*), and duck potato (*Sagittaria lancifolia*) often dominate. Coastal plain willow (*Salix caroliniana*) was observed growing within portions of the Upper Aucilla, most notably in Sneads Smokehouse Lake.

Sneads Smokehouse Lake (Figure 46) is located within the Upper Aucilla. This lake is considered an important freshwater fisheries lake (FWC 2011b). According to a news release dated September 17, 2014, the FWC stated that:

> "The FWC's Aquatic Habitat Conservation and Restoration Section has been restoring Sneads Smokehouse Lake. An old, man-made earthen dam across part of the lake was removed in November 2013 to restore the natural water flow in both the lake and the Aucilla River. This measure is intended to create a healthier lake habitat supporting fish, waterfowl and other wildlife."

> "Building the new boat ramp at Sneads Smokehouse Lake is the final stage in giving people better access to a jewel of a lake in north Florida," said Michael Hill, the FWC fisheries biologist in charge of the lake-restoration project. "Before restoration, Sneads Smokehouse had become a lake clogged with several feet of muck on the bottom and too many plants on the surface. Most fish, especially ones fun to catch and eat like bass and bream, could no longer survive there because of low oxygen levels. But the healing of the lake and adjacent Aucilla River began as soon as we removed the dam."

From this news release and informal interviews with local fishermen on March 20-21, 2015, the main fish species of interest to anglers on this lake include: largemouth bass (*Micropterus salmoides*) and various species of sunfish such as redbreast sunfish (*Lepomis microlophus*), bluegill (*L. macrochirus*), and warmouth (*L. gulosus*).

In the faster flowing segments of the Middle Aucilla, rooted and submerged aquatic vegetation are sparse along the edges of the river channel. Small clumps of duck potato and pickerelweed were observed on March 20-21, 2015, at locations along the (submerged) shoreline where a small eddy or other shelter from the main channel velocity occurred. In similar fashion, pennywort (*Hydrocotyle* sp.) was observed in these same small areas and/or encircling submerged snags (Figure 49). Overall, aquatic and rooted vegetation were uncommon within the river channel and along the shoreline of the channel in the Middle Aucilla due to a combination of steep-sided shoreline, rapid current, and dark-colored water that limits light penetration.

In the Lower Aucilla, there is a wide variety of plants that occur along the shoreline and associated with snags, including all those listed above for the Upper and Middle Aucilla sections, as well as plants such as bulrush and sawgrass (previously described). And, near the mouth, those saltmarsh plants previously described are dominant (Figure 52).

Naturally occurring snags, characterized as large woody debris >10 cm in diameter and >2 m in length, are an important habitat component (Fischenich and Morrow 2000). Snags provide protection from strong currents and overhead cover for fishes, habitat for aquatic invertebrates, and basking sites for aquatic turtles. Snags can be an important source of particulate organic matter adding to primary productivity of a stream (Fischenich and Morrow 2000). Snags also play a role in defining channel morphology, by enhancing scouring and producing localized pools that provide fish holding cover.

Table 12. Predominant hydric soils within a 2,000-foot wide corridor centered on each river

Soil series with the Aucilla River corridor	Area (acres)	Relative portion within corridor
Surrency, Plummer, And Cantey Soils, Frequently Flooded	1664	12.7%
Plummer Fine Sand, Frequently Flooded	1138	8.7%
Pamlico-Dorovan Mucks	898	6.9%
Surrency Fine Sand	831	6.3%
Nutall-Tooles Fine Sands, Frequently Flooded	781	6.0%
Tooles-Nutall Complex, Frequently Flooded	350	2.7%
Wekiva-Tennille-Tooles Complex, Occasionally Flooded	258	2.0%
Nutall-Tooles Complex	177	1.4%
Bayvi Muck, Frequently Flooded	160	1.2%
Clara, Depressional-Clara-Meadowbrook Complex, Occasionally Flooded	138	1.1%
Plummer And Surrency Soils, Depressional	109	0.8%
Plummer Fine Sand	102	0.8%
Dorovan And Pamlico Soils, Depressional	78	0.6%
Clara And Bodiford Soils, Frequently Flooded	72	0.6%
Bayvi Muck	59	0.4%
Tooles, Meadowbrook, And Wekiva Soils, Frequently Flooded	48	0.4%
Tooles-Meadowbrook Complex	17	0.1%
Yellowjacket And Maurepas Mucks, Depressional	14	0.1%
Rains Fine Sandy Loam	12	0.1%
Tooles And Meadowbrook Soils, Depressional	4	0.03%
Soil Series Within The Wacissa River Corridor	**Area (Acres)**	**Relative Portion Within Corridor**
Nutall-Tooles Fine Sands, Frequently Flooded	2463	71.7%
Nutall-Tooles Complex	139	4.1%
Tooles-Nutall Complex, Frequently Flooded	12	0.4%

Inundated snags provide attachment substrate and a source of forage for many aquatic invertebrates. The length of time for larval development is quite variable. For example, many types of Northern Hemisphere mayfly nymphs hatch out to become adults in periods ranging from 4 to 24 months (Clifford 1982). In Florida, larval instars are developing almost continuously, and all species of mayflies emerge throughout the year except during short cold spells (Berner and Pescador 1988).

3.5 Estuarine Habitat

The FNAI describes estuarine habitat as "deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the ocean, with ocean-derived water at least occasionally diluted by freshwater runoff from the land. The upstream and landward limit is where ocean-derived salts measure less than 0.5 ppt during the period of average annual low flow." The seaward limit is an imaginary line closing the mouth of a river, bay, or sound; and includes the seaward limit of wetland emergents, shrubs, or trees when not included within the river, bay, sound (FWC 2011b). The estuary includes two primary subsystems. The subtidal subsystem includes the area below the lowest tide that is permanently flooded with tidal water. The intertidal subsystem includes the area between the highest tide level and the lowest tide level; and the substrate is periodically exposed and flooded by semidiurnal tides.

The FDEP determined the extent of the Aucilla River estuary for the purpose of establishing numeric nutrient criteria for estuaries for Florida (FDEP 2014). Using surface-water quality data, the FDEP depicted the estuary as extending about 3.3 miles from the Aucilla River mouth to about 1.5 miles downstream from US98 (Figure 6 and Figure 54). Using wetland habitat classification data, the USFWS indicates a somewhat smaller estuary with an upstream extent that is about 1 mile downstream from the FDEP endpoint (Figure 55) where palustrine forested wetlands adjacent to the river (PFO1/4C) are nontidal, seasonally flooded, and associated with salinity less than 0.5 ppt (USFWS 2015a).

The estuarine forested wetlands (E2FO3P) are intertidal and flooded irregularly by tidal water less often than daily. The estuarine emergent vegetation (E2EM1P) is intertidal and persistent with perennial species that normally remain standing until the beginning of the next growing season. This emergent habitat is also referred to as tidal marsh (or saltmarsh) in a resource characterization of Apalachee Bay, the eastern portion of which includes the mouth of the Aucilla River. Estuarine subtidal wetlands (E1ABL) are deepwater habitat dominated by plants that grow on or below the water surface for most of the growing season in most years.

The riparian habitat along the Aucilla River estuary is mostly tidal marsh with a short segment of estuarine forest in the upper estuary (Figure 55). The habitat is intertidal and develops along relatively low energy shorelines (Lewis et al. 2009). Limited quantitative information is available on the specific plant species found along the Aucilla River estuary. Tree species noted during the March 2015 field inspection include bald cypress (*Taxodium distichum*), cabbage palm (*Sabal palmetto*), and red cedar (*Juniperus virginiana*).

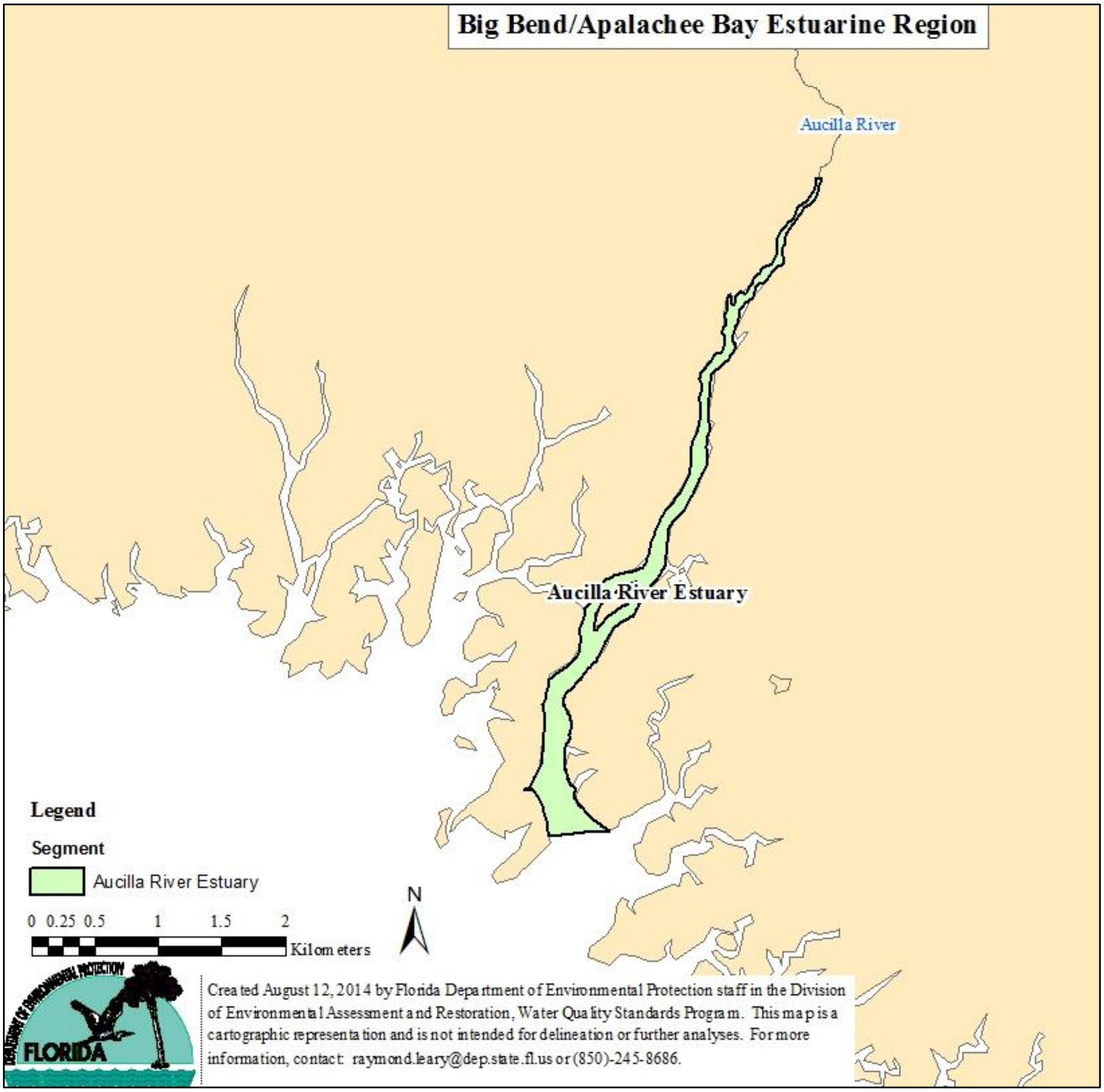


Figure 54. Extent of the Aucilla River estuary determined by the FDEP
[Source: FDEP 2014]

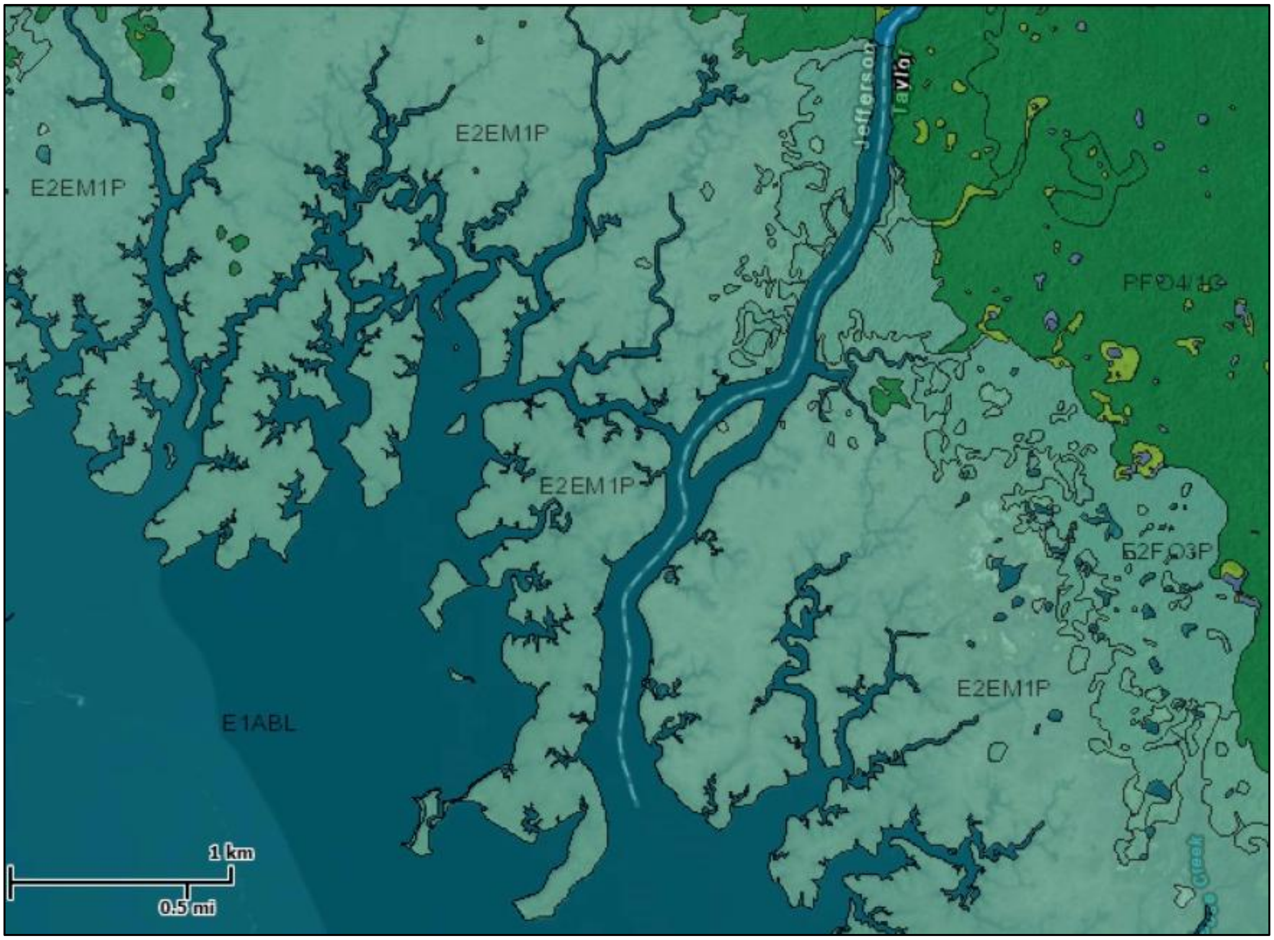


Figure 55. Wetland types in the vicinity of the Aucilla River estuary
[Source: USFWS 2015a; Classification codes denote nontidal palustrine forest (PFO4/1C), intertidal estuarine forest (E2FO3P), intertidal estuarine emergent (E2EM1P), and subtidal estuarine aquatic bed (E1ABL)]

Salt marshes in the Florida panhandle are usually characterized by large, fairly homogeneous expanses of dense black needlerush (*Juncus roemerianus*) that was observed during the March 2015 field inspection. Black needlerush is often accompanied on the water-ward side by smooth cord grass (*Spartina alterniflora*). The Juncus and Spartina zones are very distinctive and can be separated easily by elevation, with Spartina inhabiting the lower, regularly flooded zone, and Juncus found in the higher, less frequently flooded zone. Sawgrass (*Cladium jamaicense*) is a low-salt-tolerant species that is commonly found in the Big Bend region. A transition in the relative abundance of sawgrass and needlerush was documented in the upper reaches of the Suwannee River estuary, with the relative abundance of sawgrass diminishing from about 20 % at a maximum salinity of 6 ppt or less to non-existence at a maximum salinity greater than about 12 ppt (WRA et al. 2005).

Seagrass, a marine submerged aquatic vegetation (SAV), is the predominant plant that is characteristic of the nearshore area around the mouth of the Aucilla River. SAV beds support highly diverse and abundant floral and faunal communities and provide spawning, feeding, nursery and protective refugia for a wide array of aquatic organisms including many of recreational and commercial value (Lewis et al. 2009). Remote sensing technology has been used to map seagrass in the more downstream portion of the estuary and nearshore areas of the northern Big Bend region (Yarbro and Carlson 2011). Seagrass sampling during 2009 determined the following frequency of SAV and bare bottom occurrence in the monitoring locations in or near the Aucilla River estuary:

- Turtle grass (Thalassia testudinum) – ~47%
- Manatee grass (Syringodium filiforme) – ~46%
- Shoal grass (*Halodule wrightii*) and star grass (*Halophila engelmannii*) - ~11% each
- Widgeon grass (*Ruppia maritima*) - ~5%
- Bare bottom - ~35%

Detailed monitoring data for faunal communities within the estuary are not available. The dominant invertebrates and fishes found in portions of lower St. Marks River and Apalachee Bay are described by Lewis et al. (2009). Most are mobile and capable of relocating to more suitable habitat in response to changing environmental conditions. The eastern oyster (*Crassostrea virginica*) and Carolina marsh clam (*Polymesoda caroliniana*) are sessile benthic invertebrates. The oyster occurs in both intertidal and subtidal environments, whereas the Carolina marsh clam lives primarily in the intertidal zone. The oyster reefs mapped by the FWRI are located about 1 mile offshore from the mouth of the Aucilla River (Figure 56). The distribution of the Carolina marsh clam in the Aucilla River is not known, but District staff verified its occurrence in August 2015.

The salinity tolerances for the SAV, emergent plant, and benthic communities vary widely from 0 to more than 35 ppt (Table 13). A salinity intrusion associated with factors such as diminished freshwater flows and rising sea level is more likely to reduce the areal extent of habitat suitable to moderate- to low-salt tolerant species such as widgeon grass and tapegrass, than for the more tolerant species such as turtle grass and manatee grass. The shoreline length of less-salt tolerant plant species such as California bulrush and sawgrass would diminish, while the length associated with black needlerush would increase. Similarly, the available intertidal habitat for the Carolina marsh clam, characterized by the shoreline length, would also be expected to diminish. The areal extent of more salt-tolerant invertebrates like the eastern oyster and grass shrimp is less likely to be impacted.

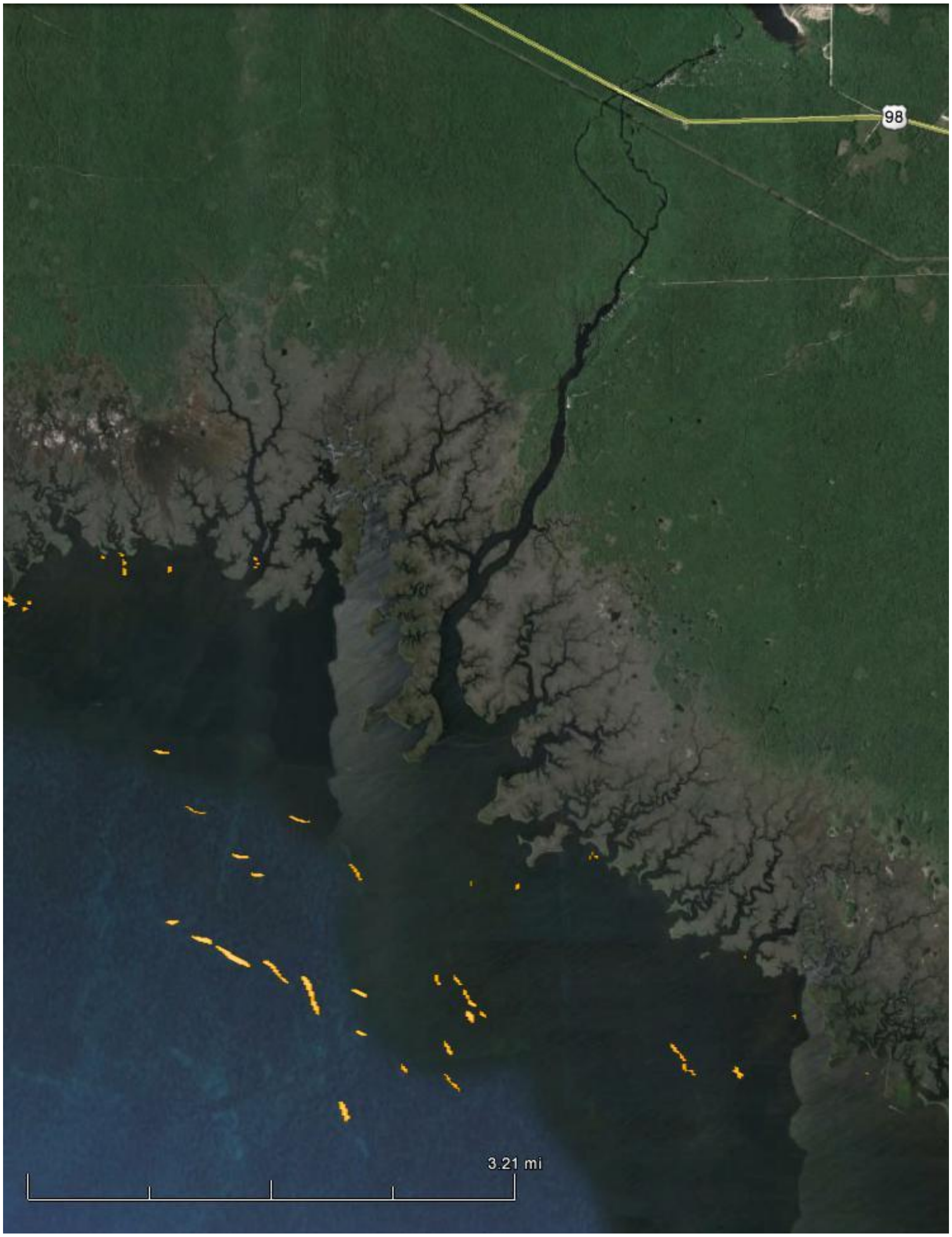


Figure 56. Oyster beds in the vicinity of the Aucilla River estuary
[Source: FWC/FWRI 2011]

Table 13. Representative salinity ranges for select species in the Aucilla river estuary, tributary tidal creeks, and nearshore vicinity

Common Name	Species	Wetland Type (Figure 55)	Salinity Tolerance	Salinity Range (ppt)	Reference
Trees					
Bald cypress	*Taxodium distichum*	Estuarine Forest	Low	0 – 4 (seedling)	WRA et al. (2005), Lewis et al. (2009)
Cabbage palm	*Sabal palmetto*	Estuarine Forest	Low	0 – 8 (seedling)	WRA et al. (2005), Lewis et al. (2009)
Red cedar	*Juniperus virginiana*	Estuarine Forest	Low to Mid-range	0 – 15 (seedling)	WRA et al. (2005)
Plants					
Black needlerush	*Juncus roemerianus*	Emergent Marsh	Mid-range	13.9 + 8.3 mean	Lewis et al. (2009)
California bulrush	*Schoenoplectus californicus*	Emergent Marsh	Low	<6 (ideal)	NRCS (2005)
Sawgrass	*Cladium jamaicense*	Emergent Marsh	Low	1-7	FDEP (2012), SRWMD (2005), Lewis et al. (2009)
Submerged Aquatic Vegetation					
Turtle grass	*Thalassia testudinum*	Aquatic Bed	High	24-35 (optimal)	FWC (2010), Lewis et al. (2009)
Manatee grass	Syringodium filiforme	Aquatic Bed	High	20-25 (optimal)	FWC (2010), SMS (2015)
Shoal grass	*Halodule wrightii*	Aquatic Bed	High	25-34 (abundant)	FWC (2010), Lewis et al. (2009)
Star grass	*Halophila engelmannii*	Aquatic Bed	High	Not evaluated	FWC (2010), SMS (2015)
Widgeon grass	*Ruppia maritima*	Aquatic Bed	Mid-range	10-20 (optimal); <28 to set seed	FWC (2010), Lewis et al. (2009)
Tapegrass (or eelgrass)	*Vallisneria americana*	Aquatic Bed	Low	0.2-3.3 (growth)	SRWMD (2005), Lewis et al. (2009), FFWCC (2005)
Invertebrates					
Eastern oyster	*Crassostrea virginica*	Aquatic Bed	Mid-range	16-22 (spat	Lewis et al. (2009)

Common Name	Species	Wetland Type (Figure 55)	Salinity Tolerance	Salinity Range (ppt)	Reference
				abundant)	
Carolina marsh clam	*Polymesoda caroliniana*	Aquatic Bed	Low	3-5 (optimal)	Cohen and Grizzle (2007), Montagna (2006)
Grass shrimp	*Palaemonetes pugio*	Aquatic Bed	Mid-range	20-25 (post-larvae optimal)	SRWMD (2005), Lewis et al. (2009)
Fishes	---	Aquatic Bed	Very broad ranges	0 – 30+ (eggs/larvae)	WRA et al. (2005), Lewis et al. (2009)

Detailed monitoring data are lacking that describe the nature and extent of the flora and fauna in the Aucilla River estuary and associated salinity regime. The estuarine WRV assessment for the Aucilla/Wacissa MFLs can be based on salinity regimes that prior assessments prepared by the District and others demonstrate are biologically relevant; examples of which follow.

Critical salinity regime	Evidence supporting critical salinity regime
<2 ppt	Jassby et al. (1995) used the 2 ppt isohaline as an indicator of overall ecosystem productivity in the Sacramento-San Joaquin estuary system; fish studies on the Lower Peace River (LPR) and Shell Creek (SC) showed that many freshwater fish and invertebrates have mean salinity of capture values of less than 2 ppt (SWFWMD 2010); analysis of fish community structure in the Lower Peace River reveals break points for distinct groups of these organisms at approximately, 2, 5, and 15 ppt; Clewell et al. (1999) and Clewell el al. (2002) described glycophytes as having low salinity tolerances with several species being most abundant where median yearly salinities are below 2 ppt; and the Lower Suwannee River MFLs was based on "average salinities of high tide waters flooding the swamps should be kept <2 ppt, with briefer periods of higher salinity tolerable (WRA et al. 2005).
<5 ppt	Oligohaline river habitats with salinities in the range less than 5 ppt have been disproportionately lost throughout the Gulf Coast (Beck et al. 2000), and that there is an opportunity to maintain such habitats in the LPR and SC given appropriate minimum flows for these systems; analysis of fish community structure in the LPR/SC reveals break points for groups of these organisms at approximately 2, 5, and 15 ppt; the Sulphur Springs MFLs (SWFWMD 2004) and Lower Hillsborough River MFLs reevaluation (SWFWMD 2006) had the goal of maintaining low salinity (<5 ppt) habitat in the Lower Hillsborough River; and close to the maximum 4 ppt that bald cypress seedlings exhibit significantly reduced physiologic responses and no recovery (WRA et al. 2005).
<15 ppt	Analysis of fish community structure in the LPR reveals transitions points for distinct groups of these organisms at approximately 2, 5, and 15 ppt; analysis of benthic community structure in the LPR and Myakka River also shows salinities of 15-18 ppt are important to maintain the integrity of a healthy mesohaline community type (SWFWMD 2011) ; and maximum salinity at

which red cedar seedlings become stressed (WRA et al. 2005).

The isohalines that are particularly relevant to an Aucilla River estuarine WRV assessment are:

- 0.5 ppt – technically distinguishes freshwater from brackish water and characterizes the upstream extent of the estuary as defined by FNAI/FWC;
- 2 ppt – represents the downstream limit of an average salinity zone suitable for glycophytes such as sawgrass;
- 5 ppt – represents the downstream limit of a salinity zone recommended for an estuarine WRV analysis (see below), the oligohaline zone (defined in the "Venice classification system"), and upstream limit for the transition of black needlerush (more salt tolerant) to sawgrass (less salt tolerant);
- 12 ppt – represents the downstream limit for the transition from sawgrass to black needlerush; and
- 15 ppt – represents a higher salinity transition point for the fish community structure and healthy benthic community structure in a healthy mesohaline community, and limit for seedlings of red cedar, a more salt-tolerant tree that exists along the estuary.

The recommended salinity range for an estuarine WRV assessment is 0.0 to 5 ppt. The areal extent of this range within the estuary is bounded on the upstream side by the physical geometry of the channel. Species known to exist within or along the estuary and adjacent tidal creeks include bald cypress, cabbage palm, red cedar, California bulrush, sawgrass, tapegrass, and Carolina marsh clam. In terms of geometric metrics for an estuarine WRV assessment:

- Bottom Area associated with average bottom salinity is appropriate for SAV such as tapegrass and sessile subtidal invertebrates such as oyster;
- Shoreline Length associated with average bottom salinity is appropriate for sessile intertidal invertebrates such as marsh clam, estuarine forest species such as bald cypress, and emergent plants such as bulrush; and
- Volume of depth-integrated average salinity is an appropriate metric, should it be necessary to evaluate fish or similarly mobile species.

3.6 Biota of Particular Interest

The FWC (2011b) considers the Aucilla River system to be one of the state's lesser known rivers. Best available data were used to describe the biotic species in the Aucilla and Wacissa Rivers and their habitats as they relate to potential reductions in flow regimes. Various taxonomic lists of invertebrates, vertebrates, and plants were reviewed to identify species dependent on the river's aquatic habitats and wetlands that could be affected by changes (reductions) in river flows. Extensive species lists may be found in: FWC (2004), Lenz (2006), the FNAI Tracking List

Database (FNAI 2010), and USFWS website pertaining to the St. Marks National Wildlife Refuge (USFWS 2015b).

Threatened and endangered (T&E) species are listed by the U.S. Fish and Wildlife Service and by the Florida Fish and Wildlife Conservation Commission (FWC 2011a and 2013) in the three-county Aucilla-Wacissa area. Species without a formal listing status were also reviewed (FNAI 2015a, FNAI 2015b, FNAI 2015c).

HSW developed a preliminary list of species of interest (Table 2). More than 20 species of animals and plants are assigned by the Florida Natural Areas Inventory or noted by Lenz (2006) as rare, imperiled or critically imperiled. Based on additional literature review and a March 2015 on-site field investigation, the list was revised to identify species of interest deemed more likely to be at risk from freshwater flow reductions (Table 14). Included within Table 14 are species of recreational and/or commercial importance such as the Suwannee bass and the blackbanded sunfish (*Enneacanthus chaetodon*) a Georgia designated endangered species (GADNR 2014) that is the subject of research concerning its population status in Florida.

The following descriptions focus on those species which are expected to be most sensitive to reductions in freshwater flows, based upon a combination of their specific habitat requirements, their ranking within Florida as indicated by one or more of the following: Federally listed as Endangered (E) or Threatened (T), State listed as either E, T or Species of Special Concern (SSC), or FNAI Tracking List designation of "S1" (critically imperiled) and their importance as a recreational resource.

Table 14. Species deemed likely "at risk" from flow and water-level reductions [State rank designated as Species of Special Concern (SSC), State Threatened (ST), Critically Imperiled (S1), Imperiled (S2), Very rare and local throughout its range (S3); Federal rank designated by Threatened (T), Proposed Threatened (PT), and Endangered (E)]

Species	Common Name	Florida State Rank	Federal Rank
Birds			
Aramus guarauna	Limpkin	SSC	---
Egretta caerulea	Little blue heron	SSC	---
Egretta thula	Snowy egret	SSC	---
Egretta tricolor	Tricolored heron	SSC	---
Eudocimus albus	White ibis	SSC	---

Species	Common Name	Florida State Rank	Federal Rank
Mycteria americana	Wood stork	S2	T
Bivalves			
Medionidus walkeri	Suwannee moccasinshell [2]	S1	PT
Decapods			
Procambarus horsti	Big Blue Spring Cave crayfish [3]	S1	---
Fish			
Enneacanthus chaetodon	Blackbanded sunfish	S3	---
Micropterus notius	Suwannee bass [4]	S3	---
Isopods			
Remasellus parvus	Swimming Little Florida Cave isopod [3]	S1 S2	---
Mayflies			
Asioplax dolani	A Mayfly	S1 S2	---
Odonates			
Macromia alleghaniensis	Allegheny River Cruiser	S1	---
Nannothemis bella	Elfin skimmer	S1 S2	---
Neurocordulia molesta	Smoky shadowfly	S1	---
Plants			
Eleocharis rostella	Beaked spikerush [1]	S1	---

Species	Common Name	Florida State Rank	Federal Rank

1. Also listed as LE: Endangered species, subspecies, or isolated population so few or depleted in number or so restricted in range that it is in imminent danger of extinction.
2. Also listed as G1: Critically imperiled globally because of extreme rarity (five or fewer occurrences or fewer than 1,000 individuals) or because of extreme vulnerability.

S1: Critically imperiled in Florida because of extreme rarity (five or fewer occurrences or fewer than 1,000 individuals) or because of extreme vulnerability to extinction due to some natural or man-made factor.
S2: Imperiled in Florida because of rarity (six to 20 occurrences or fewer than 3,000 individuals) or because of vulnerability to extinction due to some natural or man-made factor.
S3: Either very rare and local throughout its range (21-100 occurrences or fewer than 10,000 individuals) or found locally in a restricted range or vulnerable to extinction from other factors.
PT: Proposed threatened (Federal Register Vol. 80 (No. 193): 60335-60438).
Source: FWC 2015a, FNAI 2010, FNAI 2015a, FNAI 2015b, FNAI 2015c, Lenz 2006

3. Lives in aquatic caves.
4. Species important for recreational sport fishing.

3.6.1 Aquatic Macroinvertebrates

Existing data on macroinvertebrate species within the Aucilla and Wacissa Rivers are sparse, and additional sampling was not conducted for the MFLs assessment. Overall, the limited information indicates that caddisflies and chironomids likely dominate much of the Aucilla and Wacissa River ecosystems, with mayflies likely present in the faster flowing riffle and shoal areas. Habitat availability for selected groups of invertebrates under a range of flow conditions such as mayflies (Ephemeroptera), which often require water velocity and substantial dissolved oxygen and non-silt substrate, could be evaluated indirectly using hydraulic modeling.

The Big Blue Spring Cave crayfish is "listed" in the FNAI Tracking List as critically imperiled (category "S1") within Florida. This species, if present, will be subterranean, located within one of more of the sink-rise systems within the Middle Aucilla, or within the spring cave systems in the Wacissa River. Similar to the cave crayfish, the Swimming Little Florida Cave isopod (*Remasellus parvus*) is "listed" in the FNAI Tracking List as critically imperiled (S1). The susceptibility of these two species will not be evaluated quantitatively due to the paucity of information regarding habitat requirements and the unknown groundwater-surface interactions.

The A Mayfly (*Asioplax dolani*) and odonates Elfin skimmer (*Nannothemis bella*), Allegheny River Cruiser (*Macromia alleghaniensis*), and Smoky shadowfly (*Neurocordulia molesta*) are insects that inhabit freshwater streams and ponds and could possibly be affected by a reduction in flows. Their life stages and feeding patterns are such that the protection of Ephemeroptera, Plecoptera, and Trichoptera (EPT) is presumed would be protective of these four insects.

3.6.2 Freshwater Mussels

Mussels are long-lived (30-70 years for some species) bivalve mollusks that occur commonly in river ecosystems. The group is currently of high conservation interest with apparently declining but generally unknown population status in much of their range. About 30 species have been collected in the Suwannee River region (Williams et al. 2010, Slapcinsky 2012). Of these, the Suwannee moccasinshell, is listed as a species of high conservation concern in the three county study area, although its distribution and abundance are not well documented. Its federal status was elevated recently to Proposed Threatened (Table 14). The larvae (*Glochidia*) of mussels are parasitic, living typically on the gills or fins of a host fish, although the host fishes are not completely known for most species (Watters 1994). Because listed mussels or mussel species proposed for listing may occur more widely in the Aucilla and Wacissa Rivers than presently known, host fish such as the blackbanded darter (*Percina nigrofasciata*) may be used as surrogates for the possible occurrence of mussels. For example, selected host fish were modeled for a biological assessment of the Suwannee River (Warren and Nagid 2008).

3.6.3 Fish

There are no fish species listed as E, T, SSC, or S1 for the Aucilla or Wacissa Rivers. However, fish species, such as Suwannee bass (*Micropterus notius*), largemouth bass, multiple sunfish species (*Lepomis* spp.), and chain pickerel (*Esox niger*), are known as being important for recreational sports fishing in either or both rivers. Other fish species fill a trophic level as forage species or serve as possible hosts for larval mussels (e.g. brownbanded or blackbanded darter [*Etheostoma edwini and Percina nigrofasciata*, respectively]). Most of these fish species are habitat generalists. Of these, the Suwannee bass is known to prefer fast-flowing water with shoals and occurs in the Aucilla-Wacissa system (FWC 2015b).

3.6.4 Birds

The wood stork (*Mycteria americana*) is classified as endangered by both the Federal and State governments. The stork prefers to feed in very shallow water area of fine silt (mud), as are found in the Upper Aucilla, a small part of the Lower Aucilla, and along the Wacissa River.

The five other wading bird species listed as SSC's by the State of Florida (Table 14) are dependent upon wetland/river/stream/lake systems for their food and upon shoreline woody vegetation for their nesting/reproductive activities. All five are expected to be potentially affected by reductions in flows and levels within the Aucilla-Wacissa system in much the same manner as the wood stork could be affected. Little blue heron may be vulnerable to flow reductions since they rely on freshwater forage sites to raise young, until they become more tolerant of high salt content prey (FWC 2013).

3.6.5 Plants

The beaked spikerush (*Eleocharis rostellata*) is an important plant that could possibly be affected by a reduction in flows. This species is widely distributed around the United States, but unusual in Florida. USF's Atlas of Florida Vascular Plants lists it as Endangered within the State (Weaver and Anderson 2010). It is a moderately salt-tolerant, obligate wetland plant that is known to occur along the shoreline of salt (*Oligohaline*) marshes and alkaline waters. The Oligohaline regime is characterized by salinity ranging from 0.5 to 5 ppt, and reductions in freshwater flow may cause an increase in salinity and reduce the size of the Oligohaline marshes that are protective of beaked spikerush.

3.6.6 Floodplain Vegetation and Soils

Best available digital information was used to determine preliminary estimates of distribution and extent of floodplain vegetation communities and hydric soils. The FWC/FNAI land cover (CLC) and SSURGO soils shapefiles were superimposed on a shapefile of hydrography. A 2,000-foot wide corridor centered on each river was created using ArcGIS to approximate the floodplain, and the areas of land cover and soil types coincident with a river corridor were tabulated for each river.

Within the Aucilla River corridor, Mixed Wetland Hardwoods, Bottomland Forest (a sub-category of Mixed Wetland Hardwoods), Floodplain Swamp, Cypress, and Hydric Hammock combined to comprise about 50% of the corridor area. About 53% of the 13,095 acres of the soils categorized within the corridor centered on the Aucilla River main channel are classified as hydric. The fine sands of the Surrency, Plummer, and Cantey soils series are the most widespread hydric soil series, and the Pamlico-Dorovan Mucks series represents the most widely distributed soils with high organic content.

Within the Wacissa River corridor, Hydric Hammock was the predominant palustrine wetland and comprised just over 60% of the 3,437 acre corridor area. All three of the hydric soil series mapped within the Wacissa River corridor are characterized as fine sand; no muck soils were identified.

In the Upper Aucilla, hydric soils nearest the ill-defined channel are inundated regularly by the river swamp system. In the Middle Aucilla, floodplain hydric soils in swales nearest the channel are inundated semi-regularly; however, the inundation frequency diminishes quickly further from the river, and depressional wetlands in the broad floodplain are flooded rarely by the river; instead, these areas appear to be maintained generally by precipitation and drainage from the surrounding watershed. The narrow range of water level fluctuations along the Wacissa River limits the "flooding" of the adjacent wetlands. Although the floodplain wetland communities are not frequently flooded, their soil saturation is maintained by a near-static river elevation and water table that are close to land surface.

Observations made during a site-specific field work was conducted between March 20 and 22, 2015 on both rivers indicate that available land cover classification products are reasonably accurate indicators of vegetation type and wetland extent in the area. The CLC and SSURGO polygons mapped by others showed overall agreement with ground observations of land cover during the field survey at the majority of the roughly 20 locations visited. Overall, the coverages appear suitable for a MFLs assessment at the regional scale.

In the Aucilla Sinks part of the study area, depressed karst solution features became increasingly abundant in the landscape. Most of these features are observable on the LIDAR topography but are not mapped individually within the NWI, SSURGO, and FLUCCS coverages.

3.7 Biological Water Resource Value Indicators

Based on the District's experience with species used for other rivers, the species occurring in the Aucilla and Wacissa River ecosystems and review of listed species and those of high recreation/conservation interest, the individual species, guilds, and vegetative communities shown in Table 15 are proposed to be used within the subsequent MFLs analyses for the Aucilla and Wacissa systems. These selected organisms have water depth, velocity, and substrate requirements for their life stages that could be translated into relevant hydrologic indicators related to flow variation.

The MFLs technical assessment relies on metrics for biological integrity or habitat suitability that can be related to flow. Physical habitat modeling performed using the SEFA software that relies upon field surveys of channel characteristics and hydraulics. An essential input to the habitat models are the habitat suitability curves that associate a qualitative rating of habitat suitability with stream velocity, water depth, and inundated channel substrate.

Table 15. Relevant biotic indicators for the Aucilla and Wacissa Rivers

River Section	Species / Guild / FCLC	Relevance
Upper Aucilla	Largemouth bass	Apex predator. Important game fish. Large fish suitable for evaluating the passage of important game fish. Serves to protect open water at Snead' Smokehouse Lake.
	Floodplain Swamp / Cypress	Dominant CLC cover type. Important for listed wading birds and amphibians.
Middle Aucilla	Suwannee bass	Requires fast flows and shoals. Important game fish with limited distribution. Serves to protect hard rock and gravel bottom habitats that are limited in Florida rivers. Large fish suitable for evaluating the passage of important game fish. Occurrence reported by Lenz (2006).
	Mayflies	Important food source for game fish. Requires flows

River Section	Species / Guild / FCLC	Relevance
		and dissolved oxygen. Serves same protective function as Suwannee bass.
Lower Aucilla	Oligohaline zone	5ppt estimated location within estuary important to maintain for CLC types. Serves to protect the beaked spikerush, if present.
	Wood stork	State and federally listed wading bird. Freshwater colony sites must remain inundated throughout the nesting cycle to protect against predation and abandonment. See USFWS (1997 and 2011).
Wacissa River	Largemouth bass	See Upper Aucilla.
	Suwannee bass	Requires fast flows and shoals. Important game fish with limited distribution. Serves to protect hard rock and gravel bottom habitats that are limited in Florida rivers. See FWC (2015b).
	Hydric hammock	Will protect this dominant community type and the wading birds and amphibians.
	Spring-run stream	Will protect aquatic cave organisms.

For the Upper Aucilla, where river flows are slow under all but the highest of high flows, it is actually the water level and associated inundation area and depth that are the most important. There are no sandy or rocky substrates to be protected by ensuring adequate water velocities. Adequate water depths need to be maintained to protect the open water depths (hence the recreational fishery) at Sneads Smokehouse Lake. Adequate durations of inundation need to maintained to protect the dominant wetland community types along the shoreline, and to maintain the shallow near-shore environment for the use by listed wading birds for feeding purposes.

In contrast to the Upper Aucilla, the flow depth and velocity associated within the Middle Aucilla section are important to preserve. The rocky bottom, coarse sand, and shoal habitats that are unusual in many Florida streams support species such as the Suwannee bass and mayflies that are the more sensitive biotic features in this stretch of river.

In the Lower Aucilla, the freshwater discharged from the deep aquifer that supplies the Wacissa River, and likely parts of the Aucilla around the Aucilla Sinks area, is essential to maintaining a zone of oligohaline habitat downstream of Wards Island.

The Wacissa River is a valued recreational fishery that contains species that prefer a certain amount of rocky bottom and shoals (e.g. Suwannee bass) as well as those species that are more general in their habitat requirements. It is also an important area for multiple listed species of wading birds for which specific water depths are required to support foraging. Anecdotal information and personal observations indicate that all six wading bird species listed in Table 14 utilize the Wacissa River. Protecting the oligohaline habitat in the Aucilla estuary will help to protect the "Spring-fed Stream" community type and associated aquatic cave-dwelling organisms.

4 Approach to Setting MFLs

Based on the WRV screening presented in Section 1, Recreation, Fish/Wildlife Habitat and Fish Passage, and Estuarine Resources are important values associated with the Aucilla and Wacissa Rivers and can be expected to be impacted to some degree by a reduction in freshwater flow. The rivers are each classified as Outstanding Florida Waters, consequently Aesthetic/Scenic Attributes and Water Quality were also ranked as highly relevant WRVs. Based on screening criteria and the availability of information relating flow to the water resource values, further analyses will be performed to evaluate potential impacts associated with flow reductions on WRVs 1, 2, and 3. However, because potential impacts across a wide range of flows will be evaluated, and a consistent method is used to define allowable flow reductions, it is reasonable that other WRVs that might be impacted by flow reductions also will be afforded some level of protection.

The results of the background literature review, limited field investigation, and hydrologic analyses have been presented in previous sections of this report. WYs 1951 through 2014 were identified as baseline water years for the Aucilla River and the various modeling efforts included data representing this time period. When developing MFLs from a baseline condition, it is assumed that the baseline 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. In some cases, sufficient data are available to identify flow characteristics (e.g., a flow of specific magnitude and duration) that are protective of a WRV with some level of confidence.

The overall approach for setting MFLs is characterized as a weight-of-evidence approach that begins with identifying specific water resource values particularly relevant to the river (Section 1), makes use of hydrologic (Section 2) and biologic (Section 3) data analyses, and ends with a systematic analysis of possible flow reductions that would remain protective of the WRVs (Section 5). The technical approaches make use of various modeling efforts presented in Sections 2 and 3, and, later in this section. A discussion of appropriate response functions that relate flow metrics (e.g., flow, stage, velocity) to response variables (e.g., wetted perimeter, water depth, and area of inundation) is presented in this section.

4.1 Indicators and Response Functions

The WRV indicators are a collection of human activities, hydrogeomorphic processes, flora and fauna that are characteristic of the AWSS, examples of which are presented in Table 16. The WRV indicator metrics are surrogate measures of water resource values that are relatable, directly or indirectly, to flow. A metric can be associated with a discrete location such as known spawning beds for a species of special interest or an accumulation along the length of the AWSS. The association between flow (or stage or velocity) and a WRV metric is referred to as a response function.

WRV metrics can be expressed in terms of time, distance, area, or other meaningful characteristics. For example, kayakers and other recreational users of the river are more likely to relate to a flow reduction and the associated change in the probability, on a day-to-day basis, that they might expect easy paddling or boating conditions than they would to a change in navigable distance that a flow reduction might cause. Likewise, the natural life cycle of a certain fish species may require some minimum hydrologic condition sufficient for spawning that must be maintained frequently enough and for a sufficient duration to sustain the population.

The selection of WRV indicators, metrics and associated response functions for the AWSS MFLs assessment was based on available literature, consultations with District staff and scientific experts and other peers with site-specific knowledge of the river, and data developed from this study.

Two characteristics of the river that must be determined to evaluate the passage of small vessels and fish are the geometry of the river bottom along the reach of interest and the relationship between river flow and water-surface elevation, referred to as a stage-flow rating. The rating is a response function that is frequently used to evaluate recreational navigation and fish passage.

Habitat is the specific place or natural conditions in which a plant or animal normally lives. For MFLs assessment, it is useful to evaluate habitat within a river reach over a range of hydrologic conditions. Submerged, aquatic habitat is of primary interest for the low- to medium-flow conditions; whereas intermittently inundated or saturated wetlands and marshes in the floodplain are the focus during high-flow conditions.

The wood stork and limpkin inhabit freshwater and estuarine wetlands and are species of special merit to the Aucilla system. They nest primarily in cypress or mangrove swamps, and they feed in freshwater marshes, narrow tidal creeks, or flooded tidal pools. Particularly attractive feeding sites are depressions in marshes or swamps where fish become concentrated during periods of falling water levels. Stage-flow relations and the geometry of the channel and floodplain are needed to evaluate habitat relevant to theses wading birds.

Small fish from 1 to 6 inches long, such as topminnows and sunfish, provide the primary diet for wood storks and other wading birds. Sunfish and larger game fish, such as largemouth and Suwannee bass, are sought frequently by freshwater fishing enthusiasts. Water depth and velocity and the type of channel substrate are environmental variables that characterize the suitability of a particular location as habitat for fish and other aquatic organisms. The response

Table 16. Examples of Indicators, Response Functions, and MFLs Assessment Metrics for WRVs

Indicator	Relevance	Response Function	Metric	Key Source
Recreation				
River access and use	Many recreational activities involve boat access to and activates on the river.	Relationship between freshwater flow and river depth	Relative amount of time that paddling is viable due to low water conditions (i.e., stage<48 ft at Lamont)	Florida Designated Paddling Trails Guide, Aucilla River (FDEP 2013a)
Fish Passage , Fish and Wildlife Habitat				
General fish assemblage	Fish Passage	Length-integrated depth-flow curve	Flow associated with a 15% reduction in the critical proportion of river (inflection point) associated with a depth < 0.8 feet over 25% of channel bed width	Target species such as largemouth bass for Upper Aucilla and Wacissa (FWC 2015c) and Suwannee bass for Middle Aucilla and Wacissa (FWC 2015b)
General fish assemblage	Fish habitat	Length-integrated depth-velocity-flow curve	Flow associated with a 15% reduction in the critical proportion of river (inflection point) with hydraulic depth and velocity suitable for target species	Habitat Suitability Curves for target species such as largemouth bass, J. Gore (personal communication), FWC 2015c
Primary consumers	Mayfly (important food source for game fish)	Length-integrated depth-velocity-flow curve	Flow associated with a 15% reduction in the critical proportion of river (inflection point) with suitable hydraulic depth and velocity	Habitat Suitability Curves for Ephemeroptera (Middle Aucilla and Wacissa), J. Gore (personal communication), Berner and Pescador 1988
Wildlife habitat – wading bird	Wood stork and limpkin (listed species)	Length-integrated instream inundation area-flow curve	Flow associated with a 15% reduction in the instream critical area (inflection point)	Bryan 2002, Coulter et al. 1999, USFWS 1997
Woody habitat (roots and snags)	Invertebrate cover and larval substrate, fish spawning and refugia	Stage-inundation area curve	Relative amount of time (or area) that critical inundation area (inflection point) associated with large and fibrous roots and snags are inundated	Fischenich and Morrow 2000; Clifford 1982; Berner and Pescador 1988
Floodplain forest wetlands	Maintain wetland systems; represses succession	Forest stage-inundation area curve	Flow associated with a 15% reduction in floodplain habitat area.	Cowardin et al. 1979, Light et al. 2002

Indicator	Relevance	Response Function	Metric	Key Source
Floodplain forest wetlands	Maintain wetland systems; represses succession	Forest stage-inundation area curve	Frequency of 14-day event during which Floodplain habitat is inundated	Cowardin et al. 1979, Light et al. 2002
Estuarine Resources				
Tidal marsh flora	Beaked spikerush (listed species)	Relationship between freshwater flow, salinity and shoreline isohaline locations	Relative change in shoreline length of oligohaline (i.e., 0.5 to 5 ppt) conditions	DCR 2013
Tidal marsh flora in Aucilla Estuary	Beaked spikerush (listed species)	Proportion of Wacissa to combined Wacissa/ Aucilla flow curve (i.e., Reach Method)	Limiting freshwater flow (at the Lamont gage) determined for the Aucilla estuarine resources WRV	Good and Mattson 2004

functions needed to evaluate fish habitat are the relationships between freshwater flow and the combination of depth, water velocity, and inundated substrate type. Substrate includes not only inorganic media such as sand, gravel, and muck but also organic media such as submerged aquatic vegetation and woody material (e.g., snags and exposed roots).

Salinity is a measure of the dissolved salt content of water. It influences the types of organisms that live in a body of water and is an ecological factor of considerable importance to the beaked spikerush (*Eleocharis rostella*) Florida-listed plant species of special concern. Water can be classified by ranges of salinity. For example, the salinity of freshwater is usually less than 0.5 parts per thousand (ppt), and brackish marine water characteristic of the Aucilla River Estuary can be classified as oligohaline (0.5 to 5 ppt), mesohaline (5 to 18 ppt), and polyhaline (5 to 30 ppt). The oligohaline regime is of particular interest because beaked spikerush is tolerant of that particular salinity range. An important response function for evaluating estuary resources is the relationship between freshwater flow and salinity.

Summary of needed response functions:

- Stage-flow rating is a response function that is frequently used to evaluate recreation in/ on water and fish passage.
- The response functions needed to evaluate fish habitat are the relationships between freshwater flow and the combination of depth, water velocity, and inundated substrate

type. Field observations of substrate in the AWSS are limited, and it is assumed that the existence of a species of interest in the AWSS confirms the availability of a suitable substrate.

- An important response function for evaluating estuarine resources is the relationship between freshwater flow and salinity and the shoreline length of relevant salinity regimes such as the oligohaline.

4.2 Modeling

Statistical methods and numerical models are frequently used to develop response functions for MFLs assessments. Empirical data are needed for both approaches to ensure that the response functions are characteristic of the target water body. MFLs may be calculated using the best information available pursuant to Section 373.042, F.S. Best available data are considered “best” and potentially useful if the data can be associated reliably with a sampling plan that prescribes the monitoring location, collection date/time, and field procedure.

Site-specific response functions can be developed using data collected from fixed-station monitoring performed at prescribed locations. Multiple sites may be needed to adequately characterize the Aucilla River because the MFLs assessment may need to address both freshwater and estuarine resources.

Numerical and GIS models can be used to develop regional response functions, i.e. relationships between freshwater flow and a WRV metric representing an area along the length of the target water body. In such cases, empirical data are needed to calibrate the model or to characterize the spatial distribution of a WRV metric such as a floodplain wetland forest type. The data may be collected using synoptic and fixed-station field surveys or remote sensing technology.

The response functions were developed from existing databases and by post-processing river hydraulic characteristics calculated using the steady state HEC-RAS model developed for the AWSS MFLs assessment.

4.2.1 HEC-RAS Modeling

HEC-RAS models for the Aucilla and Wacissa Rivers (Section 2.7.4.2) were used to calculate steady flow profiles for 12 flow regimes ranging from 1 to 95 percent flow-exceedance frequencies. Model output was processed to characterize associations among hydraulic characteristics such as flow, water-surface elevation, depths, top width, wetted perimeter, and velocity at cross-sections. Low flow scenarios then were used to analyze environmental values associated with low flow conditions, such as recreation, fish passage, and wildlife habitat. Medium flow scenarios were used to evaluate woody habitat, and bankfull and higher flow scenarios were used to evaluate floodplain habitat.

4.2.2 EFDC Modeling

The computer programs EFDC (Environmental Fluid Dynamics Code) and ADCIRC (Advance Circulation) are coastal hydrodynamic models that can be used to calculate the water surface, depth, and velocity distributions in water with varying density (Tetra Tech 2007; Westerink 2000). EFDC is a general-purpose, public domain, modeling package that simulates three-dimensional flow, transport, and biogeochemical processes in rivers, lakes, estuaries, reservoirs, wetlands, and near-shore to shelf-scale coastal regions. It is capable of simulating temperature, salinity, sediment transport, flow dilution, transport and fate of toxic contaminants, and the dissolved oxygen/nutrient process (Ji 2008).

Primary inputs to EFDC for a hydrodynamic application are channel/estuary geometry, bottom roughness coefficient, and boundary conditions for stage and flow. When used to simulate estuaries, boundary conditions are also prescribed for water temperature and salinity. The primary model output of interest includes water-surface elevation, depth, water velocity, shear stress, flow area and for estuarine applications, water temperature, and salinity.

The Big Bend estuary hydrodynamic and water quality model has been used by the FDEP to support rule making for establishing numeric nutrient criteria. The EFDC model extends from Apalachicola in the west to Clearwater Harbor to the east and extends into the Gulf of Mexico for more than 20 miles (FDEP 2013b). Calculated water depths range from 30 meters along the offshore boundary to 1.5 meters in the embayments. The model consists of 3,995 horizontal cells, and 4 equally spaced vertical layers. The Aucilla River estuary segment designated by the FDEP for the development of numeric nutrient criteria (Figure 57 and Figure 54) is not represented currently in the Big Bend EFDC model (FDEP 2014), however the Big Bend model is still useful for evaluating boundary conditions for an Aucilla Estuary model.

An EFDC model was developed to simulate the change in salinity regimes in the estuary due to flow reduction (Appendix A). Flow data collected at Aucilla ADVM (Q_{ADVM}) from February 2, 2015, to June 8, 2015, were used to identify an association with flow data at the Lamont gage (Q_{Lamont}) using regression analysis (Appendix F). The association is given by

$$Q_{ADVM} = 557 + (1.4579\ Q_{Lamont}) \qquad (6)$$

Flow statistics for the Lamont gage (i.e., mean, median, and standard deviation) for successive two year time periods were compared to the POR flow statistics. The flow record for the period of WYs 1995-1996 was found to be most similar (Figure 58). Calculated flows at Aucilla ADVM gage for WYs 1995-1996 were selected for input into the EFDC model. The POR flows tend to be more extreme at low and high flows, which is expected when comparing the flow record over a short time period to that of a long time period.

The EFDC model was run for the baseline condition and for 5%, 10%, 15%, and 30% reductions in freshwater flow. An additional model run simulated the effects of a sea level rise of 5.1 inches, which is an estimate of the potential sea level rise for 2035. The results of this model run can be found in Appendix E.

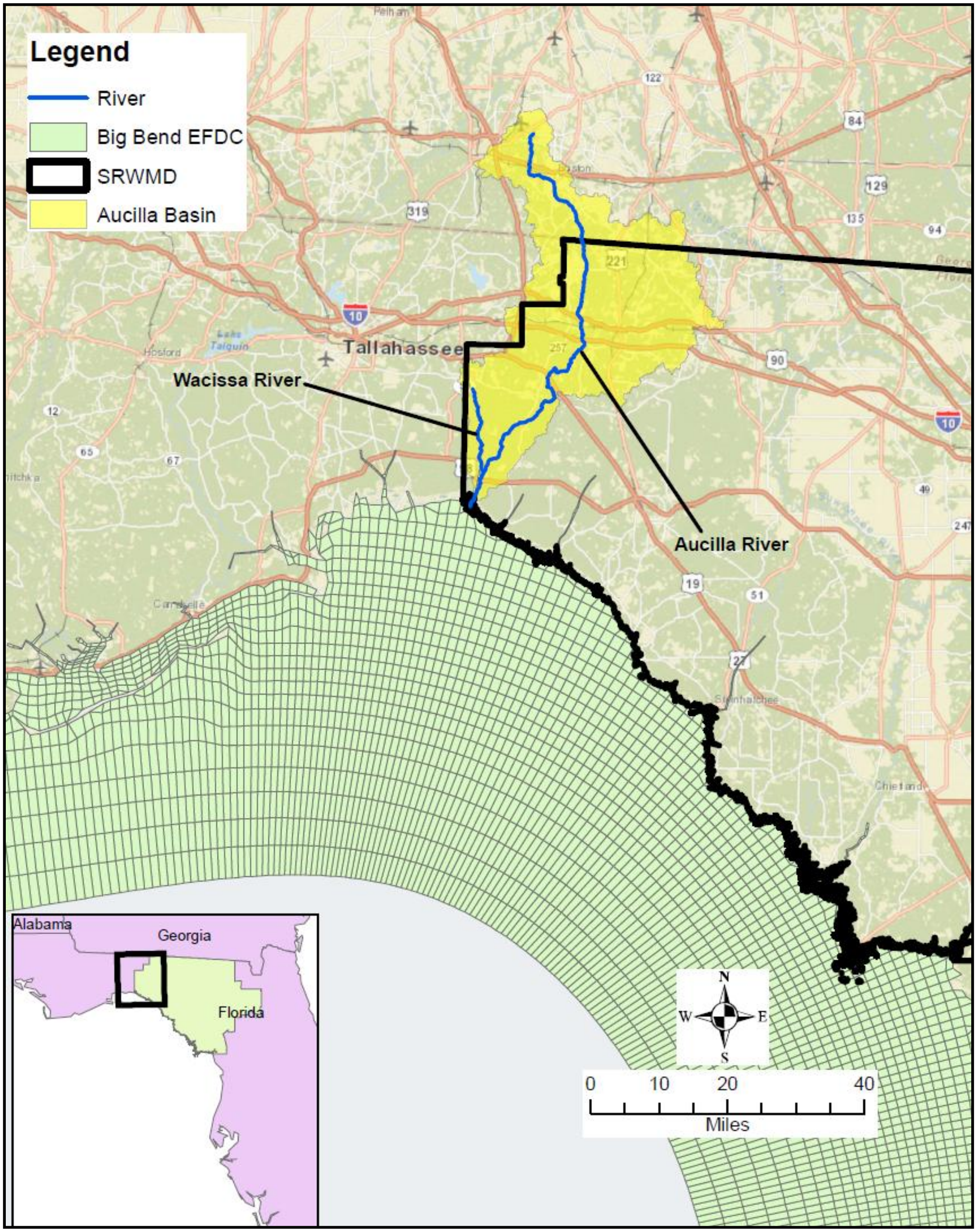
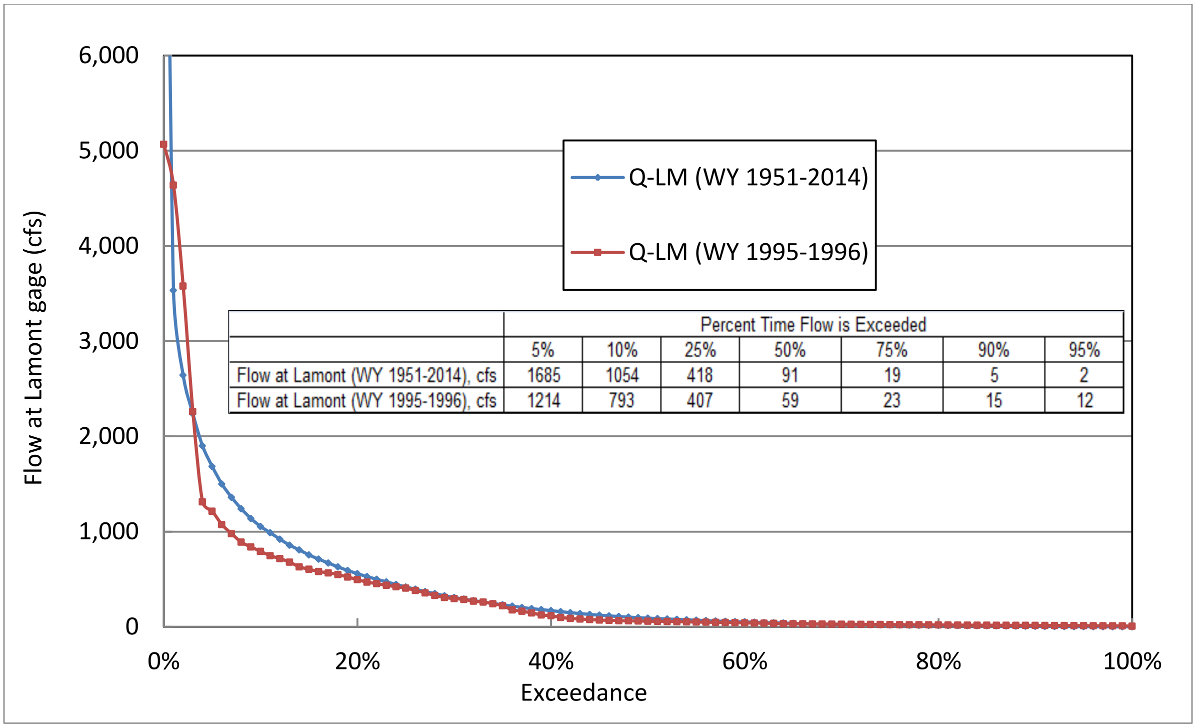


Figure 57. Extent of the Big Bend EFDC model in the vicinity of Aucilla River



	Percent Time Flow is Exceeded						
	5%	10%	25%	50%	75%	90%	95%
Flow at Lamont (WY 1951-2014), cfs	1685	1054	418	91	19	5	2
Flow at Lamont (WY 1995-1996), cfs	1214	793	407	59	23	15	12

Figure 58. Comparison of flow duration curve at Lamont gage for WYs 1995-1996 and WYs 1951-2014

4.3 MFLs Assessment Methods

Water resource and human use values have been identified that are collectively protected if a broad range of flows is maintained. The approach used for setting MFLs makes use of several methods for estimating allowable flow reductions that are discussed in this section.

The guiding premise is that high flow occurrences are not decreased too much and low flow occurrences are not increased too much such that significant harm occurs. Different approaches have been used by Florida's water management districts to meet these objectives. Explicit in this premise is an allowable change in time that a particular flow rate is exceeded (Munson and Delfino 2007). Implicit in this premise is a change in area that is inundated for a fixed amount of time (e.g., Instream Flow Incremental Methodology (IFIM)). A third consideration is the frequency and duration (number of consecutive days) that a particular flow is exceeded (or not exceeded), or an event-based approach (Neubauer et al. 2008). Regardless of the approach used, the result of the analyses is a set of threshold hydrologic conditions that differs from the baseline condition by an amount such that the resource values are protected. Therefore, the MFLs is established such that this set of threshold hydrologic conditions is met.

The event-based approach utilized to evaluate the protection of the WRVs and setting MFLs (Neubauer et al. 2008) comes under the general heading of frequency analysis, whereby statistics of long-term hydrology such as magnitude (flow and/or level), duration (days), frequency (number of events per 100 years) or return interval (RI, in years) of hydrologic events are evaluated. The assumption under this approach is that hydrologic processes that may affect the WRVs are event-driven (e.g., flood events facilitate sediment transport and river-building processes) or can be characterized by annual extreme events (e.g., minimum annual depth, for a biologically-relevant duration, at hydraulic control locations to protect fish passage). When sufficient data are available, a range of event frequencies (e.g., a flow of specific magnitude and duration) that is protective of a WRV may be known with some level of confidence. In other instances, there may be insufficient information on the frequency of an event that is protective. In these cases, the frequency of the event under a reduced flow condition can be compared to the frequency under a baseline condition. If the change is not too great, then the WRV may be considered protected.

High flow (e.g., flood or inundation) -related WRVs are considered to be protected if, under the MFLs flow regime, the high flow event of an associated magnitude and duration does not occur too infrequently. Low flow (e.g., drought or drawdown) -related WRVs are considered to be protected if, under the specified flow reduction conditions, the low flow event of a specified magnitude and duration does not occur too frequently when compared to the low flow event occurrence under a long-term baseline condition. Implicit in the evaluation of WRVs is the concept of recovery time, which can be viewed as the time between events (or the return interval) sufficient for the WRV to recover.

It also may be appropriate to consider the seasonal variations affecting flow when developing MFLs. A "building block" approach that identifies seasonal blocks corresponding to periods of low, medium, and high flows has been used to evaluate rivers and estuaries in west-central Florida, such as the Alafia River (SWFMD 2005b). The MFLs compliance standards include allowable flow reductions based on limiting potential changes in aquatic and wetland habitat availability associated with seasonal changes in flow. A low flow cutoff; i.e., a flow below which no withdrawals would be allowed, also may be included. The allowable flow reductions associated with the MFLs generally are associated with a 15% reduction in habitat area, a 15% reduction in the number of inundation days (Munson and Delfino 2007), or a low flow cutoff (e.g., associated with fish passage). Any of these criteria may be applied seasonally.

The 15% threshold has been applied in many, if not most, of the MFLs analyses performed in the State of Florida for MFLs Rule development (e.g., Munson and Delfino 2007, SRWMD 2005, SWFWMD 2010, SWFWMD 2011). The 15% threshold also was applied in the AWSS MFLs analysis recognizing that additional research and followup data collection to verify that the resources are protected is an important element of the MFLs process.

For downstream impacts such as in an estuary, the Reach method (Good and Mattson 2004) may also be appropriate, particularly when limited site specific data are available. As applied to the Wacissa River, total flow in the Aucilla River at the most downstream gage would be apportioned between the Wacissa River and non-Wacissa River flow. Ideally, flow would be apportioned over the entire total flow duration curve. MFLs related allowable flow reductions at the estuary would be apportioned consistent with the contribution of Wacissa River flow to the total flow.

For the AWSS, an approach was taken that tailored the analysis to the specific WRV being protected and the availability of defensible data and information. A substantial portion of the instream-based metrics associated with WRVs were developed using the IFIM approach, and MFLs criteria were based on an allowable 15% loss of area weighted suitability associated with some reduction in flow. Many of the metrics were developed using a 15 % change in the inundation time for the selected metric. In general, Munson and Delfino (2007) found the reduction-in-time method to be more conservative than a reduced-area method.

5 Evaluation of Water Resource Values

As discussed in Section 1, protecting water resource values related to recreation and wildlife habitats in the freshwater and estuarine portions of the river are deemed most relevant to this river system and are evaluated further in this section. Flow scenarios that are protective of these values are assumed to be sufficient to protect the overall structure and function of the river system.

5.1 Recreation In and On the Water - Aucilla River

Recreational boating on the Aucilla River primarily consists of canoeing and kayaking (Figure 59, Figure 60), with small powerboats present in the estuarine and upper portions of the Aucilla where fishing from small, shallow-draft motorized vessels is a popular activity. Before accessing the Aucilla River, paddlers and boaters are advised to assess water conditions based on water levels measured at Lamont. Water level measurements at this location are an indicator of paddling conditions throughout the lower reaches of the river, with boaters generally requiring an additional one to two feet to accommodate engine propellers. A gage reading of 48 to 50 ft NGVD is ideal for paddling (FDEP 2013a). If the level is below 48 ft NGVD, paddlers can expect frequent portaging. These readings are posted daily on the SRWMD website. Passage and clearance for powerboats is not evaluated as they are used for recreation and fishing mainly in the estuarine area (e.g., downstream of Aucilla-Wacissa confluence) and in the upper portions of the Aucilla River (e.g., Sneads Smokehouse Lake).

The amount of time that water level conditions allow for easy paddling was selected to assess protection of recreation on the river. The potentially available water under an MFLs scenario is the change in flow associated with an increase in the number of non-viable paddling days. This is the percent-of-time approach introduced in Section 4 and is used frequently by the SRWMD and SWFWMD for developing MFLs (Munson and Delfino 2007).

The critical stage for canoeing/kayaking is 48 ft and is associated with a flow of 132 cfs at the Lamont gage (Figure 36). Paddling is assumed to be impaired at a stage of less than 48 ft; hence, 132 cfs is the critical flow for assessment of the recreation metric. The flow duration curve (Figure 61) crosses the 132 cfs red horizontal line at a flow exceedance of 43.8 % under baseline conditions. This exceedance of 43.8% is equivalent to 160 days per year, on average, meaning that paddling is viable 160 days per year under baseline conditions. Reducing the exceedance by 15% to 37.2% (or to 136 days per year of viable paddling) means that the river is not suitable for canoeing/kayaking an additional 24 days per year, on average (Figure 61 and Table 17). The baseline flow associated with a 37.2% flow exceedance is 201 cfs, which represents an upper limit of flows that are relevant to this recreation metric assessment.

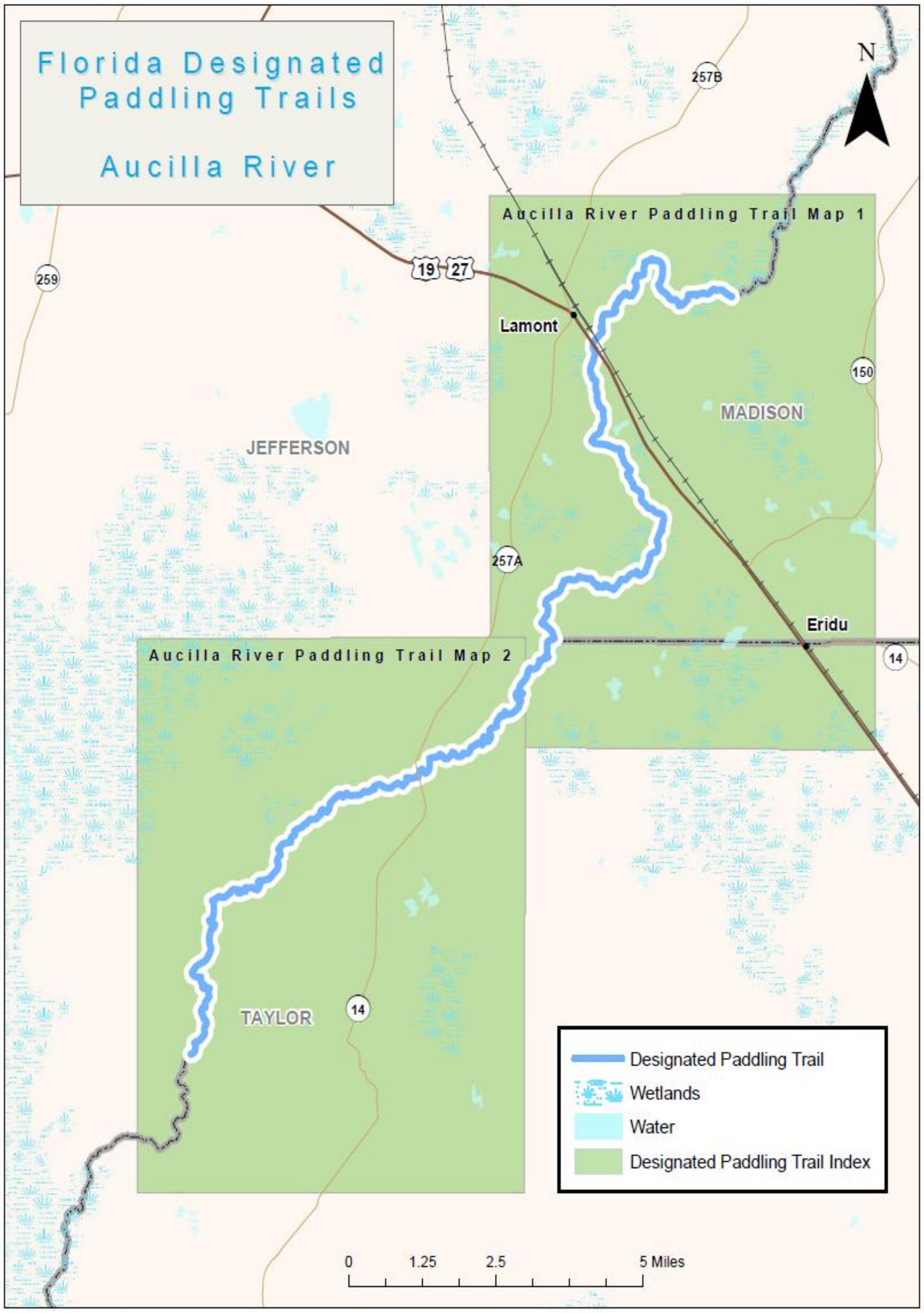


Figure 59. Aucilla River Paddling Trail
[Source: FDEP 2013a]

Figure 60. Paddling on the Aucilla River near Aucilla Rapids (River Mile 16)
[Source: http://www.clubkayak.com/greenwave/tripreport.asp?trip=431]

The associated change in flow that would be available under an MFLs based on the recreation metric is about 69 cubic feet per second (cfs) , or a 34.2% reduction in flow, when flow at the Lamont gage is 201 cfs (Figure 61 and Table 17).

5.2 Fish Passage and Fish and Wildlife Habitat - Aucilla River

Four flow regimes are considered to determine river flow requirements for in-stream and out-of-bank floodplain habitats. These include

- in-stream flows that meet critical biota requirements such as fish passage and reproduction;
- in-channel flows that maintain immediate stream banks and channels;
- overbank or near -overbank flows that maintain riparian habitats; and
- flood flows that determine the boundaries and shape of floodplain and valley features.

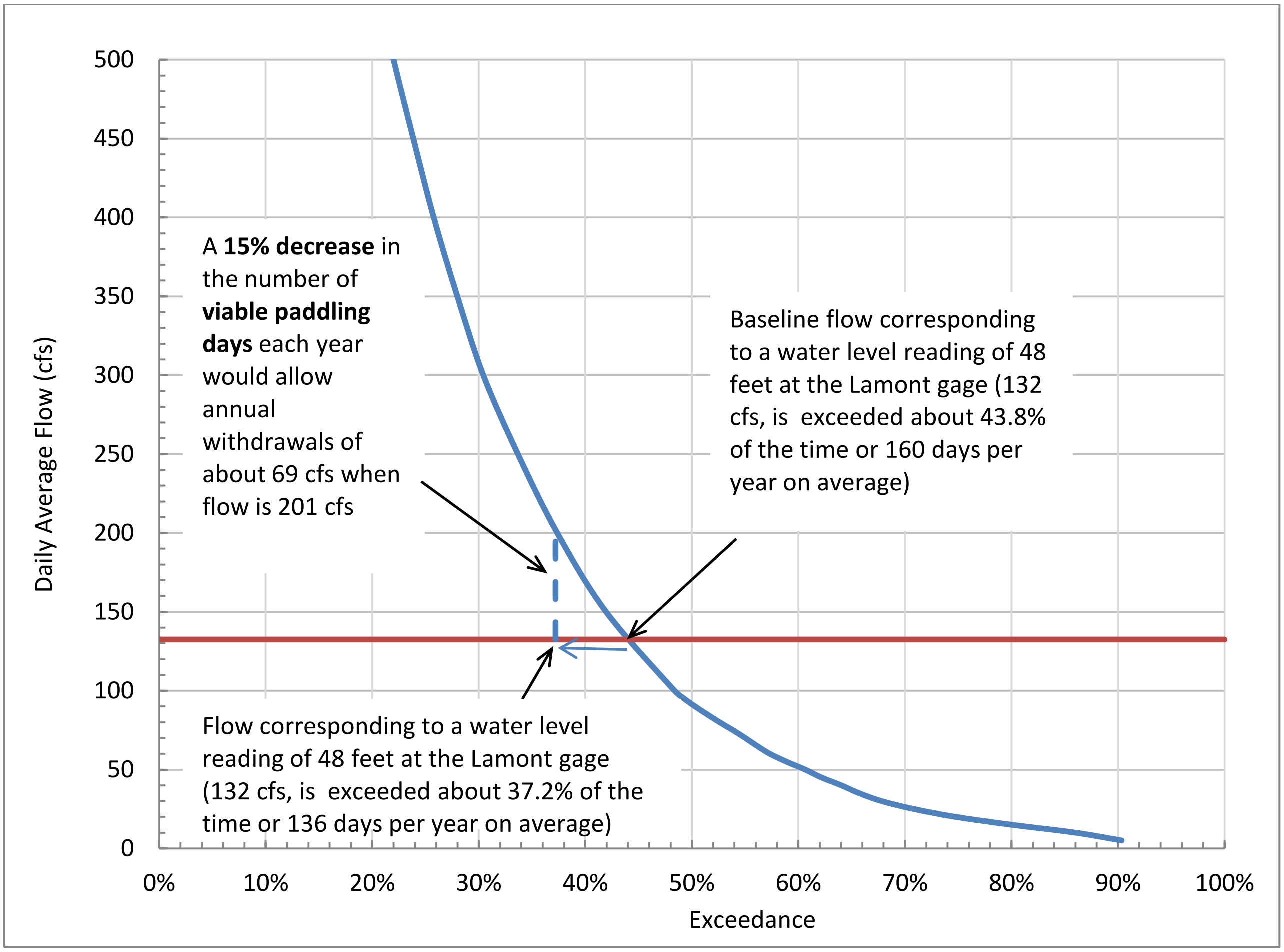


Figure 61. Baseline POR flow duration curve illustrating 15% decrease in number of viable paddling days and associated flow reduction

Table 17. Flow reduction associated with a decrease in the time that the critical stage for paddling is exceeded

Recreation Metric (Critical Stage)			Recreation Metric Associated with 15% Decrease in Time Exceeded			Decrease in Time and Flow Associated with a 15% Decrease in Time that Critical Stage is Exceeded		
Stage (Flow)	Time Exceeded		Time Exceeded		Baseline Flow [1]	Time Change	Flow Change [2]	
ft (cfs)	%	days	%	days	cfs	days	cfs	%
48.0 (132)	43.8	160	37.2	136	201	24	69	34.2

1. Flow under baseline condition associated with the decreased flow exceedance frequency.
2. The flow available and associated relative flow change for a 15% decrease in time that paddling is viable.

5.2.1 Fish passage

There are no fish species listed as E, T, SSC, or S1 for the Aucilla River. However, fish species such as Suwannee bass, largemouth bass, multiple varieties of sunfish, and pickerel are known as being important for recreational sports fishing in both the Aucilla and Wacissa Rivers. Other fish species fill a trophic level as forage species or serve as possible hosts for larval mussels (e.g. brown- or black-banded darter). Most of these fish species are habitat generalists. Of these, the Suwannee bass is known to prefer fast-flowing water with shoals (FWC 2015b).

Thompson's (1972) study on minimum depth criteria (0.6 ft – 0.8 ft) for passage of fish has been widely used throughout Florida in assessing MFLs (SWFWMD 2002, SWFWMD 2005b, c, d, and e). Given that Thompson's work was based upon fish species and streams dissimilar to Florida rivers (e.g., large species such as Chinook salmon in cold, well-oxygenated water), some fishery resource managers in Florida have cautioned against the direct use of Thompson's minimum depth range for Florida rivers and streams (Gary Warren, FWC, personal communication). HSW (2007, 2008) doubled Thompson's 0.8 ft criterion to provide a conservative safety factor when assessing MFLs within different portions of the St. Johns River. Neubauer et al. (2008) used a fish passage criterion of 0.8 ft depth over 25% of the channel as a low flow non-exceedance event, which means that the significant harm criterion is associated with an increase in the frequency of low-flow events. The SJRWMD criterion (Neubauer et al. 2008) was used by the SRWMD for recent MFLs developed for the Lower Santa Fe River (SRWMD 2013) and is used in this fish passage analysis for the Aucilla River.

Based on the HEC-RAS input/output, passage depth criteria of 0.8 ft over 25% of the river bed width are met for the middle section of the Aucilla River (US90 to the USGS gage at Scanlon) when the flow at Lamont is about 51 cfs (Figure 62). The flow of 51 cfs at Lamont is equaled or exceeded about 60% of the time (or not exceeded about 40% of the time). This means that fish passage is impaired about 39.8% the time (or 146 days per year). A 15% increase in the number of days not exceeded is associated with a flow reduction of about 22 cfs, or 30.1%, at a flow rate of 73 cfs (Figure 63 and Table 18).

5.2.2 Wildlife Habitat

Wildlife habitat occurs in the river channel (i.e., instream), along its banks, and within the bordering riparian zone (Section 3). 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.

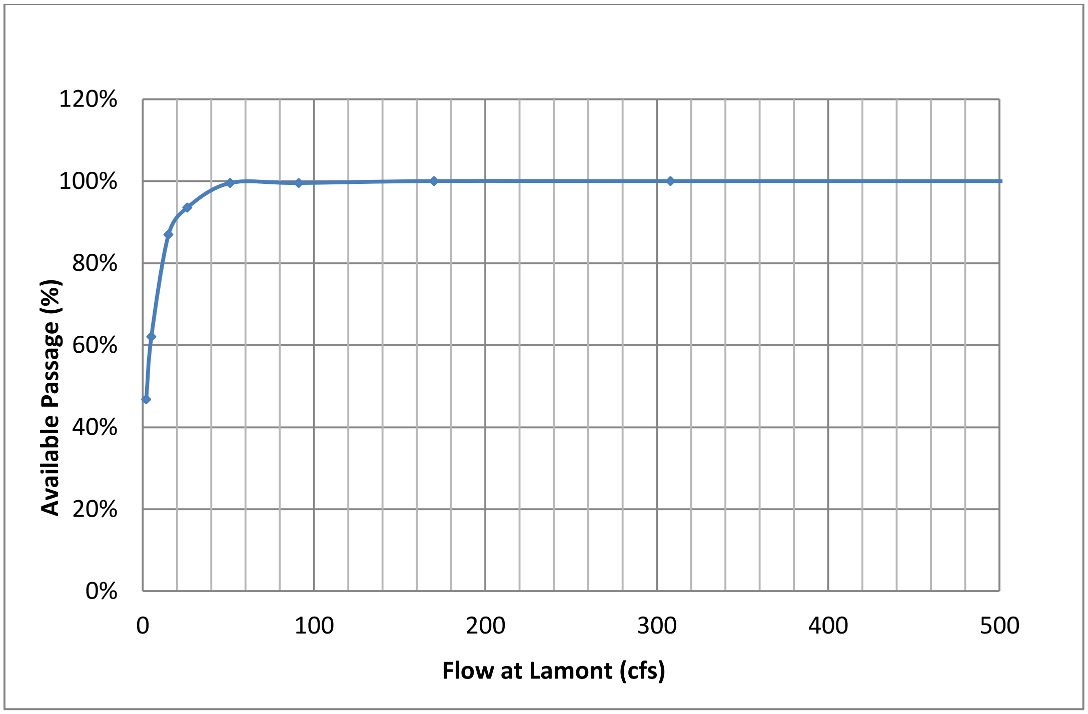


Figure 62. Available fish passage versus flow for the middle section of the Aucilla River

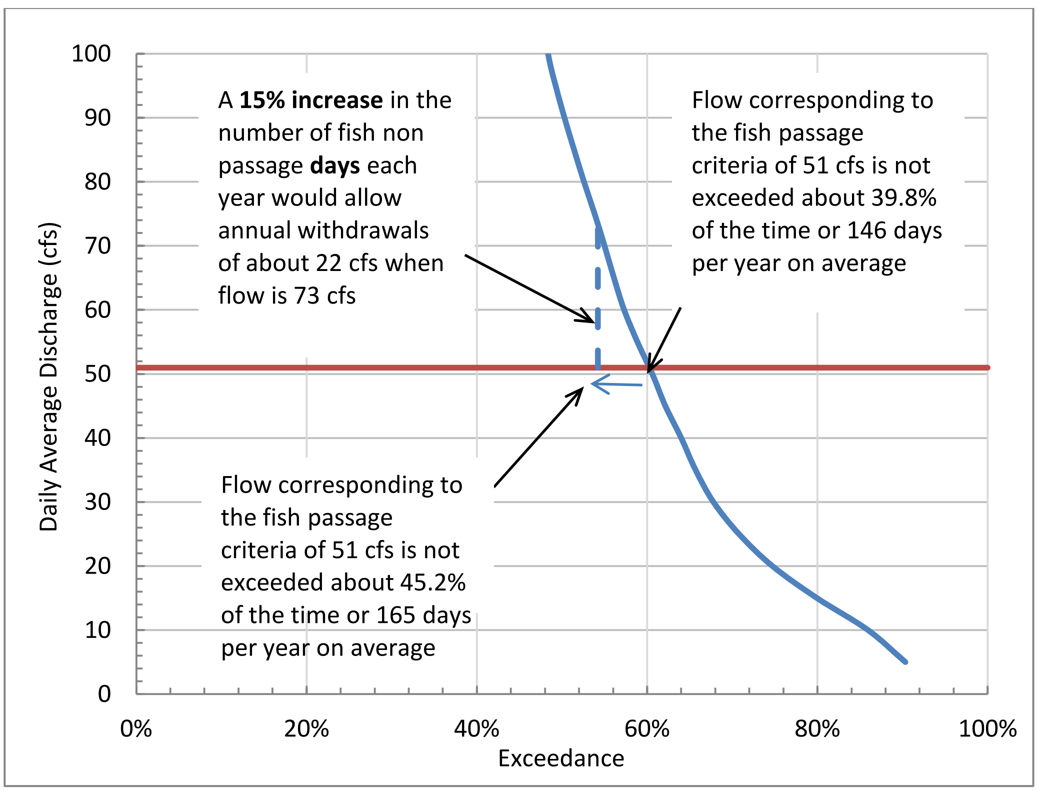


Figure 63. Baseline POR flow duration curve illustrating 15 % decrease in the number of viable fish passage days and associated flow reduction

Table 18. Flow reduction associated with an increase in the time that the critical stage for fish passage is not exceeded

Fish Passage (Critical Stage)			Fish Passage Metric Associated with 15% Increase in Time Not Exceeded			Increase in Time and Decrease in Flow Associated with a 15% Increase in Time that Critical Stage is Not Exceeded		
Stage (Flow)	Time Not Exceeded		Time Not Exceeded		Baseline flow [1]	Time Change	Flow Change [2]	
ft (cfs)	%	days	%	days	cfs	days	cfs	%
45.7 (51)	39.8	146	45.2	165	73	25	22	30.1

1. Flow under baseline condition associated with the Increased flow non exceedance frequency.
2. The flow available and associated relative flow change for a 15% increase in time that fish passage is impaired.

Physical habitat modeling was performed for the Aucilla River by the SRWMD with SEFA (Section 3) to characterize the relationship between instream habitat suitability and flow (Appendix B).

Inferences regarding riparian habitat along the river bank and within the riparian zone can be made by examining the hydraulic characteristics calculated using the HEC-RAS models currently available for the river. The inundation of shoal areas, as well as snag and root zone habitat, can be inferred using river cross-section wetted perimeter inflection points that denote the toe and top of the river bank.

The Aucilla River comprises three distinct segments referred to as the upper Aucilla, middle Aucilla, and lower Aucilla (Section 3). The upper Aucilla is largely a swamp feature. The river develops a defined channel below the upper Aucilla and is an entirely freshwater system within the middle Aucilla segment. The lower Aucilla segment begins downstream of the Cody Scarp where the river transitions from a freshwater to estuarine system (Section 2). Instream and riparian habitats were evaluated for each of these river segments.

5.2.2.1 Instream Habitat

The SEFA analysis completed by the SRWMD during July 2015 (Appendix B) was used for instream habitat MFLs analysis. SEFA is a hydraulic model coupled with habitat suitability relationships for various species and classes of species. The model calculates an Area Weighted Suitability (AWS) metric associated with a particular flow regime – e.g., baseline condition. Threshold flow conditions are developed by examining the change in AWS for various flow reduction scenarios.

The study area encompasses a 0.2 mile reach on the Aucilla River located about 11 miles downstream of US highway 27 near Lamont. Data along seven transects within the study reach were collected during three different flow conditions of 45.31, 65.91, and 73.02 cfs, and recorded data were used in the hydraulic, instream habitat, and time series routines of the model. Flow data from the USGS gage near Lamont (02326500) were used for the time series analysis portion of the SEFA program. A constant percent flow reduction from baseline flow measurements was used and corresponding changes in AWS values were calculated. Flow reduction scenarios were analyzed until a 15% reduction in baseline AWS was calculated.

Adult channel catfish, the shallow/fast habitat guild, and total Ephemeroptera, Plecoptera, and Trichoptera (EPT) were somewhat sensitive to flow reductions, with the shallow/fast habitat guild being most sensitive. A flow reduction of 35.7% resulted in a 15% reduction in the baseline shallow/fast guild AWS metric (Table 19). Adult channel catfish and EPT-Total were even less sensitive than the shallow/fast guild, with relative flow reductions of 49.7% and 46.1%, respectively, associated with a 15% reduction in the baseline AWS change criterion (Table 19).

A reliable range of habitat model applicability is between 0.4 and 2.0 times the lowest and highest measured flows, respectively, made during a targeted flow regime to calibrate the habitat model (J. Gore, personal communication). Although the District applied SEFA to all POR flows to determine a threshold flow reduction of 35% for the shallow/fast guild, a range of flows from 18 cfs to 146 cfs is prescribed as applicable for this particular metric.

Table 19. Flow reduction associated with a decrease in AWS for certain species and life stages

	Relative AWS Reduction From Baseline AWS Species/Life Stage		
Flow Reduction (%)	Channel Catfish/Adult (%)	Habitat guilds - Shallow/Fast (%)	EPT-Total (%)
25%	6.15	9.52	6.39
30%	7.57	9.52	8.03
35%	9.27	14.29	10.04
40%	10.97	**19.05**	12.04
45%	12.96	**23.81**	14.42
50%	**15.14**	**23.81**	**16.97**

Bold values indicate AWS reduction greater than 15%. Based on linear interpolation, the relative flow reductions associated with a 15% reduction in baseline AWS are 49.7% for channel catfish, 35.7% for the shallow/fast guild, and 46.1% for EPT.

5.2.2.2 Riparian Bank Habitat

Snags occur naturally and are an important habitat created frequently by treefall along the Aucilla River (Figure 64). Although snags are characterized in Section 3 as instream habitat, the protection of snags and roots, a similar woody habitat, was evaluated using stream hydraulic characteristics as a surrogate for a range in flows that inundate the river banks periodically.

Wetted perimeter (WP) is the distance along the stream bed and bank cross-section where the bottom is in contact with water. Each adjacent pair of cross-sections in the HEC-RAS model designates a river subreach with a length equal to the longitudinal distance between the cross-section locations. The average subreach WP is the average of the WPs at the pair of cross-sections that define the subreach. A weighted WP was calculated for each HEC-RAS model run by summing (for all subreaches) the products of the average subreach WPs and the subreach lengths, and then dividing by the total river reach length. A relatively level plot line in a graph with stage as the abscissa and WP as the ordinate represents an increase in stage with relatively little change in WP (e.g., river bank), while a more steeply sloped plot line depicts an increase in WP with relatively little change in stage (river bed or flood plain).

Figure 64. Snag habitat on the Aucilla River
[Source: OW 2011]

The difference between Figure 65 and Figure 66 reflects the different HEC-RAS defined geometries of the two sections (upper and middle) of the river. In general, flows at Lamont between about P70 and P20 (26 to 558 cfs) are associated with inundation from the toe to the top of bank. As discussed previously, there are limited elevation data for the channel of the Aucilla HEC-RAS model which impacts the calculated rating curves and wetted perimeter curves at the cross-sections. For example, it is difficult to identify an inflection point that would be useful in evaluating river bed habitat. However, the wetted perimeter curves, along with inspection of the individual cross-section geometries, are evidence that the river bank habitat area (toe to top of bank) is reasonably well-defined.

Bank habitat area is assumed to be protected if no more than a 15% potential loss of habitat occurs as a result of water withdrawals. A 15% reduction in the weighted WP is determined by reducing the weighted WP by 15% at several points along the curves. A flow reduction of between 12% and 22% is associated with a 15% reduction in the weighted WP, depending on which section of the river was evaluated and where the flow reduction occurs on the river bank (Table 20). When flow is at the top of bank, the wetted perimeter is reduced by 15% with flow reductions of 16% and 22%. Conversely, when flow is near the mid-bank, a 15% reduction in WP is associated with a 13 to 21% flow reduction (Table 20). Based on this analysis, a flow reduction of 12 to 13% when flow at Lamont is between 170 cfs and 558 cfs would be protective of bank habitats.

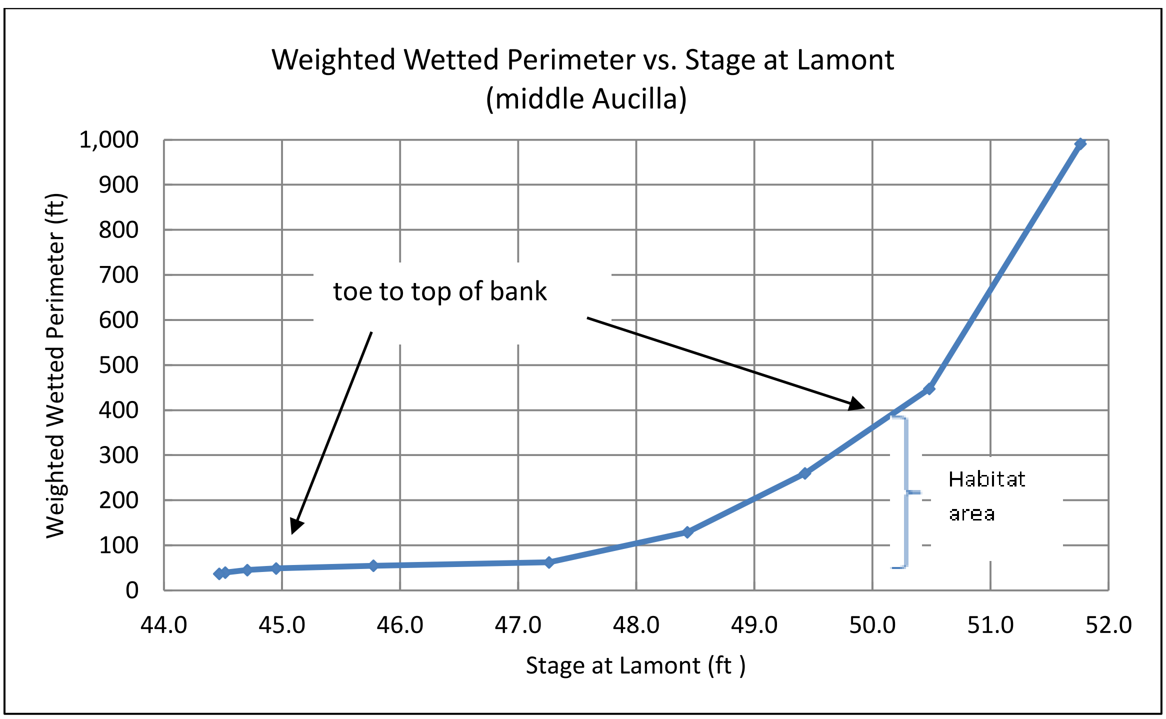


Figure 65. Weighted Wetted Perimeter of the middle Aucilla River vs. stage at Lamont

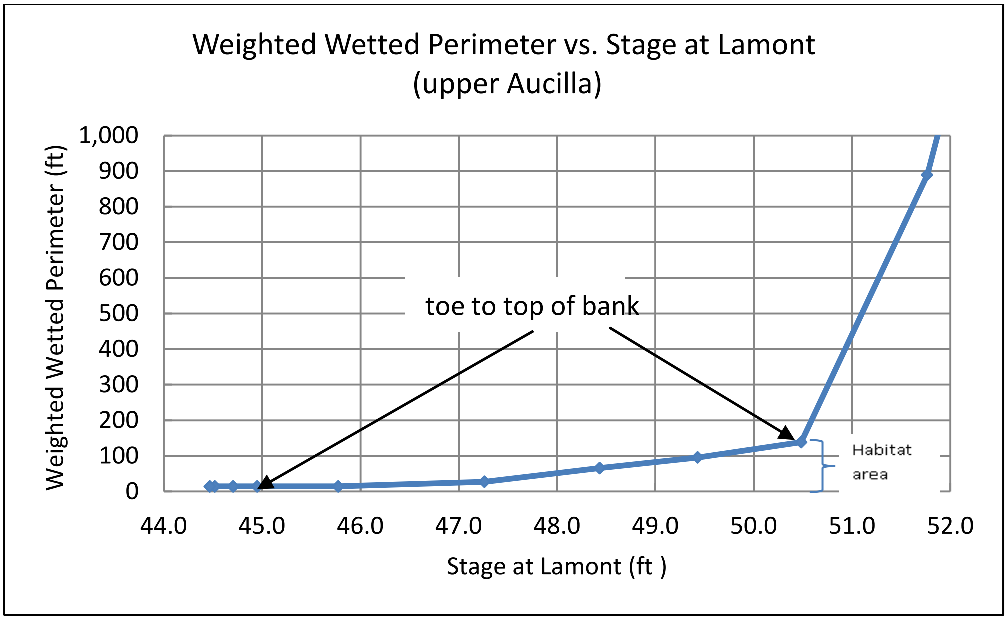


Figure 66. Weighted Wetted Perimeter of the upper Aucilla River vs. stage at Lamont

Table 20. Flow reduction associated with a 15% decrease in the Weighted Wetted Perimeter (WWP)

Baseline					Threshold Condition	
River bank habitat metric (WWP)			15% decrease in WWP			
River Section	WWP (ft)	Flow (cfs)	WWP (ft)	Flow (cfs)	Flow Available (cfs)	Flow Reduction (%)
upper Aucilla	66	170 (P40)	56	150	20	12
	96	308 (P30)	82	242	66	21
	138	558 (P20)	117	436	122	22
middle Aucilla	129	170 (P40)	110	147	23	13
	260	308 (P30)	221	267	41	13
	447	558 (P20)	380	469	89	16

5.2.2.3 Floodplain Habitat

Many fish species use both instream and floodplain habitats. Fish use of habitats adjacent to the main river channel and movement onto the floodplain during high water varies by 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). Optimally, several months of flooding should be provided to ensure fish access to the floodplain and spawning success (Knight et al. 1991).

The extent of connectivity among floodplain wetlands and the main channel largely determines the structure of fish assemblages (Galat et al. 1998, Pezold 1998, DeAngelis et al. 1997, Dunson et al. 1997, Halyk and Balon 1983). The flood-pulse and river continuum concepts emphasize the importance of floodplains to river productivity and fish population maintenance.

High water levels associated with high flows have been correlated with fish abundance, particularly small-bodied species, in Florida marshes (Toth 1991, 1993, DeAngelis et al. 1997, Jordan et al. 1998); however, seasonally flooded marshes may retain stranded fishes and produce a net negative demographic balance (Poizat and Crivelli 1997). Low water levels associated with drought or drought-simulating conditions often decrease fish populations (DeAngelis et al. 1997, Jordan et al. 1998). Maintenance of floodplain fisheries and water bird forage availability depends on the seasonally appropriate draw-down rate across the floodplain (Lorenz 2000, Lorenz et al. 2002). As water levels recede, some fishes may move into remaining deeper channels or retreat to refugia in isolated pools formed within the floodplain. Fish populations within-channel and in pools may be population sources in succeeding flood cycles. To maintain a diverse fish assemblage, water level regimes should regularly satisfy temporal and spatial reproductive requirements for channel-dependent species and for species dependent on shallow and deep marshes and wet prairies (Hill and Cichra 2002). Small fish such as the golden topminnow (*Fundulus chrysotus*), lined topminnow (*Fundulus lineolatus*), least killifish (*Heterandria formosa*), and eastern mosquitofish (*Gambusia holbrooki*), which have short life spans of 2-3 years, are among those fish species known to use floodplain habitats to complete their reproductive life cycles.

Colonial nesting water bird breeding success is generally correlated with high water levels that trigger the life cycles of aquatic invertebrates and fishes, followed by a draw-down in prairie ponds, marshes, streams, and rivers. Fish are trapped in pools, ponds, temporarily isolated marshes, and sloughs of varying sizes and depths, as water levels decline across the landscape, and become easily available to foraging birds. These lower water levels occur optimally during the nesting season for the several weeks when adult birds are feeding growing chicks.

The Aucilla River is surrounded by a nearly 2,000 ft wide floodplain made up of forested cypress and mixed hardwood wetlands, intertwined with pine and hardwood forests and agricultural uplands. The forested wetlands include six general community types (Section 3), each of which is dominated by characteristic tree species and associated with a typical hydrologic regime that sustains the community. These general floodplain vegetation communities were used to assess flow reductions that would remain protective of floodplain habitat and associated forest composition, wetland biogeochemical processes, and fish and wildlife habitat.

The areas of inundated wetland vegetation community types were determined using ArcGIS by overlaying the CLC coverage shapefile with HEC-RAS derived inundation area shapefiles (Figure

67). The process was performed for each of the 12 simulated flow regimes to characterize the association between flow and total inundated wetland vegetation area (Figure 68).

An inflection point on the total Wetland CLC line is apparent at about 1,054 cfs, where the curve begins to depart from a line tangent to the curve. Relatively little increase in wetland community area occurs at flows exceeding 1,054 cfs, because there are fewer wetlands at the elevations associated with these less-frequent high flows. The change in wetland area is much more sensitive to reduction in flows of less than 1,054 cfs; hence, it is referred to as a threshold flow condition. The total wetland vegetation community area inundated by a flow of 1,054 cfs is about 9.56 square miles (Figure 68).

The change in habitat area represents a potential loss of the vegetation community as it functioned under a baseline hydrologic condition and does not necessarily represent a predicted loss in wetland area. The floodplain wetland communities are assumed to be protected if the total inundated wetland vegetation area at the inflection point is not reduced by more than 15%. A reduction of 15% results in an inundated wetland vegetation area of 8.13 square miles and an associated flow of 870 cfs (Figure 68), a flow reduction of 184 cfs or 17% from the threshold condition (Table 21).

For some WRVs, best available data may indicate that there is a threshold flow or stage magnitude that must persist for some finite duration and occur with some minimum (or maximum) frequency to protect the WRV from significant harm. Flood depths maintained continuously for a period of 14 days that occur every two to five years were determined to be important descriptors of general flood conditions affecting tree regeneration in riverine floodplain forests (Light et al. 2002). These floods restrict regeneration in wetland forests because seedlings are unable to gain enough height during the period to survive the next flood. Larger floods occur less frequently, thus allowing more time for young trees to reach heights that exceed flood depths. The metric used for evaluating the WRV is not the flood occurrence itself but rather the time between the flood events that restricts the growth of invasive plant species. The RI of the inundation event in which flow equals or exceeds the threshold flow of 1,054 cfs for 14 consecutive days is approximately two years under baseline conditions (Figure 69), the high end of the frequency range reported by Light et al. (2002).

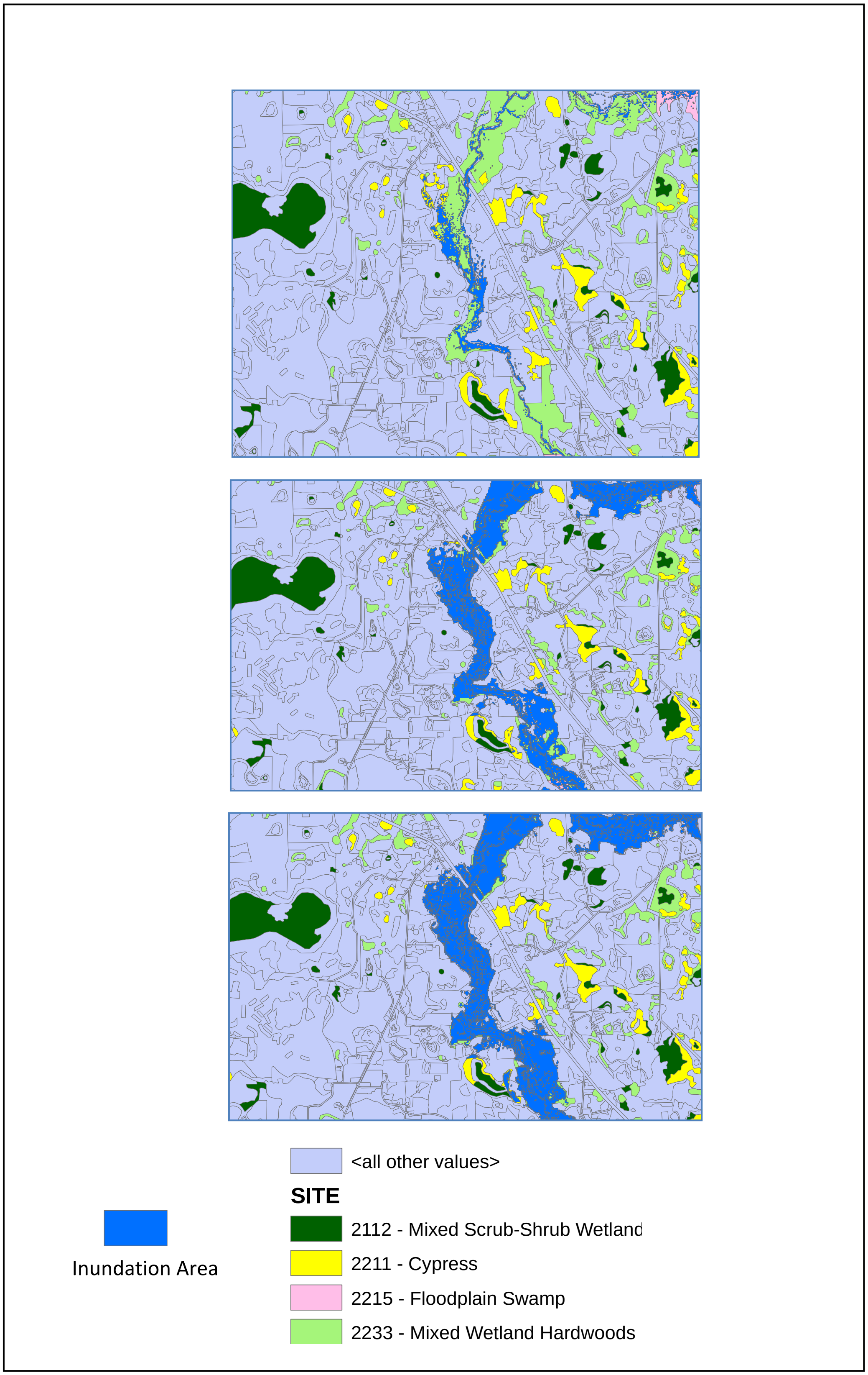


Figure 67. Inundation maps at flows of 308 cfs (top), 1,054 cfs (middle), and 3,534 cfs (bottom), with vegetative communities indicated by CLC codes
[Associated flow exceedance frequencies are P30 (308 cfs), P10 (1,054 cfs), and P1 (3,534 cfs)]

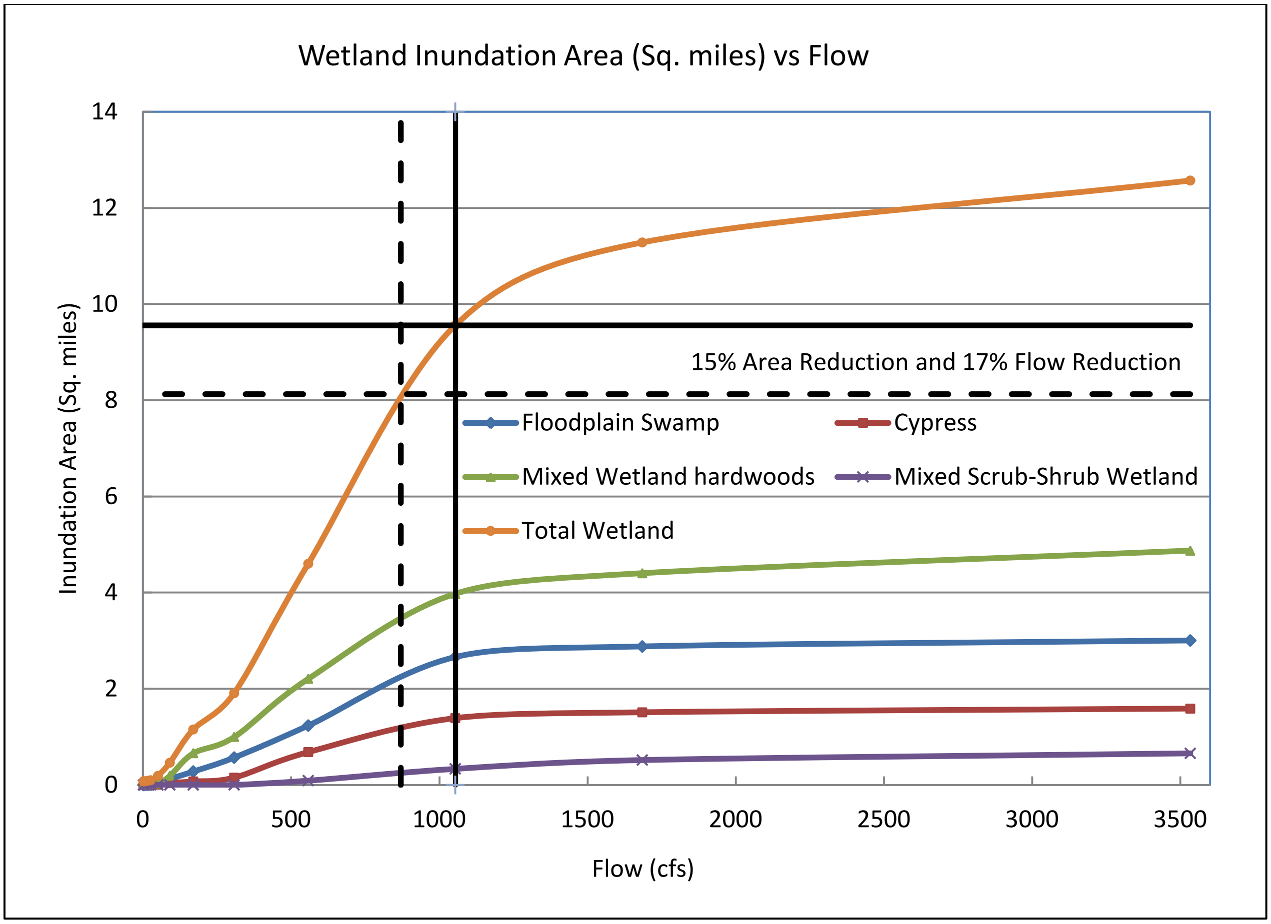


Figure 68. Association between flow at Lamont and general wetland vegetation community area
[Flow associated with top of bank is approximately 500 cfs]

Table 21. Flow reduction associated with a decrease in total floodplain inundated wetland vegetation area

Baseline				Threshold Condition		
Floodplain habitat metric (area)		Decrease in Inundation Area of Wetland Vegetation				
Flow (cfs)	Vegetation Area Inundated (mi^2)	Relative Decrease (%)	Vegetation Area Inundated (mi^2)	Flow (cfs)	Available Flow (cfs)	Flow Reduction (%)
1,054	9.56	15	8.13	870	184	17

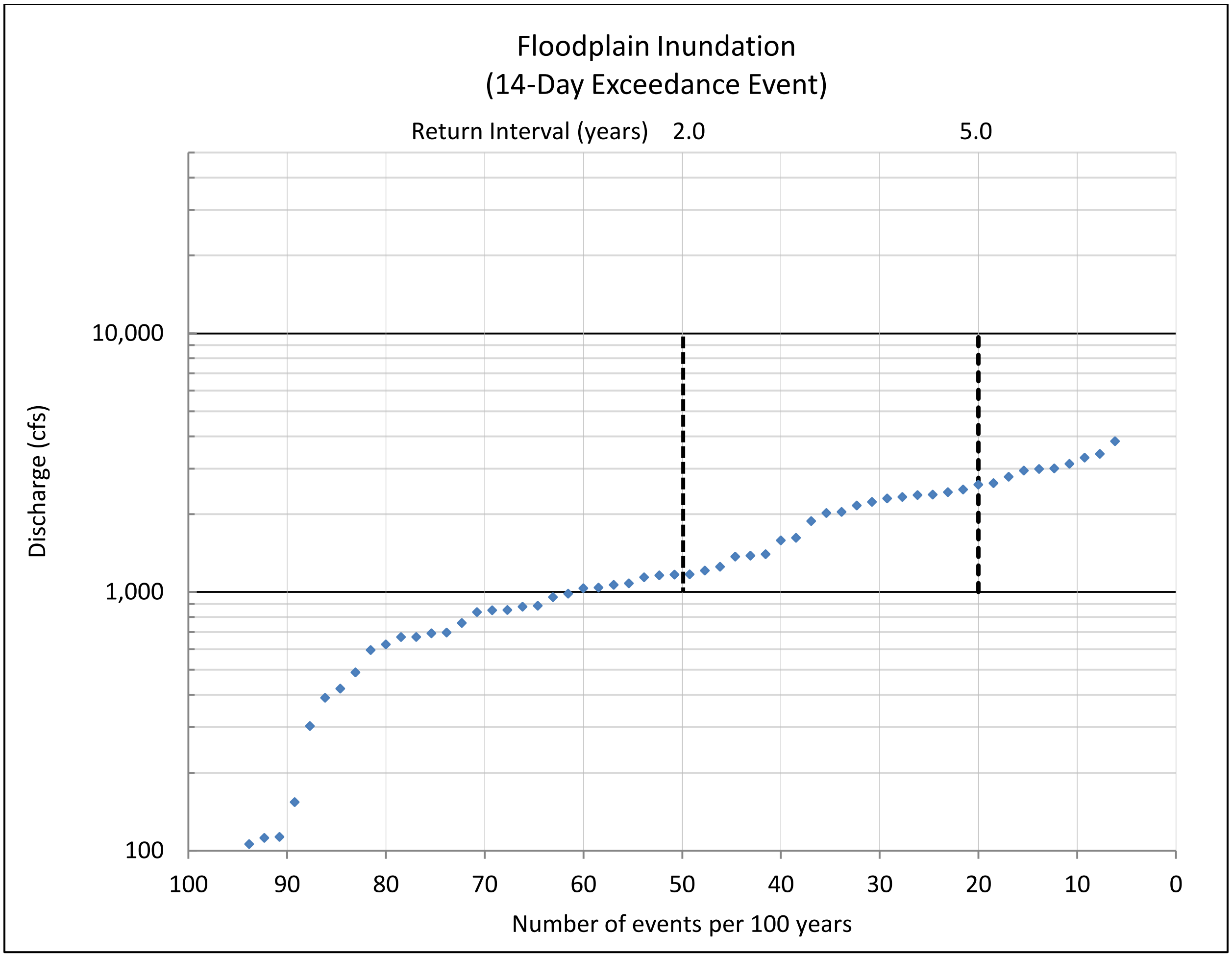


Figure 69. Baseline condition frequency of high flow events equaled or exceeded for 14 consecutive days at Lamont gage

5.3 Estuarine Resources

The Aucilla estuary model (Section 4) was applied for the two-year period of WYs 1995 and 1996. This two-year time period was selected from the baseline POR of WY 1951-2014 because the flow duration curves for the two periods are similar (Figure 58). Four salinity regimes (0-2, 0-5, 0-12, 0-15 ppt) were selected for estuarine value assessment. The 0-2 and 0-5 ppt regimes characterize oligohaline conditions that are important to less tolerant species such as beaked spikerush, a plant species listed as critically imperiled in Florida (Section 3). Volume, bottom area, and shoreline length corresponding to the four selected salinity regimes were evaluated as the habitat assessment metrics, although bottom area and shoreline length are more relevant to the species considered (Section 3). A freshwater flow reduction resulting in a habitat reduction of no greater than 15% is considered to be protective of estuarine resources.

The total volume of the EFDC model grid cells meeting a particular salinity criterion on each day of the two-year simulation was calculated to determine a daily salinity volume for each salinity regime. Daily salinity volumes for the 0-2 ppt salinity regime range from 2.8 to 73 million cubic ft (Figure 70). The maximum volume of the 0-2 ppt salinity regime, under baseline condition, is approximately 71% of the 104 million cubic ft total estuary volume. The 0-2 ppt salinity volume is less than 3.12E+07 cubic feet (i.e., 30% of the 10.4E+07 total estuary volume) about 95% of the time (Figure 70). The estuary volume occupied by 0-2 ppt during low-flow conditions is substantially less compared to the 0-2 ppt volume during high-flow conditions (Figure 71).

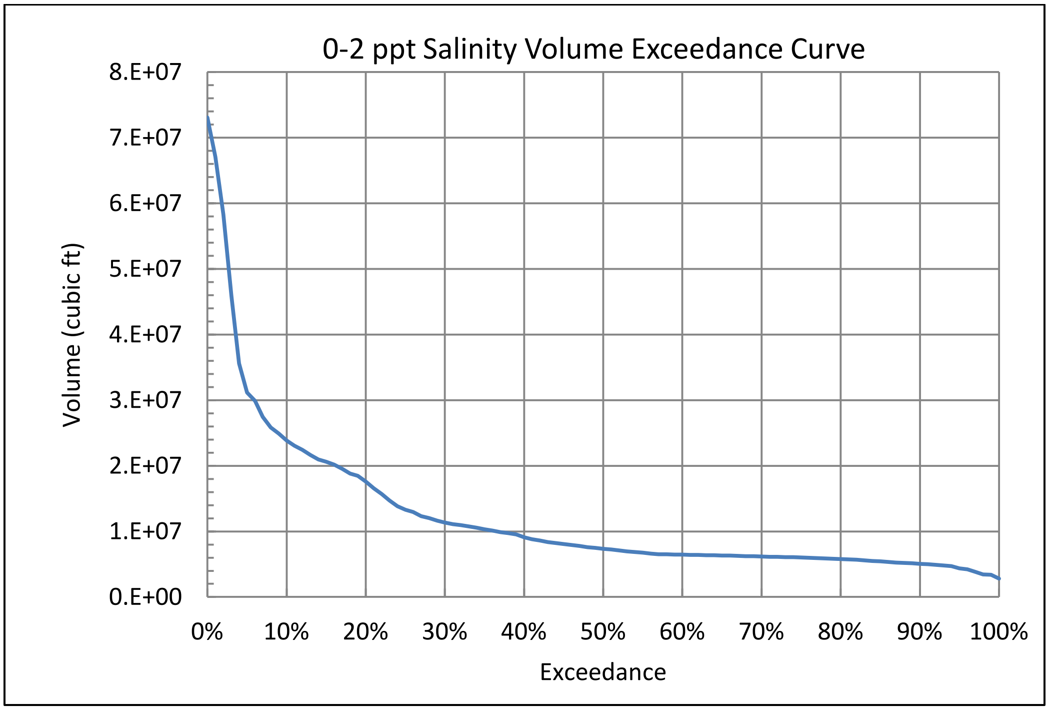


Figure 70. Salinity volume (0-2ppt) exceedance curve

SAV and benthic organisms are more likely to respond to the long-term average salinity at a particular location than to daily salinities. Average daily salinity values at a selected river centerline cell with an average POR salinity of 2 ppt under baseline conditions vary from 0 to 11.38 ppt, and the salinity is zero about 34% of the time (Figure 72). The volumes, bottom areas, and shoreline lengths were calculated for the selected salinity regimes for baseline and various flow reduction scenarios (Table 22 through Table 24). Under baseline conditions, approximately 78% of the bottom area of the estuary has an average salinity of more than 15 ppt (Figure 74).

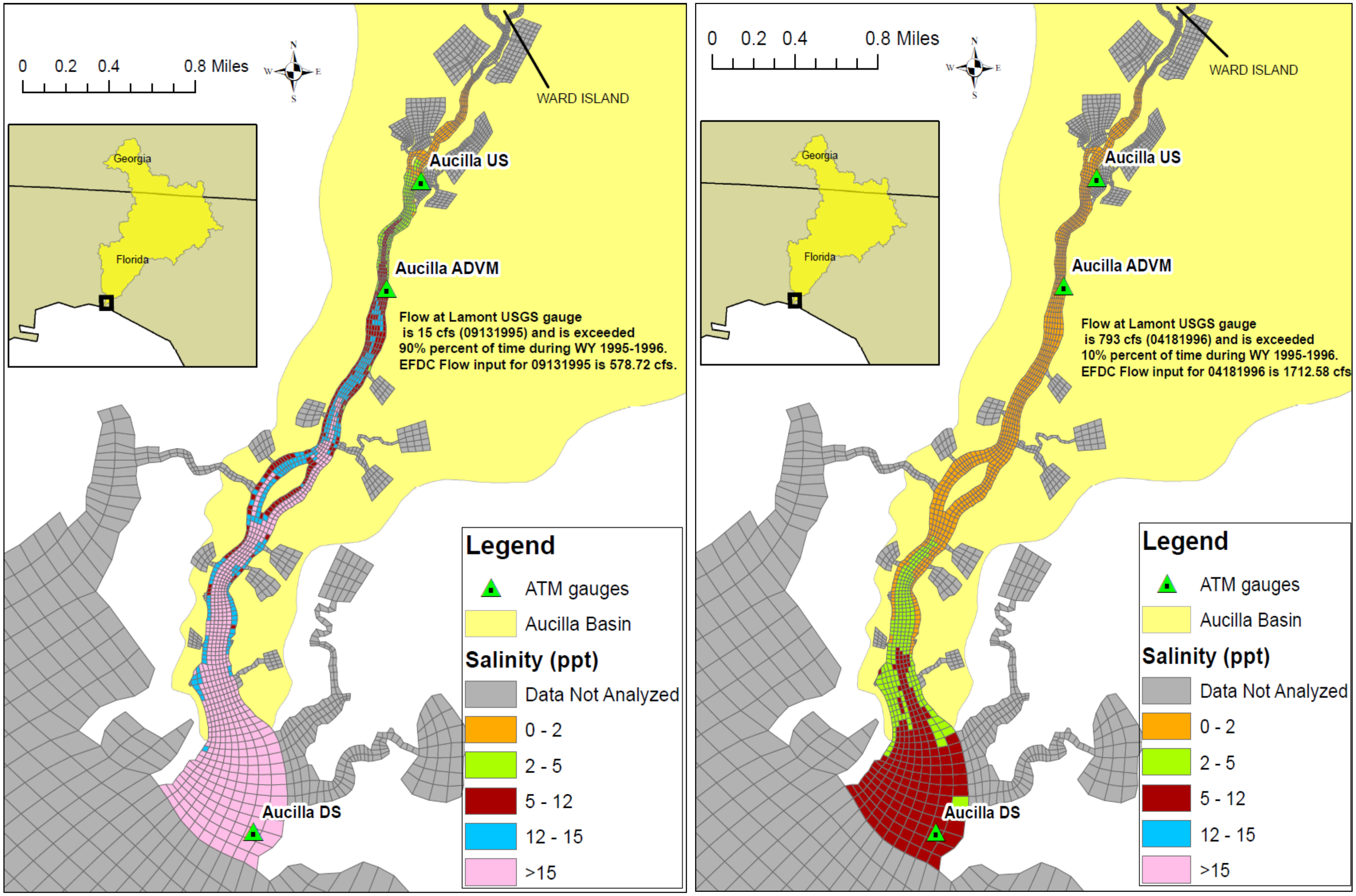


Figure 71. Salinity volumes for a low (left) and high (right) flow conditions

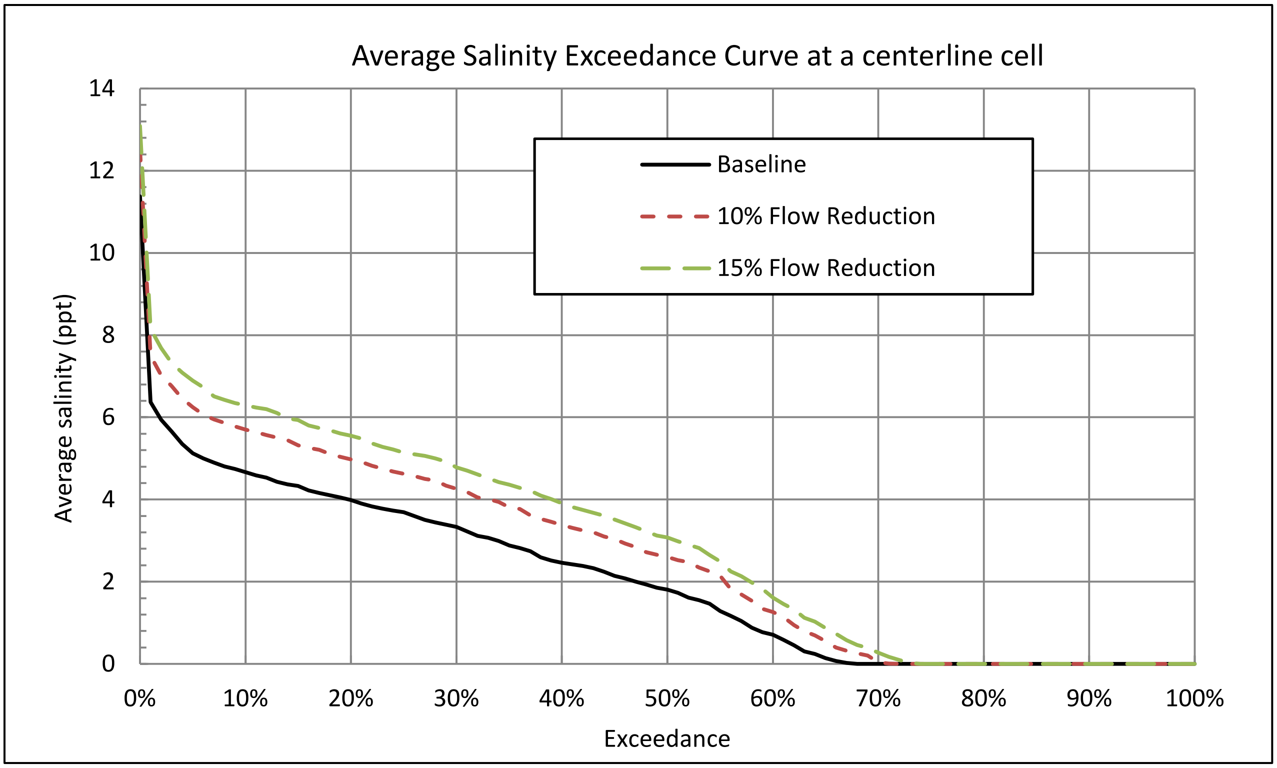


Figure 72. Average daily salinity exceedance curve at a centerline location with an average baseline salinity of 2 ppt

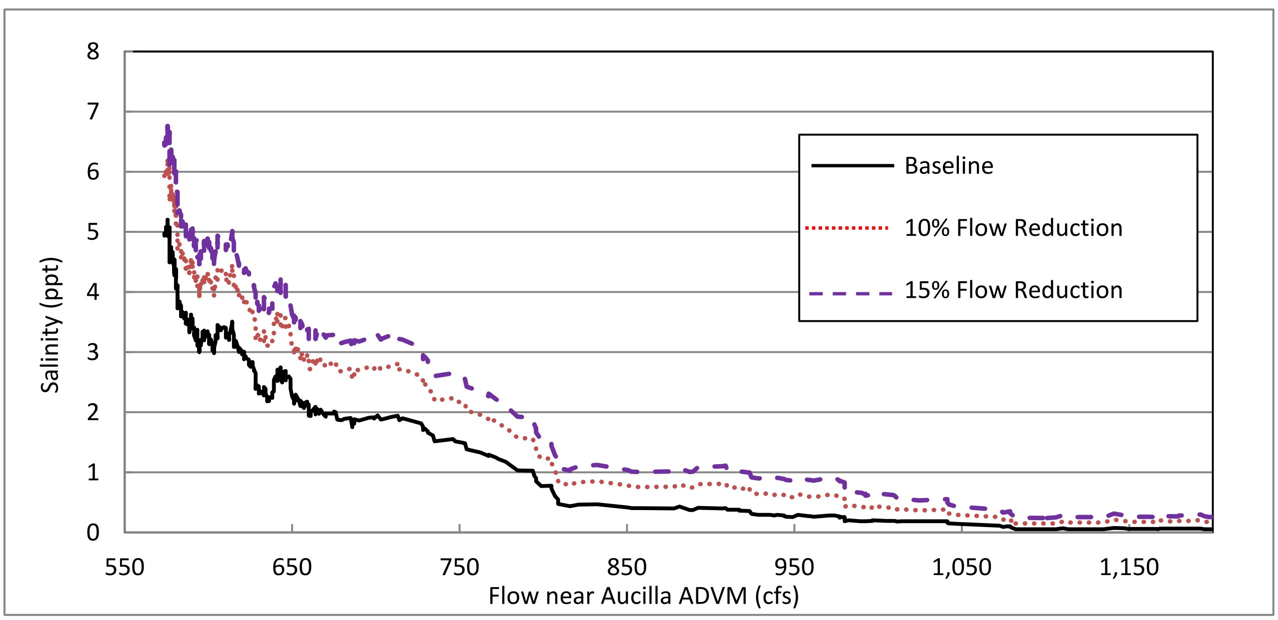


Figure 73. Flow-salinity relationship at a centerline location with an average baseline salinity of 2 ppt
[based on salinities calculated for a centerline cell]

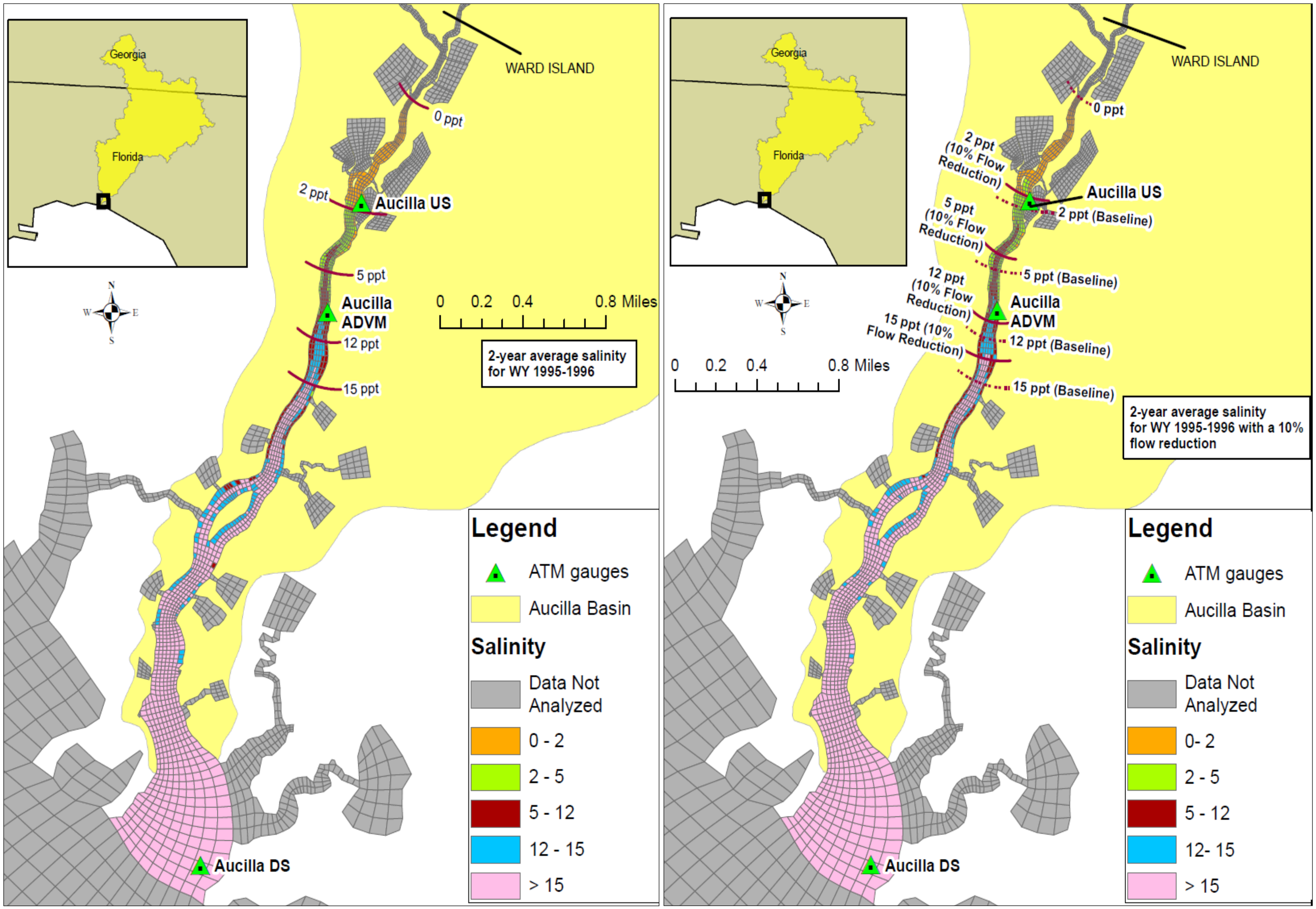


Figure 74. Average salinity distribution along the bottom area of the estuary for baseline (left) and 10% flow reduction (right)

Table 22. Average volume for various salinity ranges

	Volume (Cubic ft) Total Estuary Volume - 103,938,119 cubic ft				
	Baseline	5% Flow Reduction	10% Flow Reduction	15% Flow Reduction	30% Flow Reduction
0-2 ppt	7,583,397	6,885,487	6,541,629	6,329,911	4,765,042
% Change from Baseline		9.2	14	**17**	**37**
0-5 ppt	12,202,837	11,375,694	10,737,972	10,288,711	8,721,710
% Change from Baseline		6.8	12	**16**	**29**
0-12 ppt	32,266,576	30,635,409	29,640,514	28,323,540	22,970,019
% Change from Baseline		5.1	8.1	12	**29**
0-15 ppt	45,202,961	43,488,005	41,862,435	40,126,699	35,786,216
% Change from Baseline		3.8	7.4	11	**21**
Bold value indicates a volume reduction greater than 15%. Based on linear interpolation, the relative flow reductions associated with a 15% reduction in the baseline volumes are 12.3% for the 0-2 ppt regime, 14.1% for 0-5 ppt, 17.5% for 0-12 ppt, and 20.9% for 0-15 ppt.					

Table 23. Average bottom area for various salinity ranges

	Bottom Area (Sq. ft) Total Estuary Bottom Area - 16,074,167 sq. ft				
	Baseline	5% Flow Reduction	10% Flow Reduction	15% Flow Reduction	30% Flow Reduction
0-2 ppt	911,073	810,002	694,559	640,469	411,363
% Change from Baseline		11	**24**	**30**	**55**
0-5 ppt	1,415,159	1,372,278	1,316,914	1,285,825	1,045,929
% Change from Baseline		3.0	6.9	9.1	**26**
0-12 ppt	2,290,217	2,219,219	2,123,088	2,067,490	1,947,547
% Change from Baseline		3.1	7.3	9.7	**15**

	Bottom Area (Sq. ft) Total Estuary Bottom Area - 16,074,167 sq. ft				
	Baseline	5% Flow Reduction	10% Flow Reduction	15% Flow Reduction	30% Flow Reduction
0-15 ppt	3,485,149	3,271,145	2,962,850	2,793,228	2,310,337
% Change from Baseline		6.1	**15**	**20**	**34**
Bold value indicates a bottom area reduction greater than 15%. Based on linear interpolation, the relative flow reductions associated with a 15% reduction in the baseline bottom areas are 6.5% for the 0-2 ppt regime, 20.2% for 0-5 ppt, 30.05% for 0-12 ppt, and 10.0% for 0-15 ppt.					

Table 24. Average shoreline length for various salinity ranges

	Shoreline Length (ft) Total Estuary Shoreline Length - 41,260 ft				
	Baseline	5% Flow Reduction	10% Flow Reduction	15% Flow Reduction	30% Flow Reduction
0-2 ppt	9,927	8,921	8,191	7,486	5,249
% Change from Baseline		10	**17**	**25**	**47**
0-5 ppt	16,200	14,712	13,105	11,997	11,029
% Change from Baseline		9	**19**	**26**	**32**
0-12 ppt	28,447	28,062	27,548	26,473	23,984
% Change from Baseline		1.4	3.2	6.9	**16**
0-15 ppt	34,810	33,851	33,409	32,730	31,023
% Change from Baseline		2.8	4.0	6.0	11
Bold value indicates a shoreline length reduction greater than 15%. Based on linear interpolation, the relative flow reductions associated with a 15% reduction in the baseline shoreline lengths are 8.3% for the 0-2 ppt regime, 7.9% for 0-5 ppt, and 22.8% for 0-12 ppt. The 0-15 ppt regime shoreline length reduction was less than 15% for all flow-reduction scenarios considered.					

The 0-2 ppt salinity regime is generally the most sensitive to freshwater flow reductions with greater reductions in volume, bottom area, and shoreline length habitat compared to other salinity regimes for the same reduction in flow (Table 22, Table 23, and Table 24). Bottom area is generally the most sensitive of the metrics, with a flow reduction of about 6.5% associated with a 15% reduction in 0-2 ppt bottom area. The 0-5 ppt salinity regime is considered an important habitat within the estuary (Section 3), and a flow reduction of 7.9% is associated with a 15% reduction in 0-5 ppt shoreline habitat. However, for flows greater than about 1,075 cfs, 10% and 15% flow reductions do not substantially increase the average salinity (Figure 73).

5.4 Recreation In and On the Water - Wacissa River

Along with the Aucilla, the Wacissa River also is designated an OFW "special water". Recreation is very popular on the Wacissa and consists largely of canoeing and kayaking, with small power boats and air boats near Goose Pasture.

Yingling (1997) compiled information on boating safety and recreational use indicating 3 to 4 ft of water at the toe of a boat ramp as the minimum recommended for boat launching. Wagner (1991) reported that, for boats with outboard motors, a minimum of 3 ft of water is usually recommended for safe operation. Safe boat operation also includes adequate propeller clearance of typical vessels on the river. Canoes and kayaks used on the river have lengths of about 9 to 16 ft but require only a few inches of water depth to navigate. Typical fishing and pontoon propeller engine shaft lengths run from 20 to 25 inches (Iboats 2009). This length includes the boat transom height above the water, which means propeller clearance below the hull would be considerably less. As a result, a water depth of 2.0 feet for outboard motor clearance (depending on motor size, shaft length, and boat displacement) between the bottom of these vessels and the channel bottom should be adequate for preventing permanent damage to submerged aquatic vegetation (SAV) by props scarring the SAV substrate and physical damage to boat motors. A minimum top width of 30 feet is presumed to be sufficient for two 15-foot long fishing boats to pass each other, even if both are sideways in the current.

The shallowest transect location in the Wacissa River HEC-RAS model is River Station 33277.08 (Figure 75), located about 4,000 feet upstream from the Old Tram. Based on the HEC-RAS modeling results, at the lowest modeled flow of 233 cfs at USGS gage Wacissa River near Wacissa, the maximum water depth at the transect is about 2.03 ft (Figure 75). The lowest modeled flow of 233 cfs is exceeded 99.9% of time; therefore, paddling is not a limiting metric for MFLs evaluation.

The stage and associated flow that allow safe small motorized boat passage (i.e., 2.0 ft above the near-shore bottom and at least 30 feet of top width) at the shallowest location (i.e., HEC-RAS River Station 33277.08) within the study reach occurs at a flow of 357 cfs (PF3 in Figure 76). This flow is exceeded about 50% of the time under baseline conditions, or about 182 days per year on average (Table 25). Under reduced flow conditions that would decrease the time exceeded by 15% per year on average (i.e., from 50% to about 42.5%), power boat passage would be impaired at the shallowest location due to low-flow conditions an additional 27 days per year. The calculated depths at the Old Tram about 4,000 feet downstream, under the reduced flow condition, are greater than 2.0 feet, and safe boat passage would be maintained. This reduced-flow scenario permits a withdrawal of about 19 cfs when flow at the Wacissa gage is 376 cfs, or a 5.1% reduction in flow (Figure 77 and Table 25).

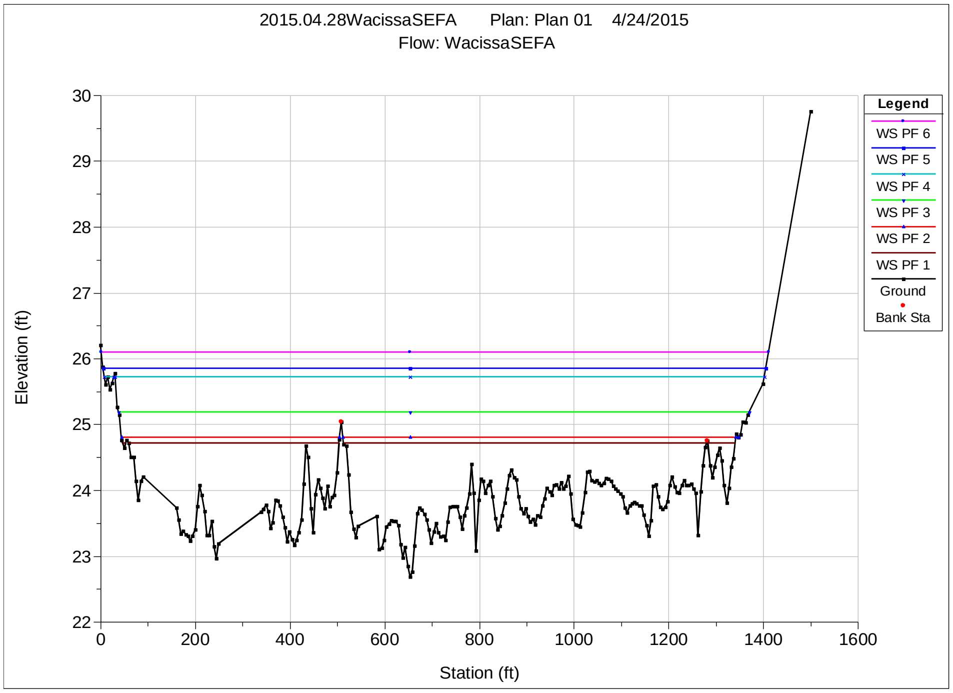


Figure 75. Shallowest main channel HEC-RAS cross section (River Station 33277.08)

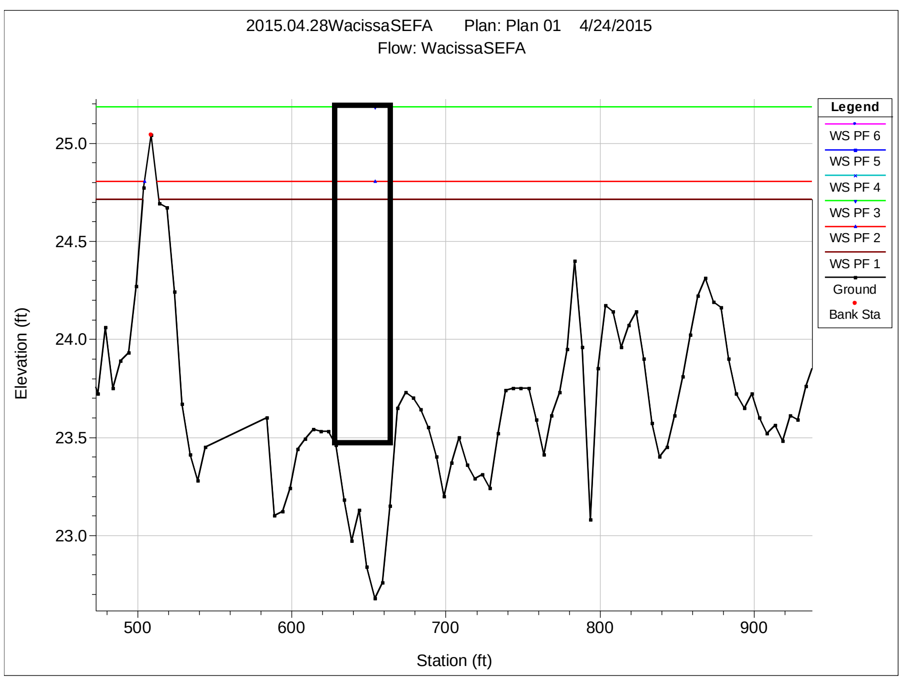


Figure 76. Shallowest main channel HEC-RAS cross section with motorized/powered boat passage criteria (River Station 33277.08)

Table 25. Flow reduction associated with a decrease in the time that the critical flow for safe boating is exceeded

Recreation Metric (Critical Flow)			Recreation Metric Associated with 15% Decrease in Time Exceeded			Decrease in Time and Flow Associated with a 15% Decrease in Time that Critical Stage is Exceeded		
Flow	Time Exceeded		Time Exceeded		Baseline flow [1]	Time Change	Flow Change [2]	
cfs	%	days	%	days	cfs	days	cfs	%
357	50.0	182	42.5	155	376	27	19	5.1

1. Flow under baseline condition associated with the decreased flow exceedance frequency
2. The flow available and associated relative flow change for a 15% decrease in safe boating time

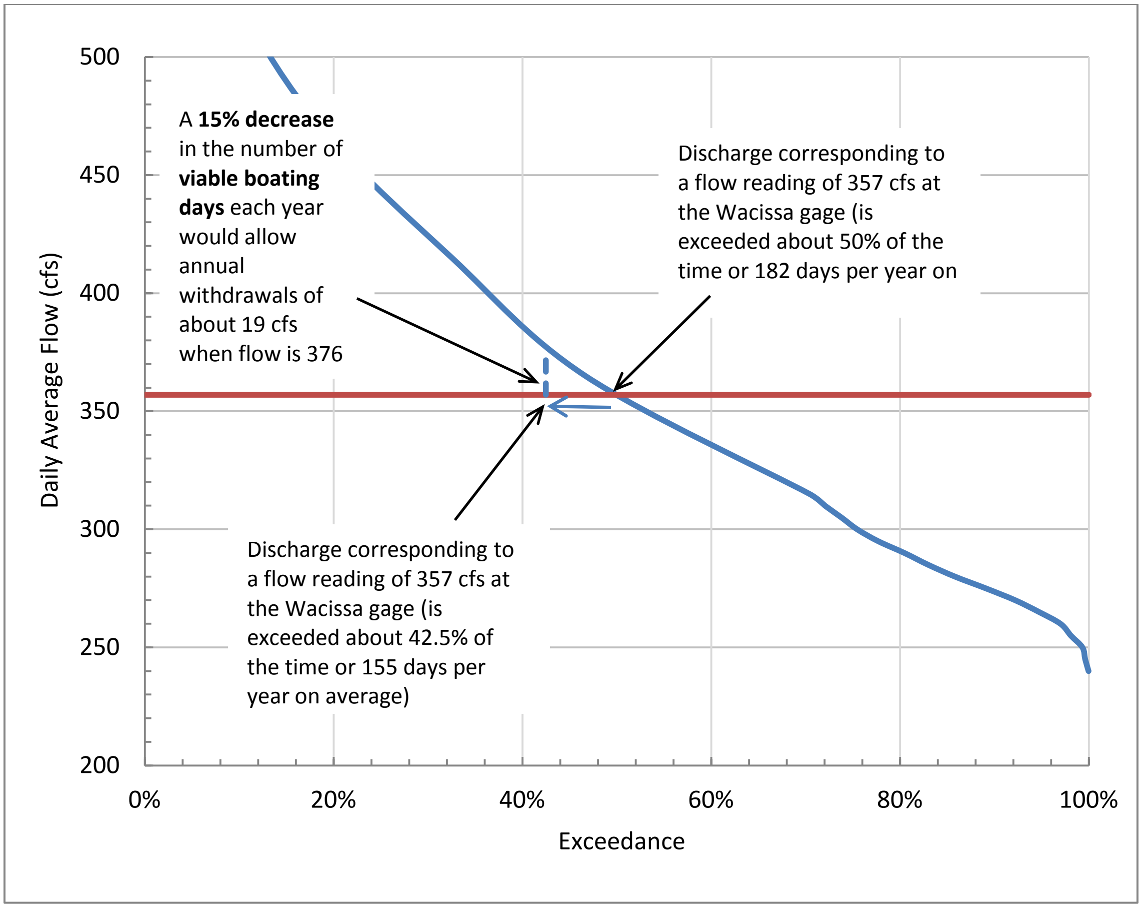


Figure 77. Baseline POR flow duration curve illustrating 15% decrease in unimpaired boat passage days and associated flow reduction

5.5 Fish Passage and Fish and Wildlife Habitat - Wacissa River

Fish passage and wildlife habitat were evaluated for MFLs assessment on the Wacissa River.

5.5.1 Fish Passage

The metric for protecting fish passage is a low water level and associated flow that corresponds to a water depth greater than 0.8 ft over at least 25% of the channel width, at a hydraulic control elevation of the river channel (Thompson 1972). As with boat passage, described in Section 5.4, the shallowest location within the study reach (HEC RAS River Station 33277.08) was analyzed for fish passage criteria. The top width of river channel at the shallowest HEC-RAS station is about 770 ft; therefore, a depth of 0.8 ft is needed for a width of 192.5 ft (0.25×770ft) for fish passage based on Thompson's criteria. A width of 192.5 ft is available at an elevation of 23.74 ft NGVD; therefore, an elevation of 24.54 ft NGVD (23.74+0.8) is needed for fish passage. This minimum elevation is below PF1 (233 cfs), which is only slightly greater than the minimum flow recorded on the Wacissa (216 cfs). Therefore, it is reasonable to conclude that the water depth requirement for fish passage would be met and that fish passage would not be a limiting metric for evaluating MFLs for the Wacissa.

5.5.2 Fish and Wildlife Habitat

As discussed in Section 3 and Section 5.2, various flow regimes should be considered when determining river flow requirements for in-stream and out-of-bank floodplain habitats. SEFA software was used to analyze the instream flows for habitat protection on the Wacissa.

5.5.2.1 Instream Habitat

The Wacissa River, from its headspring to Goose Pasture, was modeled using the SEFA software (Appendix C). Time series of daily flows for a 64-year period from WY 1951 through WY 2014 for the Aucilla and 11.5-year period from WY 2001 through WY 2014 (excluding WYs 2007-2008) and intermittent measurements between June 1977 and February 2001 for the Wacissa were used for the analyses. The tram pilings that cross the river about three miles downstream of the headspring were considered a boundary between two river segments, and two separate instream habitat models ("above tram" and "below tram") were developed. The "above tram" model includes 13 transects and the "below tram" model includes 19 transects. The SEFA models incorporate HEC-RAS modeled flows of 233, 254, 357, 518, 563, and 670 cfs. The habitats in the below tram model are more sensitive to flow reductions than the habitats in the above tram model; therefore, the following discussion is based on the below tram model. The reliable range of habitat model applicability is between 93 cfs and 1,340 cfs.

Two flow-reduction approaches were used to evaluate the change in AWS as a function of reduced flow. The first approach was to reduce all flows by a constant, based on a percent reduction in the median flow. The second approach was to apply a constant percentage flow reduction across the baseline POR. Flow reductions of less than or equal to 10% were evaluated.

For the constant flow reduction approach, the largemouth bass was most sensitive, with flow reductions greater than 9% resulting in a reduction of AWS greater than 15% criterion (Table 26). Largemouth bass fry, bluegill fry, and shallow/slow habitat guilds were each sensitive to flow reductions, with the 15% AWS change criterion exceeded at flow reductions of 7 to 9% (Table 26).

5.5.2.2 Floodplain Habitat

The interaction between groundwater and surface water in the Wacissa River watershed is very prevalent, and inundation of the floodplain is strongly influenced by groundwater levels. The dominant floodplain habitat vegetation is hydric hammock, which extends nearly two miles to the west of the River. There are insufficient historical data to determine a relationship between the frequency and duration of floodplain inundation and groundwater levels. The SEFA and estuarine modeling provide protection of the higher flow range.

Table 26. Flow reduction associated with decrease in AWS for certain species and life stages

Flow reduction approach		AWS change Species/Life Stage		
	Flow Reduction (%)	Largemouth Bass/Fry (%)	Bluegill/Fry (%)	Habitat guilds - Shallow/Slow (%)
Constant flow value reduction[1/]	7%	11.36	--	--
	8%	12.95	--	--
	9%	14.44	--	--
	10%	**15.92**	--	--
Percent flow reduction[2/]	7%	14.44	13.73	12.52
	8%	**16.35**	**15.45**	14.1
	9%	**18.26**	**17.13**	**15.61**
	10%	**18.74**	**18.74**	**17.06**

Note: **Bold** denotes >15% reduction in the AWS.

1. The method involves calculating a percent value of median flow and using it as a constant flow value reduction from each flow value for the period of simulation. Based on linear interpolation, the relative flow reduction associated with a 15% reduction in the baseline AWS is 9.4% for largemouth bass.

2. This approach involves a constant percent reduction of each flow value for the period of simulation. Based on linear interpolation, the relative flow reductions associated with a 15% reduction in the baseline AWS are 7.3% for largemouth bass fry, 7.7% for bluegill fry, and 8.6% for the shallow/slow guild.

6 Summary and Development of MFLs

6.1 Discussion and Summary

The Aucilla and Wacissa Rivers, including priority springs, were evaluated to determine flow regimes that would be protective of recreational activities and fish and wildlife habitat (WRVs 1, 2, and 3). Best available information was used to identify specific indicators for evaluating flow-reduction scenarios that would protect the resources. Multiple locations within the study area and a range of flows were evaluated.

Due to the limited specific information regarding a threshold flow reduction that would no longer be protective of the selected resources, a flow reduction that results in no greater than a 15% reduction in a metric, such as usable area and/or inundation time, was considered to be a threshold flow reduction for most of the resources evaluated. For some resource values, there is a paucity of literature with quantitative data available to support a specific metric. Professional judgment and characteristics of channel geometry were relied upon in some evaluations, such as for recreation (boating) on the Wacissa. For low-flow conditions associated with fish passage on the Wacissa, a quantitative evaluation was not performed because the critical (i.e., limiting) depth is well below the minimum depth historically observed, and the flow associated with the limiting depth is lower than the range of flows considered in the hydraulic modeling. It was concluded that fish passage would be protected under the withdrawal scenarios evaluated and that sufficient water would be available for fish passage during the lowest recorded flow.

Time series of daily flows for a 64-year period from WY 1951 through WY 2014 for the Aucilla and an 11.5-year period from WY 2001 through WY 2014 (excluding WYs 2007-2008) and intermittent measurements between June 1977 and February 2001 for the Wacissa were used for the analyses. These flow records comprise the entire POR for the respective gages.

The threshold flows are referenced to two index streamflow gaging stations: USGS station numbers 02326500 (Aucilla River near Lamont) and 02326526 (Wacissa River near Wacissa). Equations are provided in Section 2.3.2 for translating Aucilla River flows measured at the Lamont gage to two downstream gages: the USGS streamflow station 02326512 (Aucilla River near Scanlon) and the Aucilla ADVM gage established by the District near the USGS station 02326550 (Aucilla River near Nutall Rise).

Threshold flows were evaluated for protecting recreation on the Aucilla River and its riverine, floodplain and estuarine habitats (Table 27). Some threshold flows, such as for recreational paddling and fish passage, are associated with specific baseline flows. Others, such as the 0-2 ppt bottom salinity area, are associated with a range of baseline flows. The percent-of-flow reductions associated with these threshold flow regimes would shift the baseline flow duration curve by varying amounts (Figure 78). The discrete threshold flows are represented by X's on the graph, and the metrics associated with a range of threshold flows are represented by curves.

The number of viable paddling days on the Aucilla River Paddling Trail was selected to evaluate protecting recreation. A withdrawal of 69 cfs, or 34.2% of a threshold flow of 201 cfs, would result in a 15% reduction in viable paddling time under the baseline hydrology (Table 27).

Five threshold flow reductions are based on protecting riverine habitat in the Aucilla River (Table 27). The lowest threshold of 73 cfs applies to fish passage. At this flow, 22 cfs, or 30.1% of the flow, could be withdrawn. Successively higher instream thresholds of 170, 308, and 558 cfs would apply to the bank habitat in the upper and middle segments of the Aucilla River. The relative reductions associated with these flow thresholds range from 12% to 16% .

The SEFA model developed to evaluate instream habitat is reliable over a range of flows from 18 cfs to a limit of 146 cfs, and is prescribed as applicable for this particular metric.

Total wetland area inundated on the Aucilla River floodplain was selected to evaluate floodplain habitat protection. A withdrawal of 184 cfs, or 17% of a threshold flow of 1,054 cfs, is associated with a 15% reduction of inundation of floodplain wetland area under the baseline hydrology. A 17% flow reduction is applicable to a range of flows from 558 cfs (top of bank) to 1,054 cfs (the extent of wetland habitat).

Two threshold flow reductions are based on protecting estuarine habitat (Table 27), with a threshold flow reduction of 6.5% associated with a 15% decrease in the 0-2 ppt bottom area, and a 7.9% flow reduction associated with the 0-5 ppt shoreline length habitats. At flows greater than the threshold flow of 355 cfs at Lamont (or 1,075 cfs at the Aucilla ADVM gage), flow reductions have little impact on the bottom area salinity at the 2 ppt isohaline location (Figure 73). The threshold flow is similar for the 5 ppt isohaline location (Table 27). The metrics for oligohaline habitat, with average salinity of less than 5 ppt, include a more narrow range of species that exist in the upper subreaches of an estuary than the broader range that exists within the 0-15 ppt salinity range.

Four threshold flows were evaluated for protecting recreation on the Wacissa River, its riverine habitat, and the Aucilla estuary habitat (Table 28). Similar to the Aucilla River, the discrete threshold flows are represented by X's on the baseline flow-duration curve, and the metrics associated with a range of threshold flows are represented by shifted curves (Figure 79).

The number of unimpaired boating days on the Wacissa River was selected to evaluate the protection of recreation. A withdrawal of 19 cfs, or 5.1% of a threshold flow of 376 cfs, would result in 15% reduction in unimpaired boating time under the baseline hydrology (Table 28).

Table 27. Threshold flows for Aucilla River

Resource Value	Resource Metric	Threshold Condition (USGS gage 02326500 near Lamont)		
		Flow (cfs)	Flow Reduction (%)	Available Flow (cfs)
Recreation In and On the Water	Paddling during low water conditions (i.e., stage < 48 ft (132 cfs) at Lamont)	201	34.2*	69
Riverine Habitat	Fish passage-Min depth of 0.8 ft over 25% of the river bed width (51 cfs)	73	30.1*	22
	Weighted WP Mid Bank (upper Aucilla)	170	12*	20
	Weighted WP Mid-Top of Bank (middle Aucilla)	**308**	**13***	**40**
	Weighted WP Top of Bank (middle Aucilla)	558	16*	89
	Area Weighted Suitability (SEFA-shallow/fast guild)	18 to 146	35.7**	6 to 52
Floodplain Habitat	**Wetland Inundation Area**	**558 to 1,054****	**17***	**95 to 179**
Estuarine Habitat	**0-2 ppt Bottom Area**	**<355**	**6.5****	**<23**
	0-5 ppt Shoreline Length	<355	7.9**	<28

*Based on a single flow value
** Based on a range of flows
Bold indicates limiting flow reductions proposed for MFLs

Boating becomes increasingly difficult at lower flows but still occurs; therefore, the 5.1% criteria should be applicable to lower flows. A 5.1% limiting flow reduction would also be protective of the use of kayaks and other shallow-draft vessels that frequently traverse the length of this unique springflow-dominated river.

Instream habitat was evaluated using the SEFA modeling software. The weighted suitability for largemouth bass fry were determined to be the more restrictive metric, with a threshold percent-of-flow reduction of 7.3% for the below tram sub-reach. The reliable range of habitat model applicability is between 93 cfs and 1,340 cfs.

Although the Wacissa River has no estuary, it is an important source of freshwater discharged to the Aucilla River estuary. The most restrictive of the Aucilla estuary thresholds (i.e., 6.5% flow reduction) was selected for the protection of estuarine habitat, and the Reach Method (Good and Mattson 2004) was used to translate the flow threshold from the head of the estuary to the Wacissa gage. This proportioning maintains the relative flow contributions of the Wacissa and Aucilla Rivers to the total freshwater inflow to the estuary. Using the equations developed to translate Aucilla flows from the Lamont gage to Scanlon and Nutall Rise, and the

Aucilla/Wacissa flow proportioning method (see Section 2), a threshold flow of 361 cfs would remain protective of oligohaline habitat in the Aucilla River estuary.

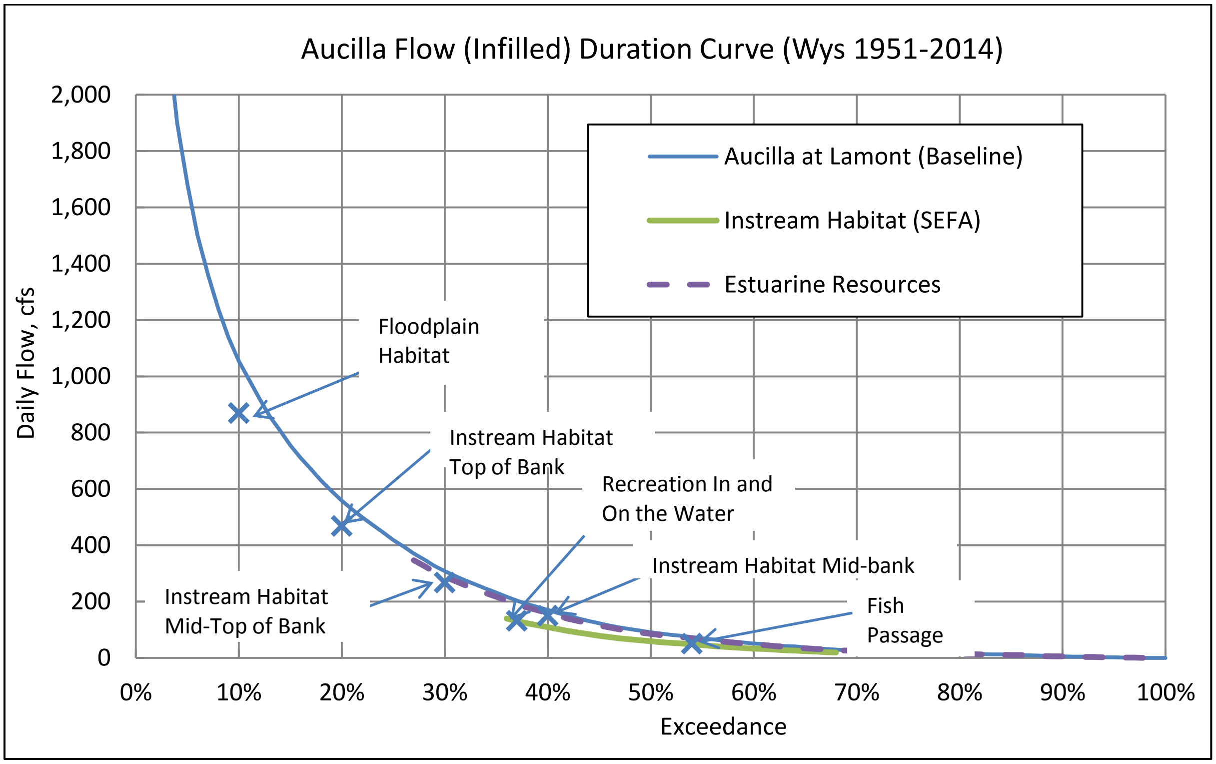


Figure 78. Flow reduction scenarios for the Aucilla River

Table 28. Threshold flows for Wacissa River

Resource Value	Resource Metric	Threshold Condition (USGS gage 02326526 near Wacissa)		
		Flow (cfs)	Flow Reduction (%)	Available Flow (cfs)
Recreation In and On the Water	**Safe boat passage (minimum depth of 2 feet over 30 feet of the channel width**	**<376**	**5.1****	**19**
Riverine Habitat	**Area Weighted Suitability (SEFA-largemouth bass, below Old Tram)**	**93 to 1,340**	**7.3****	**7 to 98**
Estuarine Resources	0-2 ppt Bottom Area	<361	6.5**	<23
	0-5 ppt Shoreline Length	<361	7.9**	<28

*Based on a single flow value
** Based on a range of flows
Bold indicates limiting flow reductions for proposed MFLs

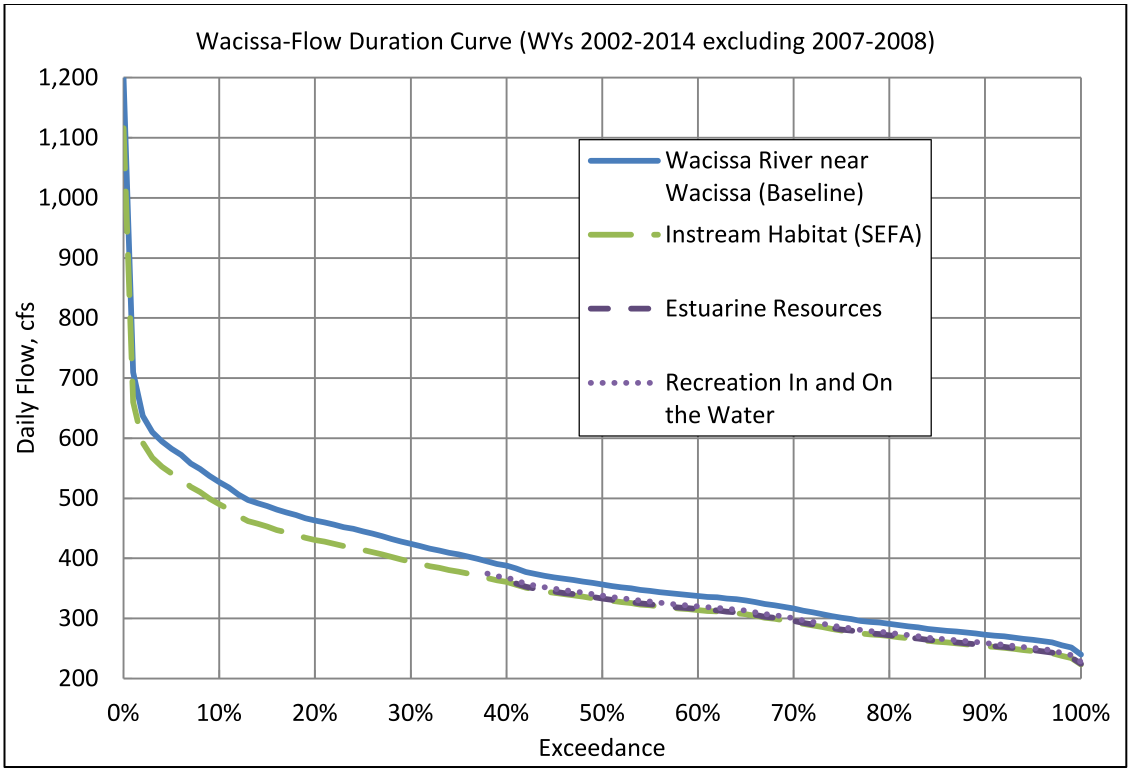


Figure 79. Flow reduction scenarios for the Wacissa River

6.2 Proposed MFLs

The MFLs recommended for the Aucilla and Wacissa Rivers are based on professional judgment supported by the weight of evidence from analyses of flow reductions that would remain protective of recreation on the rivers, riverine, floodplain, and estuarine habitats (Figure 80 and Figure 81). MFLs are represented as percent-of-flow flow reductions, absolute flow rates, or a combination of both. The percent-of-flow approach is a management approach that limits withdrawals from a river to a percentage of flow at the time of withdrawal. The stated goals of the approach when used by the SWFWMD to establish MFLs for estuaries in the Peace River and Little Manatee River are to make withdrawals mimic the temporal characteristics of the freshwater flow regimes and to protect estuarine ecosystems during the dry season when the ecosystems are more vulnerable to the effects of large withdrawals (Flannery et al. 2002). The SRWMD, SJRWMD, and SWFWMD have frequently established multiple MFLs for a river recognizing that more water is usually available for withdrawal during high flows than at low flows.

Three MFLs are recommended for the Aucilla River for successively higher flow regimes referenced to the index gage at Lamont.

- A 6.5% flow reduction during low to moderate flows would remain protective of the oligohaline salinity regime of the Aucilla River estuary. The 0-2 ppt and 0-5 ppt oligohaline regimes are most sensitive to reductions in freshwater flow of the metrics evaluated for the Aucilla River (Table 27). This estuarine flow reduction limitation applies over about 72% of the baseline flow duration curve (0 to 355 cfs). The flow reductions would range from zero when there is no flow at the Lamont gage up to 23 cfs at 355 cfs.

- A 13% flow reduction would remain protective of bank habitat for increasingly higher flows of up to 558 cfs, which is associated with the average top-of-bank stage within the middle reach of the Aucilla River (Table 27). Between 46 and 73 cfs would be available during this flow range that occurred about 8% of the time during baseline conditions.
- A flow reduction of up to 17% would remain protective of floodplain habitat for flows greater than 558 cfs, various portions of which were inundated by overbank flow about 20% of the time during baseline conditions. Beginning with 95 cfs of available water at a top-of-bank flow of 558 cfs in the middle Aucilla River, increasing amounts of water could be withdrawn as limited to 17% of flow (Table 27).

The three Aucilla River MFLs referenced to the Lamont gage can be translated to the Scanlon and Aucilla ADVM gages (Appendix D).

Two MFLs are recommended for the Wacissa River for successively higher flow regimes referenced to the index gage near Wacissa.

- A 5.1% reduction in flow during moderate to low flows equal to or less than 376 cfs would be protective of recreation activities associated with motor boating.
- A 7.3% flow reduction of Wacissa River flows greater than 376 would be remain protective of instream habitat, the most limiting of which is the area weighted suitability for largemouth bass fry. Estuarine habitat also would remain protected under this regime.

Collectively, the proposed MFLs would also be protective of the estuarine habitat on the Aucilla River.

Table 29. MFLs summary

	Threshold Habitat	Baseline Flow Range (cfs)	Percent Time MFLs is Applicable	Range of Flow Available (cfs)	Flow Reduction (%)
Lamont	Estuarine	< 355	72	<23	6.5
	Riverine	355-558	8	46-73	13
	Floodplain	>558	20	>95	17
Wacissa	Recreation	<376	52	<19	5.1
	Riverine	>376	48	>27	7.3

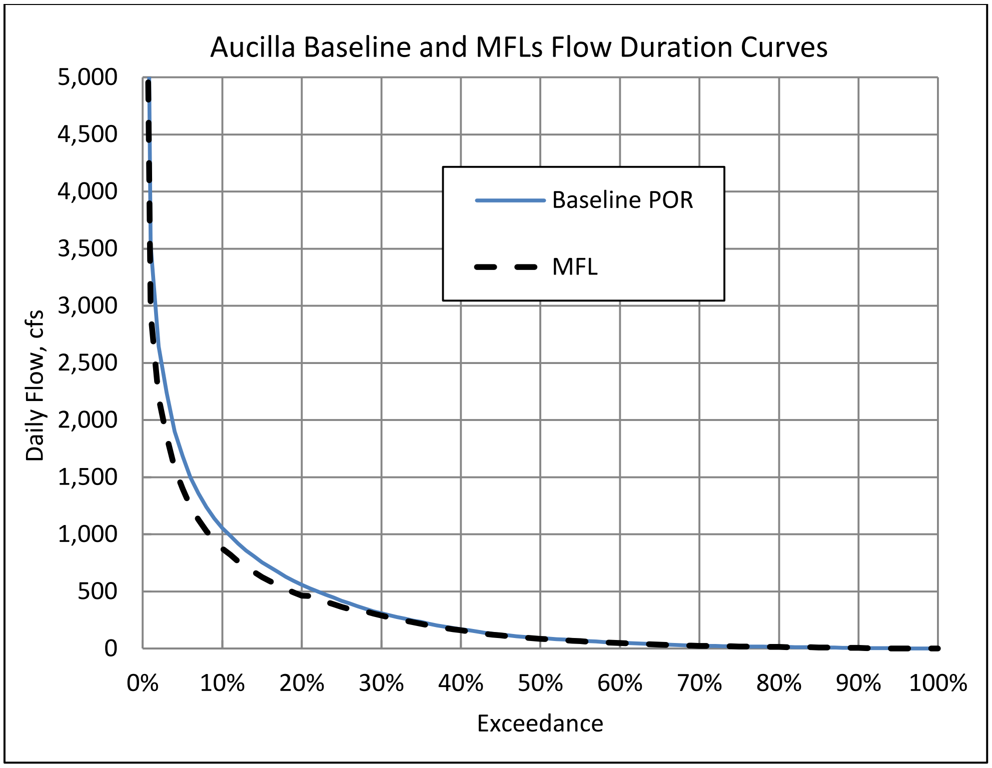


Figure 80. Flow duration curves for Aucilla River near Lamont gage (Baseline and MFLs)

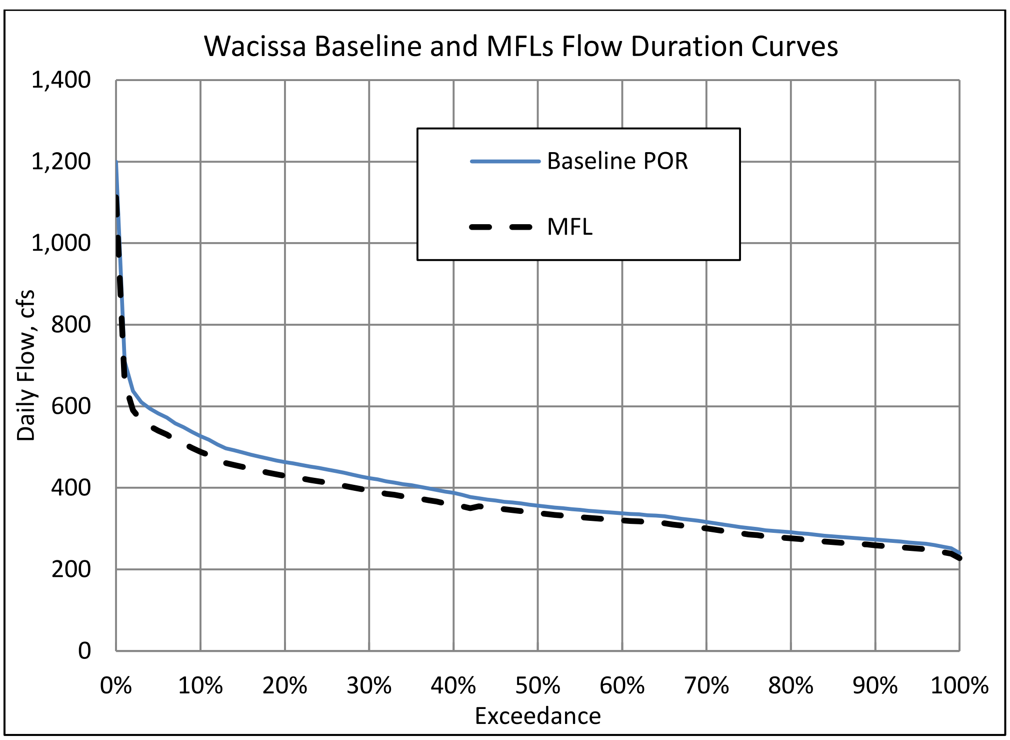


Figure 81. Flow duration curves for Wacissa River near Wacissa gage (Baseline and MFLs)

Nutall Rise and the Wacissa Springs Group are identified on the MFLs priority List and Schedule (SRWMD 2015). Nutall Rise is a resurgence, primarily of the Aucilla River, and its discharge is nearly all of the freshwater surface inflow to the upper portions of the Aucilla River estuary.

The Wacissa Springs Group consists of at least 12 springs that give rise to the Wacissa River that are located near the town of Wacissa in Jefferson County. Given the large contribution of springflow to the discharge on the Wacissa, maintenance of spring flow is essential for the protection of water resource values on the Wacissa River. The Wacissa gage is considered an index station for the combined flows of the Wacissa Springs Group, and an allowable reduction in spring flow could be translated to the Wacissa gage.

- The MFLs recommended for the priority springs are based on baseline river hydrology and the index streamflow gages for the respective rivers. Nutall Rise is a resurgence, primarily of the Aucilla River, and its discharge is nearly all of the freshwater surface inflow to the upper portions of the Aucilla River estuary. When applied to Nutall Rise, the 6.5%, 8%, and 17% flow reduction thresholds developed for the Aucilla River at Lamont gage would be protective of recreation and freshwater habitats on the Aucilla River and the estuarine habitat downstream from the rise.
- The Wacissa Springs Group is a collection of at least 12 springs that give rise to the Wacissa River (Rosenau et al. 1977), and the Wacissa gage is considered an index for the combined flows of the Wacissa Springs Group. The 5.1% and 7.3% flow reduction thresholds developed for the Wacissa River gage would be protective of recreation on the Wacissa, its riverine habitat, and the habitat in the Aucilla River estuary.

The differences between the Baseline and MFLs flow durations curves (Figure 80 and Figure 81) represent schedules of variable flow reductions for the Aucilla River near Lamont and Wacissa River near Wacissa, respectively. The reductions for the Aucilla River range between 0.1 at a baseline low flow of 1.5 cfs that is exceeded 95% of the time to 287 cfs at a high flow of 1,685 cfs that is exceeded 5% of the time (Table 30). The reductions for the Wacissa River range between 14 and 42 cfs for the same range in exceedance frequencies (Table 31).

The average baseline and MFLs flows for the Aucilla River, computed by the integration of the area beneath each FDC (Figure 80), are 405 and 343 cfs, respectively. Thus, in terms of average flow, the overall allowable flow reduction from baseline conditions is 15.3%. Similarly for the Wacissa River FDCs (Figure 81), the average baseline and MFLs flows are 385 and 361 cfs, respectively, and the overall allowable flow reduction is 6.2 percent.

Although these differences between baseline and MFLs flows represent the water availability under an MFLs regime, they do not necessarily represent the current water availability as the differences do not account for reductions in flow which may have already taken place from existing uses.

Table 30. Baseline and MFLs flow values for select frequencies of exceedance at Aucilla River near Lamont

Condition	Discharge Exceedance Amounts (cfs)						
Exceedance Frequency	5%	10%	25%	50%	75%	90%	95%
Baseline	1,685	1,054	418	91.0	19.0	5.3	1.5
MFLs	1,398	875	364	85.1	17.8	5.0	1.4
Relative Flow Reduction (%)	17	17	13	6.5	6.5	6.5	6.5

Table 31. Baseline and MFLs flow values for select frequencies of exceedance at Wacissa River near Wacissa

Condition	Discharge Exceedance Amounts (cfs)						
Exceedance Frequency	5%	10%	25%	50%	75%	90%	95%
Baseline	582	527	445	357	301	273	265
MFLs	540	489	413	338	286	259	251
Relative Flow Reduction (%)	7.3	7.3	7.3	5.1	5.1	5.1	5.1

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APPENDIX A

Aucilla River - Hydrodynamic Model Results

Hydrodynamic Model Development, Calibration, and MFL Flow Reduction and Sea Level Rise Simulation for the Tidal Portion of the Aucilla River

Aucilla River, Florida

Suwannee River Water Management District
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Live Oak Florida 32060

December 2015

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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND AND OBJECTIVES

The Suwannee River Water Management District (SRWMD) is performing a minimum flow and level (MFL) analysis for the Aucilla River. A component of the MFL analyses is the evaluation of the impacts to estuarine resources associated with potential reductions in freshwater flow in the Aucilla. A key element of the analyses is the change in salinity within the estuarine portions of the river under varying flow conditions and potential sea level rise. As such, SRWMD contracted for the development, calibration and application of a hydrodynamic model for the tidal portions of the Aucilla River. The model is used to evaluate the response of isohalines to reductions in freshwater discharge and sea level rise.

The extents of the hydrodynamic model are from offshore in the Gulf of Mexico up to a point above the limit of salinity intrusion under low flow conditions, including a sufficient distance upstream (area of coverage) to account for the magnitude of the tidal prism passing into the system. The tidal prism represents the total volume of flow that passes a point in the river through the ebb and flood cycle of the tides. For the Aucilla, the model included up to Nutall Rise. Figure 1-1a presents a project location map showing the location of the tidal portions of the Aucilla River. Figure 1-1b presents a similar map but with a broader view to include the location of the most-downstream active flow monitoring station presently maintained by U.S. Geological Survey (USGS 02326500 at Lamont, FL). The overall project for the Aucilla River included the following components:

1. A comprehensive field data collection program within the tidal portions of the Aucilla River
2. Development and calibration of a hydrodynamic model
3. Application of the calibrated hydrodynamic model under varying freshwater inflow and sea level rise

The methodologies and results from the field data collection are presented within a separate report entitled *Hydrodynamic Monitoring of the Tidal Portions of the Aucilla River* [Applied Technology and Management, Inc. (ATM), 2015]. The data presented in the report supported the development and calibration of the hydrodynamic model presented herein.

Janicki Environmental, Inc. (2007) developed a hydrodynamic model [the Gulf Coast Shelf Model (GCSM)] under contract with the Southwest Florida Water Management District (SWFWMD). SRWMD contributed funding to support that effort. One purpose of the model was to inform the future development of coastal boundary conditions (water surface elevations and salinity) for more detailed models, such as the Aucilla River model outlined in this report. The GCSM provided boundary conditions (water level and salinity) for the Aucilla River model for the MFL simulations outlined in Section 4. The GCSM model was not utilized for the model calibration since measured data were available to utilize in a boundary matching process. This is discussed further in Section 2.

1.2 REPORT OUTLINE

Following this introduction, the report is broken down into four sections. Section 2 presents the development of the model, including a general description of the Environmental Fluid Dynamics Code (EFDC) hydrodynamic model utilized for this project, the model inputs, the data sources for the model inputs, and the period of the calibration simulation. Section 3 provides the model calibration, including the data used in the model calibration, along with graphical and statistical comparisons of the model versus measured data. Section 4 presents a discussion of the scenarios run using the calibrated model for MFL development. Section 5 summarizes the results of the model development and calibration.

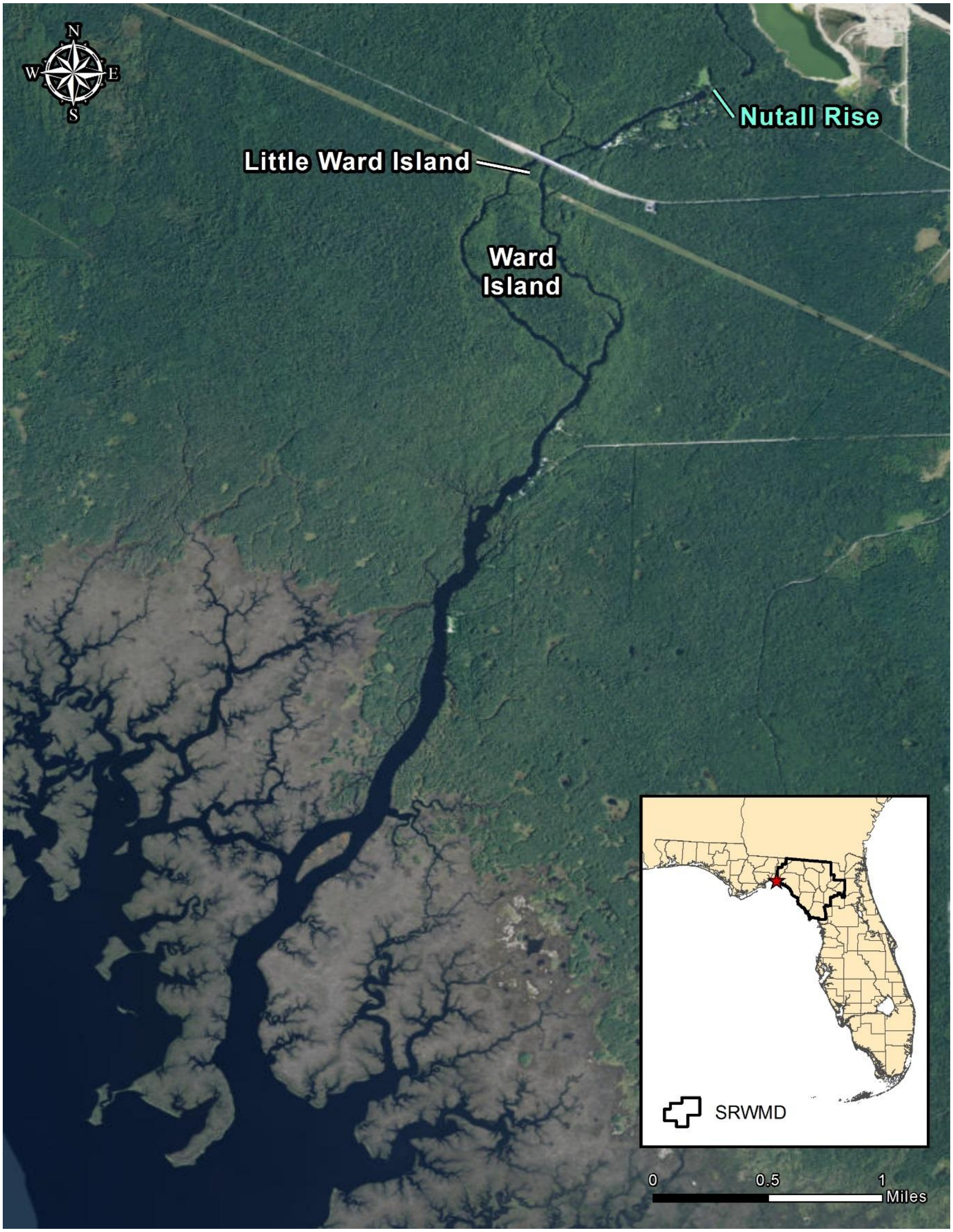

Figure 1-1a. Project Location of the Aucilla River and the Extent of the Study Area.

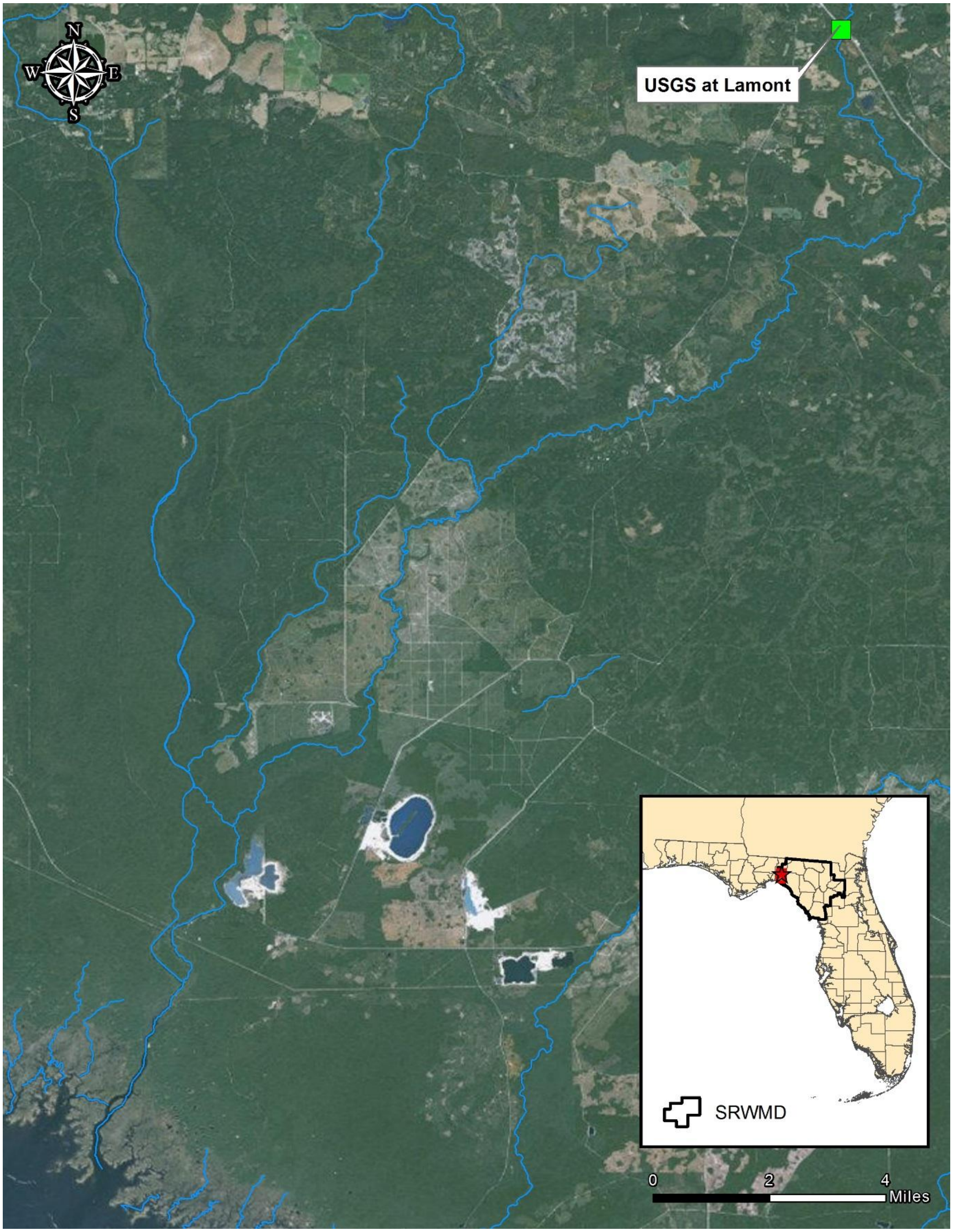

Figure 1-1b. Project Location of the Aucilla River Including USGS Gage 02326500 at Lamont, FL.

2.0 HYDRODYNAMIC MODEL DEVELOPMENT

This section provides a detailed description of the development of the hydrodynamic model for the tidal portions of the Aucilla River. As discussed in Section 1, the model extents include the offshore area (approximately 2 miles out from the mouth, and 1.5 miles in either direction along the coast), the main stem of the Aucilla River up to Nutall Rise, and necessary tidal tributaries and adjacent marsh storage areas connected to the tributaries.

2.1 MODEL DESCRIPTION

The EFDC model used in this project is a general purpose modeling package for simulating two- and three-dimensional flow, transport and biogeochemical processes in surface water systems, including rivers, lakes, estuaries, reservoirs, wetlands and nearshore to shelf-scale coastal regions. The EFDC model was developed by Dr. John Hamrick at the Virginia Institute of Marine Science and is considered public domain software (Hamrick 1992a, 1992b). EFDC is currently supported by the U.S. Environmental Protection Agency (EPA) Office of Research and Development (ORD), EPA Region 4, and EPA Headquarters. A link to the EPA website for the EFDC model is http://www.epa.gov/athens/wwqtsc/html/efdc.html. Additionally, the Florida Department of Environmental Protection (FDEP) and the Water Management Districts (WMDs) throughout the state have used this model extensively. Specific examples of FDEP and WMD applications of EFDC include Indian River Lagoon [St. Johns River Water Management District (SJRWMD)], tidal portions of the St. John's River (SJRWMD), Florida Bay [South Florida Water Management District (SFWMD)], tidal Caloosahatchee River (FDEP), Pensacola and Escambia Bay (FDEP), and the tidal Suwannee River (USGS for the SRWMD).

The physics of the EFDC model, and many aspects of the computational scheme, are equivalent to the widely used Blumberg-Mellor (1987) model. The EFDC model solves the three-dimensional, vertically hydrostatic, free surface, turbulent-averaged equations of motions for a variable density fluid. Dynamically coupled transport equations for turbulent kinetic energy, turbulent length scale, salinity and temperature are also solved. The two turbulence parameter transport equations implement the Mellor-Yamada level 2.5 turbulence closure scheme. The EFDC model uses a stretched or sigma vertical coordinate and curvilinear orthogonal horizontal coordinates.

The numerical scheme employed in EFDC to solve the equations of motion uses second-order accurate spatial finite differencing on a staggered or C grid. The model's time integration employs a second-order accurate three-time level, finite difference scheme with an internal-external mode splitting procedure to separate the internal shear or baroclinic mode from the external free surface gravity wave or barotropic mode. The external mode solution is semi-implicit and simultaneously computes the two-dimensional surface elevation field by a preconditioned conjugate gradient procedure. The external solution is completed by the calculation of the depth-average barotropic velocities using the new surface elevation field. The model's semi-implicit external solution allows large time steps that are constrained only by the stability criteria of the explicit central difference or higher order upwind advection scheme used for the nonlinear accelerations. Horizontal boundary conditions for the external mode solution include options for simultaneously specifying the surface elevation only, the characteristic of an incoming wave, free radiation of an outgoing wave or the normal volumetric flux on arbitrary portions of the boundary.

2.2 MODEL GRID AND BATHYMETRY

The first aspect of the hydrodynamic model development is the definition of the model extents or coverage. This is achieved through the development of the model grid. For the Aucilla River model grid mesh, the representation of the shoreline used was the light detection and ranging (LiDAR) data that outline elevations from 0.15 foot referenced to the North American Vertical Datum of 1988 (NAVD88) and up. These data, in essence, represent the landforms and the elevations that correspond to the edge of the open water areas for the flow. Figure 2-1 presents a contour plot of these data. For the Aucilla model grid, shown in Figure 2-2, the main stem and portions of tributary boundaries from these data were utilized to define the grid extents. The offshore boundary was extended a distance of approximately 2 miles out from the mouth. Additionally, the grid was extended approximately 1.5 miles in either direction laterally from the mouth. The purpose of the grid extension offshore was to provide sufficient area for mixing of the freshwater flowing into the Gulf of Mexico. The grid was extended upstream to Nutall Rise, including all of the main stem and the split in the system around Ward Island and Little Ward Island. The grid for the Aucilla model included 3608 horizontal cells and 8 vertical cells, with minimum sizes on the order of 8 by 30 meters and maximum sizes on the order of 200 by 200 meters.

A key aspect of the model calibration was the need to include representative storage areas along the main stem. As Figure 2-1 demonstrates, extensive areas inundate under different water level conditions (high tides can be up around 2.0 feet NAVD88 at times). As such, to accurately simulate the tidal prism moving through the system, representative storage areas were added (Figure 2-2) that fill through tributary spurs off the main stem model grid. These were roughly based upon the area of inundation shown in Figure 2-1, but were more driven by the simulation of the flow measured at one of the field data collection stations. These aspects are discussed further in the model calibration section (Section 3).

Figure 2-3 presents the bathymetric conditions in the Aucilla model for the simulations. The bathymetry came from a detailed survey of the main stem of the river extending upstream to Nutall Rise. All bathymetric conditions were referenced to NAVD88. The bottom elevations for the Aucilla River grid were interpolated using a combination of the digital elevation model (DEM) provided by SRWMD and the bathymetry points collected during the river survey. The DEM was first converted from a raster coverage to a point coverage of 10-foot horizontal resolution. This coverage was modified to remove any DEM point within the river or near a bathymetry data point. The DEM point coverage was combined with the bathymetric point coverage into a single coverage to represent both the land elevations and the bathymetric data. An inverse distance-weighted raster interpolation was performed to create a single raster coverage of the rivers and the surrounding watershed referenced to NAVD88. This coverage was used to find the mean elevation value of each model grid cell, with the mean values of rasters within a cell representing the cell bottom elevation.

USGS created the offshore bathymetry interpolated onto the model grid for the Florida Shelf Habitat (FLaSH) map study in 2007. This was a multi-agency effort that created a compilation dataset of available bathymetry from the Florida coast to the edge of the Florida shelf. This coverage is a bathymetry point file that was used to create the elevations for the model grid cells offshore in the Gulf of Mexico. Bottom elevations were converted from the vertical datum of the coverage [mean lower low water (MLLW)] to NAVD88. For the offshore bathymetric conditions in the final model grid, adjustments were made for the model to allow progression of the tidal wave to the mouth and facilitate boundary matching at the mouth. This is discussed in more detail in the model inputs section (Section 2.3).

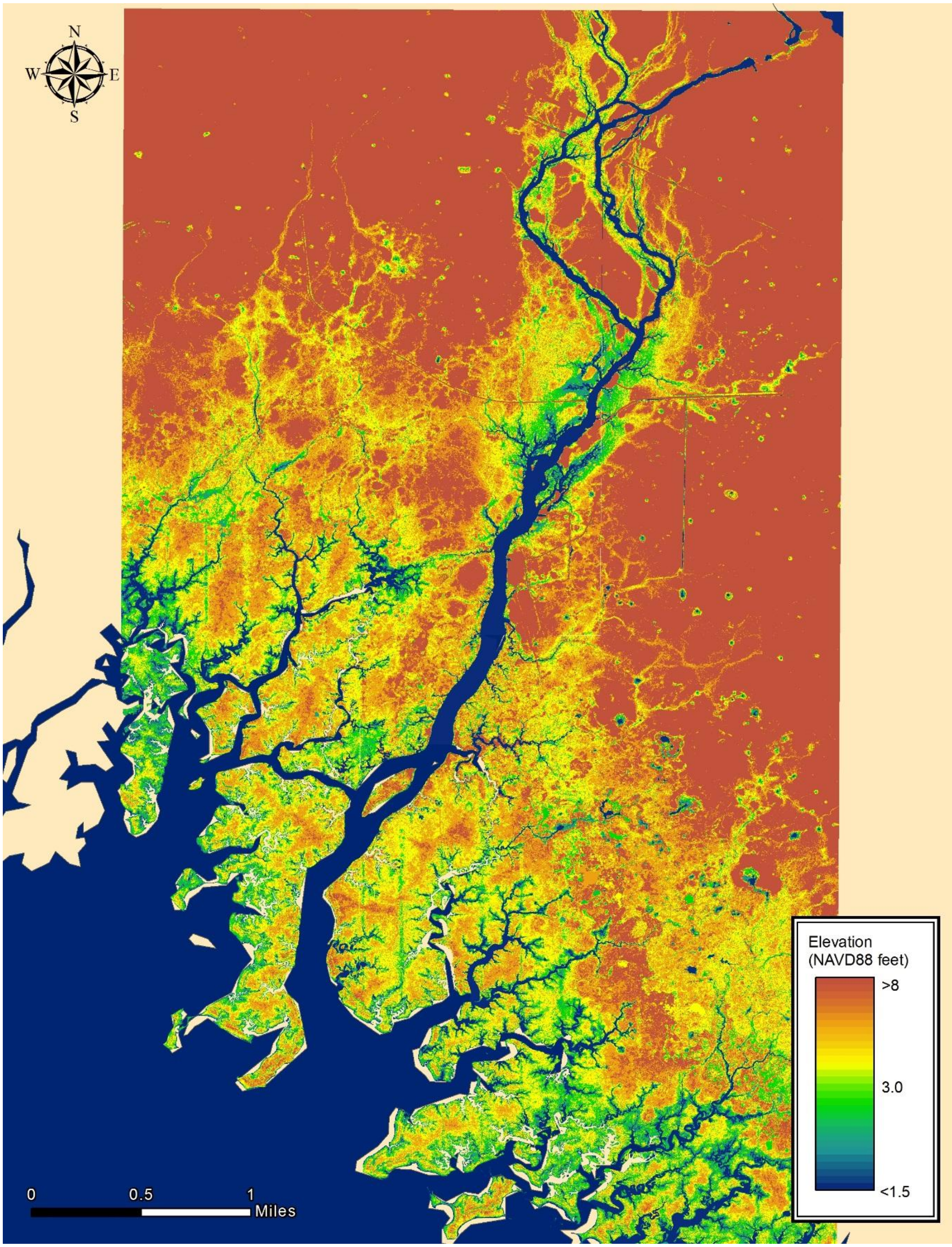

Figure 2-1. Upland Topographic Conditions from LIDAR Data.

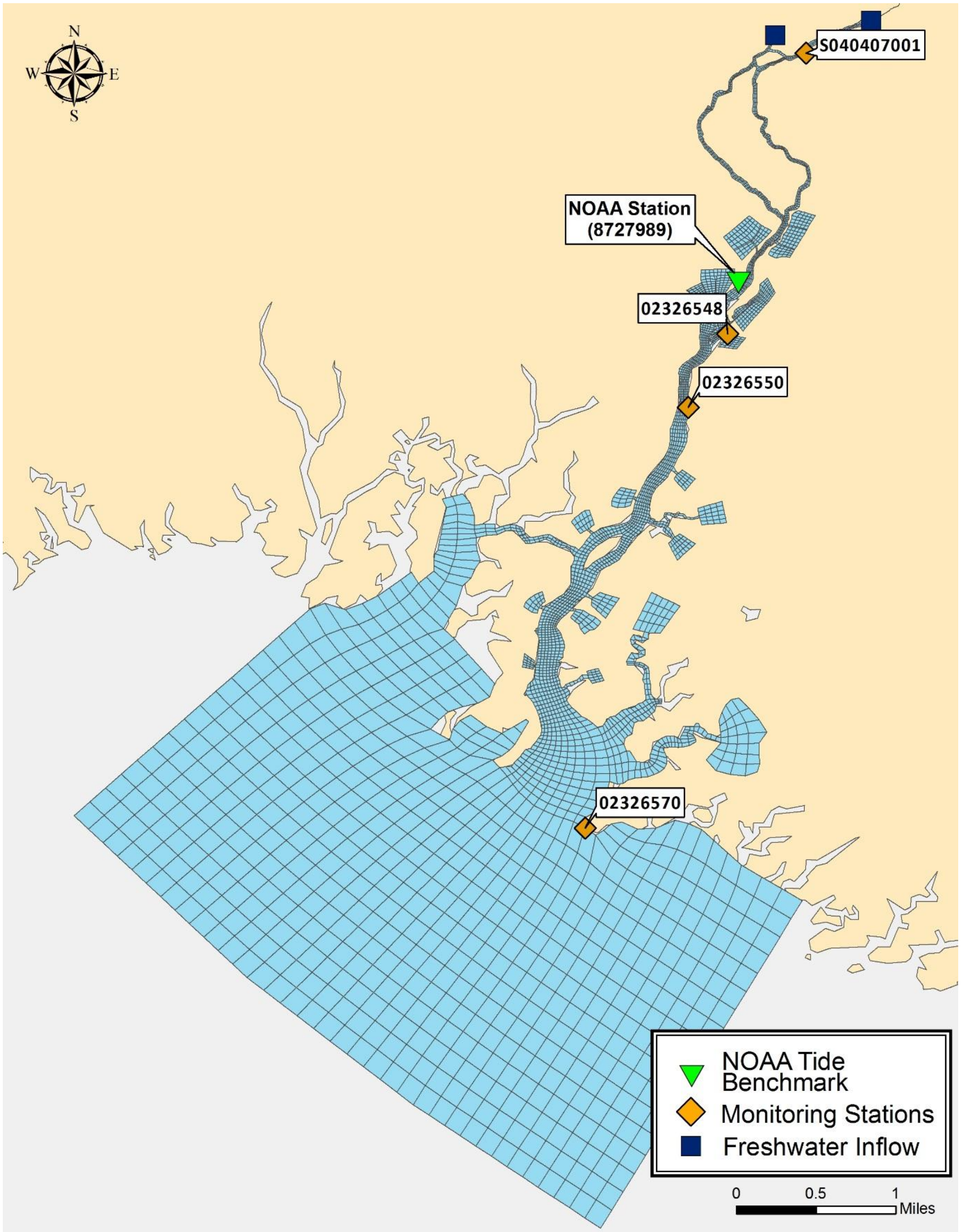

Figure 2-2. Aucilla River Model Grid.

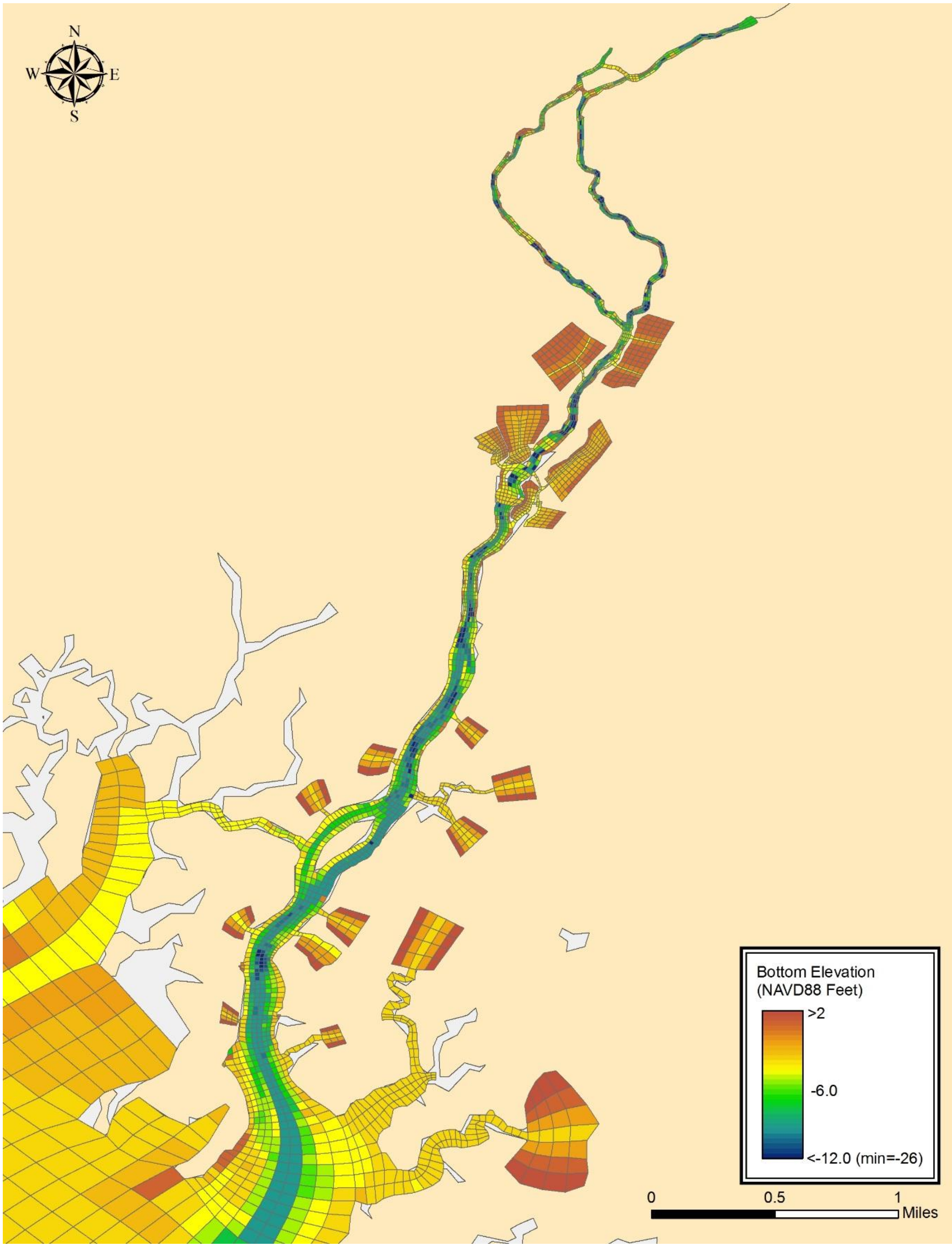

Figure 2-3. Aucilla River Model Grid Bathymetry.

2.3 MODEL BOUNDARY FORCINGS AND SIMULATION PERIOD

A number of model inputs were developed for the Aucilla River hydrodynamic model. Based on the grid provided in Section 2.2, the specific inputs include:

- Offshore water levels relative to NAVD88
- Offshore salinity
- Upstream freshwater inflow
- Meteorological inputs (wind speed and direction)

This section provides an overview of the inputs utilized in the model and how they were developed. The simulation period for the Aucilla model is from March 1, 2015 through June 1, 2015, with a period of simulation within February to allow the model conditions to reach an equilibrium (spin-up period). The spin up period is used to assure the starting, or initial conditions of the model are at equilibrium. The graphs presented reflect the time-period following the model spin-up.

The model inputs were derived from the field data collected from February through June 2015. These data are presented in detail within the data collection report (ATM, 2015). The data included water levels, salinity and flow.

Prior to the introduction of the boundary conditions, it is important to provide some background on the tidal conditions in the area since tides are a critical forcing mechanism. Table 2-1 presents the elevations of key tidal constants derived for a long-term monitoring station at a location within the estuarine portion of the Aucilla River. The location of the long-term tidal station is presented in Figure 2-2. The data are referenced to the MLLW at this station and provide the difference between the MLLW and NAVD88, the datum used for the model development. The data show that the astronomic tide range is on the order of 1.9 to 2.5 feet at this location on average. It is important to note that this station is a significant distance upstream of the mouth of the Aucilla. This does not account for mean water level fluctuations in the Gulf of Mexico and freshwater inflows that also impact the local water levels.

Table 2-1. Aucilla Tidal Datums for NOAA Station 8727985 (Aucilla River)

Datum	Elevation (ft)
MHHW	2.47
MHW	2.25
MTL	1.30
MSL	1.21
NAVD88	0.57
MLW	0.34
MLLW	0.00

2.3.1 OFFSHORE WATER LEVEL

For the model calibration period, the water levels used to drive the offshore boundary shown in Figure 2-2 were derived from the measured water levels at the mouth of the Aucilla River (Station SRWMD 02326570 in Figure 2-2). The offshore water levels were derived using a process known as boundary matching. The boundary matching process went as follows:

- First, the measured tides at the mouth (SRWMD 02326570) were utilized directly as measured for the offshore forcing function.
- Second, the simulated and measured water levels at the station at the mouth (SRWMD 02326570) were analyzed for phase and amplitude errors.
- Finally, phase and amplitude adjustments were made to the offshore to minimize, as much as possible, the errors at the mouth.

For the Aucilla model, a phase lag of 10 minutes was applied to the measured tides for use in the offshore boundary. No tidal amplitude adjustments were made to the measured data. Figure 2-4 presents a plot of the offshore tides used for the boundary forcing. A comparison of the measured versus simulated water levels at the mouth are presented in Section 3 as part of the calibration statistics.

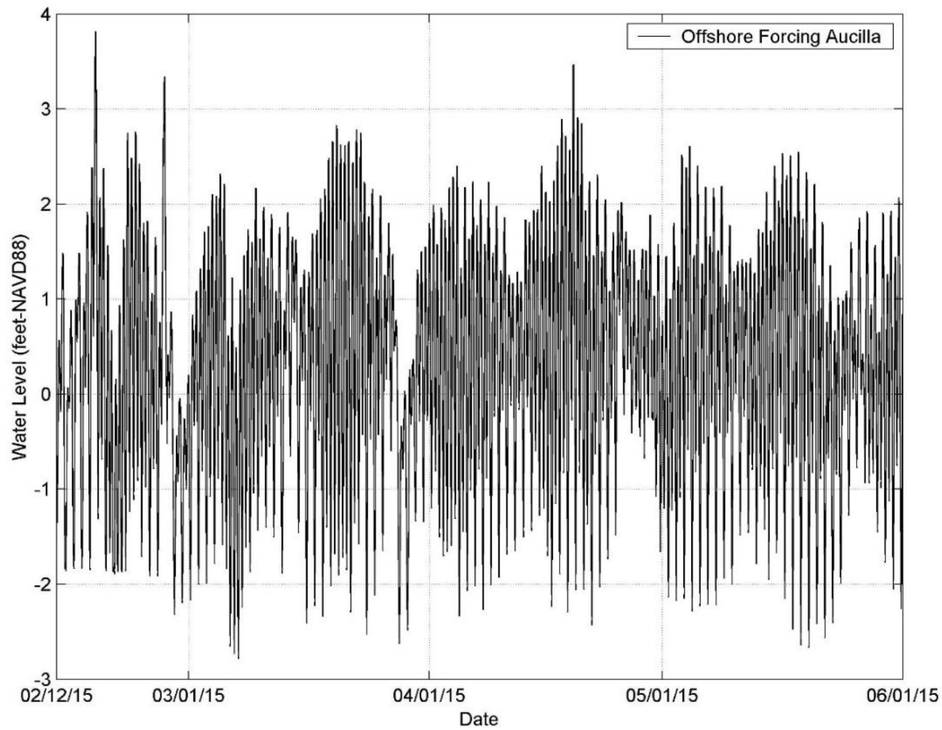

Figure 2-4. Derived Offshore Water Level Boundary Condition.

2.3.2 OFFSHORE SALINITY

The offshore salinity conditions for the Aucilla model were derived using a similar approach to that used for the tides, with one difference. For the salinity, the daily maximums measured at the mouth were utilized as the base condition to start the boundary matching process. The reason for using the daily maximums measured at the mouth is that in any one day, the station at the mouth measures the salinity through the ebb and flood cycle (inflow and outflow). At the end of a flood tide cycle (inflowing), water from offshore has moved from the offshore to the mouth to the maximum extent, therefore, the measurements at the end of the flood cycle (when the salinities are at their highest) would best reflect the conditions offshore. The following describes the boundary matching process used to establish the offshore salinity.

- First, the daily maximum measured salinities at the mouth (SRWMD 02326570) were derived from the data and used as a time series in the offshore.
- Second, the errors in the measured versus simulated salinity at the mouth were evaluated.
- Finally, adjustments were made to the baseline offshore salinity (using the daily maximums) to minimize the salinity error at the mouth (SRWMD 02326570).

Using the daily maximums as the base, the comparisons at the station at the mouth were sufficiently representative so that no manipulation of the offshore conditions was needed to achieve boundary matching. Figure 2-5 presents the time series of the boundary forcing derived for the Aucilla model.

At the offshore boundary in the model, the system was assumed to be well mixed, so that salinity at the surface and bottom are the same. The boundary matching at the mouth supported that this assumption produced reasonable salinity stratification conditions at the mouth. The offshore areas were included in the model to allow for mixing of the freshwater inflows with the offshore areas. Additionally, this provided an appropriate boundary for the output from the GCSM model as inputs to the EFDC model simulations for the MFL reduction and sea-level rise scenarios outlined in Section 4. This also provided some level of mixing of the freshwater discharges with the offshore. For the model calibration, due to the use of the boundary matching approach, the key areas of valid model simulation extend from the mouth upstream to the extent of tidal intrusion.

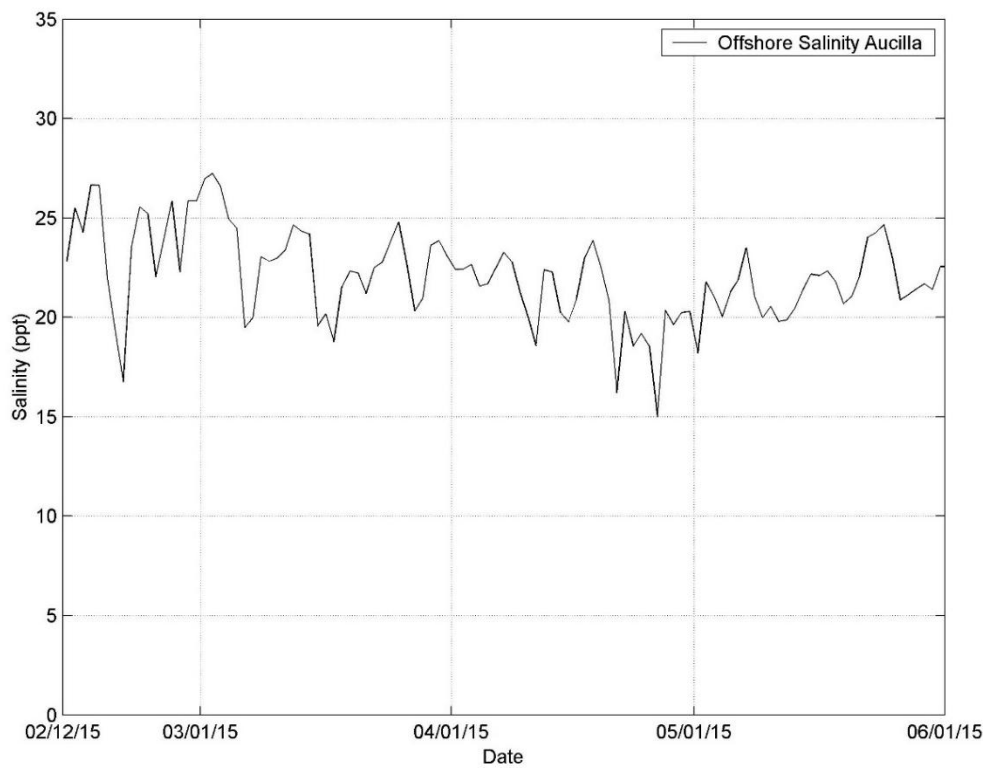

Figure 2-5.   Derived Offshore Salinity Boundary Condition.

2.3.3 FRESHWATER INFLOW

The time series of freshwater inflow used in the hydrodynamic model was derived from the flow measured at SRWMD Station 02326550[1] (Figure 2-2). At this station, an acoustic Doppler current meter (ADCP) and a water level sensor were deployed for the period of the model calibration (February 2015 through May 2015). At this site, the continuous measured velocities (6-minute interval across the river section) and continuous measured water levels (6-minute interval) were used to derive a continuous time series of tidally driven flow. The details of the deployment, and the analyses performed on these data to calculate the flow are presented in detail in the hydrodynamic data collection report (ATM, 2015). The time series of tidal flow were then filtered using a low-band pass filter to remove the tidal components leaving the net freshwater outflow. The filtered flow data were averaged over a daily time step to provide the flow input to the model. The filtered and averaged flow represents the total freshwater inflow from the watershed above station SRWMD 02326550.

For the Aucilla model, the total freshwater inflow was divided into two inflow points. One of the points is at the upper end of the grid, above Nutall Rise. The second is at a dead-end point near Nutall Rise. For the first point, 75 percent of the flow was entered, while 25 percent was entered into the second. This was based roughly on overall contribution area for the inflow points, but as these two flows ultimately merge together downstream prior to reaching the estuarine portions of the model, the split is not significant. Figure 2-2 shows the locations of the freshwater inflow points. Figure 2-6 presents the daily average total freshwater inflow input to the model.

2.3.4 WIND SPEED AND DIRECTION

The meteorological inputs to the model include the wind speed and direction acting on the water surface. The National Data Buoy Center (NDBC) Keaton Beach site was used for winds. Figure 2-7 presents the wind inputs, including the wind speed and direction.

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[1]The SRWMD Station 02326550 was previously a USGS station with the same number. Historically, this station monitored flow, but currently only gage height is measured.

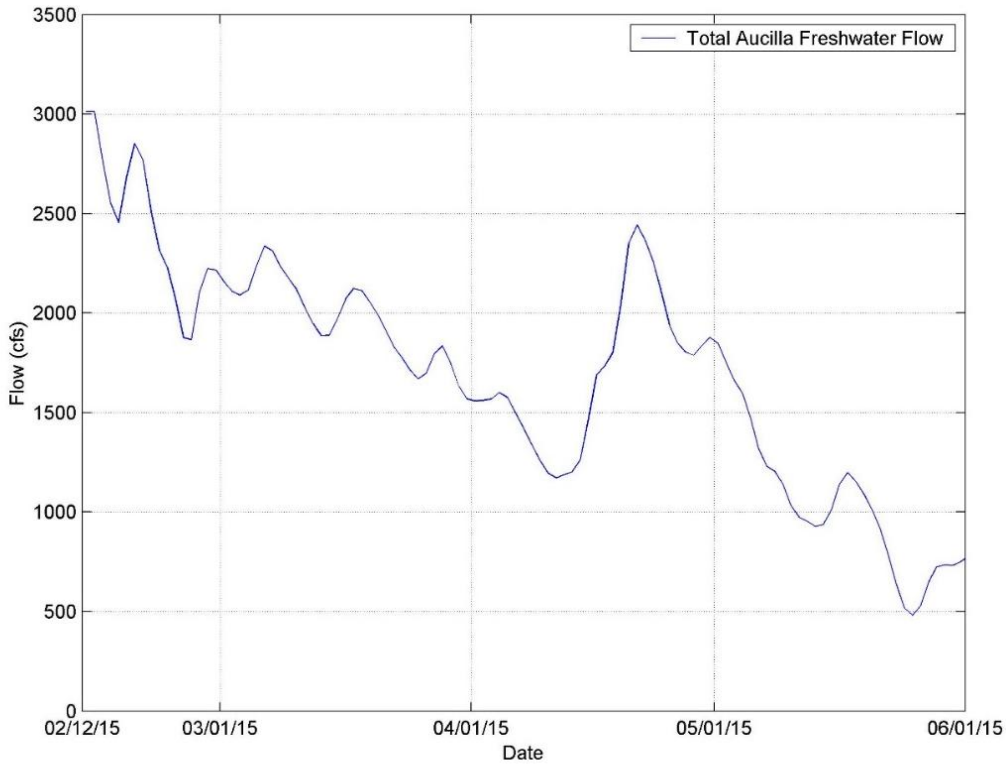

Figure 2-6. Total Freshwater Inflow.

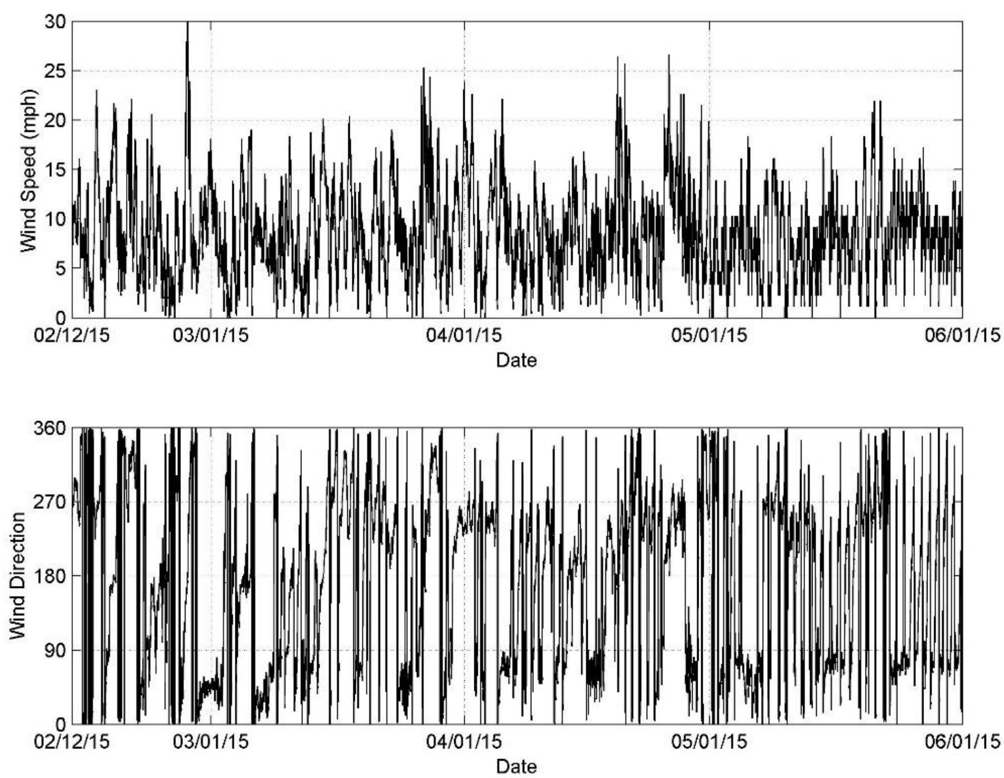

Figure 2-7. Wind Speed and Direction Model Inputs.

3.0 HYDRODYNAMIC MODEL CALIBRATION

This section provides a detailed description of the calibration of the hydrodynamic model, including the data used in the model calibration, a discussion of the calibration process used for this model, and presentation of the comparison of the model simulations to measured data for the water levels, flow, and salinity.

3.1 DATA USED IN MODEL CALIBRATION AND CALIBRATION STATISTICS

A companion hydrodynamic monitoring report (ATM, 2015) provides a detailed discussion of the data collected for this project. For the purposes of model calibration, the data used included the water levels at all three stations, the measured salinity at all three stations, and the time series of flow. Figure 3-1 presents the locations of the continuous monitoring stations along the main stem of the river. At the downstream station (SRWMD 02326570) and upstream station (SRWMD 02326548), water level and bottom salinity data were collected. At the mid-station (SRWMD 02326550), water level, flow, and bottom and surface salinity were collected. Data from March 1, 2015 through June 1, 2015 were utilized for the calibration comparisons.

In addition to graphical comparisons of the simulated versus measured results, statistical comparisons were performed, where appropriate. The statistics include the root mean square error (RMS), the mean error (ME), and the coefficient of determination (R^2). The following presents how each of these error statistics are calculated.

- Root Mean Squared Error (RMS):

$$\sqrt{\frac{\sum_{i=1}^{n}(O_i - m_i)^2}{N}}$$

- Mean Error (ME):

$$\frac{\sum_{i=1}^{n}(O_i - m_i)}{N}$$

- Coefficient of determination (R^2):

$$\left(Corrcoef\ (O_i, m_i)\right)^2$$

where: O_i = observation

M_i = model output

N = number of observations

Note: Corrcoef is a MATLAB function for correlation coefficient

The data from the model were extracted to match times of available measured data for the analyses. The statistics were then calculated from the matched data sets for the period identified.

The RMS represents the deviation of each of the individual measured-versus-simulated matched data pairs and is the most direct measurement of model-to-simulation error or difference between the results. This measure does not have a sign (i.e., negative or positive), so it does not identify if this is an under-prediction or over-prediction, simply what the overall differences are. The ME represents whether or not there is a bias in the results. For example, if the ME is less than zero, it means that overall, the model is under-predicting in an absolute sense. For both the RMS and the ME, the results are presented as values in the units of measure [feet for water level and cubic feet per second (cfs) for flow] as well as a percent error. The percent error is the value divided by the average range of the data signal being compared. The coefficient of determination (R^2) is a measure of how the model and data line up or correlate. If the model and data lined up perfectly, the R^2 value would be 1.

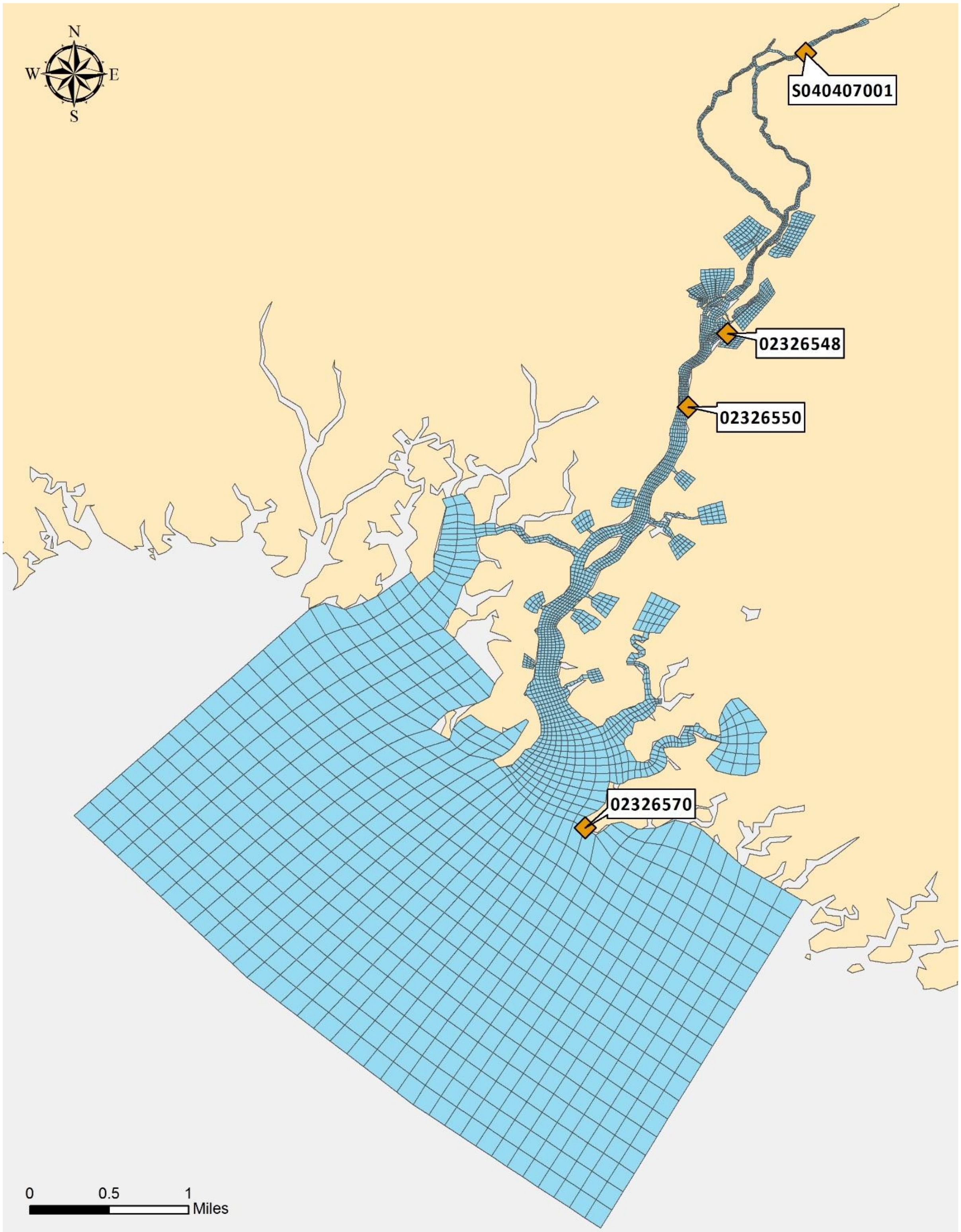

Figure 3-1. Locations of Continuous Monitoring Stations.

3.2 SIMULATED VERSUS MEASURED WATER LEVELS

Figures 3-2a through 3-2c present comparisons of the measured versus simulated water level at the three stations along the main stem of the Aucilla. The comparisons are presented by month from March through May. In addition to the three stations along the main stem, data were available from a groundwater monitoring station along the edge of the river near Nutall Rise (S040407001). The station location is show in Figure 3-1. It is important to note that the degree of damping of the tidal signal within the groundwater monitoring well in comparison to the actual water level fluctuations in the river is unknown, therefore, the model-to-data comparisons should be evaluated with this in mind.

The comparisons presented within the figures show that the model is doing very well simulating the magnitudes of the water level fluctuations and, specifically, the distribution of the damping of the tidal wave as it moves upstream. Table 3-1 presents the model statistics for the water level measurements. The results show that the RMS errors are all less than 0.2 foot, which equates to less than or equal to a 5 percent error. The percent error is based on dividing the RMS value by the average range for the tides on a daily basis over the period of the error analyses. In addition to the RMS errors, the mean errors are low and the R^2 values are very good, all above 0.96, indicating very good correlation between the measured data and the simulated results. Recent peer-reviewed work under a SWFWMD project for Tampa Bay identified an allowable error for water level for a good calibration of 0.16 foot for RMS error, +/- 0.16 foot for mean error, and 0.90 for R^2 (Janicki, 2014). Based on these criteria, the water level simulations for the Aucilla model represent a good calibration.

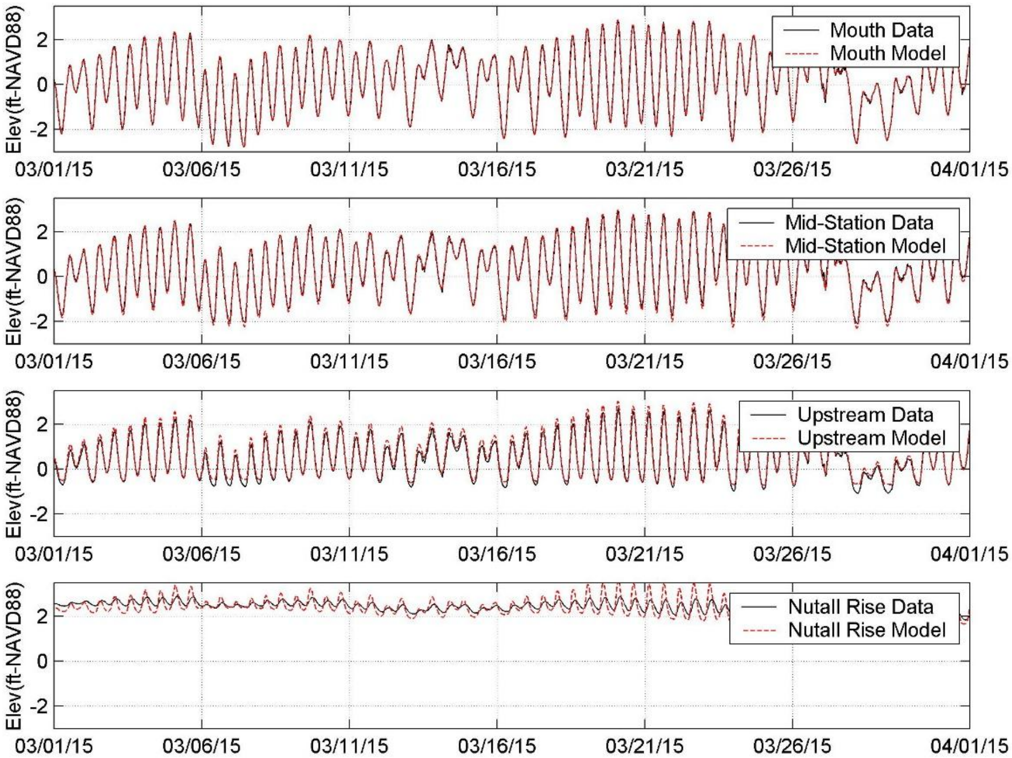

Figure 3-2a. *Simulated versus Measured Water Levels at SRWMD stations 02326570, 02326550, 02326548, and S040407001 in March 2015.*

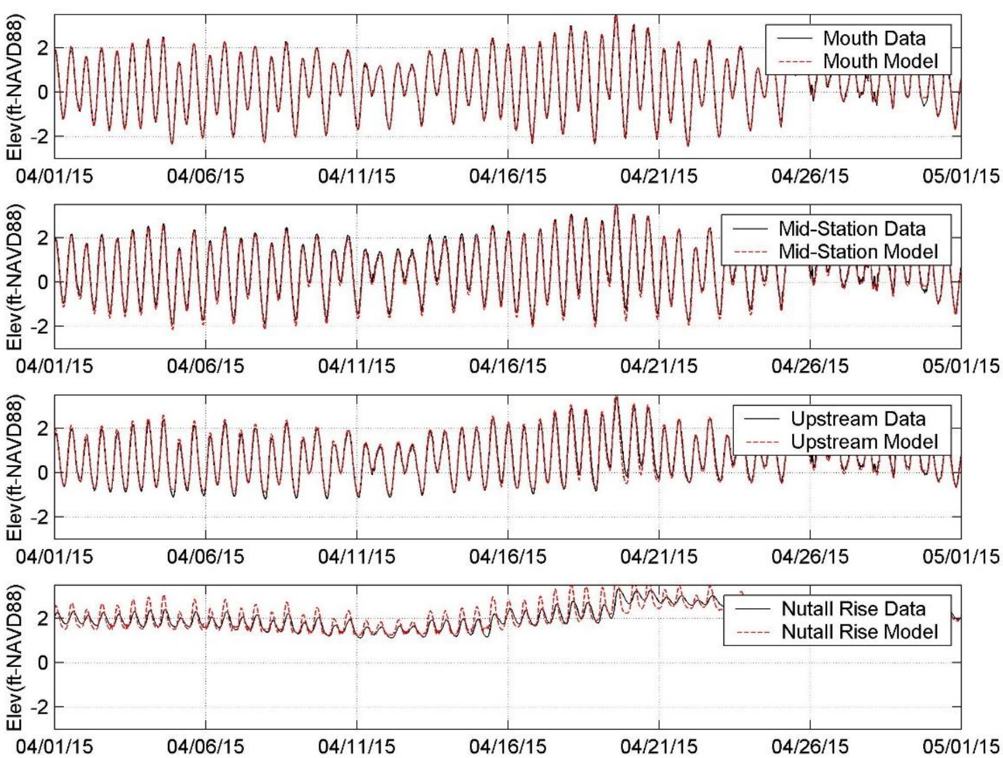

Figure 3-2b. *Simulated versus Measured Water Levels at SRWMD stations 02326570, 02326550, 02326548, and S040407001 in April 2015.*

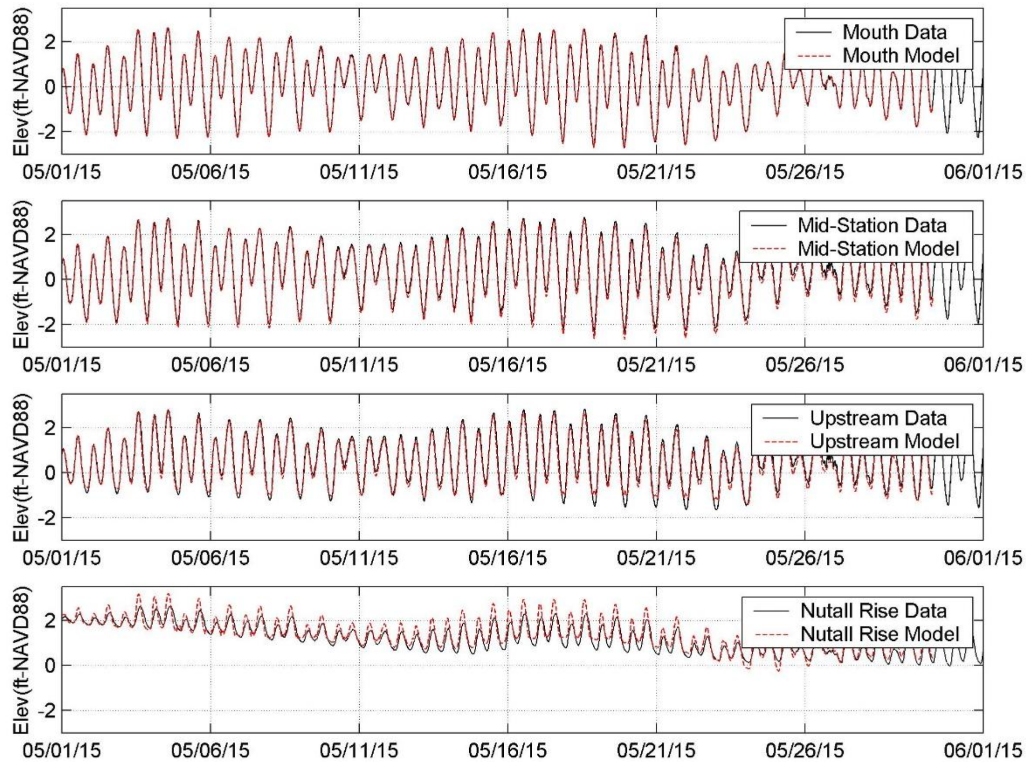

Figure 3-2c. Simulated versus Measured Water Levels at SRWMD Stations 02326570, 02326550, 02326548, and S040407001 in May 2015.

Table 3-1. Model Calibration Statistics.

Station Number	Station Name	Parameter	Units	RMS Error	RMS %	Mean Error	R^2
02326570	Aucilla - Mouth	Water Level	ft	0.06	2%	0.01	1.00
02326550	Aucilla - Middle	Water Level	ft	0.16	4%	-0.01	0.99
02326548	Aucilla - Upstream	Water Level	ft	0.19	5%	-0.01	0.96
02326550	Aucilla - Middle	Flow	cfs	471.6	16%	-0.1	0.77

3.3 <u>SIMULATED VERSUS MEASURED FLOW</u>

Figures 3-3a through 3-3f present comparisons of the measured versus simulated flow at Station SRWMD 02326550. The plots show the comparison of the simulated flows against the flows derived from the ADCP measurements as well as the direct flow measurements taken to establish the flow time series. The plots present the monthly comparisons as well as zoomed-in views of the comparisons at the time of the direct flow measurements. These comparisons show that the model is doing well simulating the magnitude, shape and timing of the flow signal. A key aspect of capturing the magnitude, shape and timing of the flow was the inclusion of the upstream storage areas that are fed through the tributaries. The storage areas flood and dry based upon the water level conditions, with the total area filled in the storage areas dependent upon the level reached under the high tide conditions. For higher tides (during spring tide conditions or periods with high mean water level in the Gulf), more of the storage areas fill and for a longer time.

Table 3-1 presents the model statistics for the flow comparisons, along with the comparisons of the water level, with the flow statistics at the bottom of the table. The results show that the RMS error is around 470 cfs, which is reflective of a 15 percent error. As with the water levels, the percent error was calculated using the average daily range of flow for the period of the error analysis. While the literature is sparse relative to tidal flow comparisons, recent peer-reviewed work for SWFWMD identified 20 percent as an acceptable percent RMS error for the simulation of tidal flow (Janicki, 2014). The mean error is very low, 0.1 cfs, and the R^2 value is 0.77, which is a reasonable correlation between the measured and modeled flow.

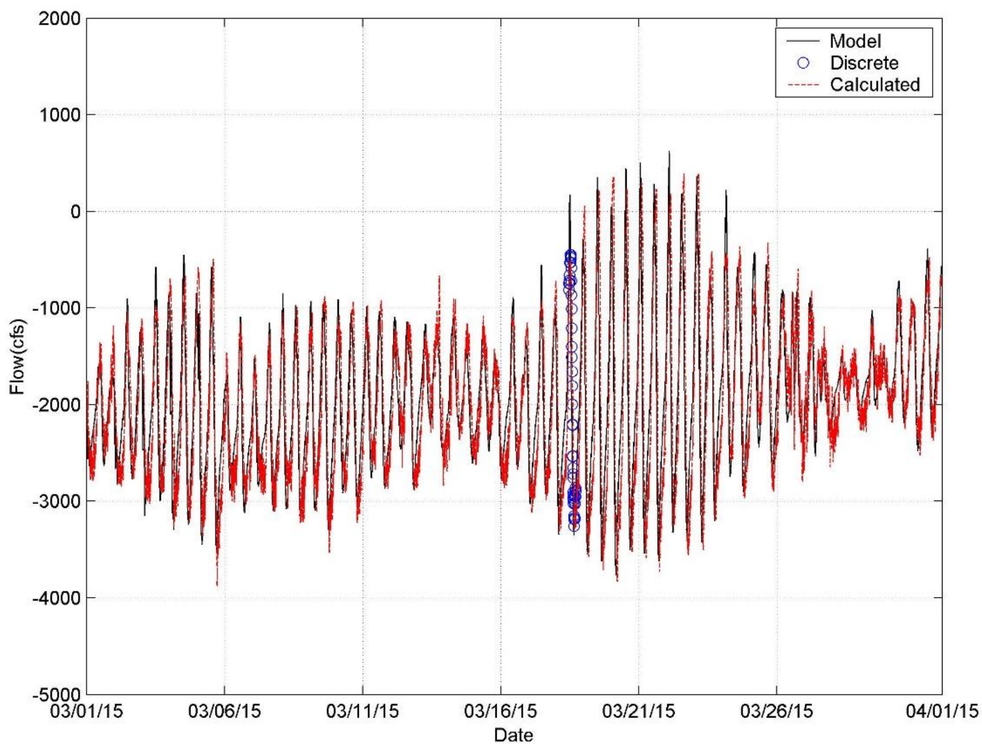

Figure 3-3a. Simulated versus Measured Flow at SRWMD 02326550 in March 2015.

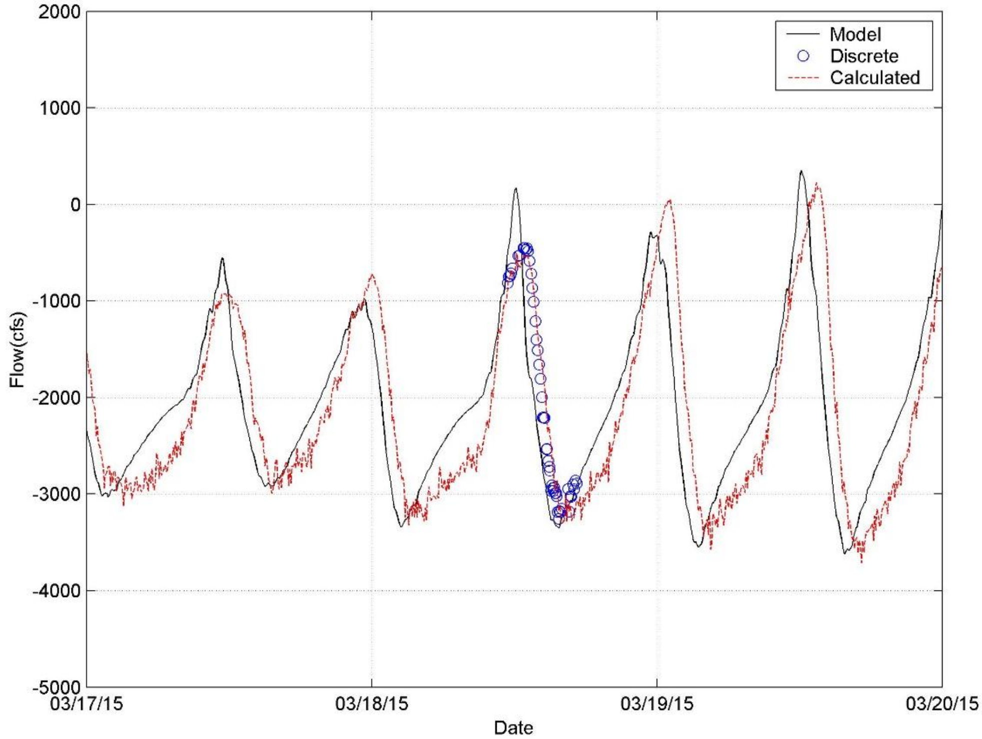

Figure 3-3b. *Simulated versus Measured Flow at SRWMD 02326550 (March 17 to March 20, 2015).*

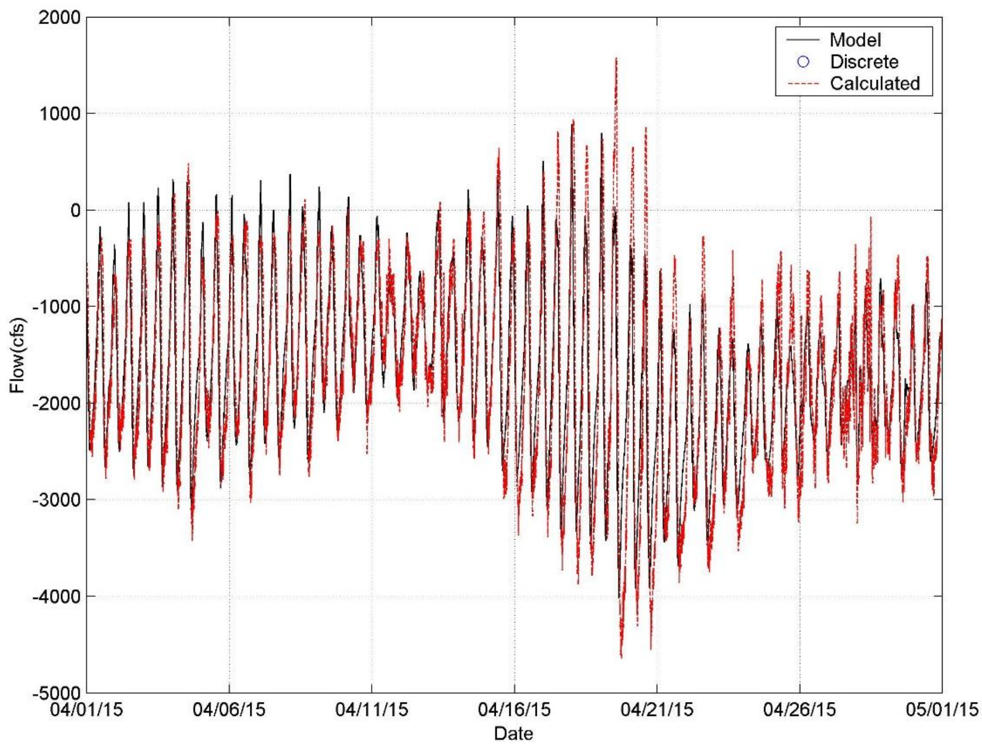

Figure 3-3c. *Simulated versus Measured Flow at SRWMD 02326550 in April 2015.*

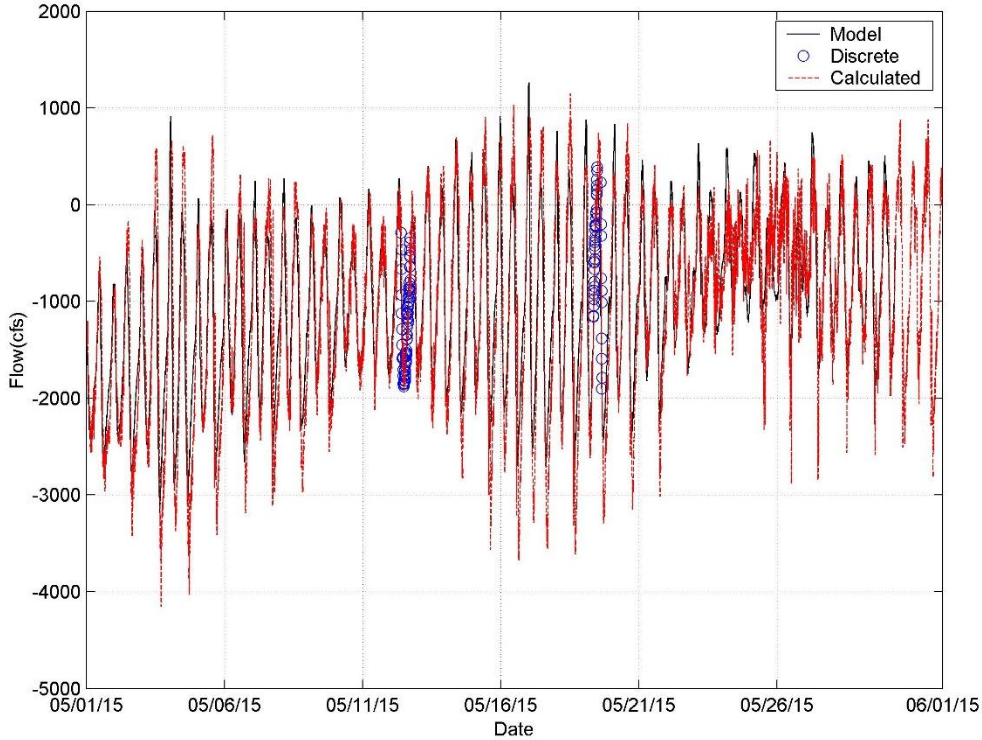

Figure 3-3d. Simulated versus Measured Flow at SRWMD 02326550 in May 2015.

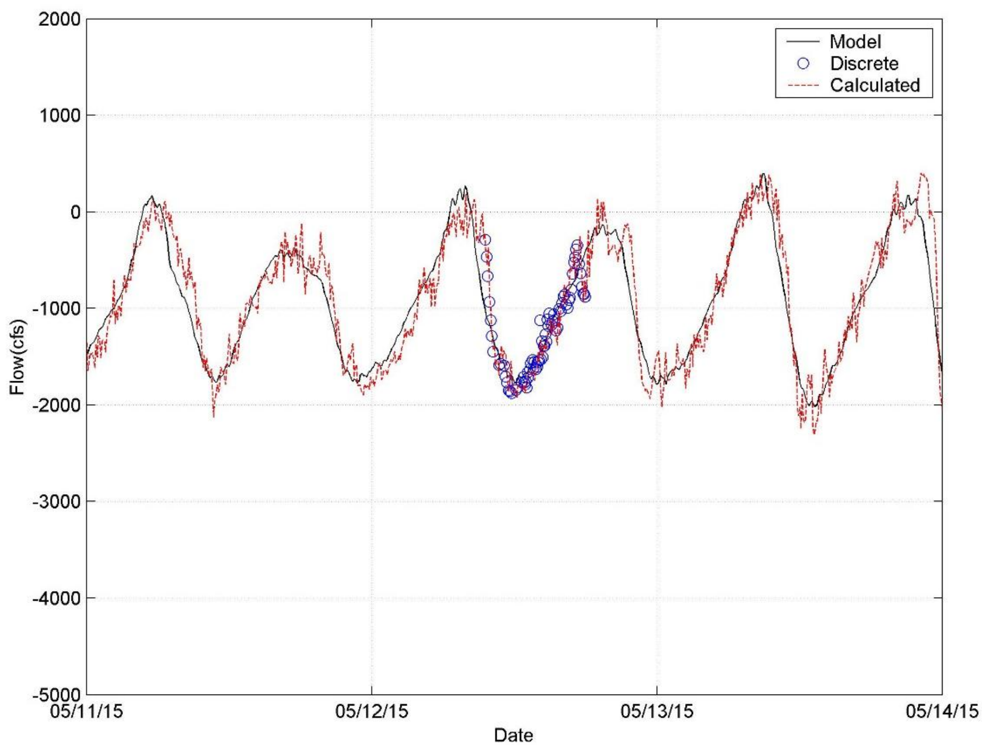

Figure 3-3e. Simulated versus Measured Flow at SRWMD 02326550 (May 11 to May 14, 2015).

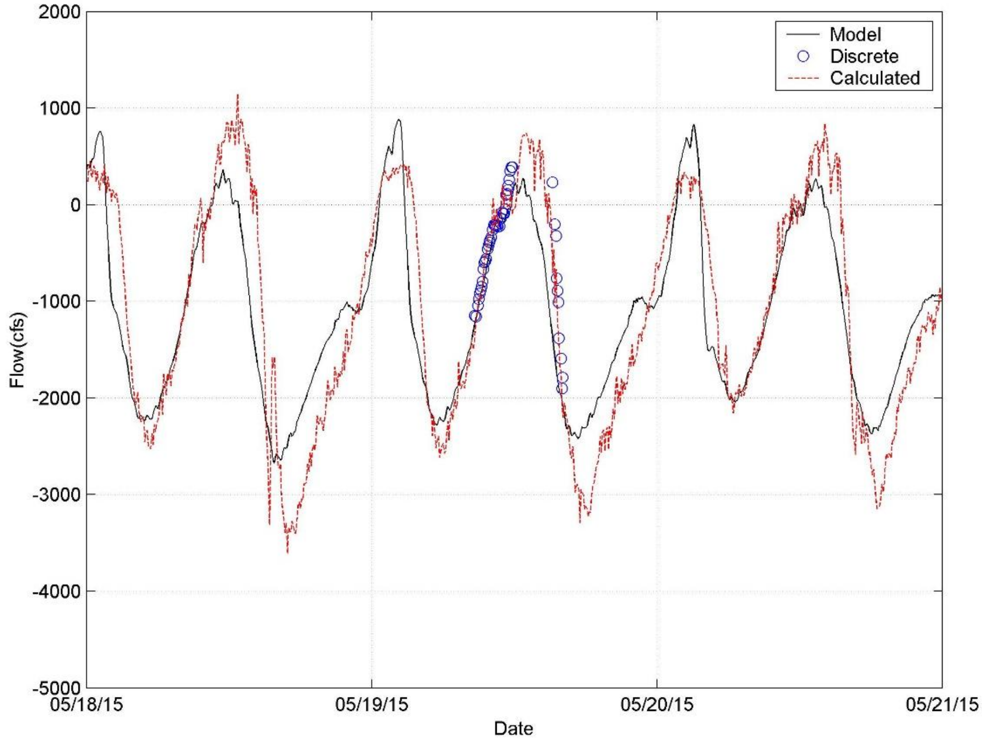

Figure 3-3f. Simulated versus Measured Flow at SRWMD 02326550 (May 17 to May 20, 2015).

3.4 SIMULATED VERSUS MEASURED SALINITY

Figures 3-4a through 3-4c present comparisons of the measured versus simulated salinity at the downstream, mid-stream, and upstream stations. For the mid-stream station, the surface and bottom results are compared. Due to the nature of the salinity data and model simulations, with intermittent time frames where the salinity intrusion reaches the mid-stream and upstream stations, the error statistics presented for the water level and the flow do not apply. Additionally, the nature of the salinity intrusion is such that a very sharp salinity front moves up into the system, with the greatest level of intrusion occurring during neap tide conditions, when the energy is low and the level or sharpness of the stratification is highest. The sharpness of the salinity stratification was seen during field measurements of vertical salinity profiles as well as through the rapid rise in salinity seen in the data as the front moves past the instruments. Due to the sharpness of the salinity front, a small error in the horizontal distance of the intrusion can result in a significant error in the salinity as the front moves up the system. For example, if the level of the salinity front intrusion in the model is 100 feet short of the location of the station where salinity measurements are taken, the data could show that salinities reach on the order of 10 to 15 parts per thousand (ppt) on the bottom, but the model simulations show zero, even though the intrusion level was only a short distance below the gage location in the model. Additionally, models, by their nature, tend to smear sharp gradients, based on the level of model vertical or horizontal resolution. For the Aucilla model, the balance between having feasible run times for model scenarios and vertical resolution (needed to represent the sharp nature of the stratification in the system) led to running the model with eight layers. While providing relatively good resolution in comparison with the depths, this level of vertical resolution still created some vertical smearing of the salinity profile. Based upon these issues, the graphical comparisons show that the model is doing well simulating the extent of the salinity intrusion and the overall magnitude response at the surface and bottom. A key aspect is that in late May, during the low flow period, the model shows that the level and timing of intrusion measured at the upstream station were very good. This comparison (where two stations longitudinally showed good response in terms of magnitude and timing) further supports the model's capability to simulate the variations in salinity intrusion under varying freshwater inflow and tidal forcing conditions.

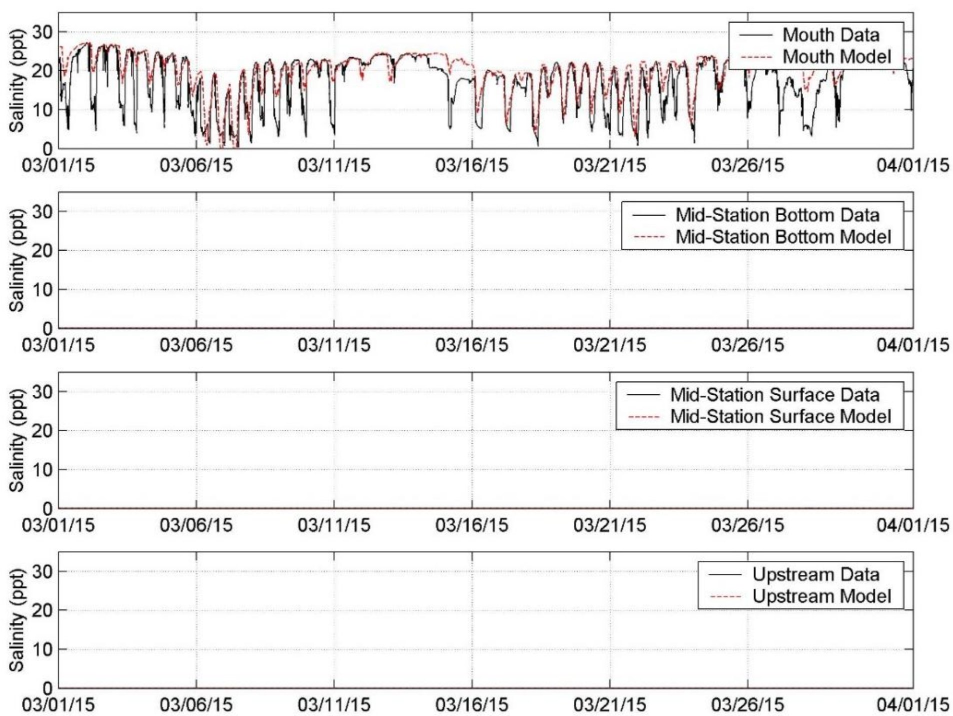

Figure 3-4a. Simulated versus Measured Salinity at 02326570 (bottom), 02326550 (surface and bottom), and 02326548 (bottom) in March 2015. Note: where salinity levels are shown at zero, the flows were such that salinity was pushed downstream of the station.

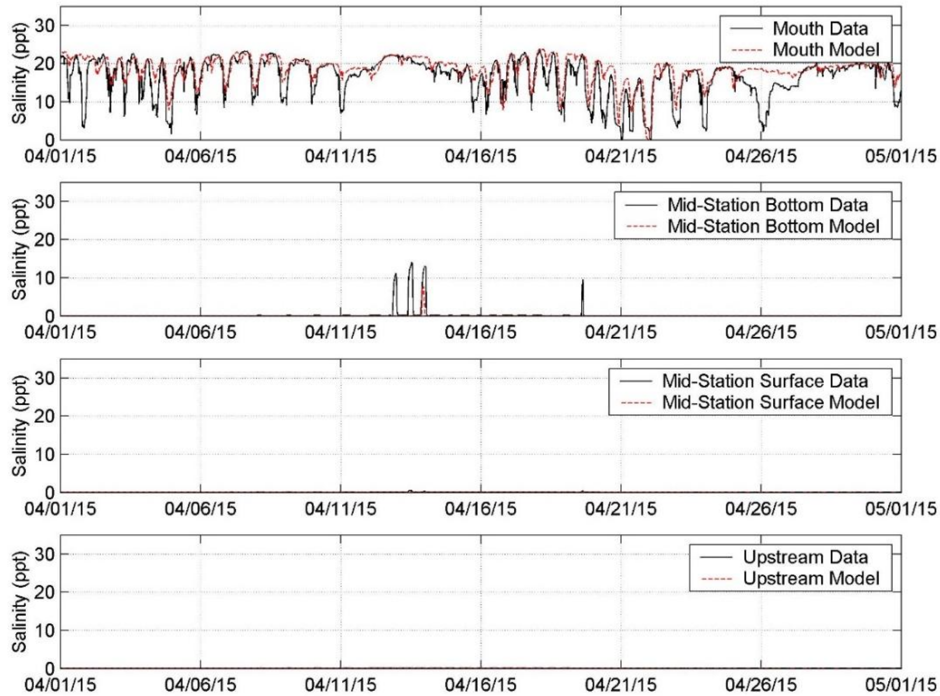

Figure 3-4b. *Simulated versus Measured Salinity at 02326570 (bottom), 02326550 (surface and bottom), and 02326548 (bottom) in April 2015. Note: where salinity levels are shown at zero, the flows were such that salinity was pushed downstream of the station.*

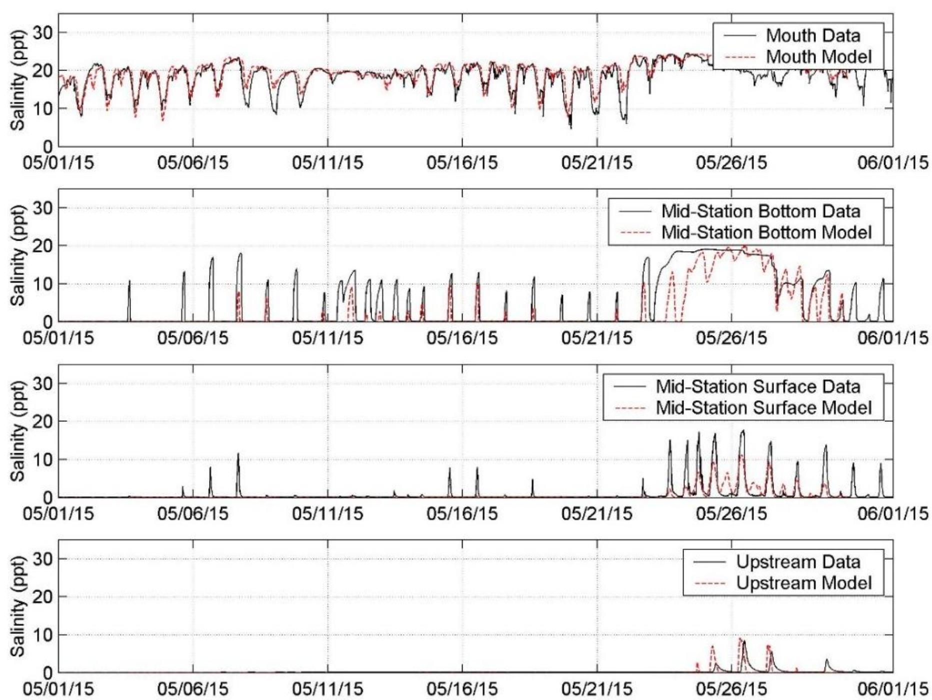

Figure 3-4c. *Simulated versus Measured Salinity at 02326570 (bottom), 02326550 (surface and bottom), and 02326548 (bottom) in May 2015. Note: where salinity levels are shown at zero, the flows were such that salinity was pushed downstream of the station.*

4.0 MFL SCENARIOS

Utilizing the calibrated hydrodynamic model, various scenarios were run to assess the impacts of flow reduction and sea level rise on the salinity conditions in the system. The salinity results from the scenario runs are presented in detail within the MFL document. In this report, the scenario conditions and model inputs are discussed. The specific model scenarios run include the following:

- Baseline condition
- 5 percent flow reduction
- 10 percent flow reduction
- 15 percent flow reduction
- 30 percent flow reduction
- Sea level rise (5.1 inches)

For all the scenarios, a 2-year period was defined as representative of the full range of hydrologic (freshwater inflow) conditions seen for the river. The MFL document provides a detailed discussion of how this 2-year period was selected. For the Aucilla River, the 2-year period was from October 1, 1994, through September 30, 1996.

For the Aucilla model baseline time period of October 1, 1994 through September 30, 1996, the offshore boundary conditions for elevation and salinity were taken from the GCSM output at grid cells near the Aucilla model boundary. The GCSM output spanned the period 1995-2002. Based on this time period, data were needed for the offshore conditions from September 15, 1994 through December 31, 1994. For this period, the GCSM output from September 15, 1996 through December 31, 1996 was used. Prior to its use, the data from this time period was checked for consistency with conditions in 1994. Additionally, wind speed and direction data were obtained from the same local gage as that utilized for the model calibration for the full 2-year period. The scenario models were run for a 15-day period from September 15, 1994, to October 1, 1994 to bring the models into equilibrium prior to start of the scenario runs.

The upstream inflow conditions were calculated based upon a relationship established between the upstream gage at Lamont (USGS 02326500) (see Figure 1-1b) and the measured flow at the mid-station (SRWMD 02326550) for the period of the field data collection (February 2015 to May 2015). The details of the relationship are presented within the MFL document, along with the flow conditions for the scenarios. For the flow reduction scenarios, the time series of flow used in the baseline run was reduced by the amounts listed above and the model simulations were run using the identical water levels, offshore salinity, and wind conditions for the 2-year period.

For the Sea Level Rise scenario, the 5.1 inches was prescribed by SRWMD staff and this value was added as a constant value to the offshore forcing tides. This simulation then represented a future condition with a static 5.1-inch rise in sea level.

5.0 SUMMARY AND CONCLUSIONS

This report provided a summary of the development, calibration, and application of a hydrodynamic model developed for the tidal portion of the Aucilla River. This included the following:

- Development of the model grid and bathymetry
- Development of the model input conditions
- Model calibration approach
- Graphical and statistical comparison of the simulations versus data
- Summary of the model inputs used for the MFL scenarios

The model extended offshore within the Gulf of Mexico and up the main stem of the Aucilla River to Nutall Rise and adjacent tributaries and tidal flats (storage areas).

The EFDC model was used to simulate the hydrodynamics, including the water levels, currents, flow, and salinity. The model simulations for the calibration extended from mid-February 2015 to the end of May 2015.

The model had one open boundary condition approximately 2 miles offshore of the mouth of the Aucilla River. The offshore water level boundary conditions were developed from measured water levels at the mouth using boundary matching techniques. The offshore salinity boundary conditions were derived from the daily maxima of the continuous salinity measured at the mouth.

Graphical and/or statistical comparisons of the simulated versus measured water levels were presented at four locations along the system. These included data at the mouth, at a mid-station and upstream station, and at Nutall Rise. The results showed good agreement both graphically and statistically to the measured data.

Graphical and statistical comparisons of the simulated versus measured time-dependent flow at the mid-station were presented. The results showed good agreement between the measured and simulated flow magnitudes, phasing and characteristics.

Graphical comparisons of the simulated versus measured salinity were presented. This included bottom data at the mouth, bottom and surface data at the mid-station, and bottom data at the upstream stations. The comparisons showed that the model captured the timing and magnitude of the responses to the freshwater inflow on salinity intrusion and the distribution of the salinity between the stations.

The calibrated hydrodynamic model was then utilized to perform MFL flow reduction simulations. The simulation period for the Aucilla River was the 2-year period was from October 1, 1994 through September 30, 1996. For this period, the offshore boundary conditions were taken from the GCSM model output for water level and salinity. The salinity and water level data, as well as the overall model geometry, were provided for use in the MFL analyses presented within the primary document.

6.0 REFERENCES

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APPENDIX B

Aucilla River - SEFA Results

Use of the System for Environmental Flow Analysis (SEFA) Software in a Minimum Flows and Levels (MFL) Study of the Aucilla River.

Introduction

The Suwannee River Water Management District is tasked with developing minimum flows and levels (MFL) on both lentic and lotic water bodies within its boundary. Each year, the District produces a document called the MFL Priority List, on which listed water bodies will be given an MFL within a specific time frame. The purpose of an MFL is to protect a specified water body from what is known as "significant harm." In order to address this, the District has adopted a threshold of no more than a 15% reduction for in-channel habitat before "significant harm" is reached.

SEFA (Aquatic Habitat Analysts, Inc. 2012) is a Windows-based program that was developed as a tool for use in studies that utilize the Instream Flow Incremental Methodology (IFIM). It contains hydraulic, instream habitat, and time series models and can be used in the development of flow recommendations. The program allows for the alteration of flows to demonstrate the effects on the availability of habitat (shown as area weighted suitability) for species of interest in the body of water (Jowett et al. 2014).

Methods

Study Area

The Aucilla River is a dark-water river system located on the border of Taylor, Madison, and Jefferson Counties in Florida and is slated to have an established MFL in 2015. The river flows relatively southward from Georgia until it eventually empties into a series of sinks north of the Florida coastline. Nutall Rise, located between river miles 5 and 6, serves as the major resurgence of the river, flowing from this point downstream towards the Gulf of Mexico. A major tributary, the Wacissa River, is a spring-dominated river that empties into the Aucilla River at multiple locations due to its braided nature.

The study area encompasses an approximately 0.2-mile reach located about 11 miles downstream of US highway 27 near Lamont, FL (Figure 1). Project staff collected data at 7 transects at the site during 3 different flow/stage conditions. The team collected the necessary survey, velocity, discharge, depth, and substrate values on June 8-9, 13, and 18, 2015. All recorded data were utilized in the hydraulic, instream habitat, and time series models of the river.

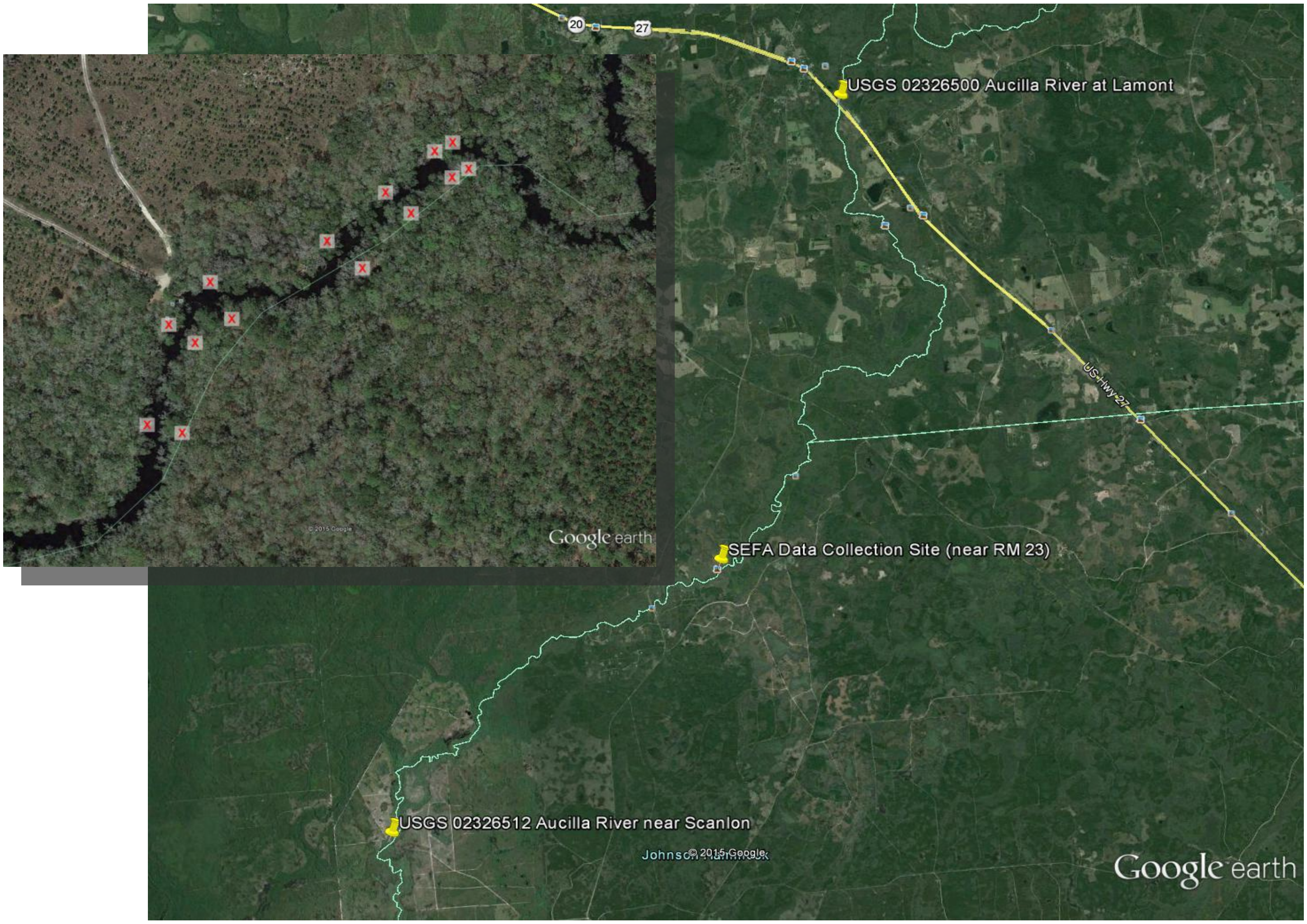

Figure 1. Map of the Aucilla River study area with transect locations.

Instream Habitat Model Calibration

The three measured stage/discharge values were used to establish log-log rating relationships for each transect in the SEFA program. The rating curves were each calculated with IFG4 emulation, the same method applied by the Physical Habitat Simulation model (PHABSIM) (Jowett et al. 2014; Milhous and Waddle 2001).

Habitat Suitability Curves

Forty habitat suitability curves of various species and life stages were incorporated into both the above and below tram instream habitat models (Table 1). Most or all of these curves have been applied in previous MFL analyses depending on the specific water body. For this analysis, the velocity, depth, and habitat preference criteria for each species and life stage were utilized in the calculation of the area weighted suitability.

Table 1. Habitat Suitability Curves used in the MFL analysis.

Species or Group	Life Stage
Suwannee Bass	Adult, Juvenile
Redbreast Sunfish	Adult, Juvenile, Spawning, Fry
Habitat Guilds	Shallow/Slow, Shallow/Fast, Deep/Slow, Deep/Fast
Channel Catfish	Adult, Juvenile, Juvenile (spring, summer, fall, warmwater), Spawning, Fry
Darters	Generic, Blackbanded
Macroinvertebrates	Ephemeroptera, Plecoptera, Trichoptera, EPT Total, *Pseudocloeon ephippiatum*, Hydropsychidae - Total, *Tvetenia vitracies*
Largemouth Bass	Adult, Juvenile, Spawning, Fry
Bluegill	Adult, Juvenile, Spawning, Fry
Spotted Sunfish	Adult, Juvenile, Spawning, Fry
Cyprinidae	Adult

Time Series Flow

Discharge data from a USGS gage (02326500, Aucilla River at Lamont) was used in the time series analysis portion of the SEFA program. Statistics for this flow record are presented in Table 2.

Table 2. Period of record flow statistics for the USGS gage 02326500 – Aucilla River at Lamont.

Statistic	Value
Sample size	13879
Minimum	0
Maximum	11500
Mean	339.77
Median	81
Standard deviation (denom. = n-1)	690.9

Flow Reduction Approach

This approach involved a straight percent reduction of each discharge measurement value in the historic period of record. Ten and 20 percent flow reductions were chosen as the starting points for all species and life stage curves. Appendix Figure A1 contains the flow duration curve along with the associated percent reductions to the flow record. Those species and life stages that showed significant decrease in mean area weighted suitability from the initial flow reductions were deemed critical species. These were then reduced by ascending percent reductions in the flow record until the percent difference between the reduced and historic discharge recorded just less than a 15% reduction in mean area weighted suitability.

Results and Discussion

Three species and life stages in this method were deemed as critical during the initial use of the 10% and 20% flow reductions. Channel catfish adult, the shallow/fast habitat guild, and total EPT were all listed as critical and were analyzed further. Each was reduced incrementally by 5% from 25-50% flow reduction in the period of record. Table 3 contains the percent flow reductions along with the corresponding percent habitat reductions for each of the critical species that were identified by this method. Duration curves containing the area weighted suitability and percent reductions across the historic flow record are shown in Appendix figures A2-A4.

Table 3. Percent flow reduction across the historical period of record and associated percent change in certain species and life stages. Red denotes a violation in the percent habitat reduction.

			Reductions			
Species/Life Stage	**25%**	**30%**	**35%**	**40%**	**45%**	**50%**
Channel catfish adult	6.15	7.57	9.27	10.97	12.96	15.14
Habitat guild - shallow/fast	9.52	9.52	14.29	19.05	23.81	23.81
EPT - Total	6.39	8.03	10.04	12.04	14.42	16.97

Of the three critical species and life stages, the shallow/fast habitat guild was the most restrictive in terms of percent reduction to the flow record. Any flow reduction greater than 35% would cause a greater than 15% reduction in the species' habitat. The low mean area weighted suitability of the shallow/fast habitat guild (0.21 ft^2/ft) causes increased sensitivity to habitat reduction when compared with the other two critical species.

It should be advised, however, that this data only represents a minor section of the Aucilla River (about 0.2 mi), and caution should be utilized whenever applying these results to the whole waterbody. Larger scale and unconstrained data collection methods should be practiced in order to interpret proper results for the entirety of the river.

References

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Milhous, R.T. and T.J. Waddle. 2001. PHABSIM for Windows User's Manual and Exercises. Open File Report 01-340. Fort Collins, CO: Midcontinent Ecological Science Center. 288p.

APPENDIX

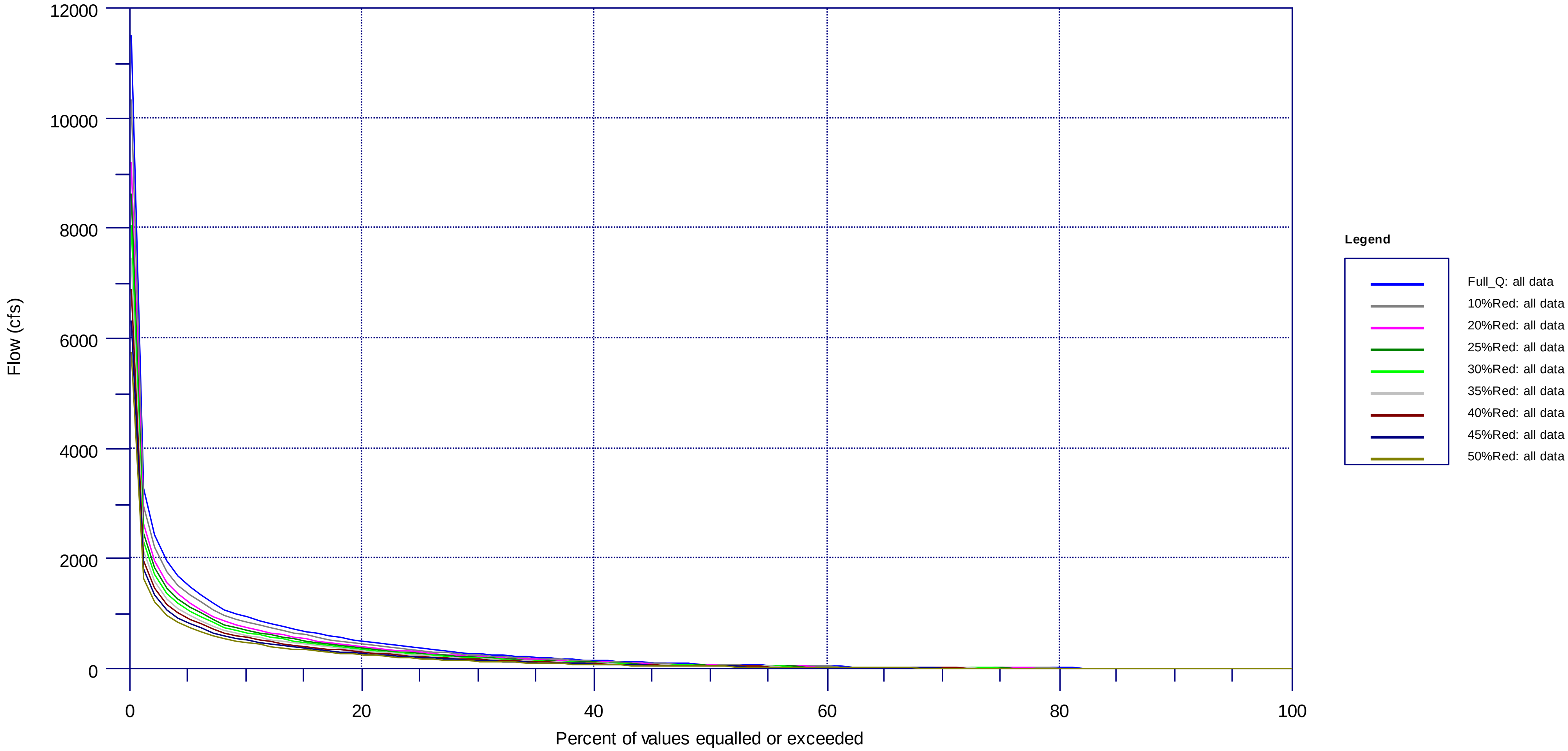


Figure A1. Flow duration curve comparing the historic and percent reduced flow records. The historic flow data (labeled Full_Q) is included for reference.

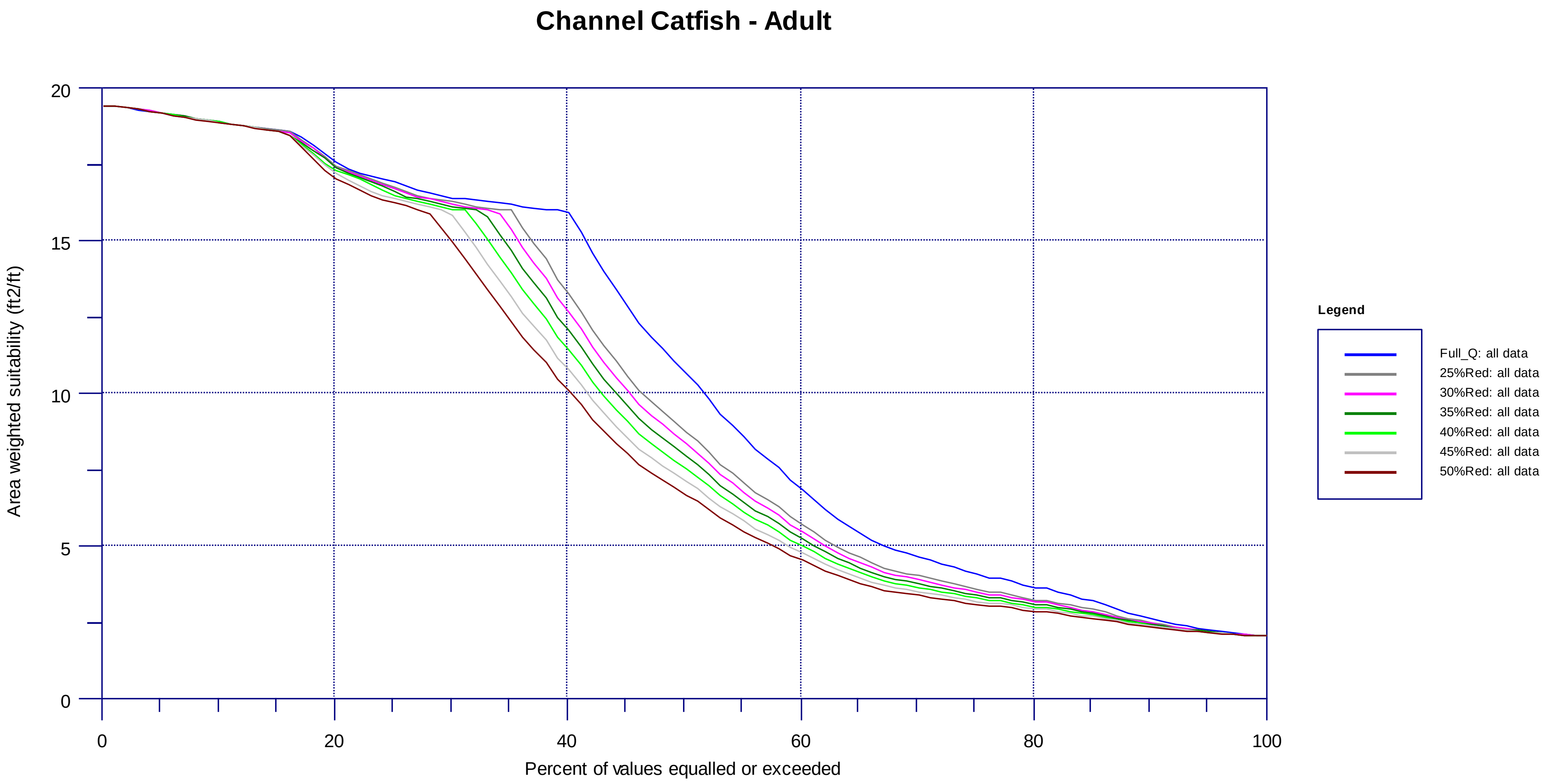


Figure A2. Area weighted suitability duration curves with historic discharge (Full_Q) including the various percent reductions for channel catfish adult.

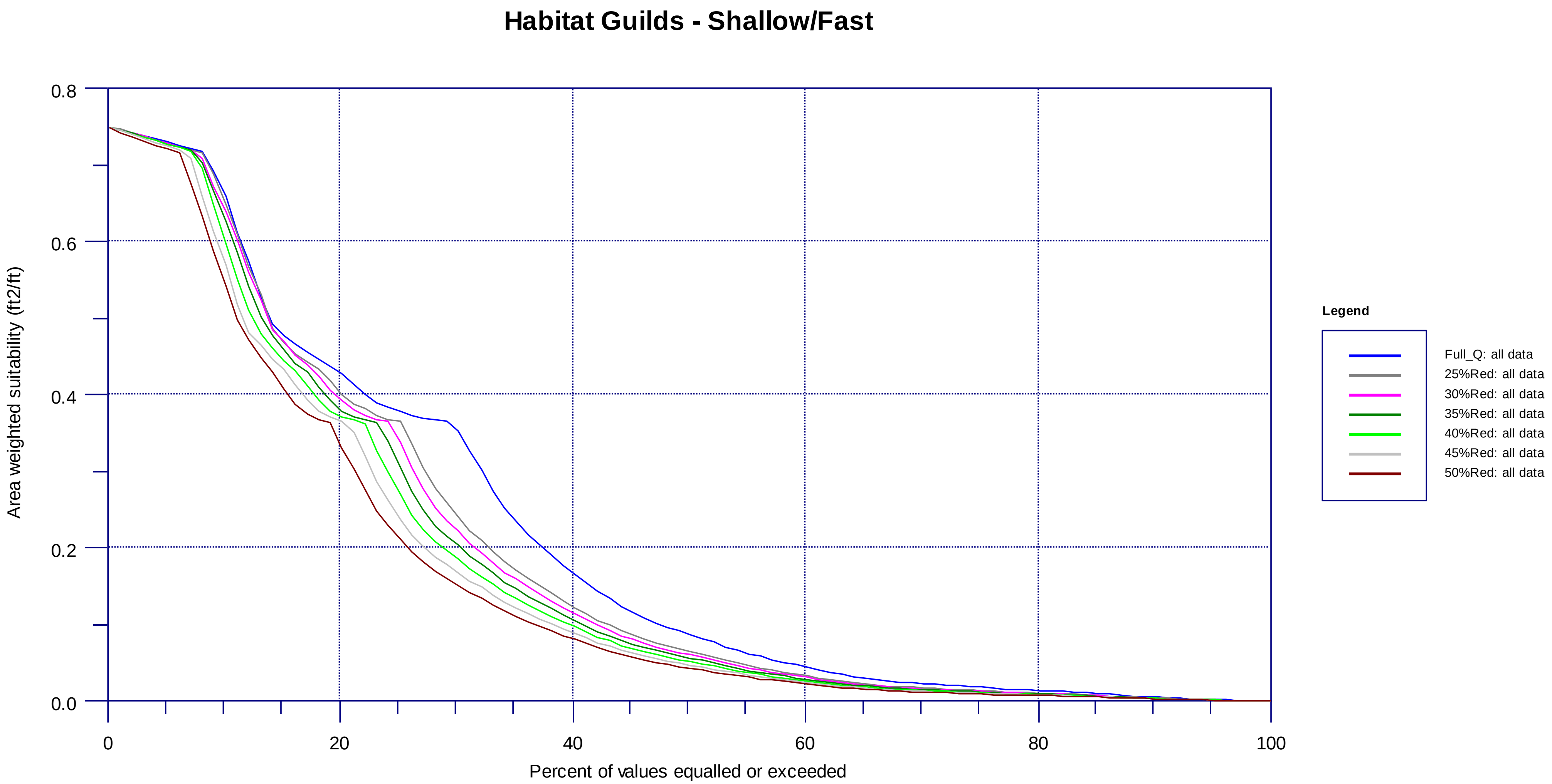


Figure A3. Area weighted suitability duration curves with historic discharge (Full_Q) including the various percent reductions for the shallow/fast habitat guilds.

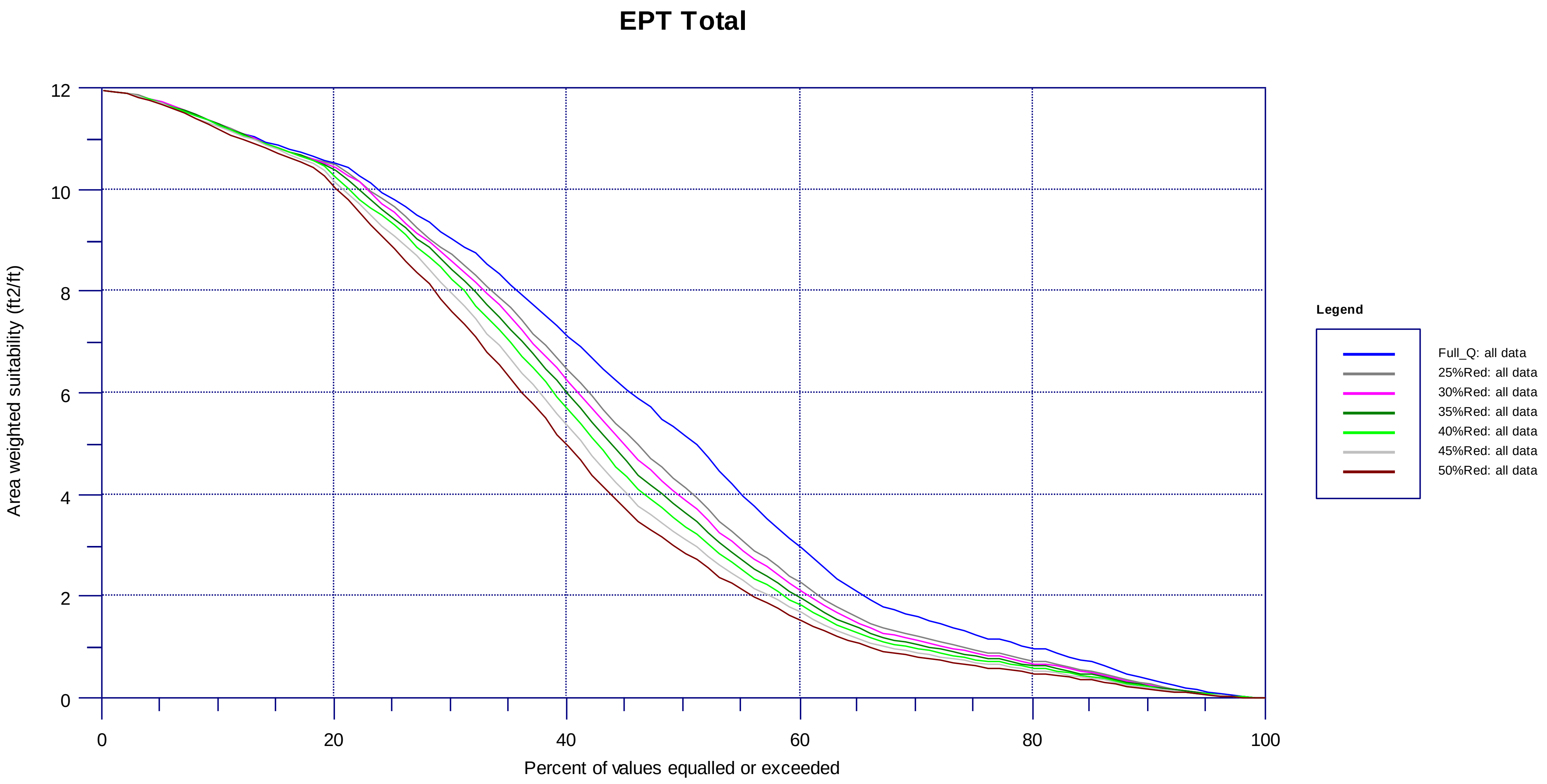


Figure A4. Area weighted suitability duration curves with historic discharge (Full_Q) including the various percent reductions for the EPT total.

APPENDIX C
Wacissa River - SEFA Results

Use of the System for Environmental Flow Analysis (SEFA) Software in a Minimum Flows and Levels (MFL) Study of the Wacissa River.

Introduction

The Suwannee River Water Management District is tasked with developing minimum flows and levels (MFL) on both lentic and lotic water bodies within its boundary. Each year, the District produces a document called the MFL Priority List, on which listed water bodies will be given an MFL within a specific time frame. The purpose of an MFL is to protect a specified water body from what is known as "significant harm." In order to address this, the District has adopted a threshold of no more than a 15% reduction for in-channel habitat before "significant harm" is reached.

SEFA (Aquatic Habitat Analysts, Inc. 2012) is a Windows-based program that was developed as a tool for use in studies that utilize the Instream Flow Incremental Methodology (IFIM). It contains hydraulic, instream habitat, and time series models and can be used in the development of flow recommendations. The program allows for the alteration of flows to demonstrate the effects on the availability of habitat (shown as area weighted suitability) for species of interest in the body of water (Jowett et al. 2014).

Methods

Study Area

The Wacissa River is a spring-fed river located in Jefferson County, Florida, and is slated to have an established MFL in 2015. The river flows relatively southward from the headspring for about 12 miles until it branches off into a large number of braided channels. The remnants of old tram pilings cross the river approximately 3 miles downstream of the headspring. These pilings can be easily crossed under normal flow but may require portage at low flows. The Wacissa eventually flows into the Aucilla River, a dark-water system that empties into the Gulf of Mexico.

The study area encompasses an approximately 10-mile area from the headspring downstream to Goose Pasture. The magnitude of the river braiding below this area is too difficult to properly model. A total of 32 cross sections, established in previous studies, were used as part of the instream habitat modeling portion of the SEFA software (Figure 1). The tram pilings were considered a natural boundary condition for the river, with 13 transects above the tram and 19 transects below used in the development of two separate instream habitat models (i.e., "above" and "below" tram models).

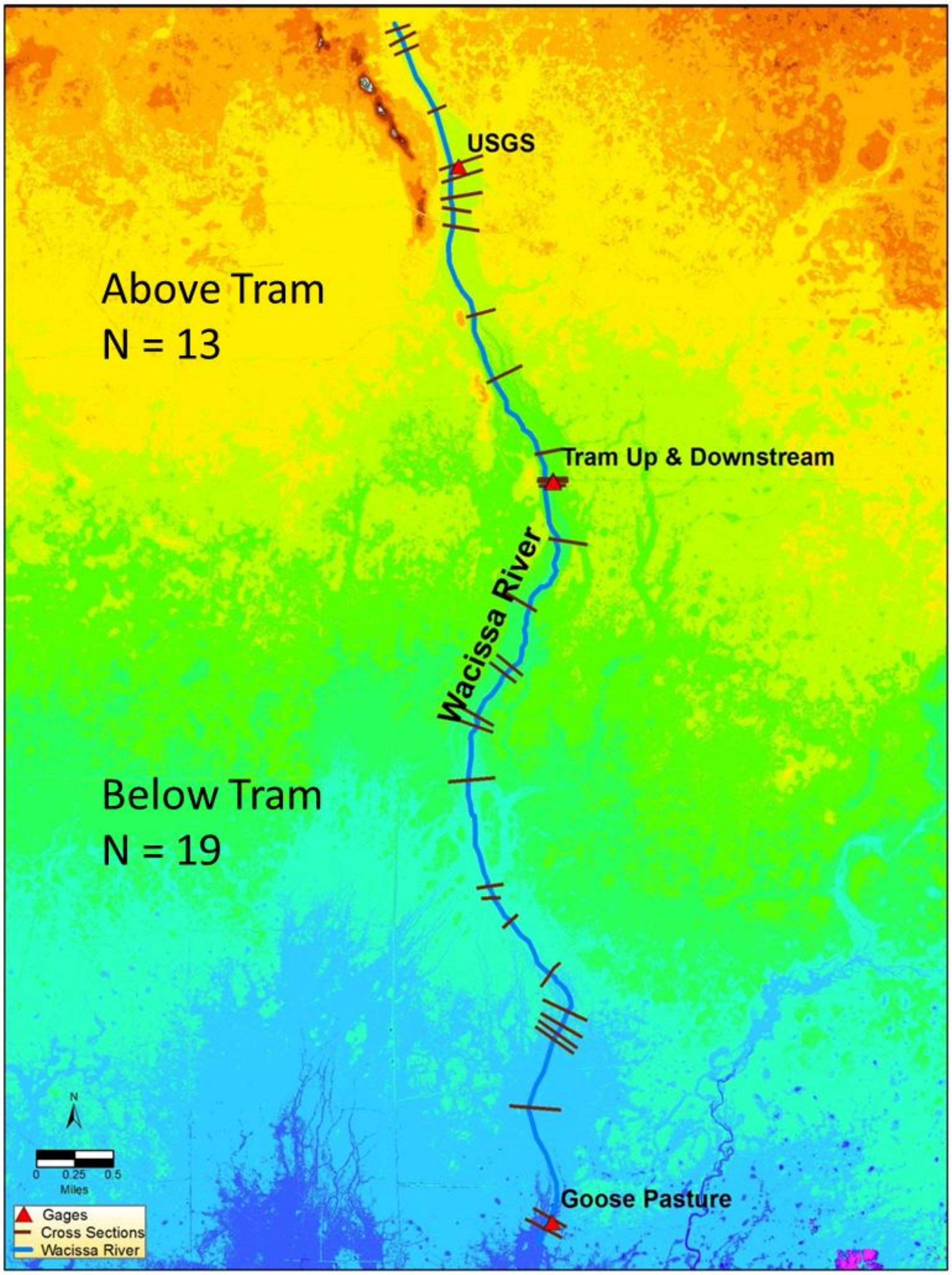


Figure 1. Map of the Wacissa River study area with transect locations.

Instream Habitat Model Calibration

Due to both time constraints and the degree of difficulty in measuring the necessary parameters in the Wacissa River, a HEC-RAS model was developed to simulate the necessary stage/discharge relationships over six different flow scenarios along with the velocities at specific points across each transect under the highest flow regime. These model calibration values were then used to establish log-log rating relationships for each transect in the SEFA program. The rating curves were each calculated with IFG4 emulation, the same method applied by the Physical Habitat Simulation model (PHABSIM) (Jowett et al. 2014; Milhous and Waddle 2001). Since no *in situ* data were collected, the substrate index codes were absent in the final calculation of the area weighted suitability for each species and life stage.

Habitat Suitability Curves

Forty habitat suitability curves of various species and life stages were incorporated into both the above and below tram instream habitat models (Table 1). Most or all of these curves have been applied in previous MFL analyses depending on the specific water body. Note that only the velocity and depth criteria for each species and life stage were taken into account in the calculation of preference habitat.

Table 1. Habitat Suitability Curves used in the MFL analysis.

Species or Group	Life Stage
Suwannee Bass	Adult, Juvenile
Redbreast Sunfish	Adult, Juvenile, Spawning, Fry
Habitat Guilds	Shallow/Slow, Shallow/Fast, Deep/Slow, Deep/Fast
Channel Catfish	Adult, Juvenile, Juvenile (spring, summer, fall, warmwater), Spawning, Fry
Darters	Generic, Blackbanded
Macroinvertebrates	Ephemeroptera, Plecoptera, Trichoptera, EPT Total, *Pseudocloeon ephippiatum*, Hydropsychidae - Total, *Tvetenia vitracies*
Largemouth Bass	Adult, Juvenile, Spawning, Fry
Bluegill	Adult, Juvenile, Spawning, Fry
Spotted Sunfish	Adult, Juvenile, Spawning, Fry
Cyprinidae	Adult

Time Series Flow

Discharge data from the USGS gage 02326526 (Wacissa River near Wacissa) were utilized in the time series analysis portion of the SEFA program. Daily values from 2001-2014 were added to sporadic measurements from 1971-1976, 1999-2000, and 2007 to form the complete period of record. Statistics for this flow record are presented in Table 2.

Table 2. Period of record flow statistics for the USGS gage 02326526 – Wacissa River near Wacissa.

Statistic	Value
Sample Size	4310
Minimum	216
Maximum	1200
Mean	376.66
Median	349
Standard Deviation (denom.=n-1)	105.71

Flow Reduction Approaches

Percent Reduction from the Median Flow Value

Two different flow reduction approaches were taken during the analysis, and the results were evaluated for similarities and usefulness in the overall establishment of the MFL. The first approach involves a constant flow reduction from the median flow value shown in Table 2 to each value in the period of record. A percent of the median value was calculated and each value in the flow record was reduced by that amount (Table 3). Beginning with a 10% of the median reduction and using a descending stepwise approach, a percent difference was calculated between the reduced and historic period of records until less than a 15% reduction in mean habitat (i.e. area weighted suitability) was shown.

Table 3. Percent discharge reductions of the median value (349 cfs) by which period of record values were reduced.

Median % Q Reduction	Value
10%	34.90
9%	31.41
8%	27.92
7%	24.42

Percent Reduction across the Flow Record

The second approach involved a straight percent reduction of each discharge measurement value in the historic period of record. Once again, ten percent was chosen as the starting point, and flows were reduced by descending stepwise percentages until the difference between the reduced and historic discharge records revealed a less than 15% reduction in mean area weighted suitability. Reductions used on the discharge record ranged from 10% down to 5%. A comparison of the two flow reduction methods is shown in Figure A1 in the Appendix.

Results and Discussion

Percent Reduction from the Median Flow Value

Initial use of the 10% constant flow reduction from the median discharge value showed only one species and life stage, largemouth bass fry, violated the 15% criterion recognized at the beginning of the study. This critical species and life stage only showed a violation in the "below tram" habitat model. A 9% reduction in the discharge record had a 14% reduction in area weighted suitability, and anything below this discharge reduction value was in the range considered to be acceptable (Table 4). A graph of area weighted suitability duration curves can be seen in Figure A2.

Table 4. Percent flow reduction from the median discharge value and associated percent change in largemouth bass fry habitat. Red denotes a violation in the percent habitat reduction.

Percent Flow Reduction	Percent Change
10%	15.92
9%	14.44
8%	12.95
7%	11.36

Percent Reduction across the Flow Record

More species and life stages in this method were deemed as critical during the initial use of the 10% flow reduction. Once again, only the "below tram" model was significant, and the largemouth bass fry along with the additions of bluegill fry and the shallow/slow habitat guilds were deemed critical. Table 5 contains the percent reductions along with the corresponding percent reductions for each of the critical species that were identified by this method. Duration curves containing the area weighted suitability and percent reductions across the historic flow record are shown Figures A3-A5.

One macroinvertebrate species, *Pseudocloeon ephippiatum*, had an extremely high percent habitat reduction of 33.3% in the "above" tram model for the initial 10% flow reduction. However, the mean of area weighted suitability prior to reducing the flow was only 0.03 ft^2/ft. It was decided that that this species should be omitted from consideration due to the extremely low mean habitat value along with the lack of residence information in the Wacissa River.

Table 5. Percent flow reduction across the historical period of record and associated percent change in certain species and life stages. Red denotes a violation in the percent habitat reduction.

	Reductions					
Species / Life Stage	5%	6%	7%	8%	9%	10%
Largemouth bass fry	10.51	12.53	14.44	16.35	18.26	18.74
Bluegill fry	10.09	11.95	13.73	15.45	17.13	18.74
Habitat guilds - Shallow/Slow	9.24	10.91	12.52	14.10	15.61	17.06

Each flow reduction scenario seems to have biggest impact on values below the 50th percent exceedance in each of the species and life stages of concern. This could be attributed to overbank flow conditions during the lower exceedances that result in a small increase in the availability of preferred depth and velocities. Additional flow reductions would result in a higher percent change in available habitat as opposed to the higher exceedances.

Conclusion

Depending on the chosen methodology, a 7% to 9% reduction in the historic flow record is allowable without violating more than a prescribed 15% reduction in habitat for critical species identified in this report. A summary of the maximum allowable flow reduction by species and method is presented in Table 6.

Table 6. Summary of critical species and maximum allowable reduction in flow by method. All critical species and life stages result from the "below" tram habitat model.

Species	Max. Reduction in Q to Avoid a 15% Habitat Reduction	Method
Largemouth Bass Fry	9%	Constant Reduction from Median Q Value
Largemouth Bass Fry	7%	Percent Reduction Across POR Flow
Bluegill Fry	7%	Percent Reduction Across POR Flow
Habitat Guilds - Shallow/Slow	8%	Percent Reduction Across POR Flow

References

Aquatic Habitat Analysts, Inc. 2012. SEFA: System for Environmental Flow Analysis (Version 1.2 build 23). Available from http://sefa.co.nz/.

Jowett, I., T. Payne, and R. Milhous. 2014. SEFA: System for Environmental Flow Analysis Software Manual Version 1.21. Aquatic Habitat Analysts, Inc. 233 p.

Milhous, R.T. and T.J. Waddle. 2001. PHABSIM for Windows User's Manual and Exercises. Open File Report 01-340. Fort Collins, CO: Midcontinent Ecological Science Center. 288p.

APPENDIX

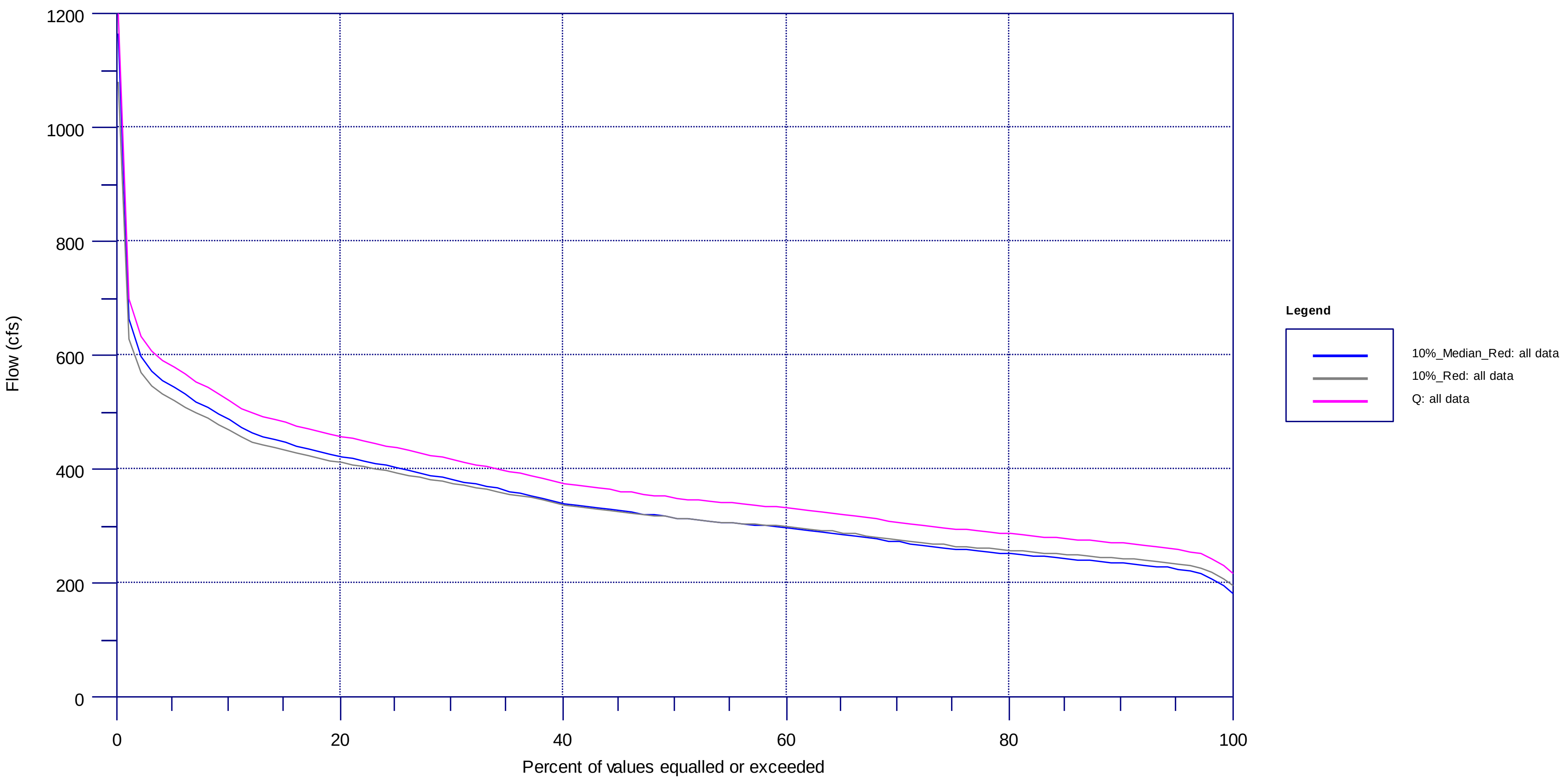


Figure A1. Flow duration curve comparing the two 10% flow reduction methods. The historic flow data (labeled Q) is included for reference.

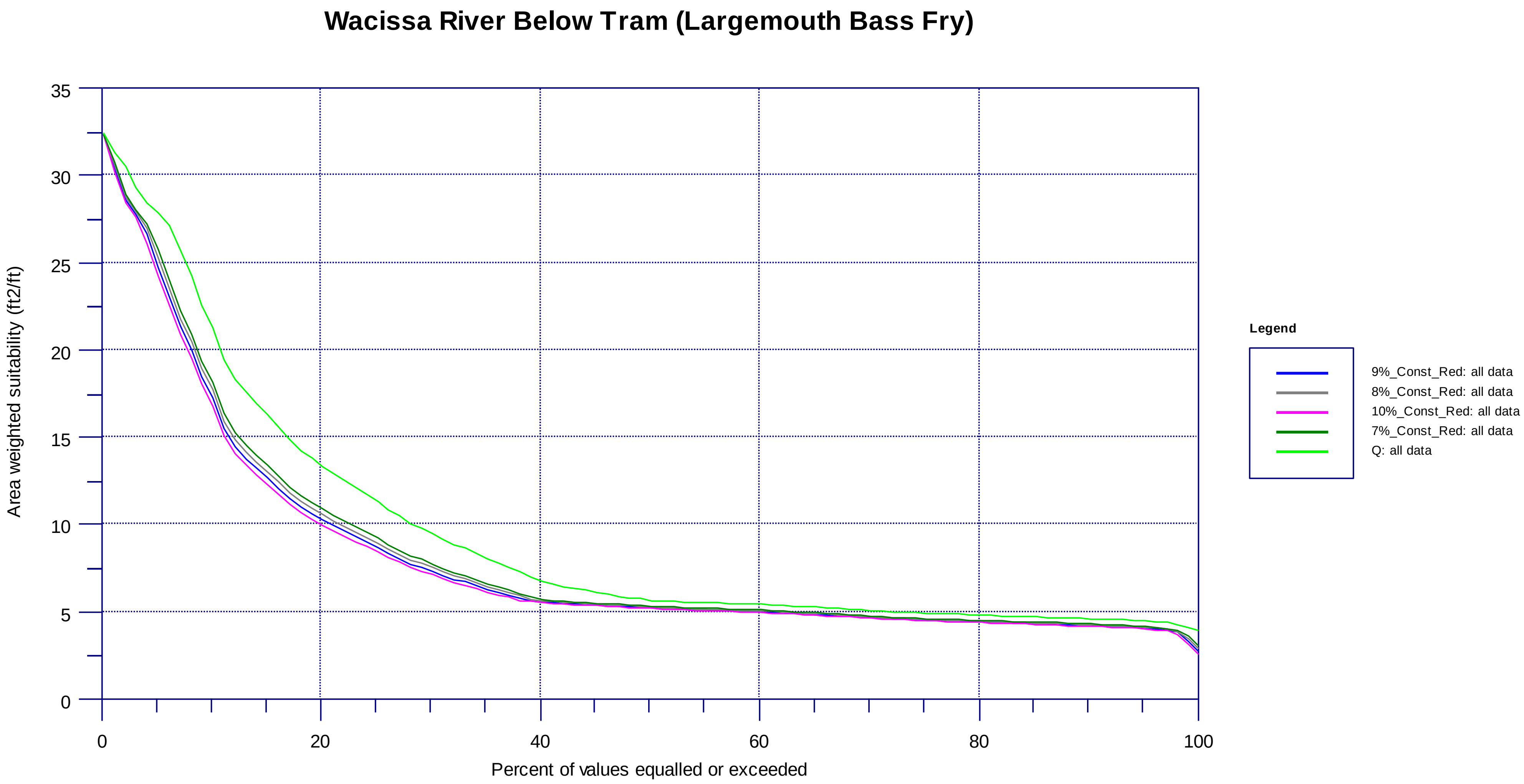


Figure A2. Area weighted suitability duration curves with historic discharge (Q) including the various percent reductions from the historic median value for largemouth bass fry below the tram.

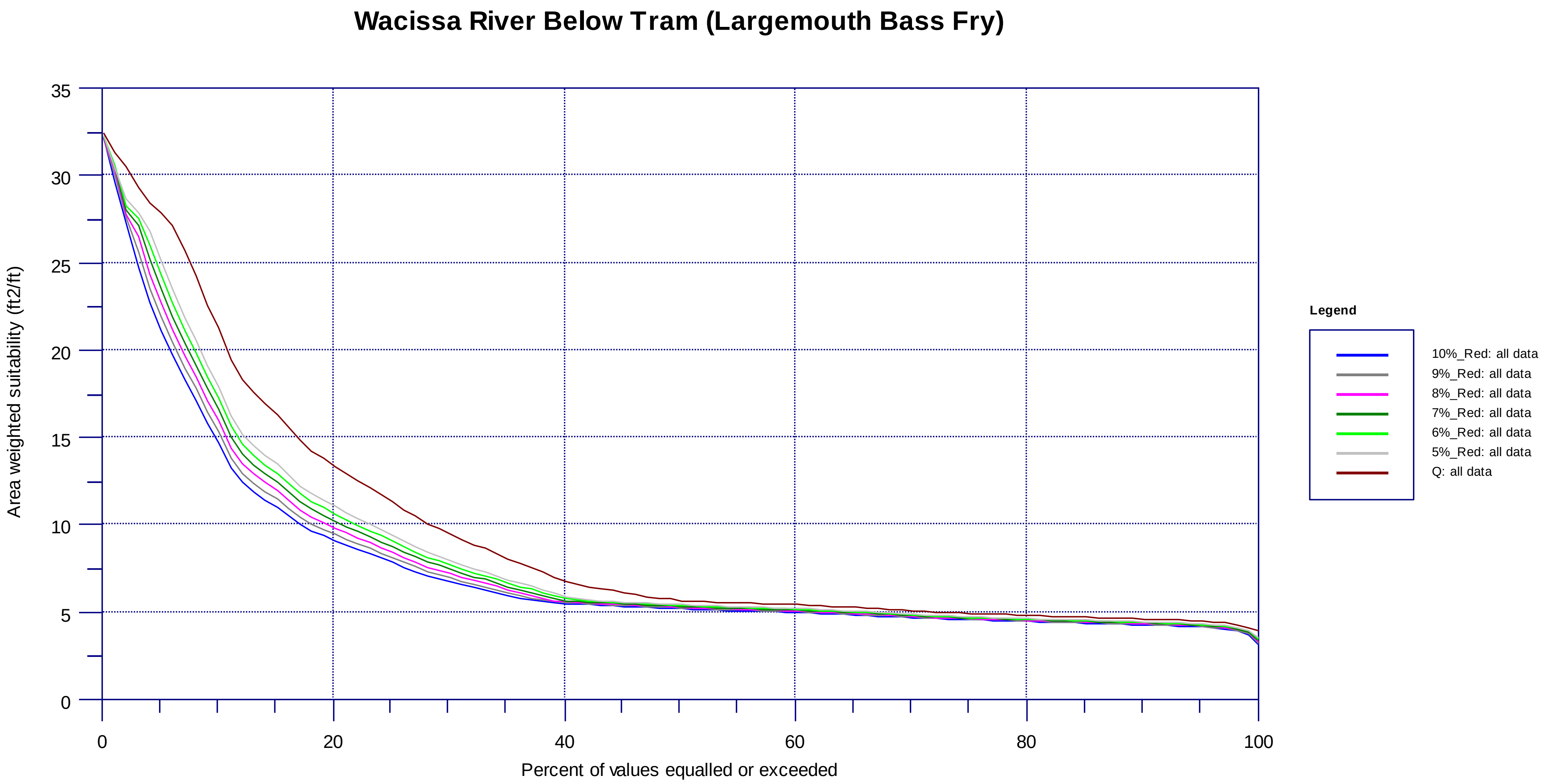


Figure A3. Area weighted suitability duration curves with historic discharge (Q) including the various percent reductions across the entire historical period of record for largemouth bass fry below the tram.

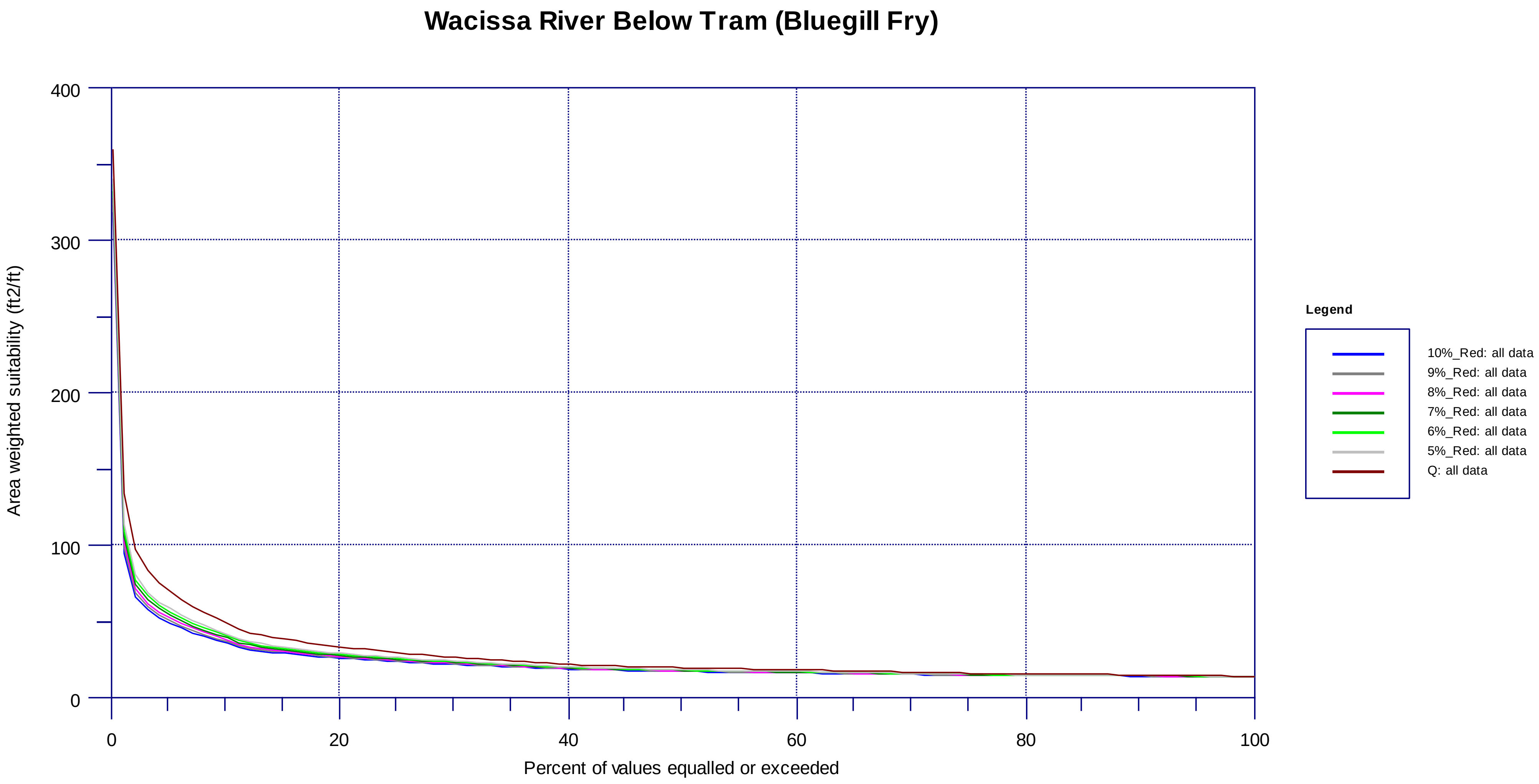


Figure A4. Area weighted suitability duration curves with historic discharge (Q) including the various percent reductions across the entire historical period of record for bluegill fry below the tram.

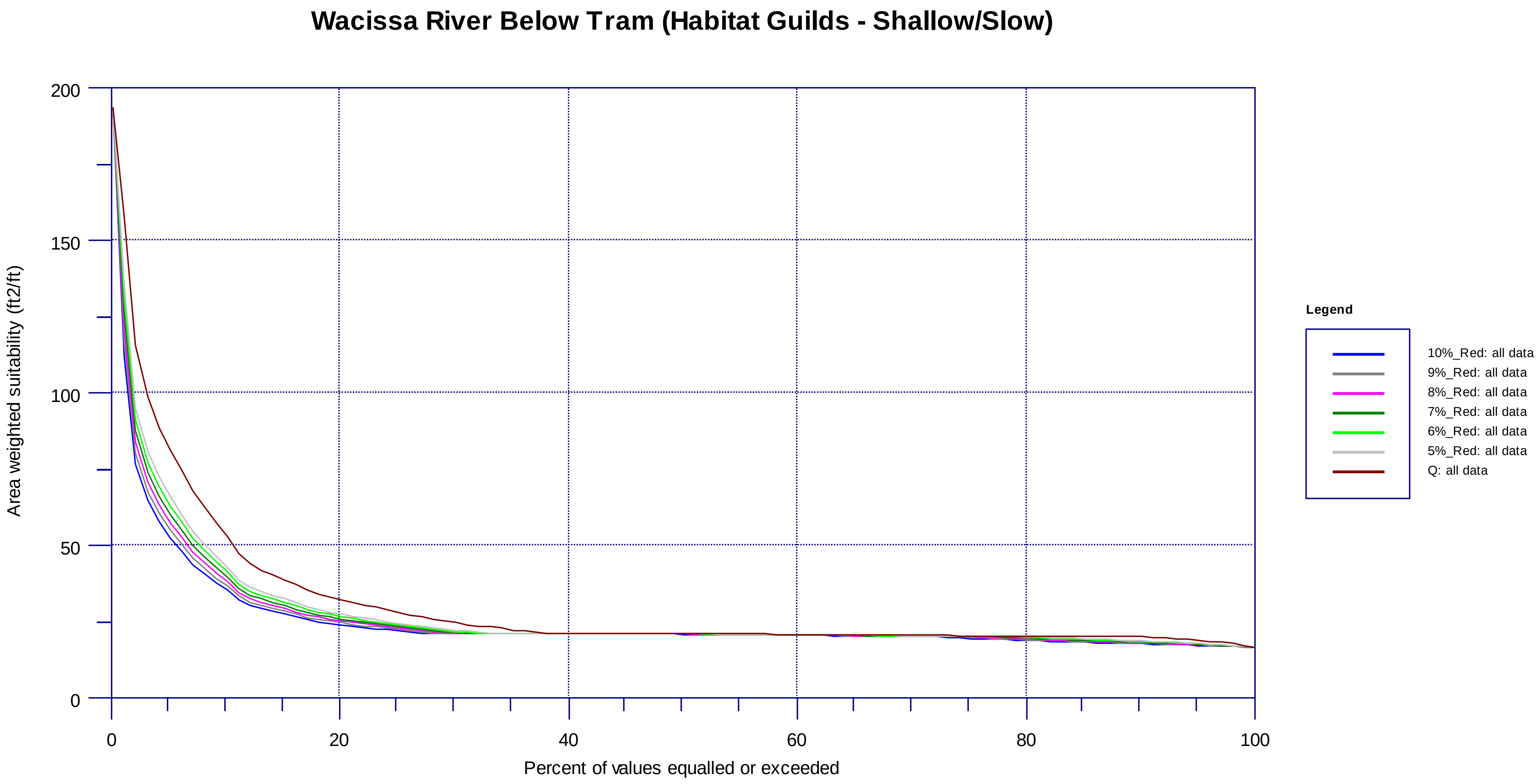


Figure A5. Area weighted suitability duration curves with historic discharge (Q) including the various percent reductions across the entire historical period of record for the shallow/slow habitat guilds below the tram.

APPENDIX D

MFLs Translations

MFL Translations

Three MFLs are recommended for the Aucilla River for successively higher flow regimes referenced to the index gage at Lamont (Figure 6 in main text).

- A 6.5% flow reduction during low to moderate flows would remain protective of the oligohaline salinity regime of the Aucilla River estuary. The 0-2 ppt and 0-5 ppt oligohaline regimes are most sensitive to reductions in freshwater flow of the metrics evaluated for the Aucilla River**.** This estuarine flow reduction limitation applies over about 72% of the baseline flow duration curve (0 to 355 cfs). The flow reductions would range from zero when there is no flow at the Lamont gage up to 23 cfs at 355 cfs.
- A 13% flow reduction would remain protective of bank habitat for increasingly higher flows of up to 558 cfs, which is associated with the average top-of-bank stage within the middle reach of the Aucilla River. Between 46 and 73 cfs would be available during this flow range that occurred about 8% of the time during baseline conditions.
- A flow reduction of up to 17% would remain protective of floodplain habitat, various portions of which were inundated by overbank flow about 20% of the time during baseline conditions. Beginning with 95 cfs of available water at a top-of-bank flow of 558 cfs in the middle Aucilla River, increasing amounts of water could be withdrawn as limited to 17% of flow.

The three Aucilla River MFLs referenced to the USGS gage at Lamont can be translated to the USGS gage location at Scanlon (Figure 6 in main text) and the temporary Aucilla ADVM gage located downstream of Nutall Rise (Figure 6 in main text) using regression equations developed for the common period flow records (Appendix F).

The respective flow reductions and thresholds at the Scanlon gage (Table 1) are:

- 6.5% of flows up to 545 cfs to remain protective of estuarine habitat,
- 13% of flows from 545 to 823 cfs to remain protective of riverine bank habitat, and
- 17% of flows greater than 823 cfs to remain protective of floodplain habitat.

The respective flow reductions and thresholds at the Aucilla ADVM gage (Table 1) are:

- 6.5% of flows up to 1,075 cfs to remain protective of estuarine habitat,
- 13% of flows from 1,075 to 1,371 cfs to remain protective of riverine bank habitat, and
- 17% of flows greater than 1,371 cfs to remain protective of floodplain habitat.

Table 1. MFLs Summary

	Threshold Habitat	Baseline Flow Range[1] (cfs)	Percent Time MFL is applicable	Range of Flow available[3] (cfs)	Flow Reduction (%)
Scanlon	Estuarine	≤545	72	<35	6.5
	Riverine	545-823	8	71-107	13
	Floodplain	>823	20	>140	17
Nutall Rise[2] (Aucilla ADVM)	Estuarine	≤1,075	72	<70	6.5
	Riverine	1,075–1,371	8	140-178	13
	Floodplain	>1,371	20	>233	17

1- Flow values for Scanlon were derived from Lamont using the regression equation ($Q_{Scanlon}$) = -0.000121*(Q_{Lamont})^2+1.48*(Q_{Lamont})+34.5. Flow values for ADVM were derived from Lamont using the regression equation (Q_{ADVM}) = 1.4579*(Q_{Lamont}) + 557.02.

2- The available water at the ADVM gage reflects the weighted average of available water at Scanlon and Wacissa so that the allowable reductions at Wacissa and Aucilla are not violated.

3- Range of Flow available (cfs) = Baseline Flow Range (cfs) × Flow Reduction (%)

APPENDIX E

Sea Level Rise Results

Sea level Rise Scenario-Hydrodynamic Model results

The Aucilla River hydrodynamic model was applied to simulate the effects of sea level rise on the baseline condition. The process used to determine the amount of rise followed that used by the SWFWMD for the Chassahowitzka River (SWFWMD 2012; USACE 2011) with the rise projected to 2035 instead of 2030. A sea level rise intermediate projection of 5.1 inches from 2015 to 2035 was computed using equation 1.

$$\text{Rise (in meters)} = 0.0017\,(t_2 - t_1) + b(t_2^2 - t_1^2) \qquad (1)$$

Where:

t_1= Time between 2015 and 1992

t_2= Time between projection date (2035) and 1992

b = Constant

The rise scenario was achieved by increasing the boundary condition water surface elevation in the hydrodynamic model by 5.1 inches. All other model inputs were the same as used in the baseline scenario.

The total volume of cells meeting a particular salinity criterion was calculated to determine a daily salinity volume for each salinity regime. Similarly, bottom area of bottom cells and length of cells along the shoreline were used to calculate daily bottom area and daily shoreline length for each salinity regime. Volume, bottom area, and shoreline length corresponding to two selected salinity regimes (0-2 ppt and 0-5 ppt) were evaluated for a sea level rise of 5.1 inches and baseline condition.

- The maximum volume (0% exceedance volume) of 0-2 ppt salinity regime for a sea level rise of 5.1 inches is 7% lower than the maximum volume (0% exceedance volume) of 0-2 ppt baseline condition.

- The average volume (Area under the Sea Level Rise exceedance curve) of the 0-2 ppt for a sea level rise of 5.1 inches is 11.5% lower than average volume during the baseline condition (Area under the Baseline exceedance curve) (Figure 1).

- Similarly, the maximum volume and average volume (Area under the Sea Level Rise curve) of the 0-5 ppt salinity regime are 5.4% and 9.1% lower than the baseline condition (Figure 2).

- The 0-2 ppt salinity regime is more sensitive to sea level rise with greater reductions in volume and bottom area, while the 0-5 ppt salinity regime is more sensitive with greater reduction in shoreline length, when compared to the baseline condition (Table 1).

Table 1. Summary of Volume, Bottom Area, and Shoreline Length change due to sea level rise

	0-2 ppt			0-5 ppt		
	Baseline	Sea Level Rise	% Change from Baseline	Baseline	Sea Level Rise	% Change from Baseline
Volume (cubic ft)	7,583,397	6,711,635	11.5	12,202,837	10,927,095	10.4
Bottom Area (Square ft)	911,073	640,390	29.7	1,415,159	1,270,914	10.2
Shoreline Length (ft)	9,927	7,703	22.4	16,200	12,221	24.5

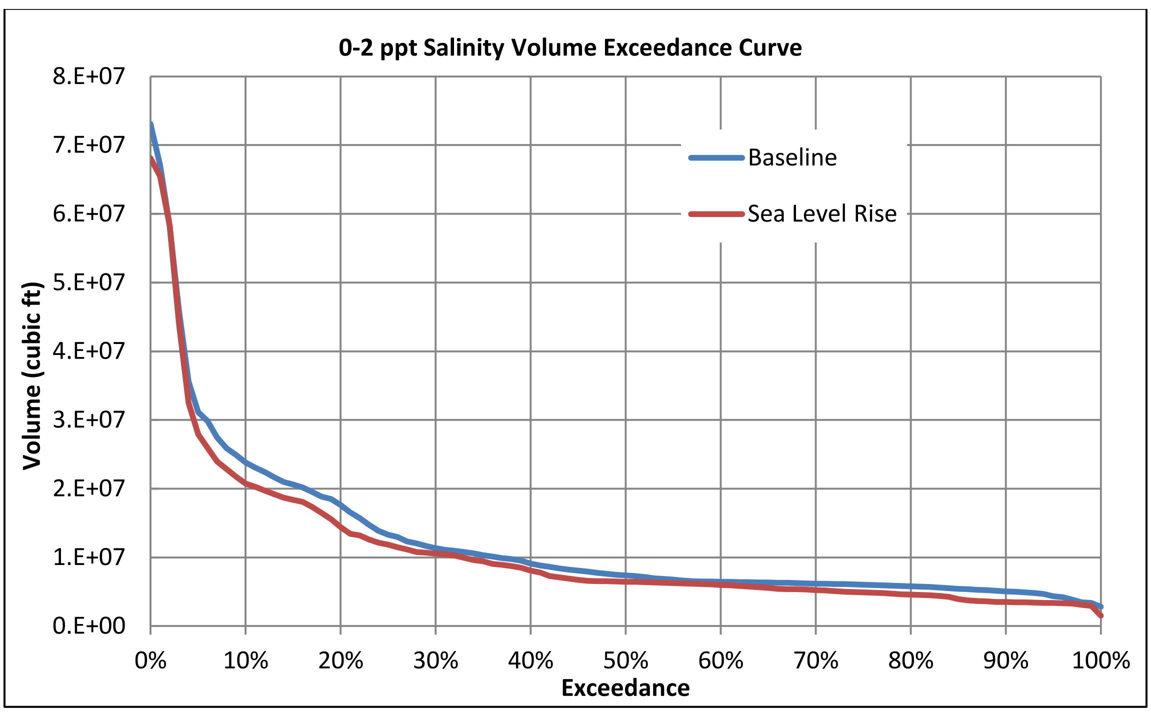


Figure 1. Salinity volume exceedance curve (0-2 ppt)

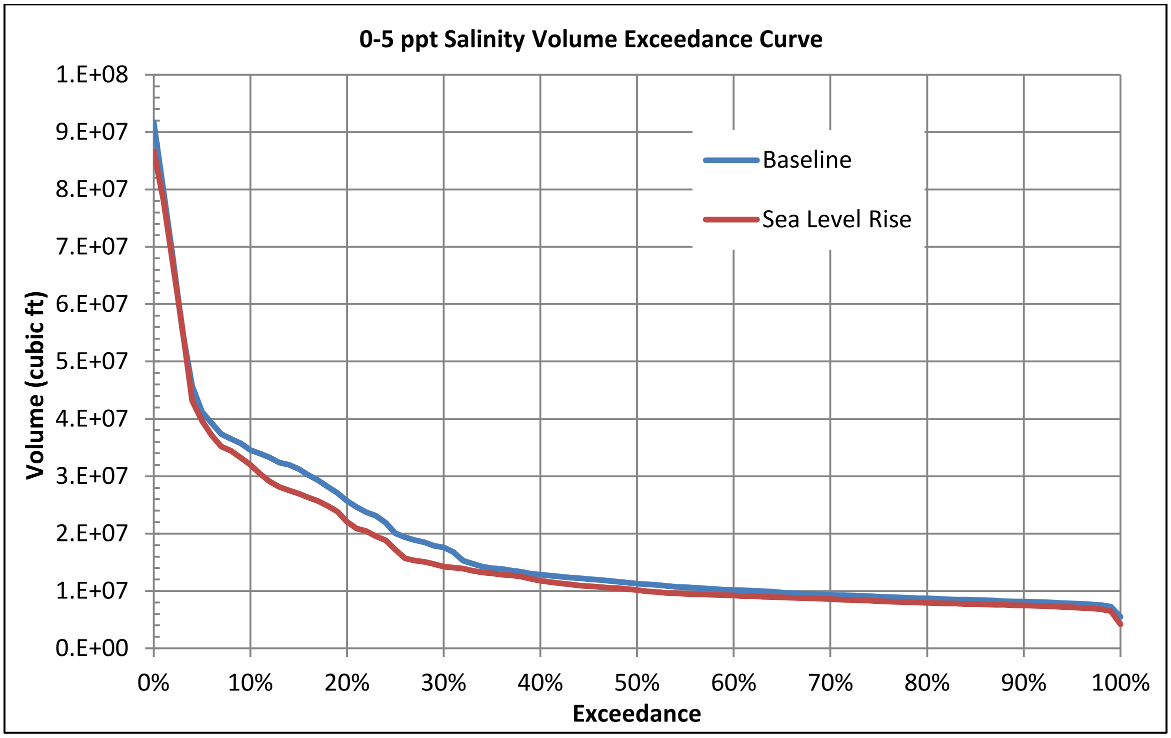


Figure 2. Salinity volume exceedance curve (0-5 ppt)

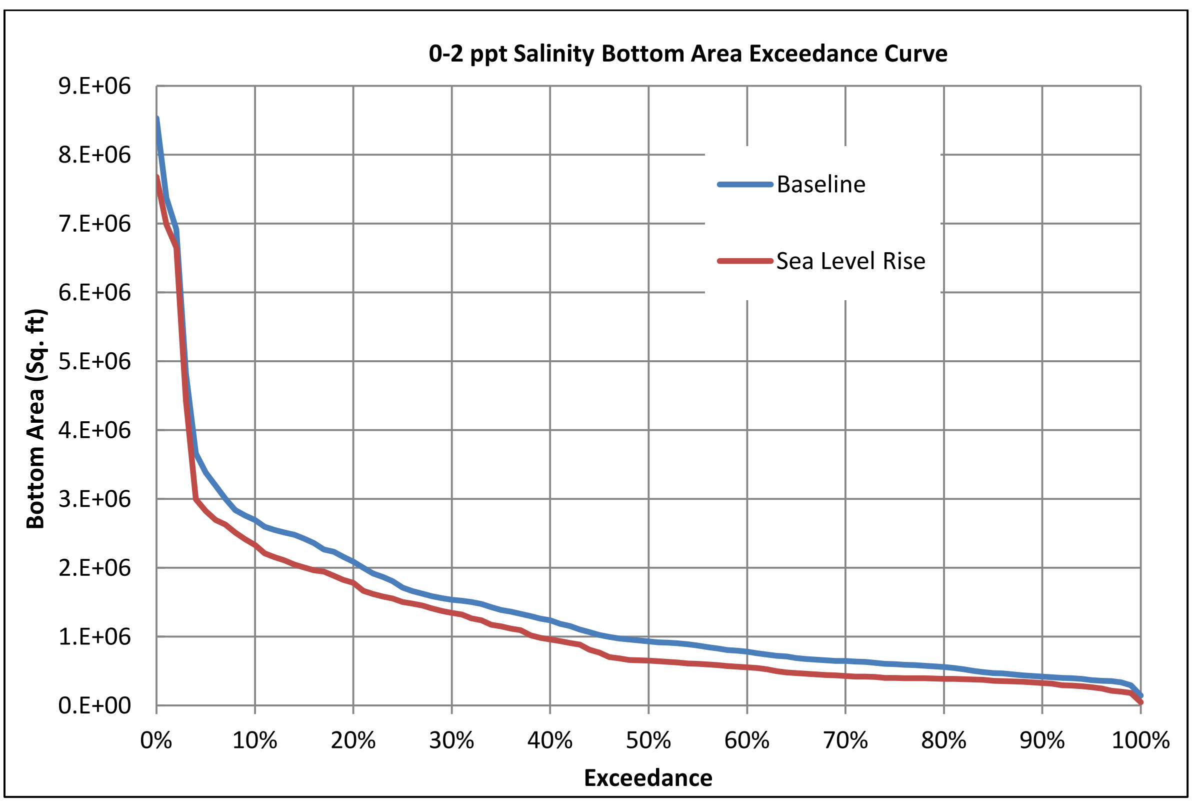


Figure 3. Salinity Bottom Area exceedance curve (0-2 ppt)

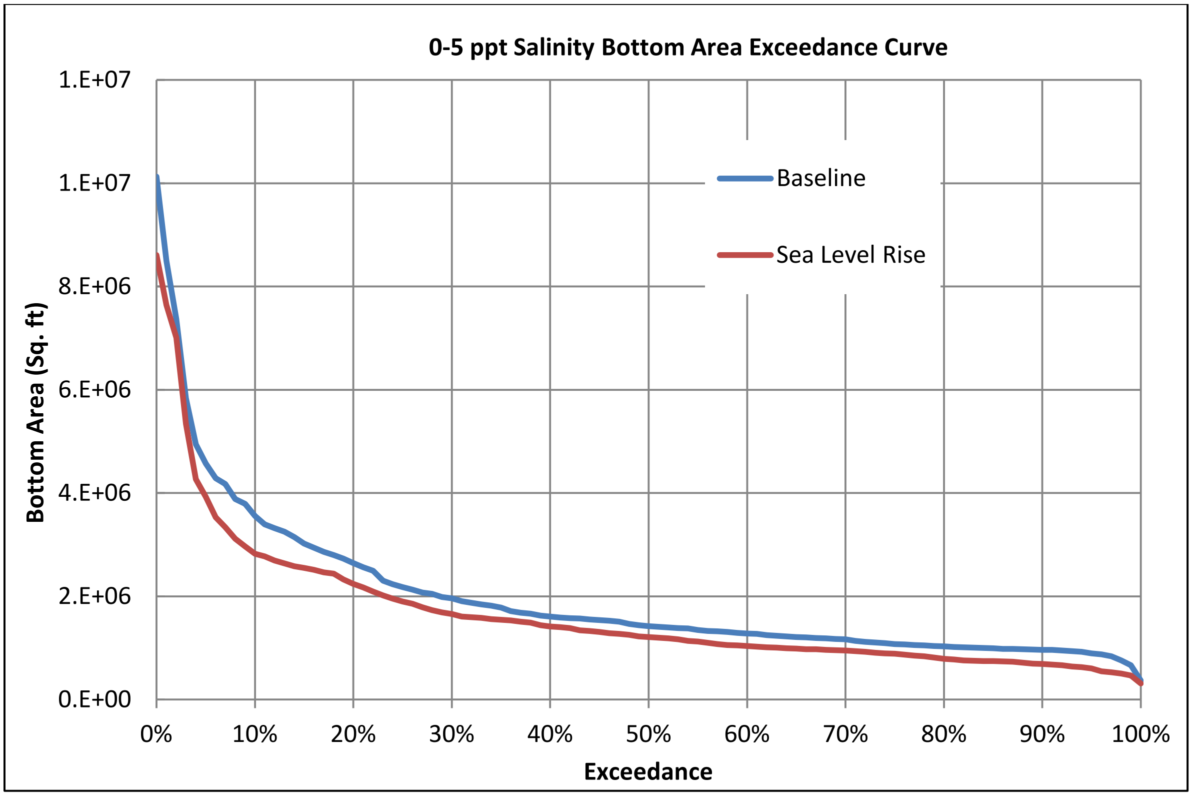


Figure 3. Salinity Bottom Area exceedance curve (0-5 ppt)

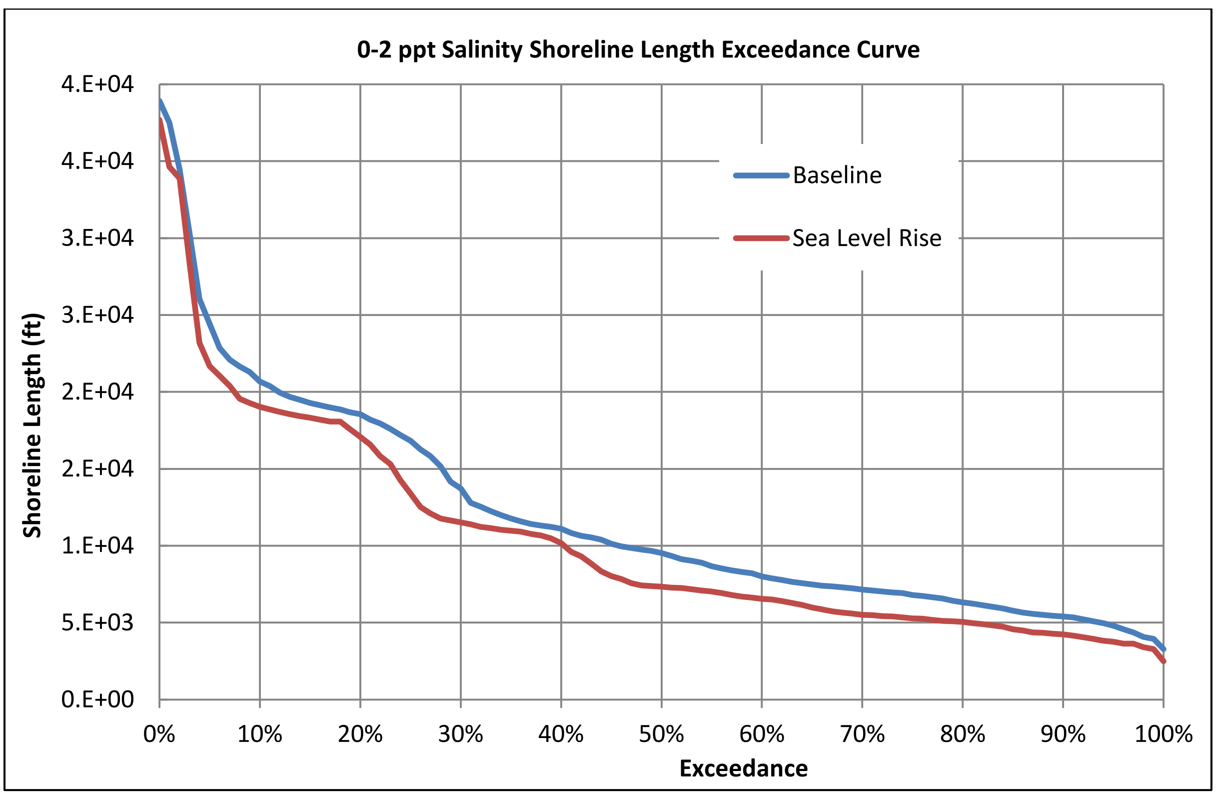


Figure 5. Salinity Shoreline Length exceedance curve (0-2 ppt)

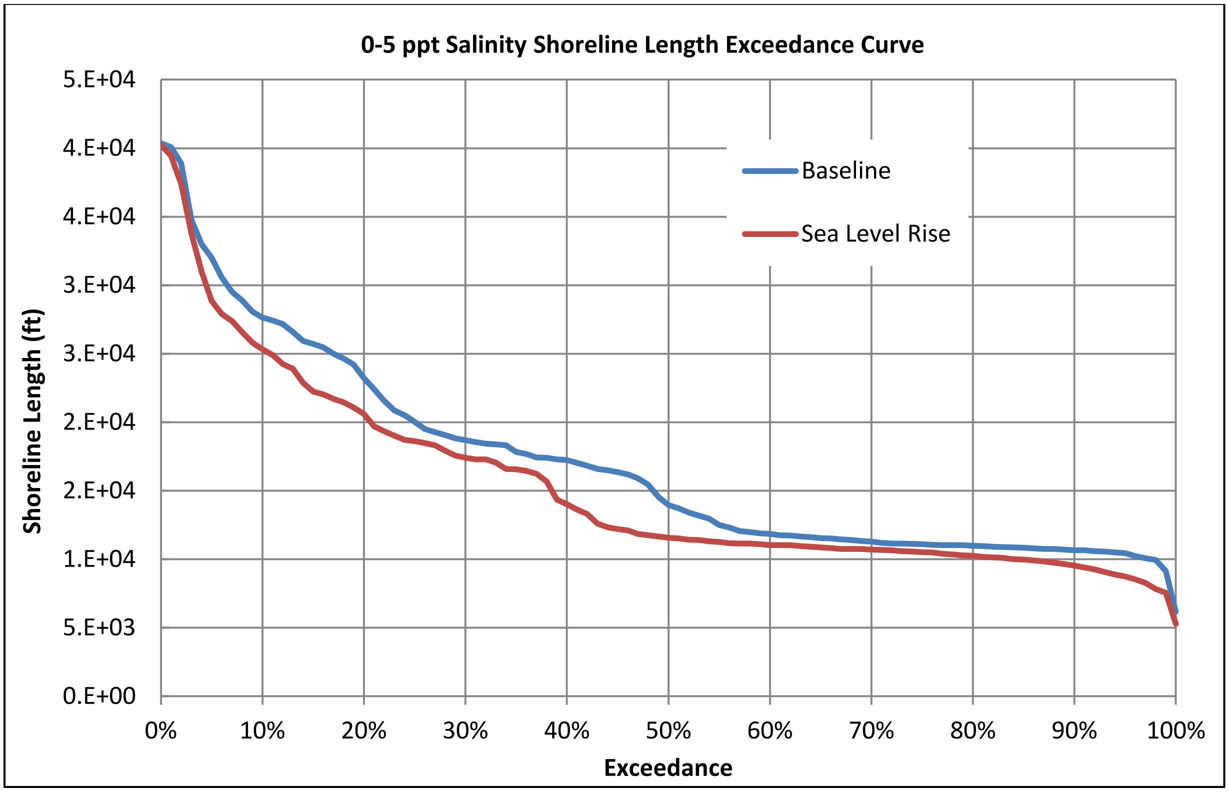


Figure 6. Salinity Shoreline Length exceedance curve (0-5 ppt)

References

U. S. Army Corps of Engineers (USACE). 2011. Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs. Circular No. 1165-2-212.
http://140.194.76.129/publications/eng-circulars/EC_1165-2-212_2011Nov/EC_1165-2-212_2011Nov.pdf

Southwest Florida Water Management District (SWFWMD). 2012. Recommended Minimum Flows for the Chassahowitzka River System. Brooksville, Florida, USA.

APPENDIX F
Regression Statistics

Regression between streamflow at USGS Lamont gage and Aucilla ADVM gage

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.956[a]	.915	.914	176.455

a. Predictors: (Constant), Lamont-flow

b. Dependent Variable: ADVM-flow

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.815E7	1	3.815E7	1225.096	.000[a]
	Residual	3549545.819	114	31136.367		
	Total	4.169E7	115			

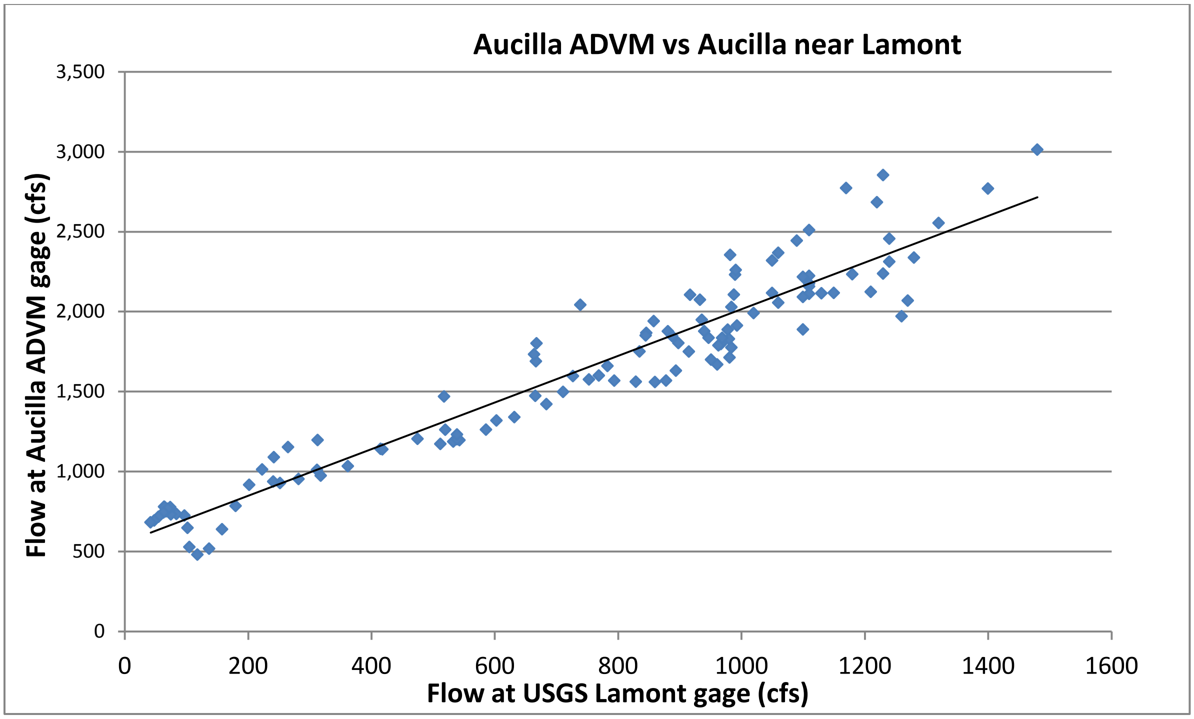
a. Predictors: (Constant), Lamont-flow

b. Dependent Variable: ADVM-flow

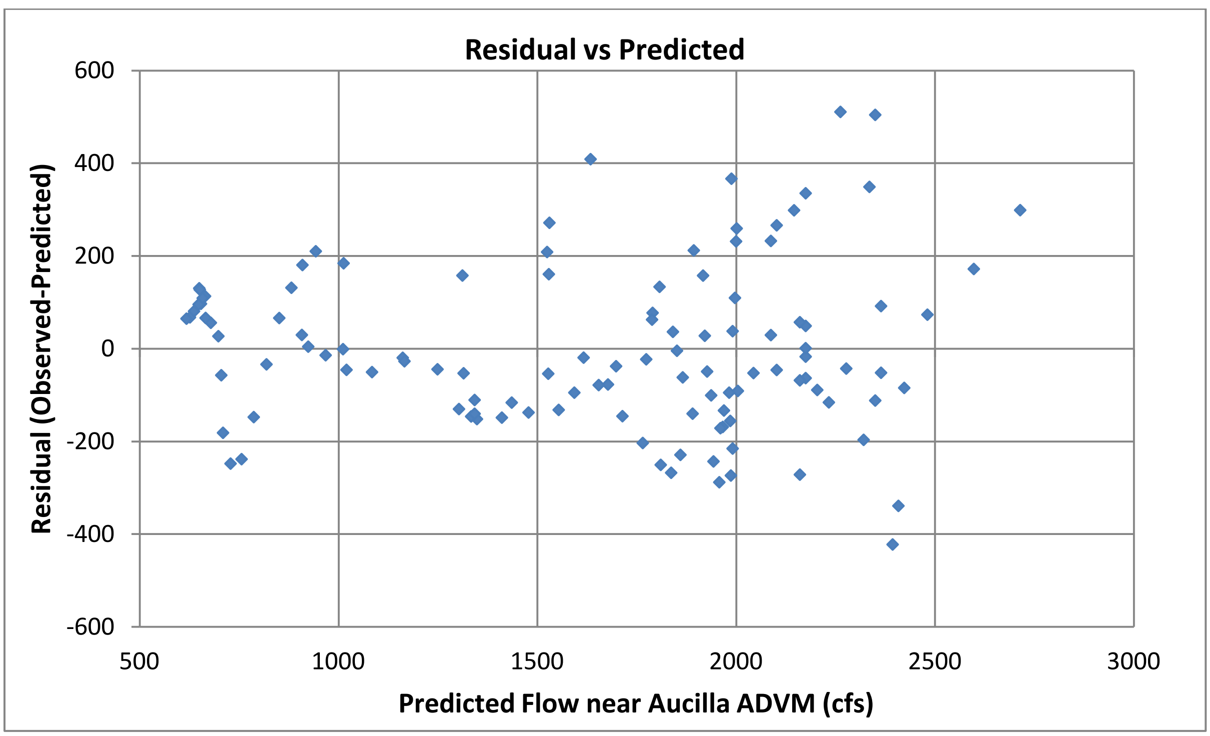
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	557.018	34.649		16.076	.000	488.377	625.658
	Lamontflow	1.458	.042	.956	35.001	.000	1.375	1.540

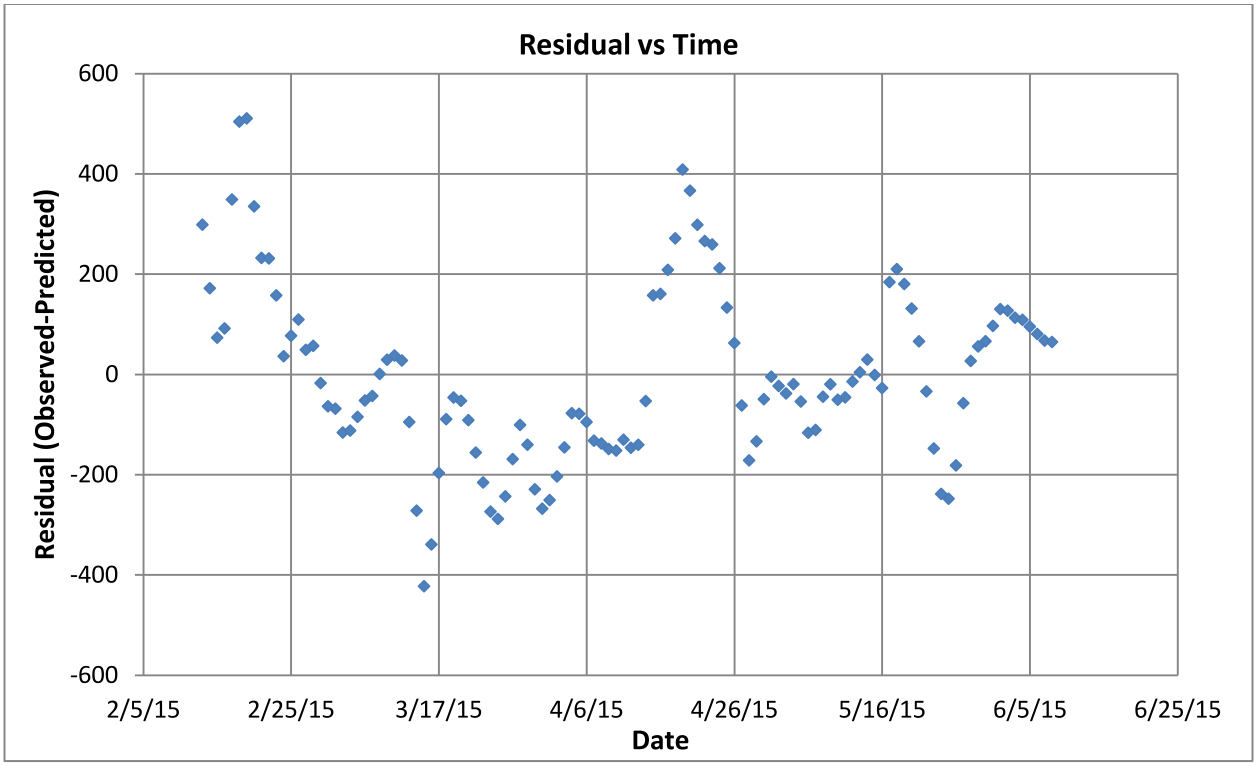
a. Dependent Variable: ADVMflow



Aucilla ADVM vs Aucilla near Lamont
Flow at Aucilla ADVM gage (cfs)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0
200
400
600
800
1000
1200
1400
1600
Flow at USGS Lamont gage (cfs)



Residual vs Predicted
Residual (Observed-Predicted)
600
400
200
0
-200
-400
-600
500
1000
1500
2000
2500
3000
Predicted Flow near Aucilla ADVM (cfs)


Residual vs Time
600
400
200
0
-200
-400
-600
Residual (Observed-Predicted)
2/5/15
2/25/15
3/17/15
4/6/15
4/26/15
5/16/15
6/5/15
6/25/15
Date

Regression between streamflow at USGS Lamont gage and USGS Scanlon gage

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.987	.974	.974	67.793

The independent variable is QSL.

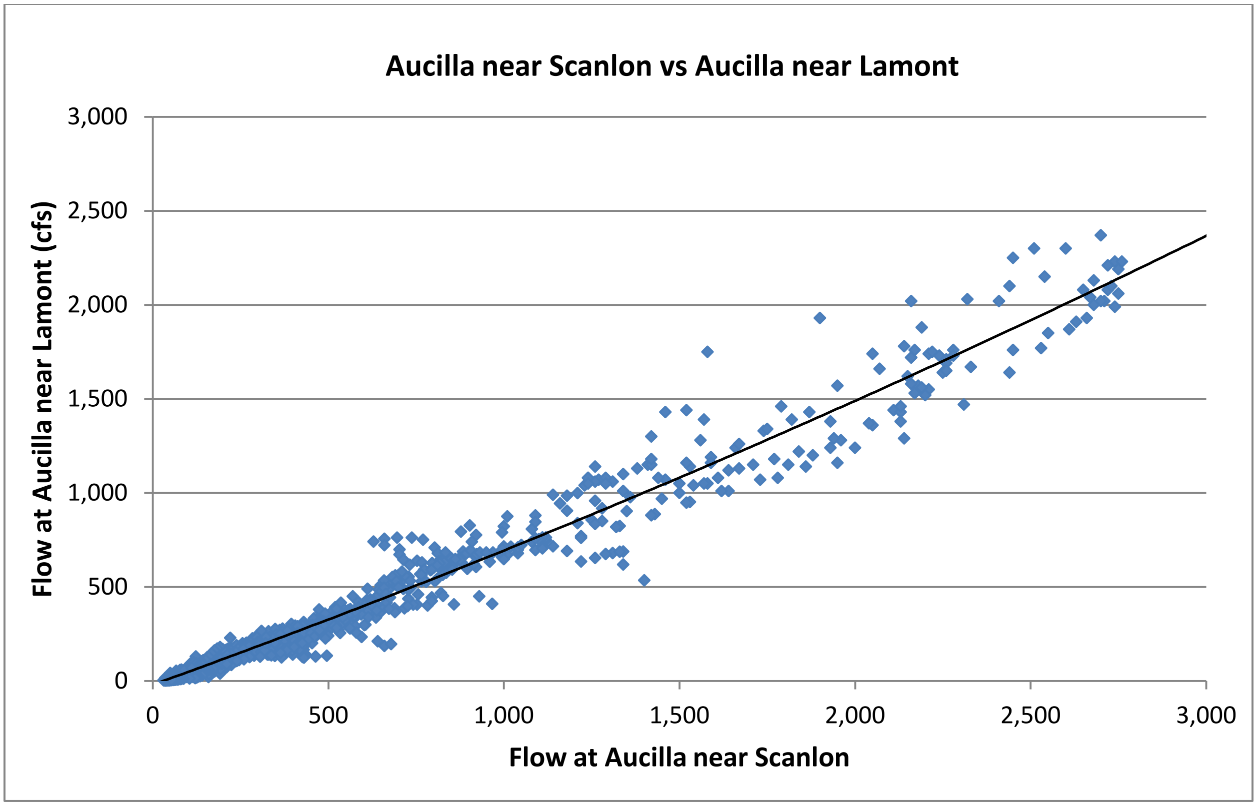
ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	2.811E8	2	1.406E8	30584.585	.000
Residual	7532565.314	1639	4595.830		
Total	2.887E8	1641			

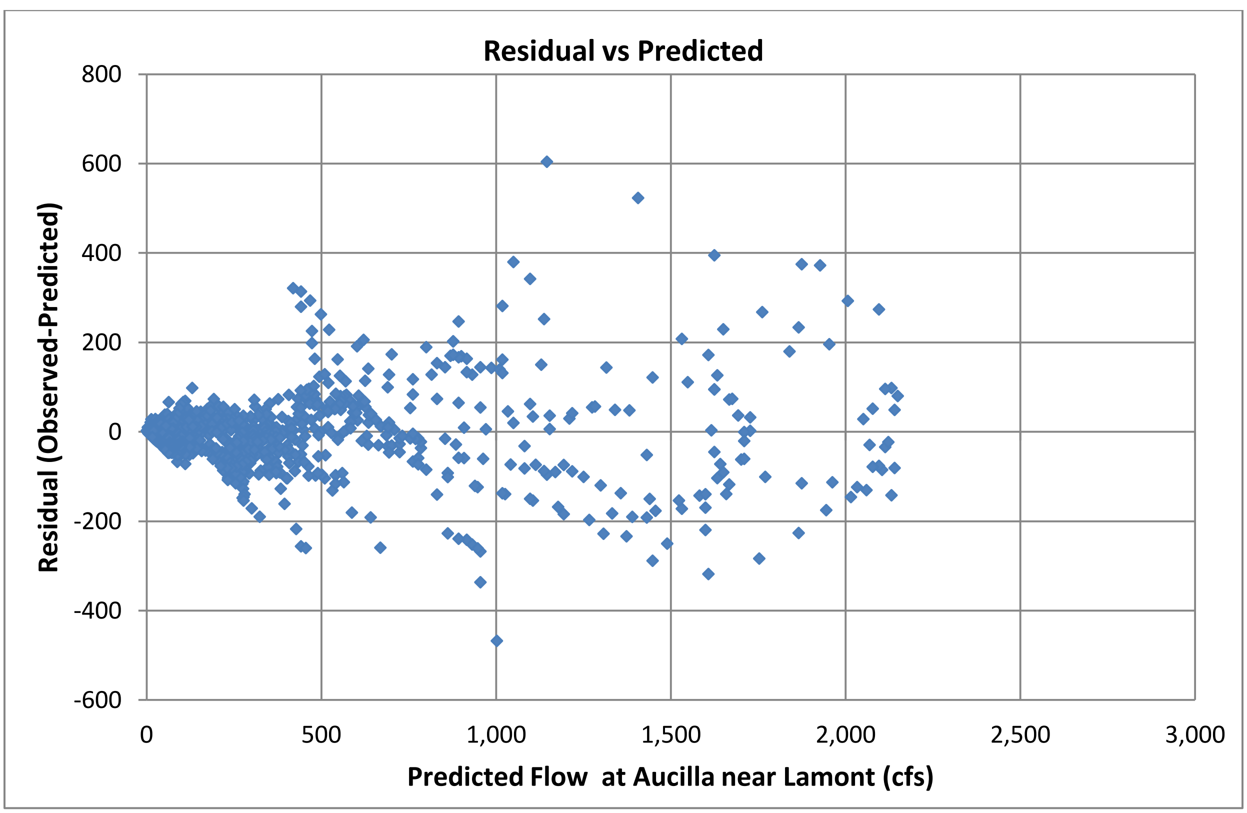
The independent variable is QSL.

Coefficients

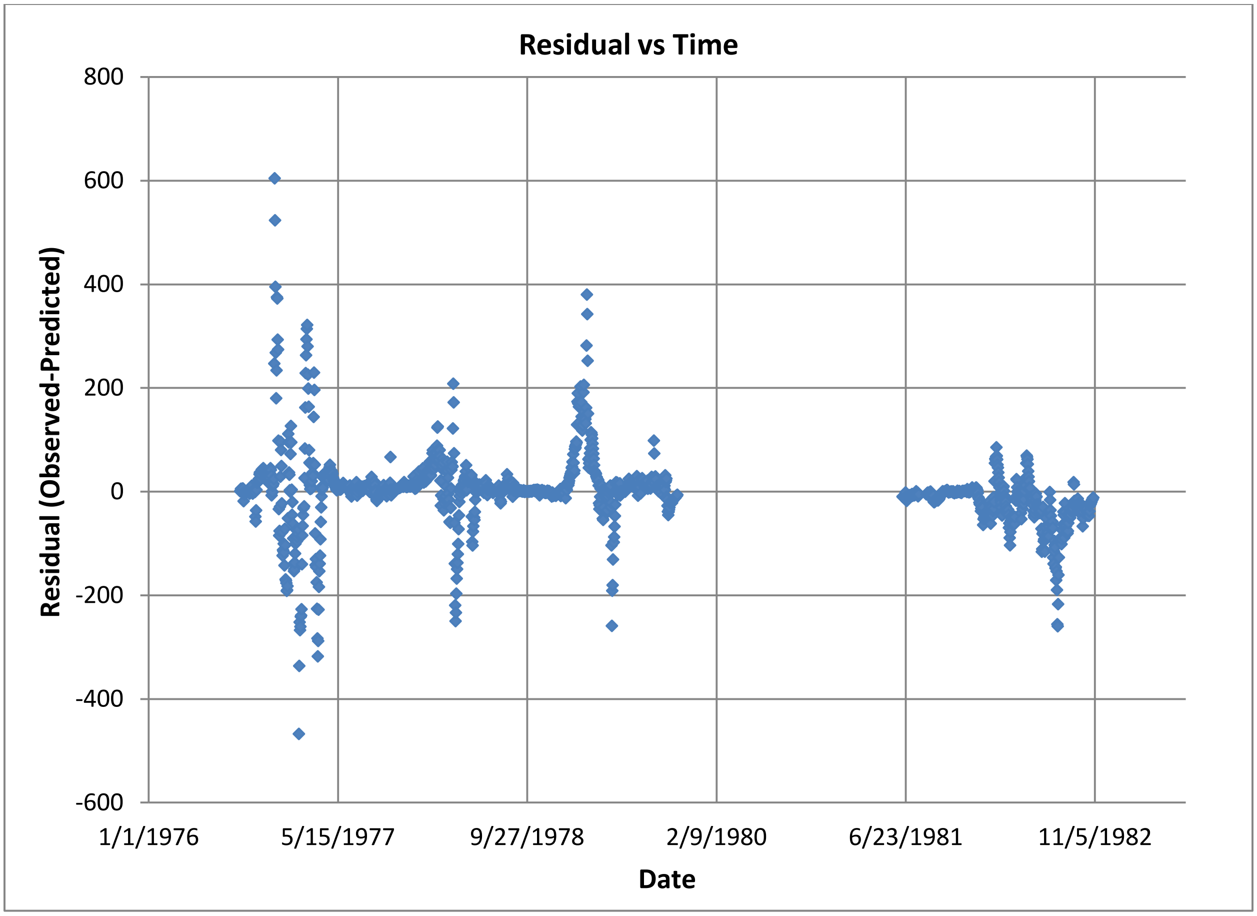
	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
QSL	.673	.009	.874	73.697	.000
QSL ** 2	4.105E-5	.000	.119	10.009	.000
(Constant)	-20.223	2.585		-7.823	.000



Aucilla near Scanlon vs Aucilla near Lamont
3,000
2,500
2,000
1,500
1,000
500
0
Flow at Aucilla near Lamont (cfs)
0
500
1,000
1,500
2,000
2,500
3,000
Flow at Aucilla near Scanlon



Residual vs Predicted
800
600
400
200
0
-200
-400
-600
Residual (Observed-Predicted)
0
500
1,000
1,500
2,000
2,500
3,000
Predicted Flow at Aucilla near Lamont (cfs)



Residual vs Time
800
600
400
200
0
-200
-400
-600
Residual (Observed-Predicted)
1/1/1976
5/15/1977
9/27/1978
2/9/1980
6/23/1981
11/5/1982
Date

Regression between streamflow at USGS Scanlon gage and USGS Lamont gage

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.988	.976	.976	85.212

The independent variable is QLM.

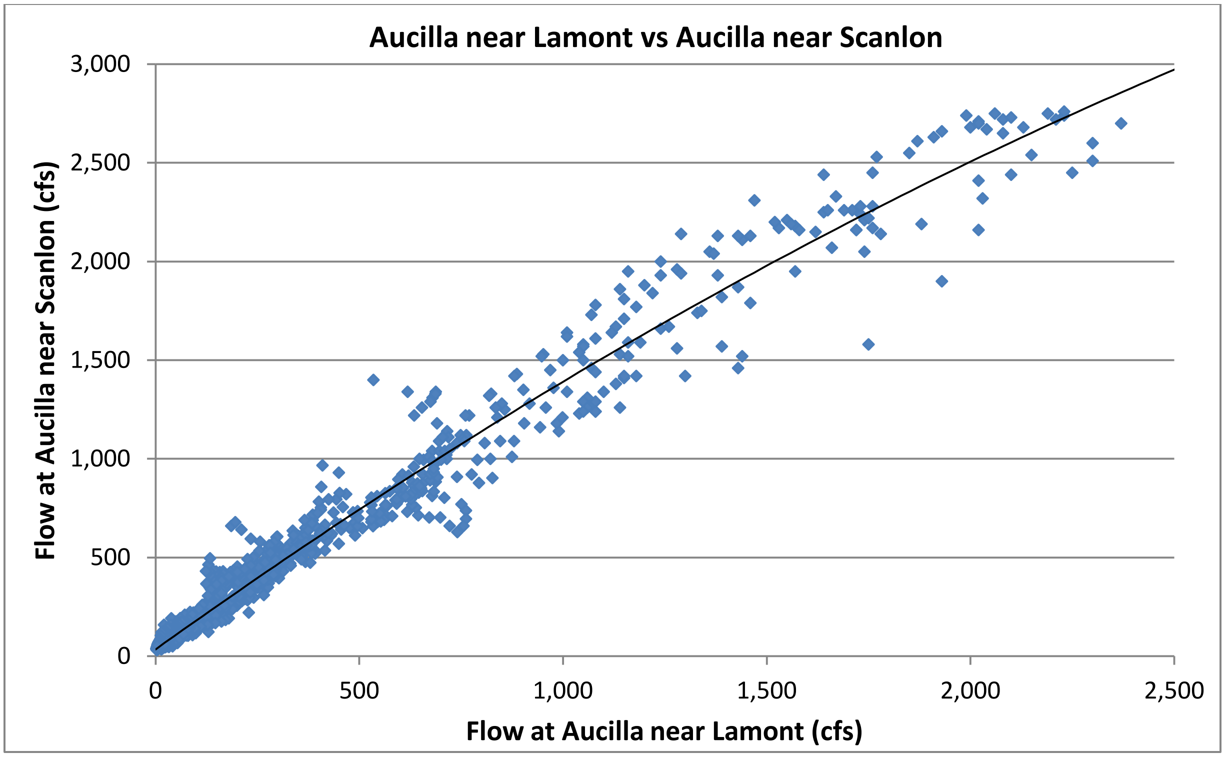
ANOVA

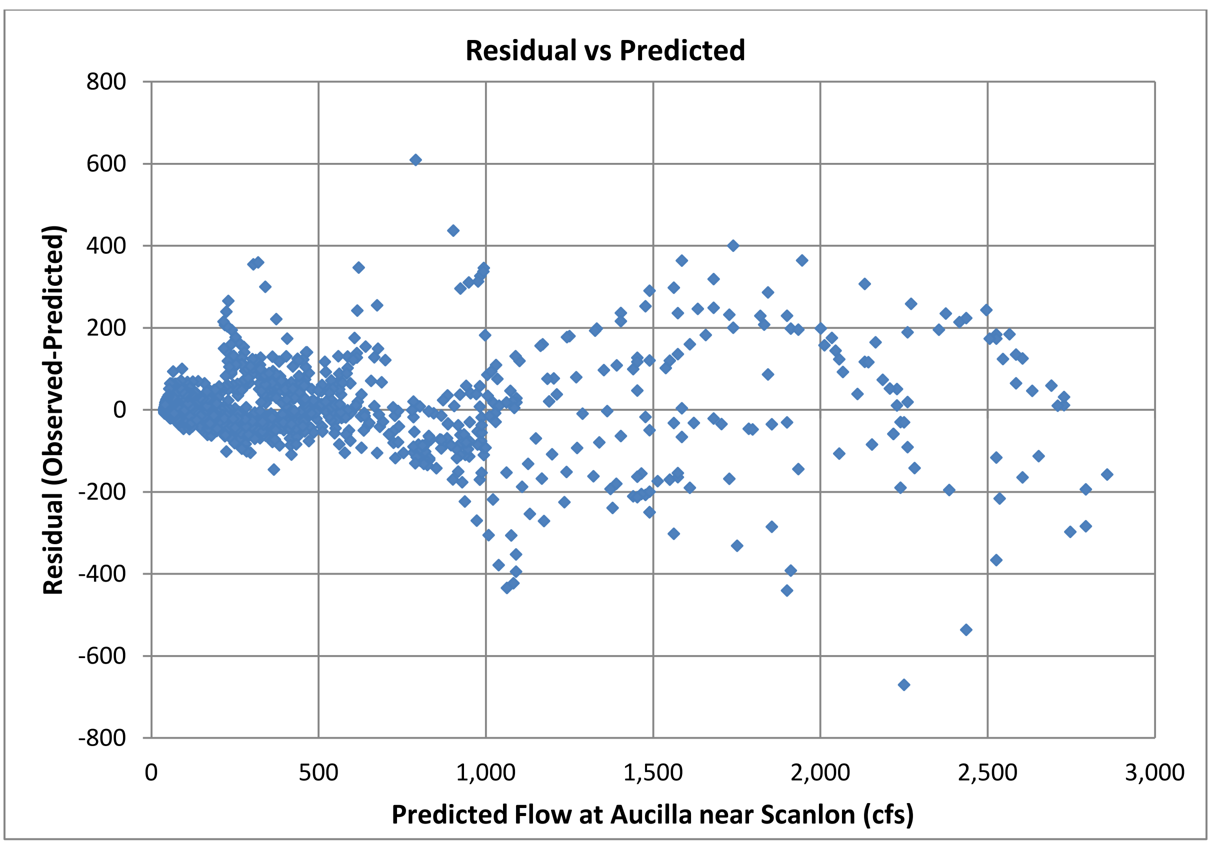
	Sum of Squares	df	Mean Square	F	Sig.
Regression	4.756E8	2	2.378E8	32747.168	.000
Residual	1.190E7	1639	7261.034		
Total	4.875E8	1641			

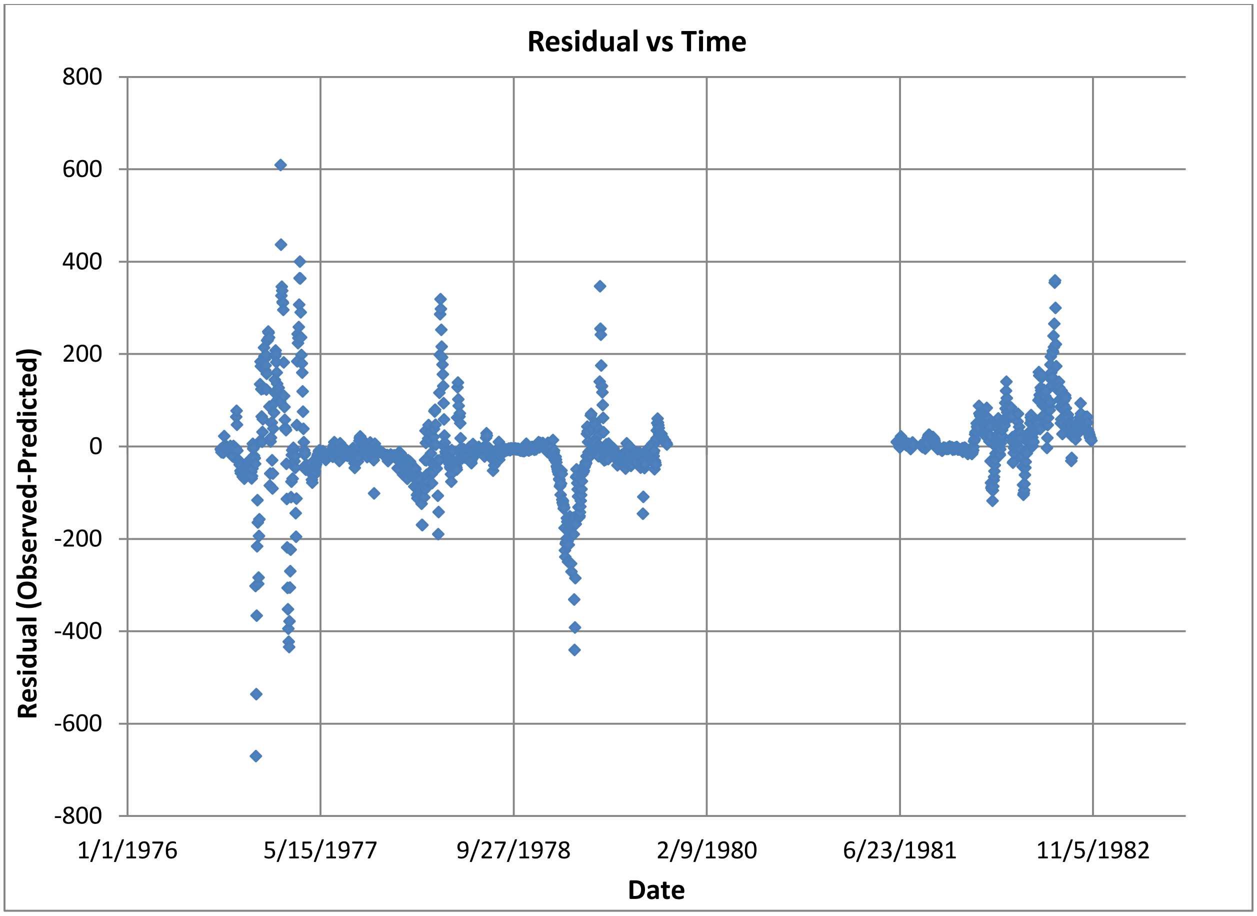
The independent variable is QLM.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
QLM	1.478	.014	1.137	104.426	.000
QLM ** 2	-.000121	.000	-.161	-14.831	.000
(Constant)	34.468	2.908		11.853	.000


Aucilla near Lamont vs Aucilla near Scanlon
Flow at Aucilla near Scanlon (cfs)
3,000
2,500
2,000
1,500
1,000
500
0
0
500
1,000
1,500
2,000
2,500
Flow at Aucilla near Lamont (cfs)


Residual vs Predicted
Residual (Observed-Predicted)
800
600
400
200
0
-200
-400
-600
-800
0
500
1,000
1,500
2,000
2,500
3,000
Predicted Flow at Aucilla near Scanlon (cfs)



Residual vs Time
800
600
400
200
0
-200
-400
-600
-800
Residual (Observed-Predicted)
1/1/1976
5/15/1977
9/27/1978
2/9/1980
6/23/1981
11/5/1982
Date

Regression between streamflow at USGS Lamont gage and USGS Econfina gage

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.794[a]	.630	.630	440.20248

a. Predictors: (Constant), QEC

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.447E9	1	5.447E9	28108.790	.000[a]
	Residual	3.203E9	16528	193778.227		
	Total	8.650E9	16529			

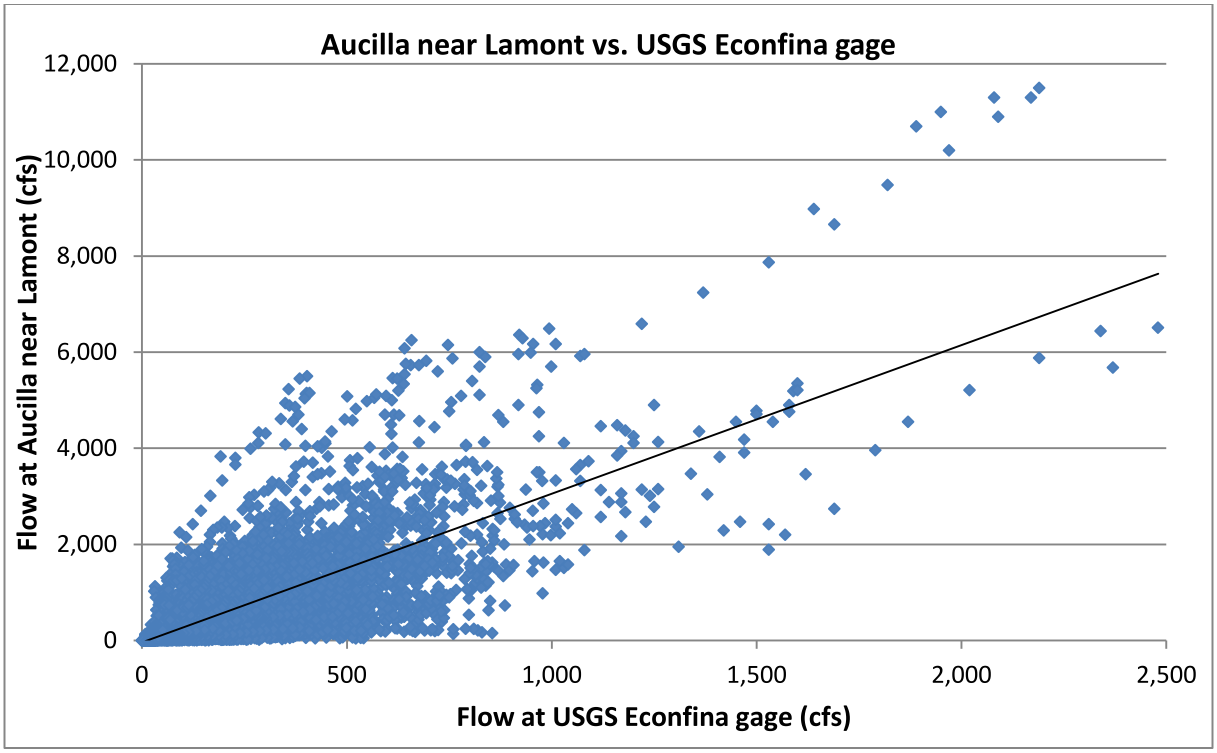
a. Predictors: (Constant), QEC

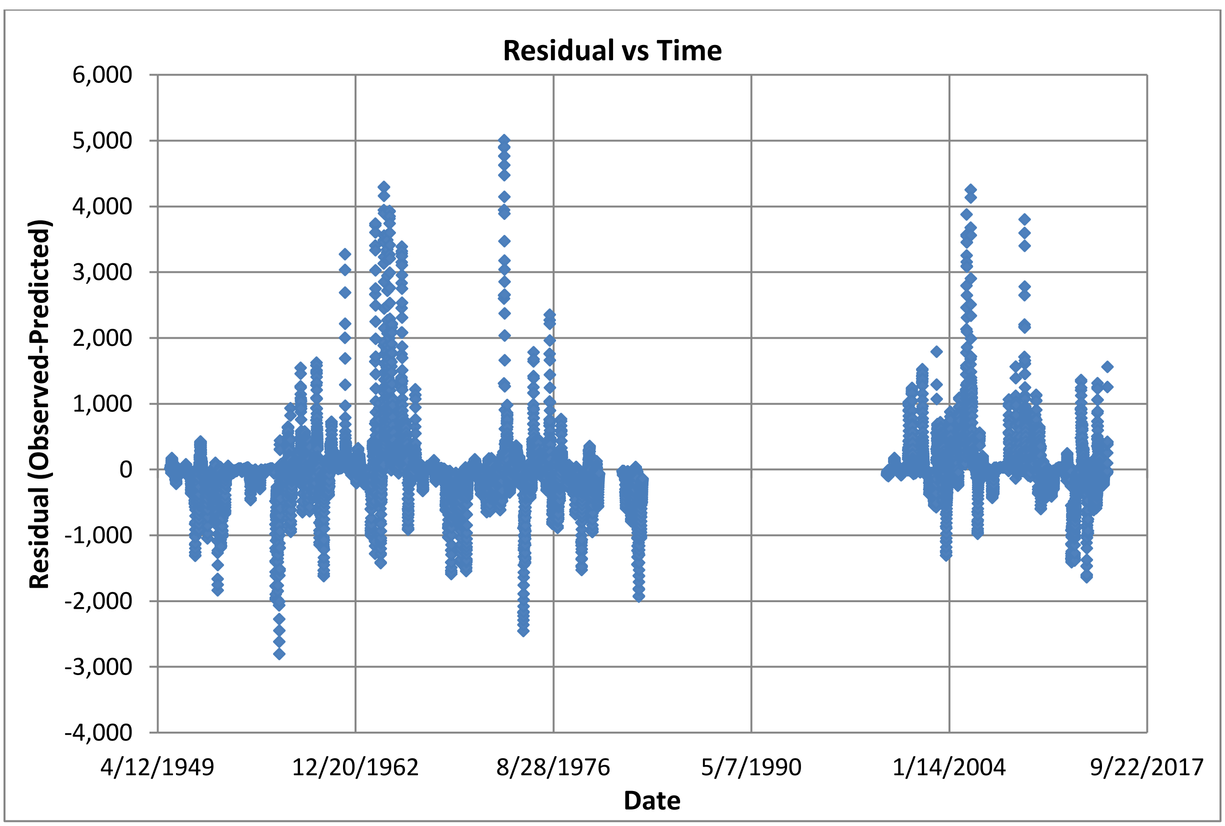
b. Dependent Variable: QLM

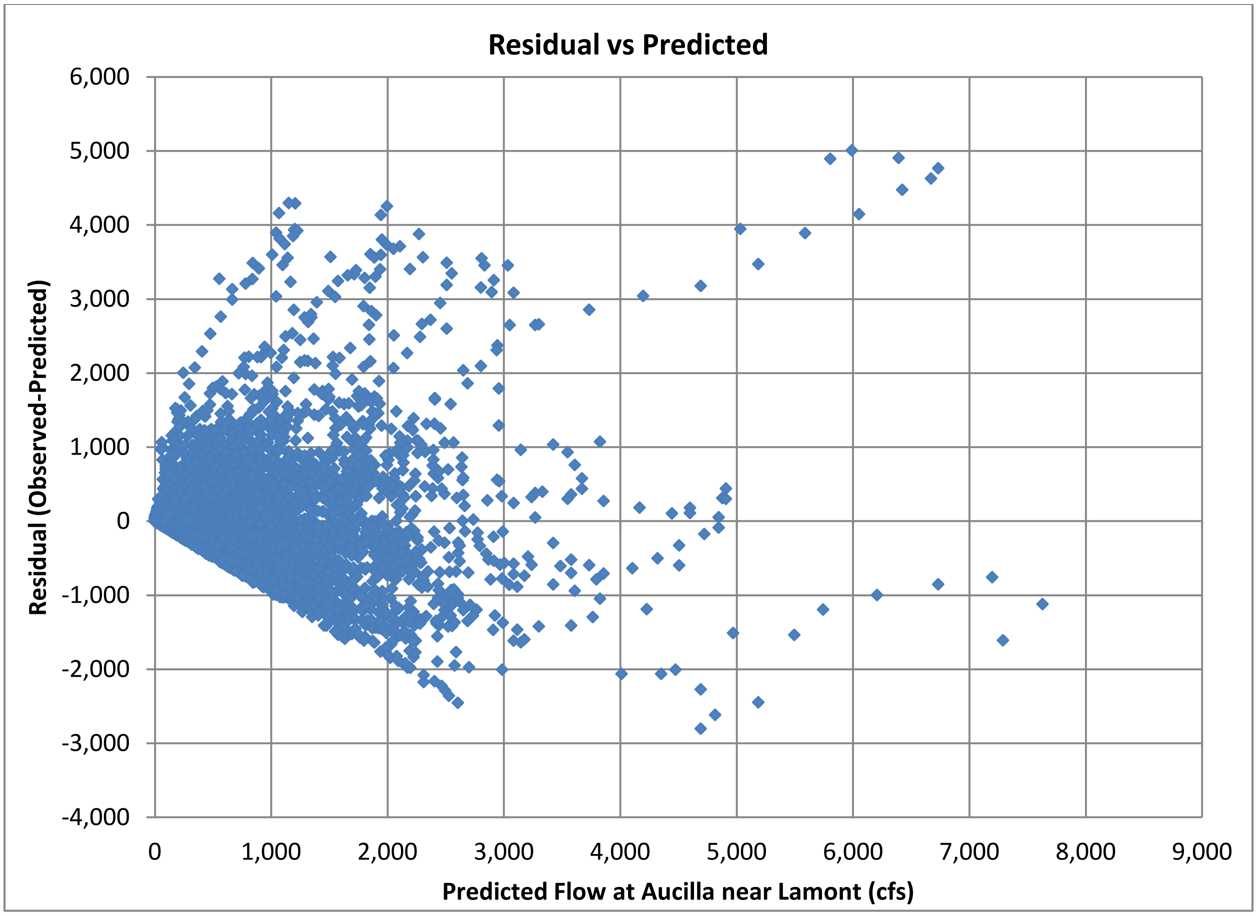
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-39.038	4.171		-9.359	.000	-47.214	-30.861
	QEC	3.092	.018	.794	167.657	.000	3.056	3.128

a. Dependent Variable: QLM


Aucilla near Lamont vs. USGS Econfina gage
12,000
10,000
8,000
6,000
4,000
2,000
0
0
500
1,000
1,500
2,000
2,500
Flow at Aucilla near Lamont (cfs)
Flow at USGS Econfina gage (cfs)


Residual vs Time
6,000
5,000
4,000
3,000
2,000
1,000
0
-1,000
-2,000
-3,000
-4,000
4/12/1949
12/20/1962
8/28/1976
5/7/1990
1/14/2004
9/22/2017
Residual (Observed-Predicted)
Date



Residual vs Predicted
Residual (Observed-Predicted)
6,000
5,000
4,000
3,000
2,000
1,000
0
-1,000
-2,000
-3,000
-4,000
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
Predicted Flow at Aucilla near Lamont (cfs)

APPENDIX G
HEC-RAS Output Tables

Aucilla HEC-RAS Output Table

River Station	Profile	Flow Total	Min Channel Elevation	Water Surface Elevation	Critical Water Surface	Energy Grade Elevation	Energy Grade Slope	Velocity in Channel	Flow Area	Top Width
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)
57.449	P1	832.65	74.1	82.94	77.26	82.94	0.000095	0.57	1462.36	1240.79
57.449	P5	386.1	74.1	82.16	76.52	82.16	0.000034	0.31	1258.83	943.81
57.449	P10	233.7	74.1	81.31	76.09	81.31	0.00002	0.22	1043.78	423.55
57.449	P20	113.93	74.1	79.14	75.58	79.14	0.000042	0.21	537.87	412.76
57.449	P30	53.55	74.1	77.41	75.2	77.41	0.000278	0.32	167.98	271.02
57.449	P40	20.25	74.1	75.69	74.85	75.7	0.002261	0.76	26.8	33.7
57.449	P50	1.13	74.1	74.33	74.33	74.39	0.197727	1.96	0.57	4.93
57.449	P60	0.1	74.1	74.19	74.19	74.21	0.270359	1.2	0.08	1.88
57.449	P70	0.1	74.1	74.19	74.19	74.21	0.270359	1.2	0.08	1.88
57.449	P80	0.1	74.1	74.19	74.19	74.21	0.270359	1.2	0.08	1.88
57.449	P90	0.1	74.1	74.19	74.19	74.21	0.270359	1.2	0.08	1.88
57.449	P95	0.1	74.1	74.19	74.19	74.21	0.270359	1.2	0.08	1.88
49.328	P1	1105.4	67.5	77.05		77.06	0.000582	0.77	1464.66	694.38
49.328	P5	512.6	67.5	75.85		75.86	0.001242	0.75	681.4	560.68
49.328	P10	310.3	67.5	74.99		75	0.000517	0.76	406.09	165.55
49.328	P20	151.3	67.5	73.84		73.84	0.000242	0.57	263.55	92.94
49.328	P30	71.1	67.5	72.49		72.49	0.00016	0.44	161.41	61.83
49.328	P40	26.9	67.5	71.11		71.11	0.000107	0.3	89.07	44.32
49.328	P50	1.5	67.5	69.55		69.55	0.000008	0.05	29.99	31.6
49.328	P60	0.1	67.5	69.11		69.11	0	0.01	18.08	21.28
49.328	P70	0.1	67.5	69.11		69.11	0	0.01	18.08	21.28
49.328	P80	0.1	67.5	69.11		69.11	0	0.01	18.08	21.28
49.328	P90	0.1	67.5	69.11		69.11	0	0.01	18.08	21.28
49.328	P95	0.1	67.5	69.11		69.11	0	0.01	18.08	21.28
40.514	P1	2477.3	58.5	65.07		65.07	0.000223	0.59	5573.04	2834.36
40.514	P5	1174.9	58.5	64.17		64.18	0.000226	0.46	3179.36	2447.87
40.514	P10	730.4	58.5	63.66		63.67	0.000293	0.43	1955.51	2302.68
40.514	P20	381	58.5	63.12		63.12	0.000422	0.38	1014.36	1168.65
40.514	P30	204.9	58.5	62.72		62.73	0.000554	0.34	597.99	949.61
40.514	P40	107.7	58.5	62.33		62.33	0.000928	0.38	280.98	554.56
40.514	P50	52	58.5	61.21		61.21	0.000617	0.59	88.67	67.91
40.514	P60	28.8	58.5	60.66		60.66	0.000671	0.52	55.14	53.44
40.514	P70	14.7	58.5	60.19		60.2	0.000676	0.44	33.15	41.29
40.514	P80	8.5	58.5	59.9		59.91	0.000644	0.38	22.33	33.75

River Station	Profile	Flow Total	Min Channel Elevation	Water Surface Elevation	Critical Water Surface	Energy Grade Elevation	Energy Grade Slope	Velocity in Channel	Flow Area	Top Width
40.514	P90	2.9	58.5	59.47		59.47	0.000596	0.28	10.18	22.42
40.514	P95	1.2	58.5	59.22		59.22	0.000532	0.22	5.41	15.9
33.336	P1	3539.3	41.7	54.95		54.96	0.000249	1.18	6273.47	1596.18
33.336	P5	1697.1	41.7	53.09		53.1	0.000309	1.19	3351.94	1536.65
33.336	P10	1063.9	41.7	52.14		52.15	0.000375	1.24	1930.95	1443.59
33.336	P20	564.4	41.7	51.13		51.14	0.000252	1.09	550.3	1298.5
33.336	P30	312.1	41.7	49.27		49.28	0.000186	0.81	385.89	69.03
33.336	P40	172.7	41.7	47.58		47.58	0.000162	0.63	272.87	64.28
33.336	P50	92.9	41.7	46.2		46.21	0.000147	0.5	187.37	59.92
33.336	P60	52.4	41.7	45.19		45.19	0.000128	0.4	130.61	52.19
33.336	P70	27.1	41.7	44.29		44.3	0.000109	0.31	86.9	45.36
33.336	P80	16	41.7	43.75		43.75	0.000103	0.25	63.03	43.32
33.336	P90	5.9	41.7	43.07		43.07	0.000099	0.17	34.18	41.16
33.336	P95	2.9	41.7	42.77		42.77	0.000095	0.13	22.01	38.63
27.091	P1	3609.2	32.4	45.38		45.42	0.000943	1.8	3383.43	2085.3
27.091	P5	1856	32.4	43.77		43.81	0.00106	1.63	1168.73	429.41
27.091	P10	1192.9	32.4	42.46		42.49	0.000656	1.42	837.96	174.5
27.091	P20	648.6	32.4	39.89		39.91	0.000462	1.26	516.45	98.42
27.091	P30	366.5	32.4	38.24		38.25	0.000345	0.99	369.56	80.4
27.091	P40	208.5	32.4	36.94		36.95	0.000265	0.77	272.16	71.67
27.091	P50	117.4	32.4	35.9		35.91	0.000222	0.59	199.06	68.5
27.091	P60	71.1	32.4	35.13		35.13	0.000211	0.48	147.3	66.2
27.091	P70	42	32.4	34.5		34.5	0.000211	0.4	105.81	64.3
27.091	P80	29.3	32.4	34.14		34.14	0.000223	0.35	83.25	63.25
27.091	P90	17.6	32.4	33.75		33.75	0.000252	0.3	58.54	62.07
27.091	P95	14.1	32.4	33.61		33.61	0.000273	0.28	49.89	61.65
20.591	P1	3681.8	13	33.75		33.78	0.000382	1.79	4707.21	2024.21
20.591	P5	2021.4	13	32.27		32.3	0.000282	1.41	2384.75	1047.54
20.591	P10	1327.3	13	29.53		29.56	0.000409	1.53	882.11	200.15
20.591	P20	736.1	13	25.67		25.71	0.000473	1.48	497.97	73.86
20.591	P30	423	13	23.02		23.05	0.000505	1.32	321.1	59.61
20.591	P40	245.8	13	21.17		21.19	0.000471	1.12	219.92	49.65
20.591	P50	142.9	13	19.62		19.64	0.00045	0.96	149.54	41.37
20.591	P60	90.5	13	18.59		18.61	0.000418	0.82	109.72	35.96
20.591	P70	57.6	13	17.78		17.78	0.000375	0.7	82.04	31.65
20.591	P80	43	13	17.31		17.31	0.000354	0.63	67.77	29.18

River Station	Profile	Flow Total	Min Channel Elevation	Water Surface Elevation	Critical Water Surface	Energy Grade Elevation	Energy Grade Slope	Velocity in Channel	Flow Area	Top Width
20.591	P90	29.8	13	16.79		16.8	0.000329	0.56	53.4	26.47
20.591	P95	25.9	13	16.62		16.62	0.000318	0.53	48.9	25.56
15.031	P1	3744	3.7	23.51		23.53	0.000138	1.42	6376.88	2313.16
15.031	P5	2162.8	3.7	22.14		22.16	0.000102	1.13	3812.35	1479.32
15.031	P10	1442.2	3.7	20.88		20.89	0.000096	1.03	2109.09	1204.51
15.031	P20	811.1	3.7	18.95		18.96	0.000057	0.75	1108.39	159.52
15.031	P30	471.4	3.7	17.67		17.67	0.000027	0.5	943.71	98.94
15.031	P40	277.7	3.7	16.74		16.74	0.000012	0.32	854.93	92.36
15.031	P50	164.8	3.7	16.08		16.08	0.000005	0.21	795.49	87.68
15.031	P60	107.1	3.7	15.68		15.68	0.000002	0.14	761.24	84.86
15.031	P70	70.8	3.7	15.41		15.41	0.000001	0.1	738.17	82.91
15.031	P80	54.8	3.7	15.28		15.28	0.000001	0.08	727.8	82.02
15.031	P90	40.3	3.7	15.11		15.11	0	0.06	713.7	80.79
15.031	P95	35.9	3.7	15.01		15.01	0	0.05	705.71	80.11
12.633	P1	3753.6	10	18.55		18.56	0.000248	1.23	8310.67	4273.45
12.633	P5	2184.8	10	17.57		17.58	0.000295	1.2	4677.24	3135.73
12.633	P10	1460	10	17.07		17.08	0.000268	1.07	3274.19	2564.71
12.633	P20	822.7	10	16.95		16.95	0.000103	0.65	2955.55	2416.29
12.633	P30	478.9	10	16.33		16.34	0.000089	0.56	1696.03	1707.75
12.633	P40	282.6	10	15.97		15.97	0.000054	0.41	1150.56	1284.87
12.633	P50	168.2	10	15.66		15.66	0.00003	0.29	804.13	920.43
12.633	P60	109.7	10	15.44		15.44	0.000017	0.21	631.88	669
12.633	P70	72.9	10	15.27		15.27	0.000009	0.15	536.53	475.76
12.633	P80	56.7	10	15.19		15.19	0.000006	0.12	501.44	380.72
12.633	P90	41.9	10	15.05		15.05	0.000004	0.09	458.91	215.13
12.633	P95	37.5	10	14.95		14.95	0.000004	0.08	442.45	158.67
4.76	P1	3753.6	-10	6.14		6.15	0.000134	0.58	9806.13	6193.4
4.76	P5	2184.8	-10	5.08		5.09	0.000257	0.62	4418.96	3704.57
4.76	P10	1460	-10	0.99		1.01	0.000224	1.21	1204.51	167.19
4.76	P20	822.7	-10	-1.95		-1.93	0.00027	1.1	750.67	141.77
4.76	P30	478.9	-10	-4.1		-4.09	0.000395	1.04	460.27	128.34
4.76	P40	282.6	-10	-5.72		-5.71	0.000685	1.07	263.34	107.66
4.76	P50	168.2	-10	-6.88		-6.86	0.001414	1.15	145.83	92.94
4.76	P60	109.7	-10	-7.64		-7.62	0.002694	1.32	83.41	70.79
4.76	P70	72.9	-10	-8.17		-8.13	0.004527	1.44	50.53	55.1
4.76	P80	56.7	-10	-8.41		-8.38	0.005961	1.5	37.75	47.62

River Station	Profile	Flow Total	Min Channel Elevation	Water Surface Elevation	Critical Water Surface	Energy Grade Elevation	Energy Grade Slope	Velocity in Channel	Flow Area	Top Width
4.76	P90	41.9	-10	-8.65		-8.62	0.007779	1.54	27.23	40.45
4.76	P95	37.5	-10	-8.73		-8.69	0.008376	1.54	24.37	38.26
3.53	P1	3753.6	-14.2	5.31	-7.47	5.34	0.0002	1.46	5459.2	5629.36
3.53	P5	2184.8	-14.2	2.83	-8.88	2.86	0.0002	1.31	1667.13	199.72
3.53	P10	1460	-14.2	-0.47	-9.81	-0.44	0.0002	1.28	1136.22	139.36
3.53	P20	822.7	-14.2	-3.35	-10.82	-3.33	0.0002	1.08	759.09	120.92
3.53	P30	478.9	-14.2	-5.56	-11.55	-5.55	0.0002	0.93	512.73	102.19
3.53	P40	282.6	-14.2	-7.29	-12.18	-7.28	0.0002	0.81	350.16	86.97
3.53	P50	168.2	-14.2	-8.51	-12.64	-8.51	0.0002	0.68	247.98	80.25
3.53	P60	109.7	-14.2	-9.56	-12.92	-9.55	0.0002	0.63	174.33	63.23
3.53	P70	72.9	-14.2	-10.31	-13.14	-10.3	0.0002	0.56	129.8	55.95
3.53	P80	56.7	-14.2	-10.7	-13.25	-10.69	0.0002	0.52	108.67	52.34
3.53	P90	41.9	-14.2	-11.11	-13.36	-11.11	0.0002	0.48	87.91	48.53
3.53	P95	37.5	-14.2	-11.25	-13.4	-11.24	0.0002	0.46	81.36	47.26

Wacissa HEC-RAS Output Table

River Station	Profile	Flow Total	Min Channel Elevation	Water Surface Elevation	Critical Water Surface	Energy Grade Elevation	Energy Grade Slope	Velocity in Channel	Flow Area	Top Width
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)
45988.37	PF 1	233	23.87	27.52		27.52	0.000491	0.25	980.3	549.89
45988.37	PF 2	254	23.87	27.68		27.68	0.000471	0.25	1071.21	609.92
45988.37	PF 3	357	23.87	28.29		28.29	0.00043	0.28	1495.3	780.94
45988.37	PF 4	518	23.87	29.01		29.01	0.000401	0.3	2097.26	881.15
45988.37	PF 5	563	23.87	29.18		29.18	0.000396	0.31	2250.73	902.07
45988.37	PF 6	670	23.87	29.56		29.56	0.000395	0.33	2609.04	971.08
39455.99	PF 1	233	21.16	26		26	0.00008	0.13	1812.25	628.5
39455.99	PF 2	254	21.16	26.16		26.16	0.000083	0.14	1920.8	718.5
39455.99	PF 3	357	21.16	26.67		26.67	0.000105	0.17	2345.92	901.42
39455.99	PF 4	518	21.16	27.29		27.29	0.000133	0.2	2914.92	936.11
39455.99	PF 5	563	21.16	27.44		27.44	0.00014	0.21	3059.3	956.47
39455.99	PF 6	670	21.16	27.77		27.77	0.000156	0.23	3382.9	1010.27
27093.71	PF 1	233	16.57	18.74		18.76	0.00042	0.99	236.09	212.67
27093.71	PF 2	254	16.57	18.83		18.85	0.000393	0.99	256.13	218.04
27093.71	PF 3	357	16.57	19.23		19.25	0.000323	1.03	346.89	240.87
27093.71	PF 4	518	16.57	19.72		19.73	0.000297	1.09	474.37	283.35
27093.71	PF 5	563	16.57	19.84		19.86	0.000291	1.1	509.71	294.19
27093.71	PF 6	670	16.57	20.15		20.17	0.000268	1.11	608.56	367.2
17666.08	PF 1	233	10.75	15.2		15.22	0.000136	1	233.89	88.8
17666.08	PF 2	254	10.75	15.33		15.34	0.000142	1.04	244.82	91.02
17666.08	PF 3	357	10.75	15.88		15.91	0.000162	1.2	300.94	120
17666.08	PF 4	518	10.75	16.62		16.64	0.000175	1.36	452.69	293.47
17666.08	PF 5	563	10.75	16.78		16.81	0.000178	1.4	504.3	334.64
17666.08	PF 6	670	10.75	17.32		17.34	0.00024	1.29	751.79	614.01
8538.354	PF 1	233	9.93	13.2		13.2	0.000145	0.7	334.42	227.44
8538.354	PF 2	254	9.93	13.31		13.32	0.000138	0.7	360.63	231.7
8538.354	PF 3	357	9.93	13.82		13.83	0.000114	0.74	482.86	249.43
8538.354	PF 4	518	9.93	14.48		14.49	0.000106	0.79	675.11	427.84
8538.354	PF 5	563	9.93	14.63		14.64	0.000112	0.8	749.08	540.11
8538.354	PF 6	670	9.93	14.94		14.95	0.000112	0.81	980.27	931.79
558.2392	PF 1	233	7.66	11.24	8.58	11.24	0.000148	0.33	731.54	372.28

River Station	Profile	Flow Total	Min Channel Elevation	Water Surface Elevation	Critical Water Surface	Energy Grade Elevation	Energy Grade Slope	Velocity in Channel	Flow Area	Top Width
558.2392	PF 2	254	7.66	11.29	8.61	11.29	0.000165	0.36	750.78	413.99
558.2392	PF 3	357	7.66	11.66	8.74	11.66	0.0002	0.43	931.79	527.31
558.2392	PF 4	518	7.66	12.22	8.89	12.22	0.000216	0.49	1258.35	642.51
558.2392	PF 5	563	7.66	12.46	8.92	12.46	0.000198	0.49	1426.23	747.75
558.2392	PF 6	670	7.66	13	9	13	0.000156	0.48	1914.53	1062.69
45209.51	PF 1	233	23.04	27.29		27.3	0.000201	0.17	1336.61	495.57
45209.51	PF 2	254	23.04	27.45		27.46	0.000204	0.18	1425.31	603.33
45209.51	PF 3	357	23.04	28.07		28.07	0.000208	0.21	1892.14	829.85
45209.51	PF 4	518	23.04	28.8		28.8	0.000218	0.24	2516.15	884.86
45209.51	PF 5	563	23.04	28.97		28.97	0.000221	0.24	2669.25	892.25
45209.51	PF 6	670	23.04	29.35		29.35	0.000229	0.26	3016.98	938.03
33277.08	PF 1	233	22.68	24.71		24.71	0.001258	0.2	1209.99	1274.51
33277.08	PF 2	254	22.68	24.8		24.8	0.001138	0.21	1322.48	1290.16
33277.08	PF 3	357	22.68	25.18		25.18	0.0008	0.21	1822.99	1332.44
33277.08	PF 4	518	22.68	25.72		25.72	0.000566	0.22	2558.01	1392.45
33277.08	PF 5	563	22.68	25.85		25.85	0.000551	0.23	2732.55	1400.2
33277.08	PF 6	670	22.68	26.1		26.1	0.000528	0.24	3083.34	1410.07
24324.64	PF 1	233	13.81	17.64		17.67	0.000365	1.29	180.33	97.11
24324.64	PF 2	254	13.81	17.8		17.82	0.000349	1.3	195.21	100.46
24324.64	PF 3	357	13.81	18.23		18.27	0.000386	1.48	241.5	110.15
24324.64	PF 4	518	13.81	18.63		18.68	0.000501	1.81	286.94	117.64
24324.64	PF 5	563	13.81	18.75		18.8	0.00052	1.87	300.51	119.78
24324.64	PF 6	670	13.81	19.12		19.17	0.000498	1.94	346.1	126.72
12463.24	PF 1	233	6.76	13.75		13.77	0.000072	0.93	249.28	62.68
12463.24	PF 2	254	6.76	13.88		13.9	0.000078	0.99	257.58	63.55
12463.24	PF 3	357	6.76	14.52		14.54	0.000102	1.19	299.49	67.79
12463.24	PF 4	518	6.76	15.21		15.24	0.000142	1.49	354.63	123.65
12463.24	PF 5	563	6.76	15.37		15.4	0.000153	1.56	376.5	153.17
12463.24	PF 6	670	6.76	15.68		15.73	0.000178	1.73	443.57	283.61