Work Plan
St. Marks River Rise, Wakulla, and Sally Ward Springs
Minimum Flows and Levels Development

and the
University of Tampa

Submitted to:
Northwest Florida Water Management District
Under Task Order 2

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Summary

This work plan outlines the methods proposed for the Northwest Florida Water Management District (District, or NWFWMD) to develop and establish minimum flows and levels (MFLs) for St. Marks River Rise, Wakulla, and Sally Ward springs. The MFLs will address protection of water resources affected by spring flows, including resources affected by spring flows in the downstream freshwater and estuarine reaches of the Wakulla and St. Marks rivers. MFLs are intended to prevent significant harm to the water resources or ecology of the spring systems that may result from water use. The approach presented here is based on a fundamental assumption that a natural spring flow pattern is necessary to protect the ecology of the spring systems.

This work plan lays out the overall framework for MFL development and, as such, is primarily for planning purposes. The plan provides the conceptual organization and general components needed for MFL establishment; details regarding specific methodologies for each component will be developed as individual tasks are initiated.

The statutory directive for minimum flows and levels (MFLs) included in the Water Resources Act was enacted by the Florida Legislature. Section 373.042, F.S., of the Act directs each water management district to establish MFLs for surface water bodies, watercourses, and aquifers within their respective jurisdictions. Under the statute, the minimum flow (or level) for a given watercourse is defined as the limit at which further withdrawals would be "significantly harmful" to the water resources or ecology of the area. In addition, the determination of MFLs must be based on the "best available" information.

Instream flows are important to maintaining a functional river or stream system, fish and wildlife habitat, recreation, navigation, and consumptive uses such as irrigation and domestic water supply. MFLs are intended to guide water resource and water supply development, ensure water resource sustainability for people and the natural environment, and “prevent significant harm as a result of withdrawals” (FDEP Office of Water Policy). MFLs will also be used to assist in making water use and other permitting decisions. In summary, the District is establishing MFLs to:

- Comply with Florida Statute 373.042(1)(a)&(b)
- Protect water resources and ecology associated with the St. Marks River Rise, Wakulla, and Sally Ward springs

The District Governing Board has the authority to set MFLs within its jurisdiction, using several guidelines provided by the state (and listed below). Water management districts submit proposed MFLs to the FDEP Office of Water Policy for review and consistency of the proposed MFL with applicable rules, statutes, and other FDEP guidance. FDEP also has the authority to establish MFLs.

The water management districts are required under Section 373.042, F.S., to develop a priority list of water bodies for which they will establish minimum flow and levels. Each year the districts update their list and submit them to the Department for review and approval. The current list is available from the District’s website.

In addition to reviewing the Districts' priority lists each year, the Office of Water Policy also reviews MFLs proposed for specific water bodies. The Office of Water Policy actively works with the Districts to ensure that the proposed MFL is consistent with applicable rules, statutes, and other FDEP guidance:

- Using the best information available
- When appropriate, setting MFLs to reflect seasonal variations
- Considering the protection of non-consumptive uses of water (e.g. fish and wildlife, recreation)

The use of MFLs for long range water resource planning could affect the use and allocation of water. Consequently, development of each MFL must be based on clearly defined assumptions and sound science. MFLs are subject to periodic revision as additional information becomes available and to address potential effects of future structural alterations on surface or ground water flows in the watershed.

If the District anticipates that actual flows or levels are, or during the next twenty years are expected to be, below established MFLs, a recovery or prevention strategy will be developed and implemented (Chapter 40D-80, F.A.C.), in accordance with state law (Section 373.0421, F.S.).

Identify water resource values

Florida's Water Resources Implementation Rule (Section 62-40.473, F.A.C.) states "In establishing minimum flows and levels pursuant to Sections 373.042 and 373.0421, F.S., consideration shall be given to natural seasonal fluctuations in water flows or levels, non-consumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology." A preliminary assessment of these environmental values, also referred to as Water Resource Values (WRVs), was made to identify WRVs:

- Relevant to MFLs for the St. Marks River Rise, Wakulla, and Sally Ward springs
- Measurable
- Related (linked) to water flows or levels
- Characterized by best available data, or can be characterized with the present work plan
- Integrates more than one resource

Results of the preliminary assessment have focused this work plan on methods for sampling and assessing minimum flows necessary for the WRVs listed below. Other resources such as sediment and detrital transport, maintenance of freshwater storage and supply, and filtration and absorption of nutrients are addressed indirectly through consideration of floodplain habitat and bankfull flows.

- Recreation in and on the water
- Fish and wildlife habitats and the passage of fish
- Estuarine resources

- Aesthetic and scenic attributes
- Water quality
- Navigation

Establish benchmark flow

To characterize the natural, or benchmark hydrologic regime, historic and current flows will be evaluated with respect to quantifying withdrawals and other anthropogenic impacts, as well as the influence of rainfall patterns on the systems under study. Periods of low, medium, and high seasonal flow periods will be identified, if appropriate, to address seasonality in flows.

Evaluate potential effects of flow reductions on WRVs

Models will be used to evaluate and predict the effects of various flow reduction scenarios on selected WRVs for developing MFLs for the St. Marks River Rise, Wakulla, and Sally Ward springs system. Models considered and addressed here include:

- The Hydrologic Engineering Centers River Analysis System (HEC-RAS) model. HEC-RAS is proposed to be used to characterize thresholds of flow reductions that correspond to unacceptable reductions in the extent of floodplain features and acres of floodplain inundated. Flows necessary to meet depths for WRVs (e.g. depth needed for fish passage) are proposed to be evaluated using the HEC-RAS model.
- Physical Habitat Simulation Model (PHABSIM), or similar model, which ties open channel hydraulics with measured elements of fish or macroinvertebrate behavior, is proposed to be used to evaluate limitations on fish and macroinvertebrate habitat availability. PHABSIM analyses are proposed to be used to identify flows associated with changes in habitat availability specific to fish species and macroinvertebrate diversity.
- The Environmental Fluid Dynamics Code (EFDC) hydrodynamic model is used to simulate transport processes, including three-dimensional velocities, surface elevation, vertical viscosity and diffusivity, temperature, salinity, and density. The EFDC model may be applied to evaluate potential impacts of reduced flows on low salinity estuarine habitats, e.g. distribution of tape grass (*Vallisneria americana*) in estuarine portion of the St. Marks River. The potential need for a thermal component to the EFDC model with respect to warm water habitat for manatee in the Wakulla River will also be evaluated.
- A groundwater model to simulate laminar flow within the matrix, turbulent flow within karst fractures and conduits, and the coupling of these two domains with each other and with surface discharges (springs and rivers). For example, a MODFLOW (with conduit flow or connected linear network packages) or FEFLOW model will be developed. The groundwater model is critical to linking flows to groundwater withdrawal impacts in this spring-driven system.

Data needs

This work plan outlines data needs for developing MFLs, including:

- Identification (and selection) of relevant WRVs and corresponding water level elevations important to each (e.g. depth for recreation, depth necessary to connect aquatic and riverine habitats, depth necessary for fish passage)
- Water velocity and depth, bottom substrate, and substrate cover data for PHABSIM model
- Surface water data to develop stage-discharge relationships for linking WRVs to flows
- Surveyed elevation cross sections to characterize channel and floodplain morphology, necessary to run the HEC-RAS model
- Data to develop and calibrate a groundwater model that can then predict the effects of groundwater withdrawals on spring and river flows
- If needed, data for a thermal model to assess extent and changes in volume of manatee thermal refuge at Wakulla Springs
- Salinity data for the estuarine system

Once data are collected and compiled and preliminary analyses completed, it may be found that some portions of the work plan can be delayed or omitted, while others may require further study. For example, one WRV (e.g. manatee passage) may require greater water depths than another (e.g. fish passage), allowing the second to be eliminated from further consideration, or the depth criteria may change seasonally depending on time of year (e.g. manatee use during cold season).

Peer review of draft MFLs

A peer review process is presented in this report that includes identification and selection of peer reviewers, facilitation of the peer review, and preparation of a peer review report that includes comments and recommendations from peer reviewers and responses from the District. The peer review will ensure that the technical basis of the draft MFLs is sound and that best available information has been used in development of the draft MFLs. Peer review is described under Section 373.042(5), F.S.

Public involvement

Public participation in the MFL process is important to ensure interested stakeholders have the opportunity to provide comments prior to inclusion of the MFLs into District rules. Therefore, a public involvement plan is included as part of this work plan and will be revised as necessary. Prior to approval of draft MFLs and rule implementation by the District's Governing Board, public workshops and opportunities for public input will be provided. The rule defines the water levels or flows necessary to protect the ecology and water resources from significant harm. The MFL is not considered "established" until the final rule is approved and adopted.

Deliverables, schedules, and costs

Deliverables under this work plan will be developed as the technical assessments proceed for the St. Marks River Rise, Wakulla, and Sally Ward springs. Completion of the technical assessments for the St. Marks River Rise is scheduled for 2018 and technical assessments for Wakulla and Sally Ward springs are currently scheduled for 2021, per the District's *Minimum Flows and Levels Priority List 2013*. The priority list is updated annually and may be found on the District's website. Cost estimate summaries are provided in this document.

1. WORK PLAN INTRODUCTION

The statutory directive for minimum flows and levels (MFLs) included in the Water Resources Act was enacted by the Florida Legislature. Section 373.042, F.S., of the Act directs each water management district to establish MFLs for surface water bodies, watercourses, and aquifers within their respective jurisdictions. Under the statute, the minimum flow (or level) for a given watercourse is defined as the limit at which further withdrawals would be "significantly harmful" to the water resources or ecology of the area. In addition, the determination of MFLs must be based on the "best available" information.

Instream flows are important to maintaining a functional river or stream system, fish and wildlife habitat, recreation, navigation, and consumptive uses such as water for irrigation. MFLs are intended to guide water resource and water supply development to ensure water resource sustainability for people and the natural environment. The MFLs will also be used to assist in making water use and other permitting decisions. In summary, the District is establishing MFLs to:

- Comply with Florida Statute 373.042(1)(a)&(b)
- Protect water resources and ecology

This work plan has been prepared to support the District as they develop and establish MFLs for the St. Marks River Rise, Wakulla, and Sally Ward springs (Figure 1, Figure2, and Figure 3). The work plan has been developed with the understanding that the science upon which the District's MFLs will be based, and the assumptions made, must be clearly defined as the MFL is developed. The District Governing Board has the final authority to set MFLs within its jurisdiction, using several guidelines provided by the state (and listed below).

- Using the best information available
- When appropriate, setting MFLs to reflect seasonal variations
- Considering the protection of non-consumptive uses of water (e.g. fish and wildlife, recreation)

The use of MFLs for long range water resource planning could affect the use and allocation of water. Consequently, development of each MFL must be based on clearly defined assumptions and sound science. MFLs are subject to periodic revision as additional information becomes available and to address future structural alterations on surface water or groundwater flows in the watershed.

This work plan includes proposed methods for the NWFWMD to develop and establish MFLs for St. Marks River Rise, Wakulla, and Sally Ward springs, inclusive of the downstream fresh water reaches of the Wakulla and St. Marks rivers and the estuarine portion of the St. Marks River. This plan lays out the overall framework for MFL development and, as such, is primarily for planning purposes. The plan provides the general components and organization of tasks needed for MFL establishment; details regarding specific methodologies for each component will be developed as individual tasks are initiated.

Data needs are identified in this work plan. Models proposed to be developed to link the resources to spring flows are described and the importance of both surface and groundwater models to MFL development is presented. Because of the importance of peer review and public involvement to the MFL process, these components are also addressed in this work plan.

Task 1. *Finalize the work plan, working with District staff to ensure that study area, goals, and approach, are agreed upon and a final work plan (with all other sections revised as appropriate) is available. The work plan will be provided to the District.*

Task 1.1 Define study area for MFLs to be established
Task 1.2 Define goals of MFLs, e.g. criterion for "significant harm"
Task 1.3 Define approach to MFLs, e.g. use of seasonal flows and habitat-based approach

1.1 Define study area

MFLs will be developed for the St. Marks River Rise, Wakulla, and Sally Ward springs, downstream freshwater reaches (spring runs) of the St. Marks and Wakulla rivers, and the estuarine portion of the St. Marks River. MFLs will be established by designating flow regimes at specific hydrologic gage stations on the water bodies. Atkins scientists will work with District staff to identify appropriate locations at which the MFLs will be established for the St. Marks River Rise, Wakulla, and Sally Ward springs.

A description of the study area is presented here and is based on information presented in the District's *Lower St. Marks River/Wakulla River/Apalachee Bay Characterization* (Lewis et al. 2009). St. Marks River Rise, Wakulla, and Sally Ward springs are within the St. Marks River watershed, which includes about 1,170 square miles (748,800 acres) in Georgia and Florida, from about Thomasville, Georgia, south to Apalachee Bay. The large contribution of groundwater to regional surface water flows is demonstrated by the contrast between the ground and surface water areas: the regional groundwater contribution zone is approximately 1,963 square miles (1,256,061 acres) in size and about 68 percent larger in area than the surface watershed. The porous nature of the Floridan Aquifer serves as the medium for the complex interaction of surface and groundwater in the watershed.

Karst features in the watershed become more numerous in southern Leon County as the confining unit over the Upper Floridan aquifer shifts from semi-confined (a partial confining unit) in the Tallahassee Hills to unconfined (100 feet or absent confining unit) south of the Cody Scarp into the Woodville Karst Plain. The unconfined limestone is more exposed and dissolution features such as sinkholes, swallets, and underground channels are also more prevalent south of the scarp.

Figure 1. Location of St. Marks River Rise, Sally Ward Spring and Wakulla Springs.

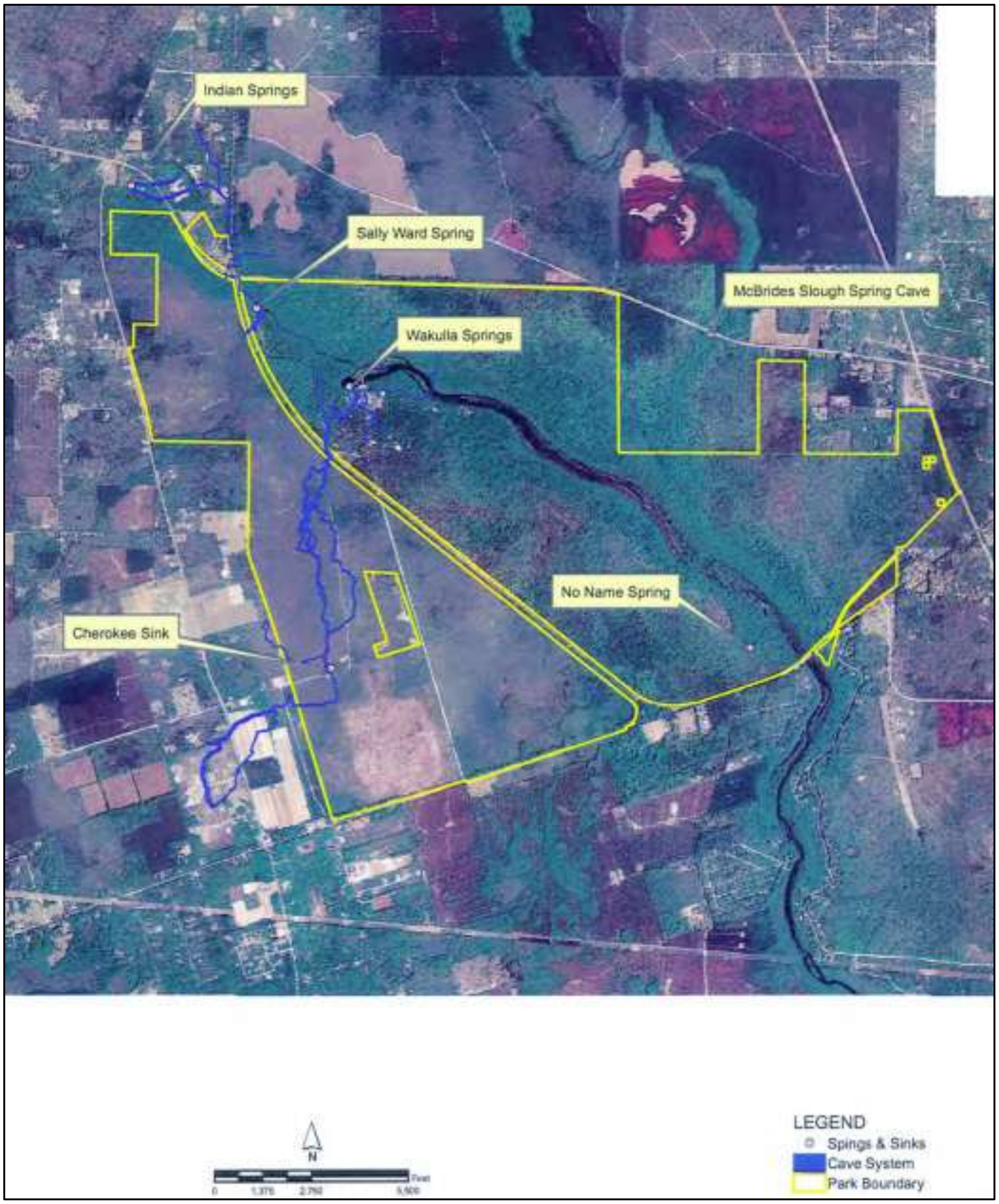


Figure 2. Aerial photograph of Sally Ward and Wakulla Springs (FDEP 2007).

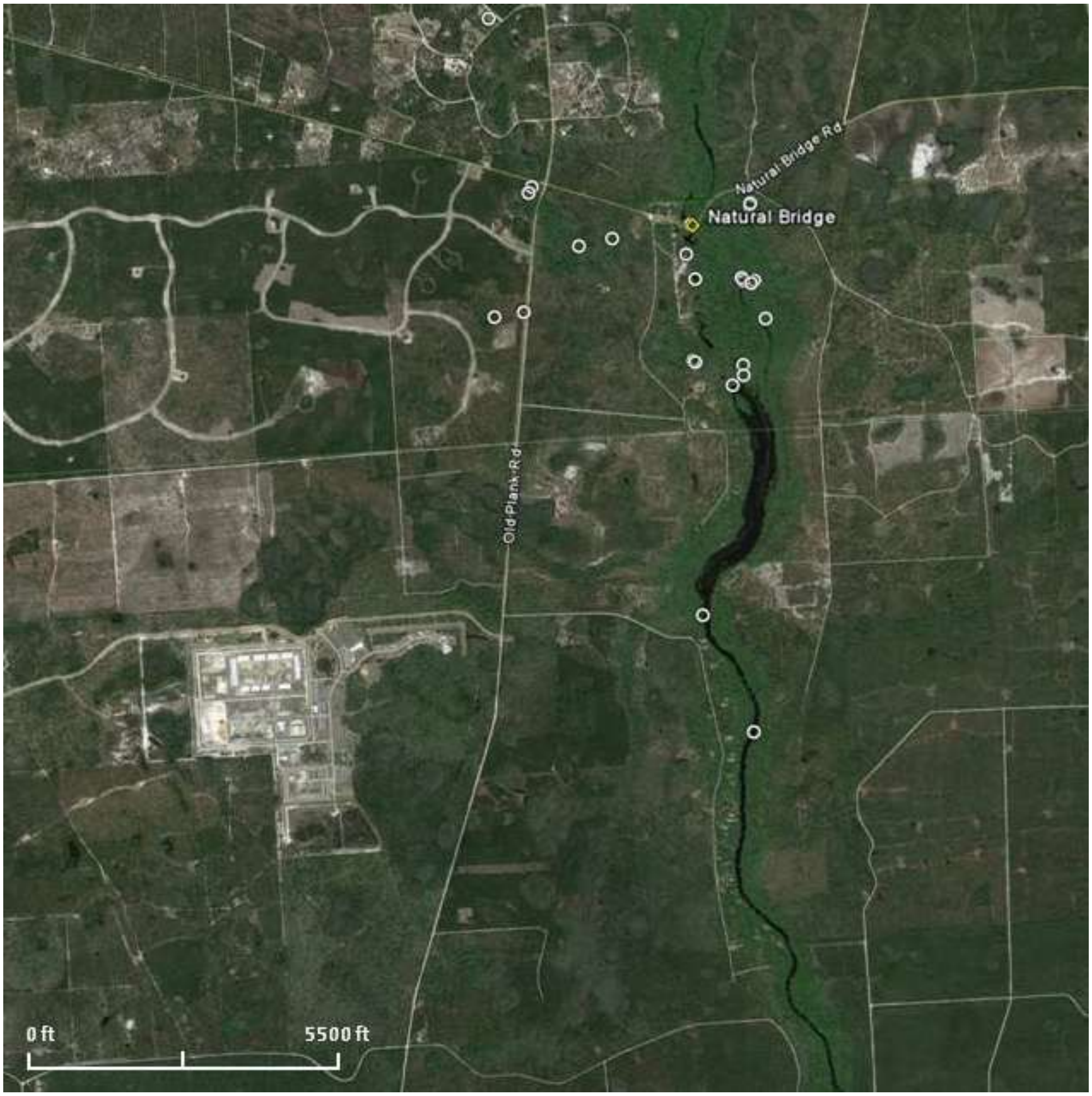


Figure 3. Aerial photograph (2013) of St. Marks River Rise (open circles represent springs).

The District reports “Approximately 42 sinkholes north of the Cody Scarp … identified and mapped by state and local agencies with about 232 sinkholes and 66 springs mapped below the scarp” (Lewis et al. 2009).

Flows at the St. Marks River Rise and Wakulla Springs contribute most of the freshwater flow to the lower St. Marks River (below the confluence of the two rivers) and accounted for a combined mean daily discharge of 1,097 cfs for 11 years of combined record (May 1997 to June 2009). During the same period of record, a low combined flow of 354 cfs and a peak flow of 8,060 cfs (after Tropical Storm Fay) were recorded. Surface water flows also contribute to the St. Marks River as it flows south through eastern Leon County, across the Cody Scarp, and into a swallet at Natural Bridge. The river re-emerges approximately a half mile south at the St. Marks River Rise, a first magnitude spring with average discharge above 100 cfs. Most of the surface water contribution to flows in the St. Marks River occurs upstream of the rise. The river flows south another 11.4 miles to the confluence with the Wakulla River at the town of St. Marks and another 4 miles south into Apalachee Bay near the St. Marks Lighthouse.

The main spring vent at Edward Ball Wakulla Springs State Park is the primary source of flow to the Wakulla River, discharging an average of about 500 cfs (about 323 mgd) to the river. The Wakulla River flows south approximately 10 miles to its confluence with the St. Marks River and is the main surface water tributary to the St. Marks River. Sally Ward Spring (averaging only 16 cfs) flows along a relatively short spring run and enters the Wakulla River just downstream of Wakulla Spring in the Wakulla Springs State Park.

1.2 Define goals of MFLs

Under this task, goals of the MFLs will be clearly defined. Consistent with methods established by the Southwest Florida Water Management District (SWFWMD) and also applied by the Suwannee River Water Management District (SRWMD), MFL standards described by Beecher (1990, as cited in Stalnaker et al. 1995), are proposed to be used to develop MFLs for the St. Marks River Rise, Wakulla, and Sally Ward springs system (listed below).

1) A goal(s) (e.g. non-degradation, protection of threatened or endangered species; prevention of significant harm)
2) Identification of the resources of interest to be protected (addressed in Section 2)
3) A unit of measure (e.g. flow in cubic feet per second, habitat in usable area, inundation to a specific elevation for a specified duration, maintenance of a given salinity zone spatially and temporally) (addressed in Section 2)
4) A benchmark period (addressed in Section 3)

Florida Statute describes a goal for MFLs that “shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area.” Unfortunately, the statute does not define “significant harm” so it will need to be defined in a quantitatively measurable manner (e.g., no more than a given percent reduction in available habitat; no more than a given percent reduction in the average number of days per year that the river is connected to the floodplain; no more than a given percent reduction in low salinity habitat).

It is anticipated that MFLs will be developed based on defining "significant harm" as an allowable percent reduction in water resources of concern. Models to be developed as outlined in this work plan are designed to measure either threshold changes in a given parameter (e.g. wetted perimeter inflection point, fish or manatee passage depth) or incremental changes in a water resource value due to incremental reductions in flow. Incremental reductions will be evaluated on a seasonal or annual basis as appropriate (yet to be determined). A percentage loss in a given resource value will be evaluated against a percent reduction in flow from the benchmark condition (i.e. flow unimpacted by withdrawals). MFLs are proposed to be expressed as no more than a given percent reduction (or set of reductions) in spring flows from the benchmark condition, with potentially different allowable percentages based on seasonality. It may also be appropriate to propose low flow thresholds.

The remaining components (resources of interest, metrics, and benchmark period) are addressed in subsequent sections of this work plan. Resources of interest are referred to under Florida Administrative Code as environmental values and are referenced as water resource values (WRVs) throughout this document. WRVs and corresponding metrics (both components of MFL development) are addressed in greater detail in section 2.0 of this work plan. The benchmark period is addressed separately in section 3.0.

1.3 Define MFLs approach

The habitat based approach to MFLs recommended here is based on the environmental flow paradigm, which acknowledges the need to maintain a hydrologic regime similar to the un-impacted flow regime. We have outlined a habitat-based approach for developing environmental flows and levels for the St. Marks River Rise, Wakulla, and Sally Ward springs including the downstream spring runs and estuarine areas. The approach incorporates techniques applied in the development of a number of minimum flows and levels rules adopted in Florida and elsewhere.

Under this task, the MFLs approach will be refined with respect to inclusion (or not) of seasonal flow prescriptions: flows for the St. Marks River Rise, Wakulla, and Sally Ward springs will be analyzed to determine how much variation in flow can be attributed to seasonal effects. Flows at the St. Marks River Rise, for example, have a larger surface water component than those at Wakulla and Sally Ward springs and may require greater accommodation for surface water flows than the Wakulla and Sally Ward springs. Summaries of flow or level records, describing hydrologic regimes for specific periods, would be developed. If a seasonal block approach is included, resource values associated with low, medium, and high flows or levels will be identified and evaluated for use in the development of a MFLs recommendation(s) if appropriate.

Much of the information related to approaches to environmental flows and levels is based on previously vetted methods (see, for example, Annear et al. 2004). Tools that can be used to establish and evaluate inundation of seasonally appropriate habitats include PHABSIM, HEC-RAS, and hydrodynamic models (Annear et al. 2004, Tharme 2003). The tools that can be applied are, of course, limited by available data and resources. These tools are not new and have been applied across a wide range of conditions and places.

Development of MFLs, as proposed, includes evaluation of a "seasonal block", or "building block" approach that integrates flow or level requirements for specific WRVs to address the seasonality of flows. Although WRVs may vary by water body, the approach is the same. Due to the relatively stable nature of the annual hydrograph in spring-flow dominated systems, it may not be possible to establish clearly defined seasonal flow blocks for either the St. Marks River Rise, Wakulla, or Sally Ward springs. Flows in the systems will be evaluated thoroughly before deciding whether to partition the hydrograph into seasonal flow blocks. The application (or not) of seasonal flow blocks will not affect the amount of field work needed for development of the MFLs. Development of flow or level requirements using the seasonal flows block approach typically includes:

- Characterization of the natural flow or hydrologic regime
- Identification of seasonal blocks associated with flow or level needs for ecosystem specific functions, biological assemblages or populations
- Assembly of the blocks to form a flow prescription (Postel and Richter 2003)

Identifying a single WRV most sensitive to incremental changes in flow as the basis for the recommended MFL is an alternative to using multiple WRVs, given the assumption that it would be protective of all other WRVs regardless of season. We anticipate evaluating multiple WRVs and using as many as are needed and appropriate to protect the full spectrum of flows.

A conceptual model (Figure 4) is presented to illustrate and summarize the seasonal block approach. In this approach, fish passage requirements are shown as a likely WRV, or resource target, for determining minimum acceptable low flows during the dry season, while floodplain inundation may be the resource target determining high flows during the wet season. Snag habitat may be important to consider between the dry season and wet season conditions, and connections between the river and the floodplain via sloughs and aquatic habitats may provide resource targets for medium to high flow conditions.

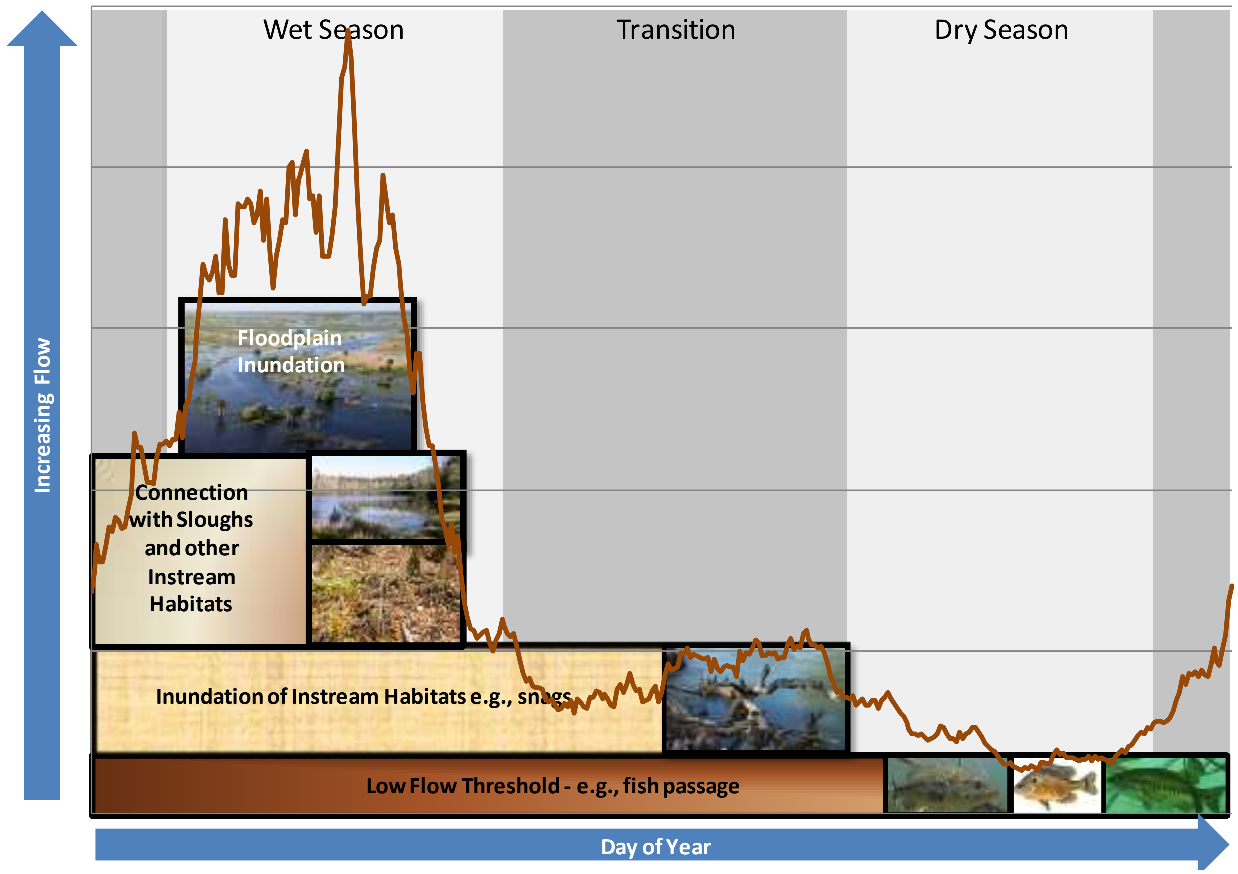


Figure 4. Conceptual approach to developing minimum flows for seasonal blocks illustrating the use of different resource targets for different times (e.g. wet and dry season) of the year.

2. IDENTIFICATION OF WATER RESOURCE VALUES

This work plan addresses MFLs for St. Marks River Rise, Wakulla, and Sally Ward springs, inclusive of the downstream freshwater reaches of the Wakulla and St. Marks rivers and the estuarine portion of the St. Marks River, as described previously. The relationship of WRVs with springs flows and water levels provides a means of evaluating potential impacts of reduced spring flows on the WRVs. Once WRVs and corresponding metrics are developed, the hydrodynamic models can be used to quantify the flows (e.g. cfs) that meet the metrics (e.g. water depth). Individual tasks are first outlined here, followed by task descriptions and a preliminary analysis of WRVs.

According to Florida's Water Resources Implementation Rule (Section 62-40.473, F.A.C.) and sections 373.042 and 373.0421, F.S., "consideration shall be given to natural seasonal fluctuations in water flows or levels, non-consumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology" and lists ten "environmental values" (referred to in this document as "water resource values" or WRVs) to be addressed:

1) Recreation in and on the water
2) Fish and wildlife habitats and the passage of fish
3) Estuarine resources
4) Transfer of detrital material
5) Maintenance of freshwater storage and supply
6) Aesthetic and scenic attributes
7) Filtration and absorption of nutrients and other pollutants
8) Sediment loads
9) Water quality
10) Navigation

Sampling efforts in support of WRV development are presented in Section 4.0 *Data Needs and Data Collection*. Models used to predict flows necessary to meet metrics and to predict impacts of reduced flows are presented in Section 5.0.

Task 2 *Identify and evaluate potential and recommended WRVs (e.g. fish passage) and corresponding metrics (e.g. cfs) specific to MFLs for the St. Marks River Rise, Wakulla, and Sally Ward springs*

Task 2.1 Evaluate available data to assess relationship of flow with recreation in and on the water; identify appropriate metrics for evaluating potential impacts of reduced flows on recreation access and passage

Task 2.2 Evaluate available data and relationships of flow with fish and wildlife habitats and the passage of fish

Task 2.2.1 Evaluate available data and relationships of flow with fish habitat using PHABSIM; evaluate potential impacts of reduced flows on the habitat (requires fish habitat sampling)

Task 2.2.2 Develop appropriate metrics, i.e. depth, necessary for manatee passage to Wakulla Springs; evaluate need for using thermal model to quantify potential impacts of reduced flows on available thermal refuge for manatee (requires additional sampling for thermal model)

Task 2.2.3 Develop flow relationships and metrics for evaluating potential impacts of reduced flow on inundation of instream wetted perimeter and snag habitat (requires instream and snag habitat sampling and elevation surveys)

Task 2.2.4 Develop metrics and flow relationships needed to evaluate potential impacts of reduced flows on extent of inundated floodplain habitat and connectivity of aquatic and floodplain habitat (requires sampling of aquatic and floodplain habitats and elevation surveys)

Task 2.3 Develop metrics and relationships of flow with salinity, submersed aquatic vegetation (SAV), and riparian vegetation, needed to evaluate potential impacts of reduced flows on these estuarine habitats (requires additional hydrologic and water quality sampling, SAV sampling, and riparian vegetation survey)

Task 2.4 Evaluate relationship between water clarity and spring flows to determine whether water clarity (number of clear water days) is a relevant WRV as a surrogate for aesthetic and scenic attributes, and if so, identify metrics needed to evaluate potential impacts of reduced flows on this WRV (requires additional hydrologic and water quality sampling)

Task 2.5 Evaluate relationship between water quality characteristics and flow (requires additional hydrologic and water quality sampling)

Task 2.6 Evaluate potential of navigation in the lower St. Marks River as a WRV and, if appropriate, develop metric for adequate water depth for existing commercial barge traffic

Task 2.7 Review and finalize WRVs and corresponding metrics with District for use in developing MFLs

While the primary unit of measure for defining MFLs is flow or discharge (in cubic feet per second, cfs), several different measures of habitat, along with elevations in feet above the North American Vertical Datum of 1988 (NAVD88) associated with habitats, may be used. Ultimately, however, different measures of habitat and inundation elevations can be related to flows.

This hydrologic and physical setting of springs and downstream spring runs provide habitat for a diverse array of plant and animal populations. Human uses of the natural resources including navigation and recreation (fishing, swimming, wildlife observation, aesthetic enjoyment, and boating) can also be an important consideration for the establishment of MFL(s). Environmental flows can be viewed as a subset (albeit a large subset) of an MFL assessment along with human uses that are not purely ecological in nature.

A preliminary assessment of the WRVs was made to identify values relevant to the St. Marks River Rise, Wakulla, and Sally Ward springs system and characterized by data adequate to support an evaluation with respect to development of MFLs. An assumption relevant to selection of WRVs is that protection of the resource, particularly those most vulnerable, extends protection to other undefined, unmeasured and less vulnerable resources. The complexity of natural systems can obscure relationships between and among biotic and abiotic variables such that many WRVs are not measurable or a relationship between a WRV and flow cannot be quantified. Therefore, in some cases, decisions must be made with respect to which WRVs will be used to develop the MFLs.

Each WRV will be evaluated with respect to MFL establishment for the St. Marks River Rise, Wakulla, and Sally Ward springs. The most conservative MFL hydrologic regime, i.e. the flows and corresponding water levels that provide protection for the largest number of WRVs and the most vulnerable WRVs, are proposed to be selected for each water body. WRVs for the St. Marks River Rise, Wakulla, and Sally Ward springs will be refined based on available information. For this study, a WRV has the elements listed below. Each potential WRV is presented with respect to MFLs for the St. Marks River Rise, Wakulla, and Sally Ward springs in the sections that follow.

- Relevant to MFLs
- Measurable
- Related (linked) to water flows or levels
- Characterized by best available data, or can be characterized with the present work plan
- Integrates more than one resource

These elements are consistent with the selection of WRVs by the Southwest Florida, Suwannee River, St. Johns, and South Florida water management districts in developing MFLs in those districts. These same elements are consistent with recommendations with regard to system-wide ecological indicators for assessing Everglades restoration (National Research Council 2003 and 2006, Doren et al. 2009) and systems in general (for example, see Dale and Beyle 2001). Kurtz et al. 2001 outline guidelines for development of ecological indicators and write "…potential indicators have little chance for success unless they address valid and relevant assessment questions."

Results of the preliminary assessment focused this work plan on the WRVs listed below and addressed more specifically in the following text.

- Recreation in and on the water
- Fish and wildlife habitats and the passage of fish
- Estuarine resources
- Aesthetic and scenic attributes

- Water quality
- Navigation

If additional information becomes available that merits examination of other WRVs, further evaluation may be recommended.

2.1 Recreation in and on the water

The St. Marks and Wakulla rivers and Wakulla Springs State Park have been designated Outstanding Florida Waters, due in part to the recreational significance of the system (Section 62-302.700, F.A.C.). Recreation in Wakulla Spring includes swimming, snorkeling, and jumping into the spring from the jump tower. Kayaking, canoeing, recreational power boating, paddle boarding, and other activities are common along the St. Marks Rise, Wakulla, and Sally Ward springs downstream runs. Water depth and water clarity are important to many of these activities, including safe depth for canoe and kayak passage. The SRWMD uses a water level stage associated with a safe boating operation water depth of 4 feet and a canoeing depth of 1.5 feet (Coarsey 2012b). The SJRWMD (2014) applied a criterion of 2.5 feet to account for motorized boats, including the glass bottom boats.

Appropriate depths for recreation will be identified specific to the St. Marks River Rise, Wakulla, and Sally Ward springs for development of the recreation WRV. HEC-RAS results will be used to evaluate the impacts of reduced spring flows on surface water levels in Wakulla Springs and the downstream spring runs comprising the Wakulla and St. Marks rivers for boat access and passage. The following criteria offer relevant and measureable relationships to the MFL relative to this WRV (tour boating is included under aesthetics):

- Swimming, snorkeling, canoeing, kayaking, in spring pools and associated spring runs
- Use of the jump tower at Wakulla Spring
- Motor boating in the rivers

2.2 Fish and wildlife habitats and the passage of fish

Both in-channel and floodplain habitats are affected by spring flows and will be evaluated in the establishment of the MFLs. Fish passage, instream woody (snag) habitat, aquatic connections and areal extent of floodplain habitat, and the habitat structure provided by submersed aquatic vegetation (SAV) are all relevant to MFL development for the St. Marks River Rise, Wakulla, and Sally Ward springs. Fish passage is especially important during low flow periods when passage may be limited by depth, as may manatee passage.

Occurrence of Suwannee bass (*Micropterus notius*) is documented in both the freshwater portions of the Wakulla and St. Marks Rivers (Walsh and Williams 2003, Cailteux 2004, 2005, T. Hoehn, FFWCC, pers. comm., after Lewis et al. 2009). We propose that fish passage depth be evaluated similarly to that done on a number of watercourses in the SWFWMD (e.g. SWFWMD 2002); however, the actual depth criterion for evaluation will be tailored to species that occur within the St. Marks River, Wakulla, and Sally Ward springs system.

2.2.1 Fish habitat

Fish habitat is proposed to be addressed using PHABSIM, or similar model. PHABSIM will be used to simulate a relationship between streamflow and physical habitat for various life stages of appropriate species of fish (detailed in section 4.3).

2.2.2 Manatee access and refugia

Wakulla Springs and St. Marks River Rise have been identified as secondary thermal refugia for the federally endangered West Indian manatee (Warm Water Task Force 2004, after U.S. Marine Mammal Commission 2006), making manatee a relevant WRV. Because manatee are known to frequent the spring runs downstream of the Wakulla Spring and St. Marks River Rise, manatee passage is also a relevant consideration; although it may be most appropriate to consider this criterion based on the seasonal likelihood that most manatee use will occur during colder months when the animals are seeking a thermal refuge (typically during the months of October through March). The assessment of manatee passage is anticipated to take into consideration historical water depths; for example, manatees may not be able to access areas upstream of shoals on the St. Marks River much of the time historically. A passage criterion of 3.8 feet has been used in several previous MFL studies (JEI and ATM 2007, Heyl et al. 2012, HSW 2010, HSW 2012, Leeper et al. 2012) based primarily on work done by Rouhani et al. (2007) for the SJRWMD. The volume or spatial extent of thermal refuge for manatees at Wakulla Springs is also anticipated to be assessed. If needed, a thermal model will be developed to ascertain whether reduced flows could significantly impact the volume of thermal refuge available to manatee at Wakulla Springs.

2.2.3 Instream and snag habitat

Wetted perimeter graphs typically exhibit inflection points that correspond to the point at which small flow reductions result in much greater reductions in wetted perimeter and associated instream habitat. These inflection points can be used to develop a wetted perimeter criterion at any transect location and are proposed to be evaluated as a potential WRV.

2.2.4 Floodplain habitat

Seasonally high flows in the rivers and springs provide inundation of aquatic and floodplain habitat. The extent of habitat loss anticipated under specific spring flow reductions provides a means of quantifying floodplain habitat loss and making recommendations based on that loss.

2.3 Estuarine resources

Freshwater from the St. Marks River Rise and Wakulla and Sally Ward springs mixes with saline tidal waters in the estuarine portion of the lower St. Marks River, strongly influencing the location and movement of the salinity gradient along the lower river, as well as the distribution and abundance of those species dependent upon estuarine conditions. Estuarine resource WRVs are relevant to the lower

St. Marks River due to its Outstanding Florida Water (OFW) designation and the vegetation (riparian vegetation, SAV) and faunal (fishes, benthos) components. Oyster reefs are conspicuous along the lower reach of the St. Marks River, especially during low tides, but are not a commercial fishery in this area and are not anticipated to be impacted by reductions in spring flows. As part of the MFL development, the potential effects of spring flow reductions from the St. Marks River Rise, Wakulla, and Sally Ward springs system on the salinity regimes in the estuarine portion of the St. Marks River are proposed to be evaluated using a hydrodynamic model. The potential need for dissolved oxygen (DO) modeling is anticipated to be evaluated under this task. The following criteria are proposed to be considered for evaluation of this WRV with respect to the MFL:

- Salinity distributions
- SAV (e.g. *Vallisneria americana*) and riparian (e.g. *Juncus roemerianus*) vegetation distributions

2.4 Aesthetic and scenic attributes

This WRV is closely related to recreation in and on the water due to the aesthetics associated with recreation, i.e. kayaking along a scenic spring run. However, glass bottom boat tours at Wakulla Spring make this resource a potentially relevant WRV. Reversals in Spring Creek during low rainfall periods are hypothesized to increase color and number of “dark water days” during which the tour boats cannot operate. We propose to further assess the relationship between water clarity and spring flows. If, for example, water clarity improves as Wakulla spring flow decreases, water clarity may not be a relevant WRV for MFL development. Excessive algal biomass can also reduce the aesthetics of the spring and spring run, although an evaluation by King (2012) of the relationship of flow and velocity with algal biomass in a Florida spring run found little information linking the two with respect to the establishment of MFL criteria. MFL considerations include maintenance of clear water days to address this WRV.

2.5 Water quality

This WRV is considered relevant with respect to low salinity habitat in the lower St. Marks River. A hydrodynamic model is proposed to be developed for the lower St. Marks River to evaluate the influence of freshwater flows on salinity and submersed aquatic vegetation (SAV) distributions. Additionally, relationships between spring flows and other water quality characteristics (e.g., DO, nutrients) will be examined.

2.6 Navigation

This WRV applies to large commercial vessels and may be relevant to the St. Marks River MFLs. A dredged channel leads from deep water in Apalachee Bay to a turning basin at the town of St. Marks and then 0.5 miles upstream to a power plant. The NOAA chart for October 2006 report controlling depths of 3.4 feet (10.3 feet at mid-channel) to the turning basin, 8.7 feet in the turning basin, thence 1.4 feet (11.3 feet at mid-channel) to the head of the dredged channel. Barges are the major traffic on the lower river and historically served a petroleum cracking facility, oil terminals, a power generating facility, and several marinas and two boat yards. The City of Tallahassee’s Sam O. Purdom power generating facility continues to operate and requires that fuel be barged to the City of St. Marks. The channel used by barges is dredged and therefore unlikely to be impacted by reduced springs flows. However, this potential WRV will be evaluated as to whether it is related to spring flow.

2.7 Other WRV considerations

In addition to the direct WRVs described above, it can be argued that, flood flows and overbank flows serve to meet, at least in part, several WRVs listed in Section 62-40.473, F.A.C, including:

- Fish and wildlife habitats
- Transfer of detrital material either by depositing material in the floodplain or by transporting materials from the floodplain to downstream locations including estuarine locations
- Maintenance of freshwater storage and supply
- Estuarine resources by transporting detrital material to downstream areas
- Filtration and absorption of nutrients and other pollutants
- Sediment loads, since most sediment is transported during periods of high flow – this serves in channel maintenance, and is important ,for example, in maintaining channel geometry and clearing spawning areas of silt and debris

Once an adequately calibrated HEC-RAS model is available for the St. Marks River Rise, Wakulla, and Sally Ward springs and downstream spring runs, it should be possible to establish bankfull elevations along each river, at which time we would propose to determine the flow necessary to obtain these elevations and using either the existing hydrologic record (e.g. St. Marks River at Newport) or a generated hydrologic record (e.g. Wakulla River with its short gauged record) determine the recurrence interval associated with these flows (i.e. bankfull). Once determined we would follow the logic as outlined by Robison (2007) to address, in part, the WRVs listed below.

- Fish and wildlife habitats
- Maintenance of freshwater storage
- Sediment loads
- Transfer of detrital material
- Filtration and absorption of nutrients and other pollutants

2.7.1 Maintenance of freshwater storage and supply

This WRV refers to the long-term maintenance (i.e. sustainability) of the water storage and supply capacity of a water body such that an adequate amount of freshwater for non-consumptive uses and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology is maintained. This WRV is presumed to be addressed as part of any MFL regime because establishment of a MFL regime also maintains availability of that water and protection of the springs and rivers from significant harm.

2.7.2 Sediment loads

This WRV is considered relevant to the St. Marks River Rise and Wakulla Spring system although data relating sediment loads to flow for these rivers are not available, precluding an analysis relevant to MFLs. An investigation of the relationship between changes in sea level and sedimentation rates within the marine coastal wetlands of Apalachee Bay by Ladner et al. (2000) found low sedimentation rates (approximately 0.72 mm per year) in the St. Marks estuarine cores. The low rates of accretion were attributed to low energy coastal dynamics, e.g. low surface water velocities and sediment load, low wave energy, and small tidal range.

2.7.3 Transfer of detrital material

Plant detritus is a principal food base in aquatic and wetland ecosystems and is transported from riverine and floodplain wetlands to the river channel where it can be an important food source to numerous invertebrates. This WRV is relevant to the St. Marks and Wakulla rivers MFLs and are proposed to be addressed using available literature and data. Transport of detrital material will be a consideration with respect to spring discharge but will be addressed by aquatic and floodplain connections under the fish and wildlife and fish passage WRV rather than as an individual WRV.

2.7.4 Filtration and absorption of nutrients and other pollutants

This WRV is considered relevant to the establishment of MFLs for the St. Marks River Rise, Wakulla, and Sally Ward springs system. Nitrogen and phosphorus concentrations are reportedly generally low throughout the system, except in Wakulla Spring, where increased densities of nuisance aquatic plants are attributed to higher nitrate levels (Lewis et al. 2009). The role of wetlands in the maintenance of water quality is well established (Mitsch and Gosselink 2000). Floodplains provided conditions for nitrogen mineralization and denitrification (Koschorreck and Darwich 2003, Kellogg et al. 2010), primarily in the upper few inches of soil, thereby reducing downstream nitrate transport (Harms and Grimm 2008) that can cause or exacerbate eutrophication and algae blooms. Wetland plants facilitate soils processes that account for short term microbial phosphorus sequestration and the burial and long term phosphorus storage into anaerobic soil layers (Noe et al. 2003, Kadlec 2006). Assessment of the floodplain habitat, where much of the filtration and absorption of nutrients and other pollutants occur, will address this WRV.

3. DEVELOP BENCHMARK FLOWS

The benchmark flow component of an MFL addresses the flow regime and is the standard against which change is measured. The benchmark should be representative of flows and levels to be expected in the absence of withdrawals. A benchmark flow requires either some historic or simulated flow or level data free of [withdrawal] impacts. Flow or water level data collected prior to a perceived impact may have been collected under climate conditions (e.g. rainfall) that were much different than current conditions. Consequently, “historic” conditions may require adjustments to more accurately depict pre-impact conditions. Therefore, climate conditions will be considered as part of the evaluation and identification of a benchmark flow period.

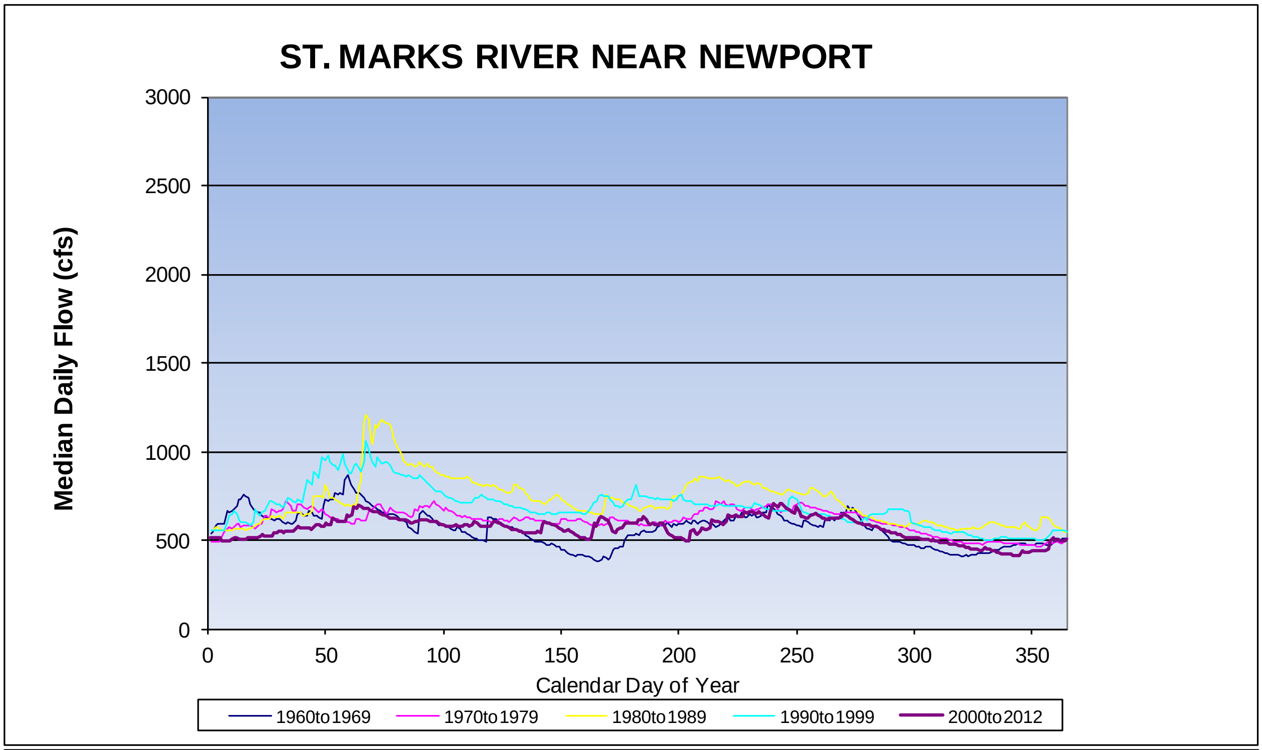
The development of benchmark flows for the St. Marks River Rise, Wakulla, and Sally Ward springs system is critical to establishing MFLs. The approach proposed here is to estimate the effect of water withdrawals from the contributing area on the springs and then basically add the withdrawal effects “back into” the system during the period of record during which withdrawals occurred, thereby building the benchmark flow. The benchmark flow will be used for comparing impacts of various spring flow reduction scenarios on WRVs. Once a benchmark flow regime is established, and the significant harm threshold established, a protection standard can be determined and expressed as a percentage reduction in flow from the benchmark. A groundwater model accounts for the groundwater contribution to the surface water flows (e.g. river baseflow), thereby linking the MFL to potential water withdrawals.

Task 3 *Evaluate historic and current spring flows in the system, with consideration for climate conditions (e.g. rainfall patterns), and recommend or develop benchmark flows for each water body, against which present day flows can be compared. Upon review and approval by the District, the benchmark flows will be used in developing the MFLs*

Although preliminary, flow data were analyzed to characterize some of the seasonality in the flows (Figure 5). Summary statistics and long term trends for the St. Marks River near Newport and the nearby Ochlockonee River near Havana indicate flows in the 1970 to 1994 time period (25 years) were, on average, 20 to 30 percent higher than more recent flows (1995-2012) and considerably higher than flows during the preceding 20 years (1940-1969). The St. Marks River downstream of St. Marks River Rise had similar long term trends; however, on a percentage basis, flow increases and decreases were considerably less. Similar patterns can be observed on other nearby watercourses. Preliminary comparisons of flows among neighboring rivers in or near the NWFWMD indicates potential differences in flows due to multi-decadal climate patterns between the rivers that should be considered as part of the MFL development. Most river hydrographs demonstrate higher flows from 1970 to 1994 than for the 30 year period preceding or the 17 year period following, suggesting higher rainfall. To establish a benchmark period in a climatically wet period could set unrealistically high standards if followed by a climatically dry period.

Comparison of the hydrographs for the St. Marks and Ochlockonee rivers (Figure 5) also demonstrates an important contrast to be considered as part of the data analysis (e.g. the use of seasonal blocks or not). The St. Marks River hydrograph shows much less seasonal variation, indicating a very large base flow (spring flow) compared with greater runoff contributions to the Ochlockonee River. Although the magnitude of flows in a spring-flow dominated system can vary measurably as a result of annual rainfall, the annual hydrograph for spring-driven systems is relatively stable compared to more runoff driven systems. However, the same two calendar years for St. Marks River and Wakulla River (Figure 6) indicate differences in flows in the two neighboring rivers that require consideration during the modeling and MFL development process.

Despite the fact that it is often assumed or suggested that a 20 year period of unimpacted flows is sufficient for establishing a benchmark (e.g. Richter et al. 2001), climatic variability needs to be accounted for in developing a benchmark. It is also clear that in the more recent multi-decadal period plotted (1995 to 2012) some rivers show lower flows when compared with preceding periods. Whether such lower flows for those rivers are largely related to rainfall or withdrawals or some combination remains to be determined, and will likewise need to be considered when establishing MFLs. Regardless, these comparisons demonstrate the importance of considering regional as well as localized hydrologic conditions and watershed or groundwater contributing area impacts. Examination of rainfall trends will be necessary to help sort out climatic effects from withdrawal impacts.



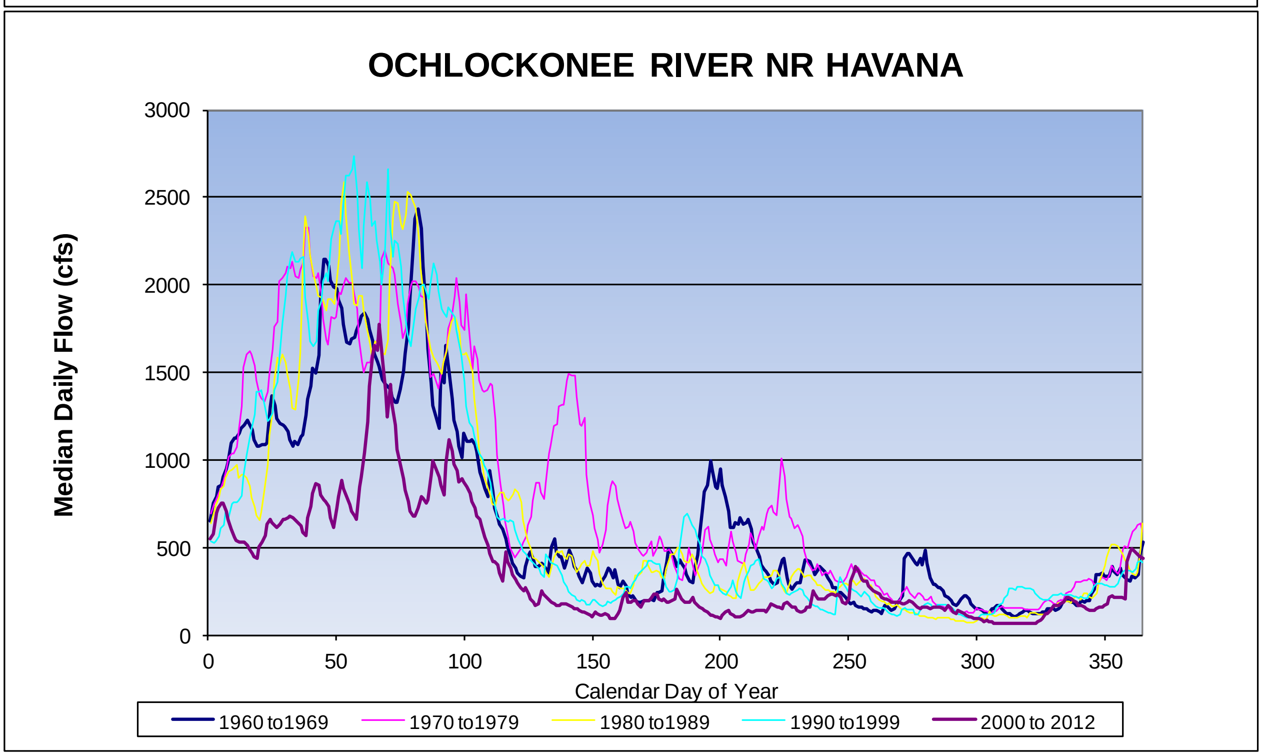
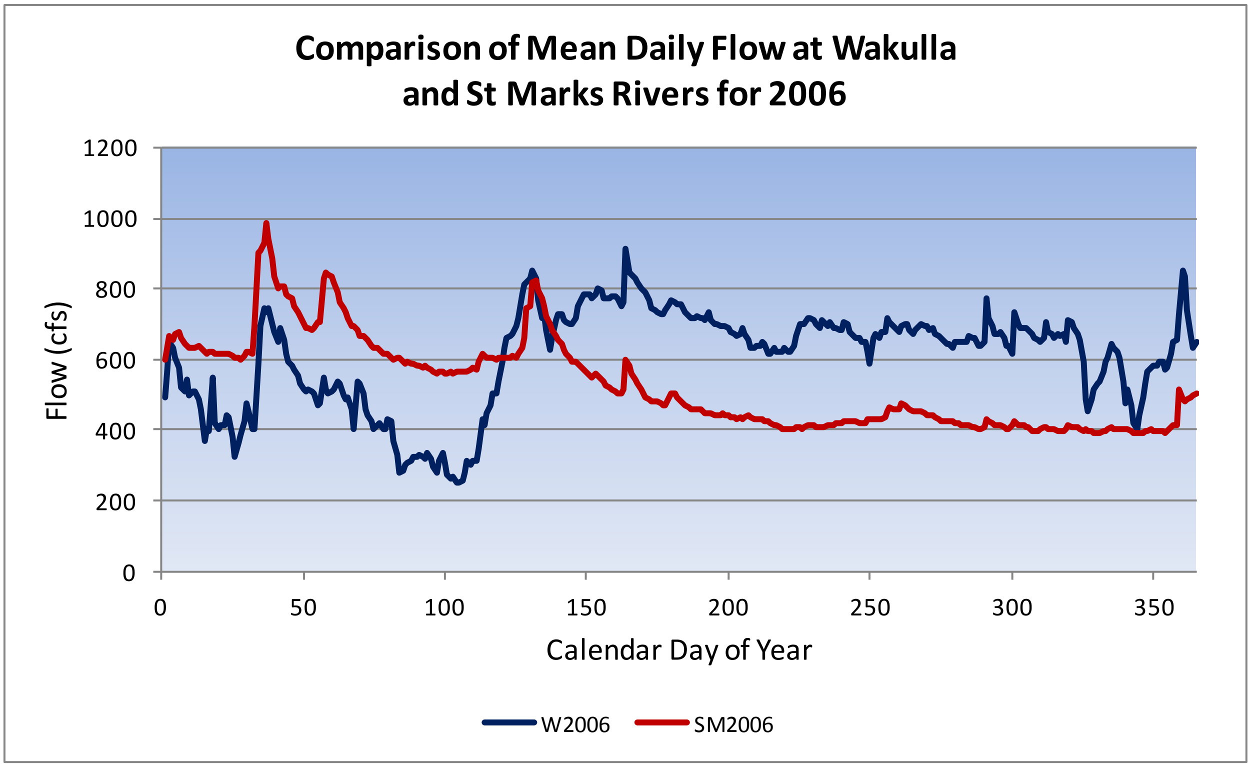


Figure 5. Decadal plots of median daily flows for the St. Marks River and the Ochlockonee River.



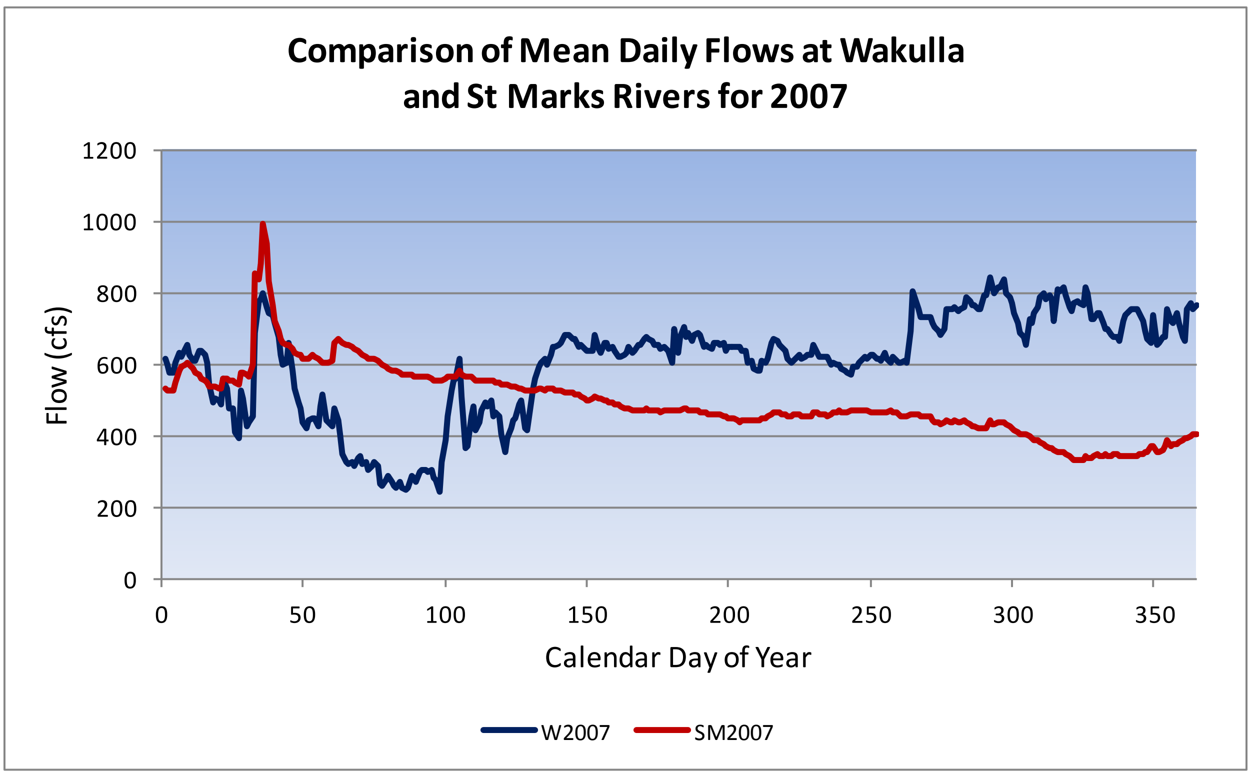


Figure 6.Comparison of mean daily flows at Wakulla and St. Marks Rivers for 2006 and 2007.

4. REFINE DATA NEEDS AND COLLECT DATA

A preliminary review of data needs for surface and groundwater modeling was completed previously under Task Order 1 with Atkins. Needs for additional data to complete the work plan and, subsequently, develop MFLs are documented and evaluated here, and a strategy or plan to collect or acquire the needed information is presented. Available data of sufficient quality will be used to the greatest extent possible. Proposed monitoring locations are mapped in Figure 7.

Task 4 *Measure, collect, and compile data necessary to develop MFLs for the St. Marks, Wakulla, and Sally Ward springs system, including surface and groundwater monitoring data, river channel cross section elevation data, floodplain elevation data, and soils and biological data needed for modeling the relationships among WRVs and river flows*

Task 4.1 Install, operate, and collect data from surface and groundwater monitoring stations to support MFL data needs, including groundwater well construction and surface water gage installation, operation, and monitoring
Task 4.2 Survey and compile channel elevation data necessary to support HEC-RAS modeling
Task 4.3 Collect, compile data for PHABSIM analysis
Task 4.4 Collect, compile data for floodplain and aquatic habitat analyses
Task 4.5 Collect and compile data for instream habitat analyses
Task 4.6 Collect, compile hydrographic data for estuarine (EFDC) model
Task 4.7 Collect, compile temperature data for manatee thermal refuge model

4.1 Install, operate, and collect data from surface and groundwater monitoring stations

There are two USGS gages on the St. Marks and Wakulla rivers: (one in each river upstream of the confluence of the rivers) and a NWFWMD gage at the confluence of the rivers. There is also a recently installed stage sensor at the Wakulla Springs boat launch. MFLs are proposed to be established at two locations:

- For the St. Marks River Rise, at the existing long-term USGS gage just below the St. Marks River Rise
- For Wakulla and Sally Wards springs, at the stage sensor located at the boat launch facility approximately 0.5 miles downstream of the Wakulla Springs pool

Additional gages are needed on both rivers to monitor stage, flow, conductivity, and rainfall for the springs and rivers. New groundwater wells are proposed to be installed to collect geologic data and monitor groundwater levels. Without data, the surface and groundwater models cannot be used to develop flows necessary to meet the water depths associated with selected WRVs or predict the potential impacts of groundwater withdrawals on spring flows. The following components are included under this task:

- Groundwater wells installation (with survey) and monitoring. The District is coordinating with the FGS for potential installation of wells at four of the sites.
- Installation and operation of surface water gages, with elevation survey (for reference to a benchmark elevation)Groundwater and surface water monitoring, downloading, processing

4.1.1 New wells and enhanced groundwater data collection

The Task 1 report identified existing wells monitored continuously, wells monitored quarterly that could be instrumented with continuous recorders, and potential new well locations for continuous monitoring that would fill data gaps in the groundwater model domain. Subsequently, NWFWMD staff adjusted several of the proposed well locations slightly in order to site the wells on public lands and to provide ease of access. Proposed new and enhanced groundwater monitoring stations are listed in Table 1. In addition to these new and enhanced sites, there are additional monitoring sites with water level data that may be useful for groundwater model development and calibration within the groundwater contribution area. Further review of potential groundwater monitoring sites is planned. Measuring points at groundwater sites will be surveyed and referenced to NGVD 29.

4.1.2 Surface water monitoring for groundwater model

Proposed monitoring stations for surface water stage and discharge were presented briefly in the Task Order 1. Subsequently, during a January 23, 2014 site visit, an additional surface water monitoring station was identified. Near the Lost Creek Swallet by Harvey Mill Road, surface water flows exceeding the capacity of the swallet can ‘pop off’ at a low point in the stream bank and continue flowing southeast towards the coast. A streamflow gage in Lost Creek at or near US 319 will help quantify the Lost Creek flows that do not enter the aquifer via the main swallet. Proposed surface water monitoring stations (existing and to be installed) are listed in Table 2 (surface water monitoring stations for the hydrodynamic model in the estuarine portion of the system are also listed). Measuring points at surface water sites will be surveyed and referenced to NGVD 29.

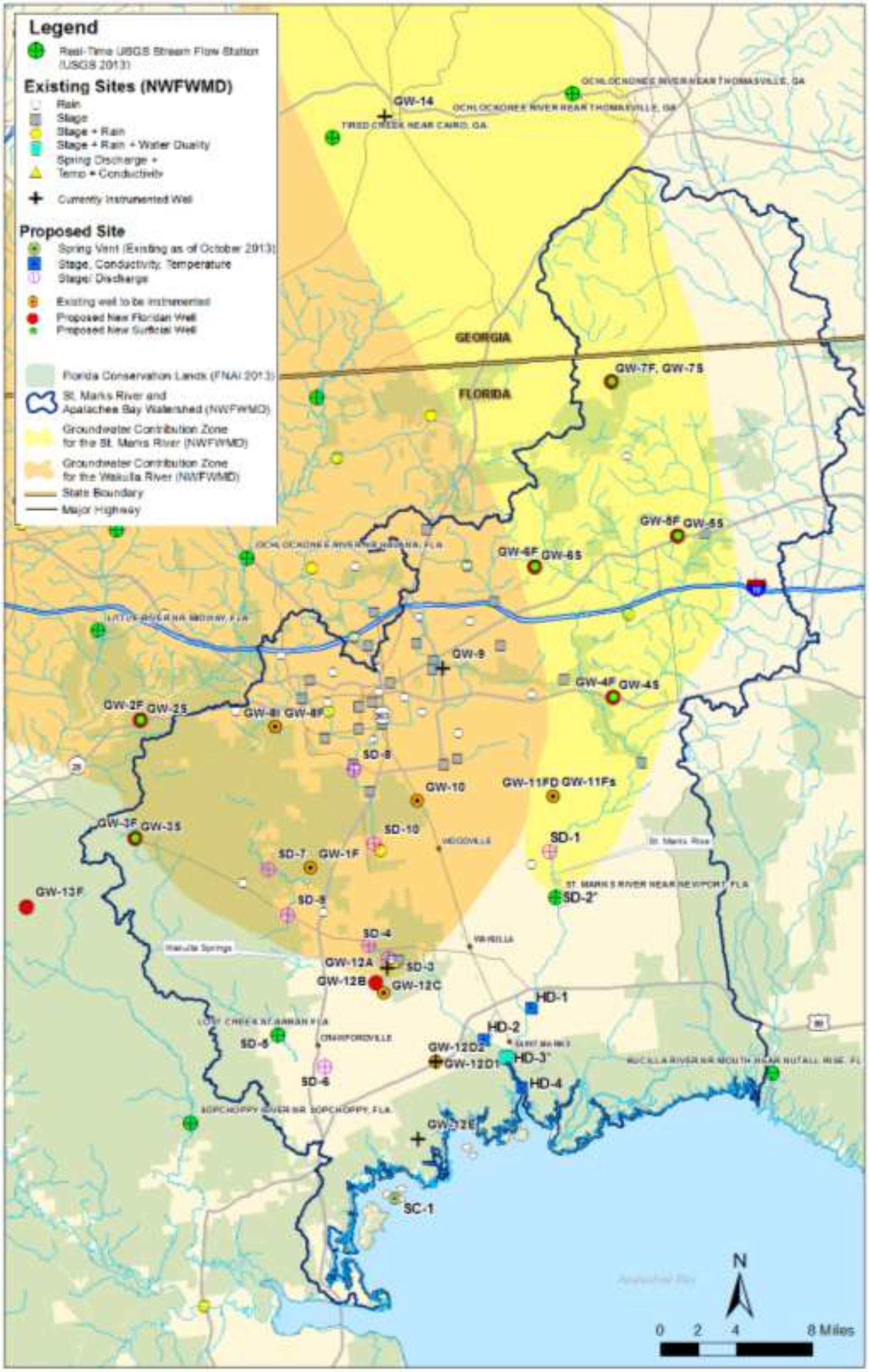


Figure 7. Locations of proposed monitoring equipment to address data needs for the MFLs.

Table 1. Proposed enhanced groundwater monitoring stations.

Map ID	Status	Status	Well diameter	Aquifer
GW-1F	Existing Floridan	to be instrumented	2"	Floridan
GW-2F	Proposed New Floridan	to be constructed and instrumented	4"	Floridan
GW-2S	Proposed New Surficial	to be constructed and instrumented	4"	Surficial
GW-3F	Proposed New Floridan	to be constructed and instrumented	4"	Floridan
GW-3S	Proposed New Surficial	to be constructed and instrumented	4"	Surficial
GW-4F	Proposed New Floridan	to be constructed and instrumented	4"	Floridan
GW-4S	Proposed New Surficial	to be constructed and instrumented	4"	Surficial
GW-5F	Proposed New Floridan	to be constructed and instrumented	4"	Floridan
GW-5S	Proposed New Surficial	to be constructed and instrumented	4"	Surficial
GW-6F	Proposed New Floridan	to be constructed and instrumented	4"	Floridan
GW-6S	Proposed New Surficial	to be constructed and instrumented	4"	Surficial
GW-7F	Proposed New Floridan	to be constructed and instrumented	4"	Floridan
GW-7S	Proposed New Surficial	to be constructed and instrumented	4"	Surficial
GW-8F	Existing Upper Floridan	to be instrumented	4"	Floridan
GW-8I	Existing Intermediate	to be instrumented	4"	Intermediate
GW-9	Existing and instrumented	-	4"	Floridan
GW-10	Existing Upper Floridan	to be instrumented	4"	Floridan
GW-11Fs	Existing Upper Floridan	to be instrumented	4"	Floridan
GW-11Fd	Existing Upper Floridan	to be instrumented	4"	Floridan
GW-12A	Existing	(conduit well)	4"	Floridan
GW-12B	Proposed New Floridan	to be constructed and instrumented	4"	Floridan
GW-12C	Existing Upper Floridan	to be instrumented	4"	Floridan
GW-12D1	Existing and instrumented	-	4"	Floridan
GW-12D2	Existing	-	4"	Floridan
GW12E	Existing and instrumented	-	6"	Surficial
GW13F	proposed Upper Floridan	to be constructed and instrumented	4"	Floridan
GW14** (GA)	Existing and instrumented	-	Unknown	Floridan

To be instrumented only

To be constructed and instrumented

Existing well, instrumented

Table 2. Existing and proposed surface water monitoring stations.

Map ID	Location Description	Agency	Period of Record	Status	Data to be collected
HD-1	St. Marks River, estuarine, above confluence with Wakulla River	NA	NA	Proposed	Stage, conductivity, temperature
HD-2	Wakulla River, estuarine, above confluence with St. Marks River	NA	NA	Proposed	Stage, conductivity, temperature
HD-3	St. Marks River at the confluence with Wakulla River	NA	NA	Existing	Stage, rainfall, salinity
HD-4	Downstream of confluence of Wakulla and St. Marks River	NA	NA	Proposed	Stage, conductivity, temperature
SC-1	Spring Creek	USGS	Jun 2007–Sep 2010	Active	Keep operational
SD-1	Upper St Marks River	NA	NA	Proposed	Install new stage-discharge Station
SD-2	St. Marks River near Newport	USGS	Oct 1956 – Present	Active	Keep operational
SD-3	Wakulla River near Crawfordville	USGS	Oct 2004 – Present	Active	Keep operational
SD-4	Sally Ward Springs	NA	NA	Proposed	Install new stage-discharge Station
SD-4A	Indian Springs	NA	NA	Proposed	Install new stage-discharge Station
SD-5	Lost Creek at Arran Rd	USGS	Oct 1998–Sep 2005	Discontinued	Resume operation
SD-6	Lost Creek at US 319	NA	NA	Proposed	Install new stage-discharge station
SD-7	Fisher Creek Near Spring Hill SR 373	USGS	May 2007–July 2010	Discontinued	Resume operation
SD-8	Munson Slough at Capital Circle	NWFWMD	1987-2013	Active	Develop current stage-discharge rating curve
SD-9	Black Creek at SR267	NA	NA	Proposed	Install new stage-discharge station
SD-10	Munson Slough at Oak Ridge Road	NA	NA	Proposed	Install new stage-discharge station
SD-11	Wakulla Springs, Site Station #98	NA	NA	Proposed	Stage and velocity

To resume operation

To be constructed and instrumented

Constructed and instrumented

NA=not applicable

4.2 Survey and compile transect data necessary to support HEC-RAS model

Model needs for HEC-RAS include an estimated 25 cross sections downstream of the St. Marks River Rise and Wakulla Springs to establish channel elevations and, subsequently, flows from the springs along the rivers. Five of these transects are proposed to be established below the confluence of the Wakulla and

St. Marks rivers to address the estuarine portion of the system. Cross sections at approximate half mile increments along each river will provide a relatively accurate flow model. LiDAR data will be used to supplement surveyed transects. Cross sections for the 20 floodplain transects will be extensions of the HEC-RAS cross sections; PHABSIM and instream habitat transects will be co-located with HEC-RAS cross section locations. Data needs for HEC-RAS are tied to elevation survey needs.

Cross section elevations are critical to development of an MFL as they provide the data needed for the HEC-RAS model, which is necessary to quantify the flows with respect to elevations or water surface elevations associated with selected WRVs. The HEC-RAS model will allow the District to establish the flows necessary for selected WRVs.

There are presently no surveyed elevation cross section data for the St. Marks River Rise, Wakulla or Sally Ward springs or spring runs. However, a HEC-RAS model, which provides the link between water level elevations along specific transect locations and flows at a gage, is considered critical for developing MFLs for the St. Marks River Rise, Wakulla, and Sally Ward system. For HEC-RAS modeling, large uniform rivers with gradual slopes require fewer surveyed cross-sections, while rivers with more variable morphology require more cross sections. In systems with variable morphology, the greater number needed to provide adequate precision for the hydraulic behavior of the channel, must be balanced with cost effectiveness (Cook 2008). Cook also reports (after (Samuels 1990), that cross sections "should be placed at model limits, either side of hydraulic structures, sites of importance to the client, and at all flow or water surface elevation measurements".

The minimum number is the six sets of PHABSIM cross sections, each set including a pool, riffle, and run corresponding to a shallow portion of the river. The transects are referenced to an arbitrary benchmark which is then surveyed for reference to NAVD88. This would provide fish habitat data for MFL development. The District's field work on the St. Marks River indicates four shoals, three of which are proposed to be included for the PHABSIM model. HEC-RAS cross sections are proposed to include the four shoals.

4.3 Collect and compile data for PHABSIM

Data required for PHABSIM include sample transects downstream of the St. Marks River Rise and Wakulla springs, with cross section channel elevations (completed for HEC-RAS model). Field sampling efforts will be made over a range of flows. Calibration of the hydraulic component of the model (IFG4) (Figure 8) requires measurements of mean water-column velocity, depth, and substrate or cover criteria for sets of transects located at hydrologically "typical" stream reaches. These values will be measured and recorded at low flows (when substrates can be best characterized), medium flows (only velocities and water surface elevations), and high flows (only water surface elevations).

IFG4 is the subroutine that predicts changes in velocity as a back-step through Manning's equation. Stage-Discharge relationships can come from real data or can be predicted from various subroutines. For each transect set, usually from a control (shoal or pinch in the channel) moving upstream, at least 20 measurements across each transect must be recorded. These measurements are tied to an arbitrary benchmark located at each transect set. Using a standard surveyor's level, measurements of channel profile are obtained at 20 segments within the wetted channel and continuing upland on both sides of the channel to a point determined to be above the average high-flow level. At each vertical, depth, mean water-column velocity, and substrate character are recorded.

Three transect sets on the St. Marks River, two transect sets on the Wakulla River, and one transect set downstream of Sally Ward Springs have been identified. Target organisms for evaluation will be identified after review of existing literature and field collection data. Existing habitat suitability curves will be incorporated for the identified organisms.

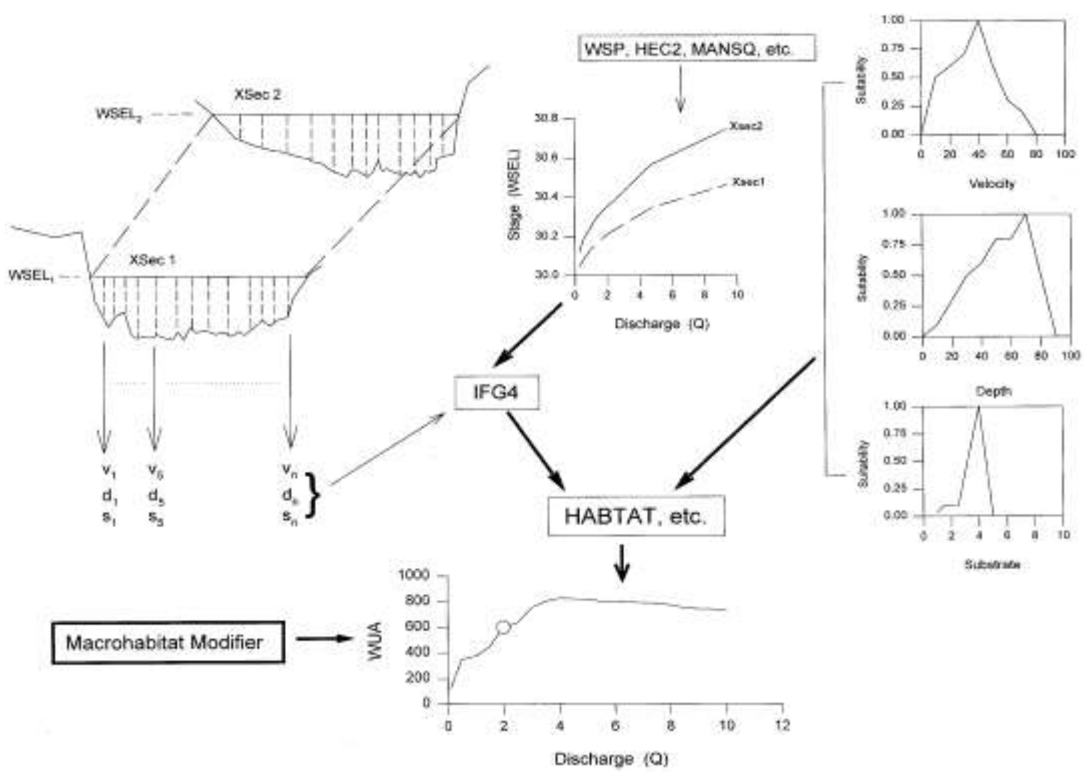


Figure 8. Schematic diagram of the Physical Habitat Simulation (PHABSIM).

4.4 Collect and compile data for floodplain habitat and floodplain – aquatic habitat connectivity analyses

Floodplain vegetation is one of the best and most easily measured integrator of environmental and historic site conditions. Sampling methods for this study are designed to provide data needed to characterize the wetlands and associated vegetation and soils along the river corridors. Vegetation classes, plant species metrics, soil characteristics, and elevations will be sampled and analyzed along a number of transects along the St. Marks and Wakulla rivers, downstream of the St. Marks River Rise, Wakulla, and Sally Ward springs.

Vegetation communities will be identified and selected based on general community type, species cover, elevation, and soils using map data and then used to select potential sampling transects. Final sampling transects will be selected based on field visits. Dominant tree species and their importance values are proposed to be used to characterize vegetation “classes” such as cypress swamp, hardwood swamp, and hydric hardwood hammock. The extent of each vegetation class will be mapped along transects and average ground level elevations for each community will be provided from elevation surveys.

4.4.1 Vegetation transects

The sampling transects selected along the St. Marks River Rise, Wakulla, and Sally Ward springs runs will reflect the floodplain vegetation classes, or communities, along each of the rivers. Data sources to be reviewed for developing the preliminary sampling transects will include, but not be limited to:

- FDEP land use or land cover data
- Vegetation communities based on National Wetlands Inventory (NWI) and Florida Gap analysis vegetation classification
- U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) soils classifications and Hydric Soils Groups
- United States Geological Survey (USGS) elevation or topography and water level gage locations
- Aerial photography
- Land use (re: alterations)
- Lower St. Marks River/Wakulla River/Apalachee Bay Resource Characterization (NWFWMD 2009)

Ten sampling transects downstream of the St. Marks River Rise and 10 downstream of Sally Ward and Wakulla springs (i.e. the rivers) are anticipated, although final transects will depend on field verification, access, and other possible constraints. Vegetation sampling transects will be co-located with HEC-RAS cross sections downstream of the springs and will extend into the floodplain, perpendicular to the channel, to the landward extent of the floodplain wetlands Density, frequency, basal area data will be collected using the point-centered-quarter (PCQ) method of vegetation sampling along transects. Connectivity between aquatic and floodplain habitats, important for fish access and detrital transport for example, will be included in the floodplain surveys. Connections such as backwater sloughs or creeks that allow direct water exchange between the floodplain and spring runs will be identified, located with respect to floodplain transects, and surveyed for elevations.

Along the estuarine reaches of the river characterized by herbaceous marsh, linear extent of vegetation community, e.g. *Juncus roemerianus* (black rush), along the channel will be recorded and combined with aerial photography to document the upstream-downstream extent of plant communities.

4.4.2 Data collection protocols and verification

Data collection protocols (QA) and verification (QC) by qualified personnel will be implemented to ensure data are accurate and meet the needs of the overall project (i.e. to support the establishment of MFLs). QA/QC actions will be implemented for sampling along the river corridor transects.

4.4.3 Soils

Hydric and nonhydric determinations and seasonal high saturation (SHS) determinations are proposed to support MFL development for the rivers. SHS is the highest depth below the surface where water is expected to remain for a period of approximately 30 or more days during the wettest part of years with normal annual and wet season precipitation, with possible flooding (Hurt et al. 2000). Soil cores will be exhumed to a minimum depth of 50 cm (20 inches) using a soil probe and examined for each sampling point along each transect, with three samples per vegetation community. The presence of hydric or flooding indicators, saturation or inundation, and depth to seasonal high water, will be recorded and included in the characterization of vegetation communities and soils with respect to elevation.

4.5 Collect and compile data for snag instream habitat analyses

Instream habitat modeling is proposed to be completed using the HEC-RAS model, given mean elevations of, for example, woody snag and root habitats along the water body. Instream habitats, which are influenced by variations in flow conditions, will be examined as a result of their productivity and importance to instream fauna. Among the various instream habitats that can be influenced by different flow conditions, woody habitats (snags and exposed roots) are especially important. For each instream habitat cross-section, elevations (feet NAVD88) and linear extent (along the cross-section) will be measured for the following habitat features listed below. Mean elevations will be used to develop criteria for instream habitat.

- Bottom substrates (which included sand, mud, or bedrock)
- Exposed roots
- Snags or deadwood
- Submersed aquatic vegetation
- Emergent aquatic vegetation

Sampling for the instream habitat will be co-located with PHABSIM sample transects. Elevations of exposed root and snag habitat will be recorded between the center transect and the upstream transect of the PHABSIM transects. The elevations will be considered representative of the vertical distribution of woody habitats in the sampling area. The upper and lower vertical extent of the habitat will be tied to a reference point for establishing elevations relative to NAVD88.

4.6 Collect and compile salinity and temperature data for estuarine (EFDC) model

Estuarine modeling will require additional dataloggers for salinity and temperature. Two of the dataloggers will be combined with the existing USGS real-time flow stations that provide stage data. The addition of instrumentation to the existing USGS station will be evaluated. Data from longitudinal salinity, temperature, and dissolved oxygen (STD) water column profile transects over a several day period are required for the hydrodynamic model. An evaluation of available DO data will be completed to establish whether DO modeling is necessary.

4.7 Collect and compile data for manatee thermal refuge model

As part of the model development process, it is necessary to first determine the critical conditions for manatee, i.e. conditions during which the coldest conditions would make use of the springs as thermal refugia most likely. Available air and water temperature records will be evaluated to identify these conditions. Temperature data, together with estimates of the volume of thermal refuge and the potential effects of changes in spring flow on manatee habitat, may be assessed to determine the necessity of performing thermal modeling for Wakulla Springs. If needed, a two-month period for the temporal domain of the model will be selected. Also necessary to the model development are several types of information for the springs and spring runs, as follows:

- Spring discharges
- Bathymetry
- Water surface elevations
- Water temperature data

Spring discharge estimates are already available for Wakulla Spring. Data collection for the remainder of these characteristics will be required at a sufficiently high spatial resolution to allow accurate simulation of the systems.

- For the bathymetric data needed, transects may be taken in the springs and spring runs extending from the springs downstream. The distance downstream and spacing (for example, 2 km downstream, with transects every 200-400 meters) will be determined at a later date based on a review of available information.
- Continuous records of water surface elevations and water temperature data are necessary both in the springs and spring runs. An example spacing could be intervals of 0.5 km downstream for 2 km, so that five continuous monitoring sites will be sampled.
- Every other week (four sampling periods) during the identified two-month critical period, longitudinal water temperature transects will be collected from the spring head to the downstream location.

Thermal modeling will require depth and temperature data at numerous locations downstream of Wakulla Spring. Temperature transects, for four days, twenty thermographs, and three water level recorders (Solinst type) are proposed to be deployed for approximately two weeks near the springs. The continuous recorder water elevation and temperature information and the longitudinal transect water temperature information will be used for hydrodynamic model calibration. Prior to using these data, the work effort will include data analysis and quality control to ensure the data are reasonable and appropriate for use in the model development and calibration.

5. PERFORM DATA ANALYSIS AND MODEL DEVELOPMENT: FLOWS AND LEVELS ASSOCIATED WITH WRVS

Appropriate models will be used to evaluate or predict the effects of flow reduction scenarios on selected WRVs in the development of MFLs for the St. Marks River Rise, Sally Ward and Wakulla springs.

Task 5 *Develop and apply appropriate models and statistical analyses to link water level elevations of selected WRVs to spring flows.*

Task 5.1 Develop HEC-RAS model
Task 5.1.1 Developing MFLs
Task 5.1.2 Target elevations and flows
Task 5.2 Develop PHABSIM model
Task 5.3 Develop relationships among elevation and floodplain habitat and floodplain – aquatic connectivity, as appropriate
Task 5.4 Evaluate snag and instream habitat
Task 5.5 Develop groundwater model
Task 5.5.1 Perform a groundwater data review and evaluation to develop estimates of recharge to the Upper Floridan aquifer in support of an analytical water budget
Task 5.5.2 Develop conceptual groundwater model
Task 5.5.3 Develop mathematical and numerical groundwater modeling approach
Task 5.5.4 Modeling of Lost Creek/Wakulla Springs/Spring Creek complex
Task 5.5.5 Modeling recharge
Task 5.5.6 Input data preparation
Task 5.5.7 Perform model calibration and sensitivity analysis
Task 5.5.8 Run predictive model simulations
Task 5.6 Develop EFDC estuary model
Task 5.7 Assess need for, and develop if appropriate, thermal model for Wakulla Springs
Task 5.8 Meet with District to discuss results of analyses and models

Models anticipated for use in developing the MFLs for the District are listed below and briefly defined. A summary table of the proposed models and corresponding purposes, applications, data needs, and outputs, as they pertain to this work plan, is provided in Table 3.

- Hydrologic Engineering Centers River Analysis System (HEC-RAS) model developed by the USACE is proposed to be used to produce spatially explicit representations of hydraulic habitat over a range of flows.
- Physical Habitat Simulation (PHABSIM), or similar model, will be used to correlate open channel hydraulics with measured elements of fish or macroinvertebrate behavior. Time-series (natural,

historic, predicted flow records) and flow characteristics (magnitude and timing) is proposed to be used to address calibration and verification of habitat models via hydrographic series analyses.

- Environmental Fluid Dynamics Code (EFDC) hydrodynamic model is proposed to be used for evaluating salinity and temperature distributions, and if considered appropriate, dissolved oxygen (DO), in the estuarine reaches of the system and thermal habitat for manatee for Wakulla Springs.
- A groundwater model will be developed to simulate both laminar flow within the matrix, turbulent flow within karst fractures and conduits, and the coupling of these two domains with each other and with surface discharges (springs and rivers), for example, MODFLOW (with conduit flow or connected linear networks) or FEFLOW software packages.

Table 3. Summary of models, anticipated applications and corresponding WRVs

Purpose	WRV Addressed	Application	Data Needs/Requirements	Field Data Needed	Model Output
MODEL: Integrated surface and groundwater model (e.g. MODFLOW, FEFLOW)					
Will be used to estimate groundwater discharged to surface watercourses under varying conditions of rainfall and groundwater withdrawals	Aesthetic and scenic attributes - clear water days	Generate benchmark flows and altered flow regime due to groundwater withdrawals Generate boundary conditions and inputs for HEC-RAS Evaluate relationship between water clarity and spring flows Evaluate need for recovery or prevention strategy	Rainfall and recharge, stage, discharge Water clarity, groundwater elevations, land use or land cover, Hydrography, topography, Hydrostratigraphy, conduit alignments, geometry, flow velocities Consumptive use data	Rainfall Stage discharge Hydrostratigraphy Aquifer parameters Groundwater elevations	Groundwater volume (discharge) to surface waters (e.g. baseflow) Groundwater levels
MODEL: PHABSIM					
Quantify changes in available habitat for select fish species, fish guilds or macroinvertebrates	Fish and wildlife habitat	Assess within bank flows	Habitat Suitability Criteria (HSC)for selected organisms	Transect information, including water depth, velocity, substrate, cover under varying flow conditions	Habitat as measured by Weighted Usable Area (WUA)
MODEL: HEC-RAS					
Relate changes in instream and out of bank flows to quantifiable changes in various metrics	Fish passage	Sufficient water depth over shoals	Surface water levels and flows	Water depth needed for fish passage	
	Wildlife passage (manatee)	Sufficient water depth over shoals seasonally	Surface water levels and flows over shoals,	Water depth and temperature at and downstream of springs	Flows at gage locations that correspond to flows and levels at measured transect locations and at measured WRVs.
	Recreation: boat passage	Sufficient water depth in channel	Surface water levels and flows	Water depth required for boat access	
	Navigation: commercial barge traffic	Sufficient water depth in channel in select river sections		Water depth needed for barge access to power facility	
	Fish and wildlife habitat	Sufficient instream flows and water elevations for inundation of snags and exposed roots	Surface water levels and flows	Surveyed mean elevations of snags and exposed roots in select stream reaches	
		Sufficient recurrence of bankfull and overbank flows with sufficient recurrence interval for channel maintenance	Surface water levels and flows	Surveyed bankfull elevations	
	Maintenance of freshwater storage and supply	Sufficient flows or levels to connect aquatic and floodplain habitat	Surface water levels and flows, areal extent of habitat types	Surveyed elevations connecting various floodplain and instream habitats (sloughs)	
	Sediment loads	Addressed under connected floodplain habitat	Addressed under other WRVs	Elevations and area of connected sloughs and floodplain wetlands	
	Transfer of detrital material		Addressed under other WRVs		
	Filtration and absorption of nutrient and other pollutants		Addressed under other WRVs		
MODEL: Hydrodynamic for estuarine portions of the Wakulla and St. Marks rivers, e.g. EFDC					
Quantify changes in thermal area or volume used by manatee as seasonal refugia	Wildlife habitat: manatees	Quantifies three-dimensional velocities, surface elevation, vertical viscosity and diffusivity, temperature, salinity, and density.	Bathymetry, flow and temperature data throughout reaches during manatee season	Bathymetry, flow and temperature data, stage discharge data	Volume of water of appropriate temperature
Quantify changes in salinity zones within estuarine areas	Estuarine resources		Bathymetry, salinity, tide, wind speed and direction, etc.	Bathymetry, stage discharge data, salinity, tide, wind speed and direction	Volumes of water, bottom area and shoreline length exposed to various salinities
	Water Quality: salinity				

5.1 Develop and calibrate HEC-RAS model

A HEC-RAS model will be developed and used to establish the relationship between flows and surface water elevations that will be used to quantify changes in habitat availability under various flow scenarios. The model will be used to predict surface water elevations based on the relationship between flows at long term gaging stations to water elevations of specific selected WRVs at surveyed channel cross sections. For example, flows associated with surface water elevations (and therefore water depth) that provide fish passage across a shoal, connect river channel and floodplain habitats, or provide adequate depth for recreational boat use. We anticipate using HEC-RAS results to address the following WRVs:

- Recreation in and on the water: sufficient depth for recreational boating and others, if appropriate
- Fish and wildlife habitat and fish passage: floodplain and instream habitat, fish passage, manatee use

HEC-RAS is a one-dimensional steady state model, intended for hydraulic analysis of river channels, in which the stream morphology is represented by a series of cross-sections. The model is a well-established means of defining the change in water levels based on flow across sections of a channel. The HEC-RAS 4 model supports water surface profile calculations for steady and unsteady flows. Given the flow and water surface elevation at one cross-section, the water surface elevation at the adjacent cross-section is predicted.

Calculations are based on energy losses between two neighboring cross-sections (USACE 2002) and simulations require channel geometry and steady-flow connectivity data for the river system, reach length, energy loss coefficients due to friction and channel contraction or expansion, stream junction information, and hydraulic structure data, including information for bridges and culverts.

HEC-RAS models can be used in the development of minimum spring flows for fish passage if maintaining access along a river corridor is considered consistent with historic (unimpacted) conditions. Depth of water, for example, 0.6-foot, was developed as a fish-passage criterion for a low flow threshold by the SWFWMD for several rivers [(upper Peace (SWFWMD 2002), Alafia (Kelly et al. 2005a), middle Peace (Kelly et al. 2005b) and Myakka (Kelly et. al. 2005c)].

5.1.1 Developing MFLs

Survey of elevations for 25 instream channel cross sections and reference to NAVD88 are proposed (section 4.0) in support of the HEC-RAS model. Geometry from the elevation surveys of the main river channels will be supplemented by Light Detection and Ranging (LiDAR) data from the District to extend model cross sections into overbank areas where necessary. USGS and District gages to be used were described in section 4.0 also. The HEC-RAS model will be used to predict flows necessary to inundate specific floodplain and instream elevations. This work plan assumes:

- Cross section data will be surveyed, collected, compiled, and made available with common datum for reference. An estimated 25 cross sections are anticipated along the St. Marks River (downstream of St. Marks River Rise), the Wakulla River (downstream of Wakulla Springs), and upstream of Wakulla Springs to Sally Ward Spring
- USGS and proposed new monitoring station data will be available
- Bridges not included in model will not affect low flow levels

The HEC-RAS model will be developed and applied for several flow scenarios targeting specific water levels associated with selected WRVs, e.g. fish passage, wetted perimeter, and connected aquatic and floodplain habitats, bankfull flows, and navigation. Modeling results will be documented and used to interpret impacts of reduced spring flows on selected WRVs. The consultant team will:

- Integrate data from approximately 25 surveyed cross sections into the HEC-RAS model
- Calibrate the model with available gage data
- Export and merge surveyed bathymetric data, topographic information, LIDAR data, into GIS to generate model cross sections that extend above water stage elevations relevant to the study
- Run model iterations and determine flows for stage elevations associated with selected WRVs
- Prepare a technical memorandum that documents all model assumptions and model conclusions
- Provide the HEC-RAS model development and calibration report, in an Appendix to the draft MFL report

5.1.2 Target elevations and flows

Estimated flows and water surface elevations at select cross sections will allow predictions of inundation of selected WRVs and changes in inundation periods predicted as a result of changes in flows. For example, changes in the inundation frequency or extent (in acres) of aquatic floodplain habitat connections can be evaluated by comparing the annual number of days a specific water surface elevation is reached under different flow reduction scenarios against the benchmark condition. Modeled flows will be incrementally reduced until a pre-determined “allowable” habitat reduction is exceeded.

5.2 Develop PHABSIM model

Linked models tie open channel hydraulics with measured elements of fish or macroinvertebrate behavior, thereby addressing the components necessary for an MFL (as described in section 1.2 after Stalnaker et al. 1995). The most widely used example of this model is the Physical Habitat Simulation (PHABSIM) (Bovee 1982, Nestler et al. 1989). PHABSIM is the model most frequently used within the procedure called the Instream Flow Incremental Methodology (IFIM); other similar models will be evaluated to determine the most suitable model for this system.

Habitat suitability is treated as both macrohabitat and microhabitat in IFIM. Macrohabitat suitability is predicted by measurement or simulation of changes in water quality, channel morphology, temperature, and discharge along the length of the managed reach, which can strongly influence conditions at the microhabitat level. Microhabitat suitability consists of individual species' preferences for these same criteria, reflected as depth, velocity, substrate or channel condition, and cover. Those individual preferences are incorporated into PHABSIM to obtain predictions of changes in available habitat at selected stream segments "typical" of the reach being evaluated. In combination, microhabitat and macrohabitat provide the information necessary to adequately evaluate mangement alternatives.

Through a series of subroutine programs in PHABSIM, a prediction of the amount of available habitat (as weighted usable area, WUA) for a target organism over a range of discharges is created. HABTAT and its associate programs require hydrologic information in the form of transect (cell-by-cell) information on depth, velocity, cover value or substrate composition) and biological information in the form of preferences or suitabilities for these conditions by the target organism. Decisions can be made as to what percentage of the time a selected flow is met or exceeded during an average hydrographic and during unusually wet or dry years using the Habitat Time Series (HTS) component of IFIM (Milhous et al. 1990). Such conditions as median habitat value over 10 or 20 years of record, the percent of available habitat if certain magnitudes of flood were attenuated or enhanced, and the duration of low habitat conditions are typical predictions of a HTS evaluation. As previously mentioned, the benchmark period must be carefully identified as the most representative hydrograph under the least impaired conditions. Recently, for example, Kelly and Gore (2008) have reported the effects of changes in the Atlantic multi-decadall Oscillation (AMO) on regional weather paterns in the southeastern United States and have suggested that two benchmarks be analyzed; a wet-weather period and a dry-weather period.

Habitat suitability information can come from a variety of sources. Most frequently, resource managers use published suitability curve information (the so-called "Blue Book" series published by the U.S. Fish and Wildlife Service; see Aho and Terrell 1986, for example). Habitat suitability among fish species is most often generated for spawning, incubation, fry, juveniles and adult stages.

Although dynamic flow models can predict the different changes in depth and velocity during the rise and fall of "flood" events (hydro-peaking generation, for example), the typical application of PHABSIM models assumes a relatively steady state condition. In their current form, these models are not able to predict changes in channel geometry or condition. Thus, the impacts of extremely high flow events (channel-shaping floods, for example) cannot be examined directly, and after such events, transects must be re-measured to reflect the accompanying changes in channel shape and form. Finally, accuracy and precision are critical components of all modeling systems.

PHABSIM and similar models have been successfully employed in a variety of locations to create adequate management strategies under conditions of new regulated discharges. The United States Supreme Court has determined that the IFIM procedure is valid and an applicable management tool for negotiating water reservations (Gore 1989, Stalnaker et al. 1995). The current model is sufficiently robust to provide guidance on the restoration of lotic ecosystems (Shuler and Nehring 1993) and on management of introduced and endangered species (Gore et al. 1991, 1992). The predictions of linked models may be revisited and revised as Richter et al. (1996) suggested for building-block models, as new hydrological and biological information becomes available. The ultimate product of the habitat analysis (through PHABSIM and time-series analysis, using TSLIB) will be an estimate of habitat gain or loss associated with a suite of flow reduction alternatives.

5.3 Develop relationships among elevation and floodplain habitat and floodplain – aquatic connectivity elevations

Relationships among vegetation, soils, and elevations along spring runs will be used to develop the floodplain vegetation and hydric soils WRVs for developing MFLs. Vegetation data will be used to characterize the plant communities and develop a potential WRV for floodplain connectivity. Density, basal area, and Importance Values (IVs) will be calculated for each tree species, by transect and vegetation class. Vegetation will be identified as to hydric status and graphed to indicate general community patterns. For example, as shown in Figure 9 obligate and facultative wetland species can be color-coded to demonstrate the shift in species from wetlands to uplands (Atkins 2012). Relationships between vegetation classes and corresponding environmental parameters are proposed to be examined for this study to ascertain potential differences in:

- Species composition and dominance between or among vegetation classes
- Elevation, soils, and distance from channel between or among vegetation classes

Appropriate statistical analyses will be used to evaluate relationships among vegetation, soils, and elevations. Vegetation classes are typically small in number and nonparametric statistics may be applied to compare species dominance between vegetation classes or differences in species IV between individual communities, for example differences in species dominance between willow marsh and hardwood swamp vegetation classes.

The sample size for comparisons of elevation and soils among vegetation classes is typically larger and a parametric discriminant function analysis (DFA) may be applied to quantify the contribution of elevation and soils (and distance from river channel) in defining vegetation classes, based on relationships between environmental variables and species composition and dominance along sampling transects.

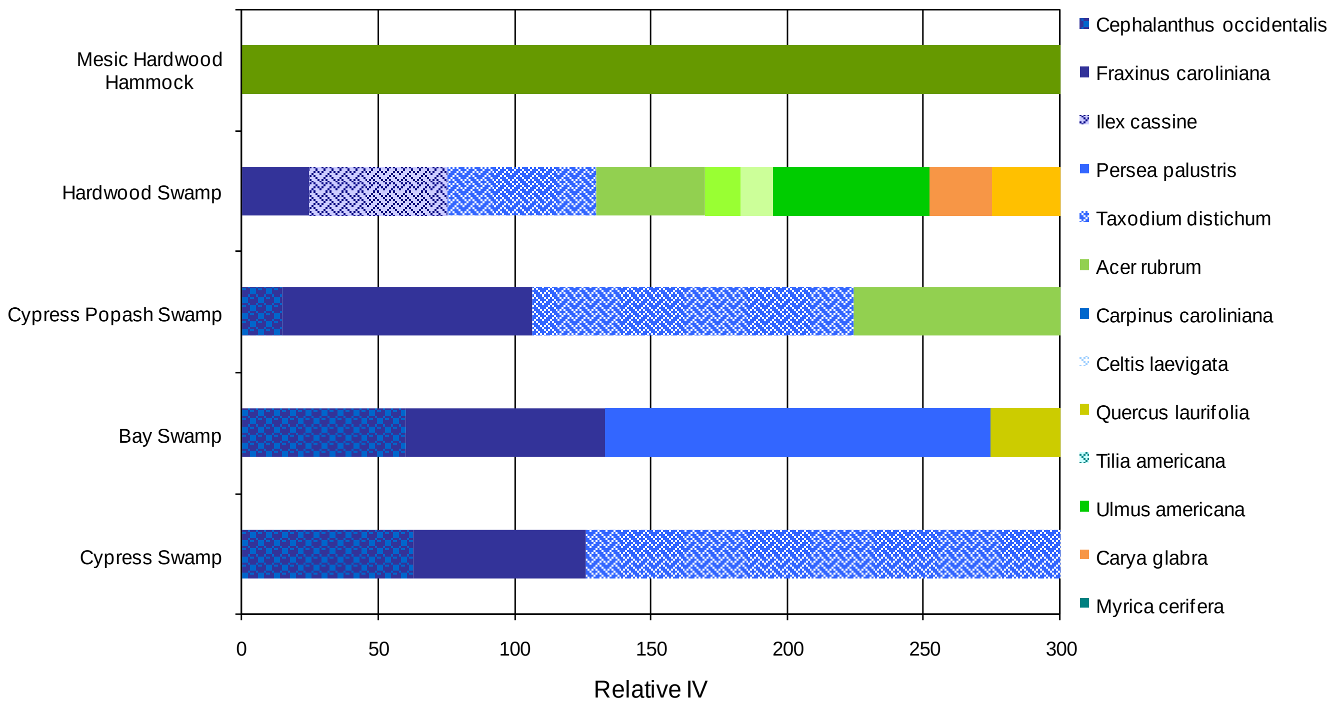


Figure 9. Tree species Importance Values (IV) in vegetation classes along the Ichetucknee River study corridor (Atkins 2012)

These relationships will confirm the extent and type of riverine wetlands and characterize wetlands with respect to elevation. HEC-RAS results will be used to predict the water surface elevations needed to connect the river channel to the "wettest" vegetation communities at the lowest elevations (e.g. cypress-tupelo swamps), as well as communities at higher elevations that are inundated only during seasonally high flows (e.g. hardwood wetlands).

Aquatic and floodplain connectivity may be evaluated by combining elevation surveys with LiDAR data and digital elevation models (DEMs) and used (in GIS) to evaluate the extent (in acres) of floodplain habitat connected to aquatic habitat under different flows and the change in areal extent of habitat (acres) under various flows. Acres of habitat loss anticipated under specific flow reductions can provide a means of quantifying habitat loss and making recommendations based on that loss. The steps of identifying flows, flow-habitat relationships (from Light et al. 1998), and flow-based habitat impacts (for the St. Marks River Rise and for the Sally Ward and Wakulla springs complex) are listed below:

- Identify low, medium, and high seasonal flow periods, based on evaluation of long-term hydrographs, to determine if seasonal flow blocks are appropriate (described earlier)
- Develop relationships for acres of habitat inundated under various flow regimes by combining LiDAR (to determine elevations of habitats) with HEC-RAS results that provide the flows

necessary to inundate the target elevation, and using GIS to quantify the areal extent of target habitats
- Calculate acres of inundated habitat under each flow over period of record, for high, medium, and low flow periods for the benchmark data
- Compare acres of habitat under benchmark, flow reduction scenarios, and current conditions flows to quantify change in extent of aquatic and floodplain habitats.
- Calculate loss of habitat from the benchmark under increasing flow reductions to quantify the flow reduction that corresponds to a given percent loss (e.g. 5, 10, 15, 20, 25 percent) of aquatic and floodplain habitat
- Identify differences between the acres of available habitat under benchmark conditions and acres of habitat under a given percent loss scenario

If the flows needed to connect aquatic and floodplain habitat (via HEC-RAS) can be calculated, the acres of floodplain habitat inundated under current and benchmark flows can be calculated and a recommendation for acres of connected habitat can be developed.

5.4 Evaluate snag and instream habitat

Inundation of woody habitats including snags and exposed roots in the stream channel will be evaluated against multiple iterations of the HEC-RAS model using measured (mean) elevations of snags and exposed roots in select stream reaches. The model will also be used to generate graphs of wetted perimeter versus flow for HEC-RAS cross-sections below the St. Marks River Rise and Wakulla and Sally Ward springs. Wetted perimeter graphs, which represent changes in wetted perimeter (inundated transects across the stream) in response to incremental changes in discharge, typically exhibit inflection points that correspond to the point at which small flow reductions result in much greater reductions in wetted perimeter. The inflection point on the curve represents a flow at which the water surface recedes from stream banks and fish habitat is lost at an accelerated rate. These inflection points can be used to develop a wetted perimeter criterion at any transect location.

Mean elevations of snag and exposed root habitats will be calculated for the PHABSIM transects with which instream habitat sampling will be co-located. Flows at the upstream gage needed to inundate the mean snag and exposed root elevations at each cross-section will be determined using the HEC-RAS model. The number of days over the period of record during which the (mean elevations of) the snag and root habitat were inundated will be calculated and the percent-of-flow reductions that would result in no more than the selected percent reduction in number of days of inundation will be determined.

5.5 Develop and calibrate the groundwater model

The primary objective of the groundwater modeling component presented in this work plan is to develop a groundwater model that simulates changes in spring flows in response to rainfall and consumptive use withdrawals within the groundwater contribution zones of the St. Marks River Rise, Wakulla, and Sally Ward springs system. The changes in spring flows (and corresponding surface water levels) will be evaluated with respect to potential impacts to selected WRVs and are critical to the development of MFLs for the system. Available information for the system is limited, however, and we anticipate adapting and refining our model approach, in consultation with the District, as preliminary analysis and model results provide a better understanding of the system, which may in turn call for additional changes to model assumptions, objectives, or approaches.

The spring flows in Wakulla Springs, Sally Ward Springs, and St. Marks River Rise are the dominant components of river flows in both the Wakulla River and in the St. Marks River downstream of the rise. Local runoff to these river segments are believed to be very small compared to spring flows under the majority of hydrologic conditions. Simulated spring flows from the groundwater model are proposed to serve as upstream boundary flows for the river hydraulic models. The resulting relationships between stage, discharge, depth, and area of inundation will be used to address the WRVs related primarily to fish and wildlife habitat and recreation in and on the water. The groundwater model may be used to develop benchmark spring flows that exclude groundwater withdrawal impacts.

Water clarity in the main pool of Wakulla Springs has been identified as an aesthetic WRV that seems to be related to environmental flows. Dark (tea-colored) water is frequently evident in the spring basin, which limits the number of days when the state park's glass-bottom boats can operate. The periods of dark water in Wakulla Springs are variable and appear to be the result of natural processes. The dark water probably results from tannic surface waters (stained brown in color from percolating through organic matter) being carried to the aquifer by surface runoff following rainfall (Loper et. al. 2005). The number of "dark water days" in Wakulla Springs has reportedly increased in recent years. A potential goal of this MFL study will be to investigate the mechanisms influencing the occurrence of dark water in the springs basin, evaluate the interrelationships between flow at Wakulla Spring and Spring Creek, and using the best available data, to determine the relationship between water clarity and flows at Wakulla Spring. Although no water quality modeling is anticipated as part of this Task, a well-formulated integrated water quantity model may provide some insights into this issue.

5.5.1 Data review and interpretation

Initial data gathering efforts were documented in the previously completed Task 1 Data Inventory, Sampling and Model Recommendations Report. In the proposed Work Plan, these efforts will be expanded to include additional data gathering and a review and interpretation of the data. The following data will be reviewed and evaluated for potential incorporation in the modeling effort:

- Measured rainfall (point rain gage measurements and NEXRAD data)
- Measured spring and river discharges
- Measured flow velocities in the Wakulla Springs conduit complex (see note below)
- Information on water clarity in Wakulla Springs Basin from the State Park
- Groundwater level observations
- Topography
- Land use or land cover, and soils
- Hydrography

- Lithology and hydrostratigraphic mapping
- Cave surveys
- Data from dye tracing studies
- Consumptive use data (groundwater extractions)
- Aquifer performance testing data
- Previous model datasets (USGS Hal Davis MODFLOW)

Wakulla Springs is fed by an array of karst conduits. These conduits were originally instrumented with meters by a consortium consisting of Florida State University (FSU), the Wakulla Karst Plain Project (WKPP), and others and funded by the Florida Geological Survey (FGS). Currently, flow velocity is measured in conduits B, C, D, A/D, A/K, and K (refer to Figure 10). Other variables monitored at these locations include stage, electrical conductivity, and temperature. There are concerns regarding the QA/QC status of the pre-2013 data. For example, there appear to be cumulative errors in the water level data at some of the locations that may or may not be possible to correct. The consultant team may review this data to determine which datasets are reliable enough to use in our modeling efforts 'as-is' and which datasets must be corrected or discarded. Beginning in 2013, improved QA/QC measures were implemented and newer conduit data collected by the FGS is anticipated to be more reliable.

Total discharge from the conduits, through the main vent, and into the Wakulla River, is measured at the NWFWMD velocity gage in the main vent and at the USGS gage at Shadeville Road. Although the cross sectional areas of the contributing conduits at the meter locations have been estimated from field measurements, the relationship between velocity and discharge within the conduits is uncertain due to variability of the velocity profiles.

It has been reported that at any point in time, the velocities can vary both in magnitude and direction throughout the cross section of the conduits (Kris Barrios, NWFWMD, pers. comm.). In this task, efforts will be made to develop a mathematical solution to relate the velocities of the individual conduits to the discharge through the main vent.

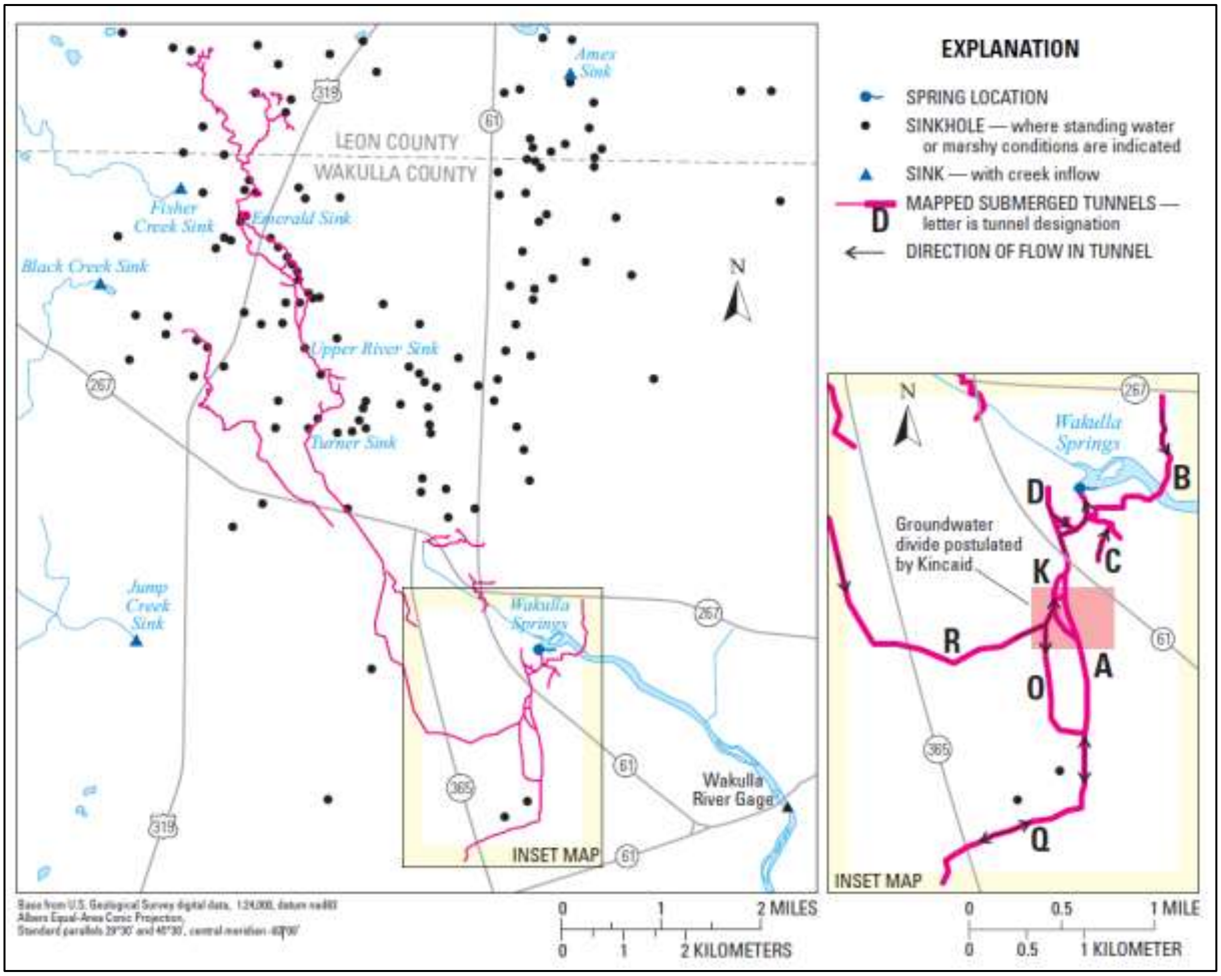


Figure 10. Wakulla Springs cave system (from Davis et al. 2010).

5.5.2 Conceptual and analytical modeling

Using information from our review and analysis of available data and building on previous investigations, conceptual and analytical modeling are proposed to include the tasks listed below.

- Verify and refine (if necessary) surface water and groundwater contribution zones previously developed by the District
- Define model domain and boundary conditions
- Develop analytical water budgets for the groundwater and surface water contribution zones. The water budgets may have to be restricted to low-to-medium flows due to the possible existence of unmapped relic submerged springs offshore, which become active during periods of extremely high rainfall.
- Characterize, to the extent practical, the relative contributions to discharge at Wakulla Springs and the St. Marks River Rise from the following sources:
    - Direct surface runoff
    - Floridan Aquifer groundwater

  - Indirect surface runoff from sinking streams (swallets)
  - Spatially distributed recharge, including sprayfields
- Develop hydrostratigraphic data layers using geologic data developed by the FGS, the District, and published reports. This task is anticipated to require a thorough review, merging, and analysis of the following datasets:
  - Florida Aquifer Vulnerability Assessment (FAVA-1) prepared by the FGS. Many of the wells in this dataset are not properly located. Some locations are represented as the centroid of the section in which it is located rather than the true geographic coordinates.
  - Leon County Aquifer Vulnerability Assessment (LAVA), which is available on Leon County's website. http://www.adgeo.net/lava.php
  - FGS geodatabase. The FGS database may contain additional data points not used in the FAVA-1 analysis. Many of the wells in this dataset are not properly located. It is anticipated that the District will work with the FGS to verify and correct this data.
  - NWFWMD data
  - USGS data. The USGS has compiled hydrogeologic data as part of the Floridan Aquifer System Groundwater Availability Study. http://fl.water.usgs.gov/FASWAM/
- Interflow will collaborate with NWFWMD in compiling data and interpreting hydrostratiographic units. Interflow will conceptualize model layers from information provided by NWFWMD. As a part of this effort Interflow will compile data available for Georgia or other Districts and provide to NWFWMD. If requested by the District, a technical memorandum will be prepared to describe the conceptual model.

Development of an analytical water budget will require initial estimates of average annual recharge to the Upper Floridan aquifer based on analysis of readily available data. These estimates must consider rainfall, evapotranspiration, streamflow, deep percolation, and point recharge from sinking streams (swallets). Measured rainfall and streamflow data will be used initially in conjunction with estimates of evapotranspiration and deep percolation from literature and previous investigations. These estimates will be refined spatially and temporally in the numerical modeling analysis phase. For the sinking streams in the groundwater contribution zones, streamflow records are available for the larger streams (Fisher Creek, Lost Creek, and Munson Slough) but over relatively short time periods. In this approach, the streamflow records could be artificially extended in time using regressions with nearby long-term gages. Efforts will be made to estimate diffuse recharge using statistically or analytically-derived relationships between rainfall and groundwater levels.

5.5.3 Mathematical and numerical modeling approach

In this task, a numerical modeling tool will be selected that can represent the important processes described in the conceptual model, and provide a platform for addressing the modeling objectives. As indicated in the Task 1 Data Inventory, Sampling and Model Recommendations Report, the groundwater software package must have the ability to simulate both laminar flow within the matrix, turbulent flow within karst fractures and conduits, and the coupling of these two domains with each other and with surface discharges (springs and rivers). Examples of such modeling packages include MODFLOW with the Conduit Flow Process (CFP) package (see http://water.usgs.gov/ogw/cfp/cfp.htm), FEFLOW with Discrete Feature Elements (see http://www.feflow.info/fracture.html), and MODFLOW Unstructured Grid (USG) with the Connected Linear Network (CLN) Process (see http://water.usgs.gov/ogw/mfusg/). FEFLOW and MODFLOW USG both offer a flexible mesh approach to discretizing the model domain. This provides an advantage over the traditional MODFLOW rectilinear grid, as a flexible mesh is more conducive to representing high levels of detail where necessary (e.g. near wells, spring vents, and other locations where steep gradients in the potentiometric surface are expected), and lower resolution where detailed results are not needed.

Considering the physical connection between Spring Creek and Wakulla Springs (Davis et. al. 2010), and the dependence of flow direction on salinity levels within the conduit system, the model must account for the dynamic effects of salinity within the karst conduits near Spring Creek, and the effects of sea level rise. Rather than implementing a code that explicitly models variable density groundwater flow (such as SEAWAT), we propose to account for the effects of salinity using an equivalent freshwater head approach.

5.5.4 Modeling Lost Creek/Wakulla Springs/Spring Creek system

In addition to the MODFLOW or FEFLOW model of the entire combined Wakulla Springs/St. Marks River contribution zone, a Karst Flow Model (KFM) simulation of the Lost Creek, Wakulla Springs, and Spring Creek system should also be considered. KFM is a mathematical model of flow in a karst aquifer capable of predicting the time history of discharge from a karst aquifer, given the recharge history within the groundwater recharge area and the time history of the head at the spring (Loper and Chicken, 2011). One of the advantages of KFM is that it is possible to obtain a very good model calibration even when the locations of the karst conduits are unknown. More information about KFM can be found via the following link: http://stat.fsu.edu/techreports/M1010.pdf.

The KFM model could serve as an inset model to supplement the more regional MODFLOW or FEFLOW analysis. This approach would have the potential to provide additional information about the behavior of the unique and largely unmapped Lost Creek/Spring Creek/Wakulla Springs conduit system on a short time scale. Specifically, the KFM analysis could provide a set of optimized hydraulic parameters for the conduit system connecting the Lost Creek swallet to Spring Creek and Wakulla Springs. These hydraulic parameters would then be input into the MODFLOW or FEFLOW model.

5.5.5 Modeling recharge

Spring discharges in Wakulla Springs have been shown to be highly responsive to rainfall events due to the well-developed network of karst conduits in the study area. Development of model time series of recharge to the Upper Floridan aquifer must consider rainfall, evapotranspiration, streamflow, deep percolation, and point recharge from swallets on a daily or sub-daily time scale. Although it may be possible to generate these time series using analytical methods, it is anticipated that some form of coupled or integrated groundwater and surface water modeling may be required. The surface water routines must be capable of simulating spatially distributed rainfall and runoff processes on a short time scale. In the model code selection task, potential approaches to simulating recharge will be evaluated. Three potential approaches (out of several) are discussed briefly below.

- Develop recharge data sets using analytical methods. For the sinking streams in the groundwater contribution zones, streamflow records are available for the larger streams (Fisher Creek, Lost Creek, and Munson Slough) but over relatively short time periods. These datasets would be augmented and extended (e.g. to Black Creek) with the additional stream gaging recommended in this work plan. In this approach, the streamflow records would be artificially extended in time using regressions with nearby long-term gages. Diffuse recharge would be estimated using statistically-derived relationships between rainfall and groundwater levels developed in the conceptual and analytical modeling task. However, it is unknown at this time whether or not these statistical relationships will be acceptable for modeling purposes.
- Surface water flows for sinking streams could be estimated using long-term rainfall records as input to a simple runoff-coefficient approach, similar to the EPA SIMPLE method for estimating long-term continuous hydrologic flows for pollutant loading calculations. The runoff coefficients will be varied based on land use and possibly by season in an effort to calibrate the runoff model to measured flows.
- Apply a Green-Ampt infiltration method (or equivalent) and the MODFLOW-2005 Unsaturated-Zone Flow, Lake, and Streamflow-Routing Packages, similar to the approach used in the Central Florida Water Initiative's East Central Florida Transient (ECFT) model (Sepulveda et. al., 2012). However, that approach has been criticized for using the Green-Ampt method over monthly stress periods. The Green-Ampt method was originally developed to simulate infiltration and runoff on a time scale of individual storm events. If the Green-Ampt approach is used in this study, consideration should be given to applying it with sub-daily time steps.

5.5.6 Input data preparation

Upon selection of the model code(s), transient model input datasets will be prepared using standard pre-processing software such as ArcGIS and Groundwater Vistas. These digital datasets will represent the structure of the model (vertical model layers, horizontal discretization, boundary conditions, temporal resolution, and parameters) as well as the forcing functions (recharge, withdrawals, tidal fluctuations, etc.). More details on this sub-task will be generated following completion of the conceptual model and selection of the modeling code. At a minimum, this is expected to include the following sub-tasks:

- Develop spatially and temporally distributed recharge datasets using the analytical or numerical techniques described above
- Perform surface water modeling for 'point recharge' from sinking streams (swallets)
- Develop pumpage files
- Develop MODFLOW or equivalent model datasets
- Develop karst conduit datasets for input to MODFLOW
- Apply KFM to Spring Creek-Wakulla-Lost Creek System

5.5.7 Calibration and sensitivity analysis

Calibration criteria for goodness-of-fit with measured values of water levels and discharge rates will be developed in consultation with the District at the beginning of this task. The calibration will address aquifer levels, spring and river flows, conduit flows or stage, and groundwater velocity or travel times. Model results will be compared with data from dye tracing studies to ensure karst feature connectivity (including travel time) is adequately represented. The calibration will assess model results under high, medium, and low flow or recharge conditions. Efforts will consist of adjusting model parameter values, within acceptable ranges, in an effort to meet the calibration criteria and to ensure an acceptable level of reliability in the model results. As part of the calibration process, results will be reviewed to ensure that there is no spatial or temporal bias. Selected parameters will be adjusted to test the sensitivity of the model results within the range of parameter adjustments.

5.5.8 Predictive model runs

In consultation with NWFWMD staff, the consultant team will identify predictive scenarios. Interflow proposes to conduct up to 10 predictive runs to: (1) develop benchmark conditions, (2) explore relationships between spring flow, recharge, and groundwater withdrawals, (3) quantify relationships between spring flows and WRVs, and (4) assess the need for a recovery or prevention strategy based on whether current or projected future groundwater withdrawals within the contribution zone of Wakulla Springs, Sally Ward Springs, and St. Marks River Rise impact the proposed MFL hydrologic regimes. It is assumed the District will develop the projections of future groundwater use to be simulated in the model. The predictive runs may also consider the potential effects of sea level rise.

Model output will include simulated spring discharge time series for St. Marks River Rise, Wakulla, and Sally Ward springs. It is anticipated that these time series will be used as inflows for the river hydraulics models of the Wakulla and St. Marks Rivers.

5.6 Develop hydrodynamic model to evaluate estuarine resources

A hydrodynamic model is proposed to be developed and used to predict changes in water surface elevations, temperature, and salinity resulting from changes in freshwater inflows. The output from the hydrodynamic model will be used to address potential effects on water quality, specifically the temporal and spatial salinity distributions, in response to freshwater inflows. Comparisons of these distributions will provide quantifiable changes in availability of volumes of salinity envelopes important for critical biotic components, including both floral (riparian vegetation, SAV) and faunal (fishes, benthos) components.

An important consideration in developing the model so that it provides meaningful results is the identification of critical biotic communities that likely respond to changes in freshwater inflows and salinity. This effort will include specification of the salinity ranges for taxa commonly found in this general geographic region and within the estuarine system. These salinity ranges of occurrence will aid in directing the development and calibration of the model, ensuring that the model accurately simulates these important salinity regimes.

Key biological resources, where they are likely to be found in the project area, and their specific habitat needs, particularly as they relate to salinity, will be identified. Dissolved oxygen is proposed to be evaluated with respect to its relevance to springs flows and whether there are adequate date to develop a relationship between springs flows and DO. The steps in the hydrodynamic model development are outlined below.

1) Support the choice of hydrodynamic model to be used for this effort. Although the recommended model is the EFDC hydrodynamic model, we will provide a model selection section in which several commonly-used hydrodynamic models are reviewed and compared, including the EFDC model. This will provide assurance that the selected model is the most appropriate for this effort.
2) Define objectives to be met by the hydrodynamic model including definition of spatial and temporal model domains. The domains will largely be dependent upon not only model objectives but also on data availability and specific regions of interest within the spatial model domain.
3) Identify available data and any additional data needed (bathymetry, meteorological, salinity, temperature, elevation, inflows). The specific data needs are:
    a. Inflows from the watershed and any point sources
    b. Withdrawals from the system, if any (not anticipated)
    c. Rainfall
    d. Air temperature
    e. Dew point temperature or relative humidity
    f. Solar radiation
    g. Evaporation
    h. Cloud cover
    i. Wind speed and direction
    j. System bathymetry
    k. Downstream water surface elevation boundary condition
    l. Downstream salinity and temperature boundary conditions

4) Identify data needed to calibrate hydrodynamic model and provide model skill assessment, i.e. uncertainty, in how well the model compares to observations
5) Develop model grid extent based on overall model domain and availability of upstream inputs, downstream boundary conditions (salinity, temperature, elevation)
6) Develop model grid resolution that depends upon observed horizontal and vertical salinity and temperature gradients, spatial resolution of data for calibration, identification of important scales to satisfy model objective
7) Define the benchmark condition for the hydrodynamic model
8) Develop model calibration criteria based on the salinity distributions associated with the key biological resources to be protected by the eventual proposed MFL

9) Identify model evaluation techniques for supporting calibration (time series plots, cumulative distribution frequency plots (CDFs), statistical analyses)
10) Develop model input files
11) Exercise model for the benchmark condition
12) Calibrate model and perform model skill assessment

Data needs for the hydrodynamic model were presented previously in section 4.6. Specifically, new data collection efforts were identified. These included installation of continuous recorders in the river and potentially in the lower portion of the river. Other data collection is proposed to include seasonal longitudinal surveys conducted by boat during which surface salinity would be continuously recorded and vertical profiles of salinity, temperature, and DO would be taken at 0.5 km intervals.

Once the hydrodynamic model is deemed calibrated it will be used to estimate the expected changes in salinity distributions due to changes in freshwater inflows. We propose several habitat metrics to be used in these analyses and have been used in setting estuarine MFLs by the SWFWMD and SRWMD. The salinity predictions will be expressed as water volume (critical for fish habitat), shoreline length (critical for riparian vegetation), and bottom area (critical for benthic invertebrates and bottom fishes). For example, the volume of water with salinity less than 5 PSU for a series of model conditions can be compared.

Having defined the critical habitat needs as expressed by salinity and the methods by which model outputs can be compared, the hydrodynamic model can be exercised for a series of flows that represent various reductions in flow from the benchmark. These flow reductions will be defined at the gages at which MFLs will be expressed. Any significant covariance in flows at these gages will be retained, i.e. the flow reductions to be assessed will not ignore the degree to which the flows co-vary.

For comparison of model output, salinity distributions can be compared over the entire model spatial domain as well as over specific targeted portions of the domain, as deemed appropriate. Similarly, distributions can be temporally compared for seasonal and annual differences resulting from changes in freshwater inflows. Examples of comparison metrics include potential changes in salinity zones (habitats), such as volume of water within a given salinity zone (e.g. volume of water less than 5 PSU), the aerial extent of estuarine or bay bottom covered by a given salinity zone, and the extent of shoreline exposed to a given salinity.

Given a threshold level of acceptable decline in available habitat, the specific flow that results in exceedance of this threshold for the each critical estuarine resource will be estimated. These flows represent potential draft MFLs.

5.7 Assess need for thermal model for Wakulla Springs

Springs are important thermal refugia for manatees during critically cold periods. Wakulla Springs and the St. Marks River Rise are secondary thermal refugia to manatee and provide cold water refuge during the critical cold periods as manatees can use the warmer waters of these springs. The available area and volume of water for the manatees to use is dependent on spring flow rates and the intrusion of colder denser waters from downstream beneath the outgoing spring discharge. At higher flows, the spring flows are able to push colder waters further downstream, increasing the refugia region. Higher flows also serve to increase the depths within the spring runs with increased temperatures, providing greater volume of warmer water within a given area. Reduced spring flows reduce the volume and area of available refuge. Therefore, available data and information will be evaluated with respect to the potential need for developing a thermal model that would quantify the amount of available thermal refuge at Wakulla Spring with respect to the number of manatee that visit the spring.

If determined necessary, the potential changes in refuge volume and area resulting from reduced spring flow would be evaluated using the thermal component of the EFDC hydrodynamic model for the spring. Based upon the flow/area/volume relationships developed from the model results, allowable flow reductions will be identified to assure that no significant harm will occur to the manatee populations that can find shelter in these springs and their runs.

5.8 Meet with District to discuss results

The Atkins team will meet with District staff throughout the project to present and discuss results of analyses and models to clarify any questions the District may have regarding implications of the work.

6. ASSESS EFFECTS OF REDUCED FLOWS ON WRVS

Using the concept of the natural flow regime and the basic assumption that flows are a major determinant of the ecological communities that develop within a watercourse either directly (e.g. flow cues, cleaning spawning areas, allowing for fish passage) or indirectly (e.g. sizing or inundating available habitat, maintaining salinity within tolerance levels, maintaining channels), the proposed work plan for scientifically defensible MFLs recommendations is outlined below. Standards developed are intended to prevent significant harm to the water resources or ecology of the springs and downstream river reaches that may result from water use. Results of the previously completed tasks will be combined to develop MFLs for the St. Marks River Rise, Wakulla, and Sally Ward springs. The use of MFLs for long range water resource planning could affect the use and allocation of water. Consequently, development of each MFL must be based on clearly defined assumptions and sound science.

Task 6 *Combine and integrate previous work plan components into a document that quantifies the effects of reduced flow scenarios on selected WRVs. Based on discussions with the District, hydrologic flow regimes (e.g. MFLs) necessary to avoid significant harm to the selected WRVs will be proposed for the St. Marks River Rise, Wakulla, and Sally Ward springs (i.e. establish allowable spring flow reductions for each of the individual systems). The results will be included in a Draft MFLs document. After review and approval by the District and preparation of a second draft, the final MFL document will be prepared and submitted to the District.*

Task 6.1 Prepare and submit documentation of effects of reduced flows from the St. Marks River Rise and the spring flows necessary to protect selected WRV criteria

Task 6.2 Prepare and submit documentation of effects of reduced flows on flows from the Wakulla and Sally Ward springs system and the spring flows necessary to protect selected WRV criteria

Task 6.3 Meet with District staff to review and discuss results

Task 6.4 Prepare and submit first draft report

Under Task 6, results of previous tasks will be combined to develop draft (and then final) MFLs for the St. Marks River Rise, Wakulla Spring, and Sally Ward Spring. A summary of the development of MFLs, i.e. evaluating impacts of reduced flows on WRVs, is outlined below.

MFLs: EVALUATING IMPACTS OF REDUCED FLOWS ON WRVs

- Determine water resource values that will be assessed
  - WRV to be assessed should be quantitatively related to flow and/or water level
  - Data on the WRV should reflect best available information
- Develop appropriate model or models that relate flow/water level to the WRVs of interest
- Determine acceptable level of change in WRV, i.e. significant harm level

  Acceptable level of change is determined from benchmark: benchmark is the flow regime that exists or would exist in the absence of withdrawal impacts
- Establish benchmark condition
  - Benchmark condition could be existing flow/level record if the record is relatively free of withdrawal and climatic impacts
  - If current condition is impacted but flow record sufficiently long could use part of the existing record as benchmark
    - This would assume that climatic conditions are similar between current and benchmark conditions
    - May need to evaluate record for shifts in climatic condition
  - If current condition is impacted and flow record is not sufficiently long so that part of the existing record can be used as the benchmark, will need to construct a benchmark condition
    - Could develop a benchmark using statistical relationships with other watercourse(s)
    - Could develop a model of the system that simulates effects of changes in rainfall/recharge and withdrawals and is calibrated to existing conditions and establish benchmark by removing effects of withdrawals. This model may be needed in any case to evaluate the impact of current and projected future withdrawals on proposed MFLs
- Using models that relate withdrawals to flows and levels, incrementally increase withdrawals (or decrease spring flows) until unacceptable impacts occur for each WRV to be evaluated
  - The MFL hydrologic regime is based on the set of WRVs most sensitive to change
  - The WRV that is most sensitive to change may vary seasonally

The Draft MFLs document will be developed under this task, with review and approval by the District. The document will include a detailed description of the work performed and results of tasks listed above as MFLs. The Draft MFLs document will include an analysis of percent change in various metrics (WRVs) under various flow reduction scenarios and recommendation(s) with respect to acceptable change levels for each of the named water bodies.

7. ASSESS THE NEED FOR A RECOVERY OR PREVENTION STRATEGY

Following completion of the technical assessments and the development of proposed MFL hydrologic regimes, the District will determine the need for a recovery or prevention strategy for each water body. The determination will be based on whether the proposed MFL hydrologic regime is being exceeded or is expected to be exceeded within 20 years. The District is anticipated to perform the majority of this analysis with support, as needed, from the consultant team.

8. FACILITATE PEER REVIEW

With respect to MFL peer review, "The department or the governing board shall give significant weight to the final report of the peer review panel when establishing the minimum flow or level (Section 373.042(4)(b), F.S.). "Independent scientific peer review" is defined by the Central Florida Water Initiative (CFWI 2012) to mean "the review of scientific data, theories, and methodologies by a panel of independent, recognized experts in the fields of hydrology, hydrogeology, limnology, and other scientific disciplines relevant to matters being reviewed under Section 373.042" (Section 373.019(11), F.S.). The District has previously determined that it will undertake voluntary peer review for the St. Marks River Rise, Wakulla Springs, and Sally Ward Spring MFLs.

Task 8 *Identify, recruit, and contract with three peer reviewers; facilitate review; prepare report; present findings to District staff and Governing Board (if necessary)*

Task 8.1 Identify, contact, and select peer review candidates
Task 8.2 Initiate peer review
Task 8.3 Implement peer review process
Task 8.4 Final peer review and report preparation

As described in previous sections of this report, MFLs for the St. Marks River Rise, Wakulla and Sally Ward springs are being developed to protect selected WRVs from significant harm that may result from water withdrawals in the basin. The peer review process will provide an evaluation of the scientific basis of the MFL based on the available information, and the process may be refined as necessary, in consultation with the District, to meet the needs of the review. The peer review process is intended to accomplish the goals listed below.

- Provide the District an independent, unbiased scientific evaluation of the assumptions, methods, analyses, and interpretations completed as part of development of the draft MFLs
- Ensure the quality and credibility of the scientific information that will be used by the District to make decisions with respect to the MFLs
- Be applied consistently among MFLs within the District and be consistent with other management Districts while accommodating variation due to differences in resources

The peer review process will be a managed evaluation in which scientific or technical information is fairly presented with no attempt to influence or affect decision-making. It is important that scientific integrity be maintained and that any scientific evaluation not be compromised by management concerns. Therefore, peer reviewers will be given explicit instruction and careful guidance. Scientists in review processes are always instructed to make no policy recommendations and reminded of the differences in standards between academia (e.g. statistical conventions of 95 percent certainty) and water resource management (i.e. best available science). To accomplish this, the peer review approach is modeled after that developed by the National Academy of Science (NAS) and National Research Council with respect to thoroughness.

At a national level, the Office of Management and Budget (OMB) follows National Academy of Science guidelines for peer reviews and defines “a scientific assessment” as “an evaluation of a body of scientific or technical knowledge that typically synthesizes multiple factual inputs, data, models, assumptions, and applies best professional judgment to bridge uncertainties in the available information (OMB 2004). However, NAS reviews rely on volunteer reviewers and may take up to two years for a comprehensive academic-style review. Therefore, peer reviewers will be selected from among agency staff, academics, and other professional experts. Reviewers will be chosen who understand relevant scientific and technical issues within a regulatory and policy context and who can meet the timelines associated with the MFL development.

The peer review process is anticipated to occur over approximately three to four months, making established procedures and selection of reviewers critical. The review process will be refined as necessary to meet District needs and ensure that valid scientific opinion is represented and heard. The peer review process is outlined below.

8.1 Identify, contact, and select peer review candidates

Identify candidate peer reviewers based on qualifications developed, with additional input from District staff, who have sufficient expertise and experience. Criteria may include level of education, years of experience, number of peer-reviewed publications, specialized experience, and experience conducting similar reviews. The balance of the panel in terms of field of specialization, affiliation, scientific perspective, and other factors that may be relevant to the review, is also important.

We will apply the National Academy of Sciences’ (NAS) Background Information and Confidential Conflict of Interest Disclosure form to establish screening criteria for candidates regarding balance, independence and conflict-of-interest. In consultation with District staff, “independence” for the peer review will be defined for use in selecting peer reviewers. For example, factors to consider in determining independence may include employer, research funding sources and relationship to study authors. Potential conflicts of interest must also be determined. A definition of “conflict of interest” will be prepared (standard is NAS) and questions related to personal or professional relationships and investment, property or other interests that may constitute a conflict will be prepared. Appropriate District staff will be contacted as questions emerge, but the potential candidates will not be named. Candidate peer reviewers’ availability over the period of performance will be ascertained to ensure schedules are met.

Recruitment of panel members is perhaps the most critical component in the peer review process, as the contractor must identify scientists with the appropriate expertise and availability, and with no conflicts-of-interest. Additionally, prospective panel members must have a reputation for effective team participation.

8.2 Initiate peer review

Once reviewers have been selected and have agreed to participate in the process, a kick-off teleconference will be convened to discuss the peer review charge, schedule, and materials prior to commencing the review. The importance of focusing on the technical scope of the peer review and not commenting on policy areas that are the purview of the District will be emphasized. Reviewers will be instructed to protect information and make certain that their review comments consist of unbiased assessments. All peer review-related inquiries from outside sources must be forwarded to the Atkins' project manager; reviewers will not communicate with those inquiring about the review. Clarification from District staff will be requested as appropriate and the District will be updated as the process proceeds. The charge, schedule, and other information will be included in the scope of services attached to each reviewer's subcontract.

The coordination meeting with all panel members prior to commencing the review provides all reviewers with the same information and provides a forum for questions regarding peer review protocol, charge, schedule, report format, and protocol for handling external inquiries. It also builds cohesiveness among panel members, which is particularly important when collective comments are required.

What constitutes best available science needs to be clearly defined prior to (or early on during) conduct of the peer review so it does not hinder the peer review process or become a source of contention between reviewers and agency staff.

8.3 Implement peer review process

The reviewers will be provided the document for review with specific questions regarding the adequacy of the report. The selected reviewers will be asked to read the document and provide written responses to questions or statements that may include, for example, but will not be limited to:

- Is the information presented adequate for making the conclusions made?
- Is there more literature, more relevant literature, or more information available that should be included in the analysis? If so, what is it?
- Are the WRVs selected adequately represented by adequate data and related to flows? Are there WRVs that would better represent the resources that are also represented by adequate data and related to flows?
- Do the draft MFL recommendations adequately address the flow requirements of the selected WRVs, based on the available information? If not, why not? If not, how can they be corrected?
- Do the results of the MFL analyses support the conclusions made and presented in the draft MFL report? If not, why not? If not, how can they be corrected?
- Please make recommendations to address any of your concerns with respect to the analyses and conclusions presented in the draft MFL.

As questions or issues are submitted by reviewers, responses will be communicated to all reviewers via email. If necessary, a teleconference may be convened for further clarification. The comments from individual reviewers will be unattributed, although reviewers themselves will be listed as peer reviewers in the final MFL report. The reviewers will be instructed to prepare a summary report with a consensus review of the draft MFL report and the report reviewed by Atkins for submittal to the District as a draft report.

The draft report will include:

- Background, purpose, and scope of the peer review including the specific questions for reviewers
- An outline of the peer review process, including selection of reviewers, document review, and report development
- Summary report from the reviewers
- Appendix of the combined comments from the reviewers (unattributed)

8.4 Final peer review and report preparation

Once the draft has been submitted and District staff has conducted their review, a teleconference will be convened to discuss questions and comments. Reviewers will revise the draft report for clarification if necessary and make revisions if necessary.

After all comments have been addressed in the summary report, Atkins' technical editor will conduct a final review and prepares a PDF version. Atkins submits the final report (as both Word and PDF files) to the District.

9. IMPLEMENT PUBLIC INVOLVEMENT PLAN

Public and stakeholder involvement and input are critical to successful MFL establishment. A public involvement plan (PIP) is presented here that, in coordination with the District, will be revised and enhanced as appropriate. The PIP will address the timing and approximate number of public workshops, web-based information exchange, and other mechanisms that may be useful to facilitate stakeholder involvement.

A PIP will be implemented to ensure the public is informed of the MFL process and has opportunities to comment on the process and the draft MFLs. The PIP and associated venues, activities, information posters, presentation, and opportunities for questions and answers, will occur in coordination with, and approval by, the District. The PIP developed to date is presented here.

Task 9 *Implement PIP and develop associated materials needed for the PIP, including two public meetings*

Task 9.1 Prepare and implement PIP; coordinate with PIP specialist
Task 9.2 Prepare documentation in support of public involvement
Task 9.3 Attend two workshops in support of public involvement

9.1 Prepare and implement PIP; coordinate with PIP specialist

This PIP (or plan) has been prepared to set standards for public involvement throughout the course of developing minimum flows and levels (MFLs) for the St. Marks River Rise, Wakulla, and Sally Ward Springs system. This plan includes public outreach and will be implemented through public meetings and other public involvement coordination activities. The District and its contractors will oversee the implementation of the use of the public involvement tools and activities outlined in this plan.

The PIP is intended to provide information and opportunities for stakeholder involvement regarding the establishment of MFLs for the St. Marks River Rise, Wakulla, and Sally Ward springs system. Public involvement tools and activities outlined in this plan will be used to inform stakeholders, community members, and other interested parties with respect to the MFL process. This plan addresses:

- The project background of the St. Marks River Rise, Wakulla, and Sally Ward springs system
- Stakeholders and targeted audiences
- Public involvement tools and activities
- Opportunities for public comment
- Planned public involvement activities

The District will use the following tools and activities to support the public involvement program for the development of MFLs for the St. Marks River Rise, Wakulla, and Sally Ward Springs system. Each of these items will provide an avenue for sharing project information with the public and an opportunity for the public to provide input:

- Designate point of contact for information requests
- Designate District website for public to access information
- Identify stakeholders and targeted audiences
- Develop email list for contacts
- Facilitate public meetings and workshops
- Assist District with public notice preparation as appropriate

The District will use these tools and activities throughout the MFL process to ensure that the public is well-informed and to ensure that the public has sufficient time to provide comment.

9.1.1 Identify point of contact and website

To maintain communication between the District and stakeholders, the District will designate point(s) of contact to respond to information requests.

9.1.2 Support documents to be placed on project website

Selected documents will be placed on the District's home page on the internet http://www.nwfwater.com. The website will provide the District's MFL priority list and schedule, which is required to be updated annually and submitted for approval to the Florida Department of Environmental Protection. A dedicated webpage will be maintained to facilitate public access to information about the schedule and activities pertaining to the St. Marks River Rise, Wakulla, and Sally Ward Springs system MFLs. The website will also provide notices of opportunities to provide comments and concerns regarding the draft MFL technical assessment reports and proposed rule language.

9.1.3 Identify and develop list of stakeholders and targeted audiences

Stakeholder and target audiences for the St. Marks River Rise, Wakulla, and Sally Ward Springs system MFLs may include, but are not limited to:

- City of St. Marks
- City of Tallahassee
- FDACS, including Florida Forest Service
- Florida Department of Environmental Protection
- Florida Fish and Wildlife Conservation Commission
- Friends of Wakulla Springs State Park
- Gadsden County
- General public
- Jefferson County
- Leon County
- Local elected representatives
- Local media
- Other Non-governmental organizations (NGOS)

- U.S. Forest Service
- USFWS (St. Marks National Wildlife Refuge)
- Wakulla County
- Wakulla Springs Alliance

A list of contact information for local, state, and federal governmental leaders, governing environmental regulatory agencies, and other stakeholders will be compiled and maintained. This list will be used to contact stakeholders and the targeted audiences concerning the opportunity of attendance at general public informational meetings. The list will be updated as necessary to maintain contact with appropriate officials, agency representatives, local media, community groups, and other interested parties and will be used in emailing informational project materials and meeting announcements as appropriate.

9.1.4 Develop project email list

The District will maintain an email listing of federal, state, and local officials; local media; community groups; and other interested parties. This project emailing list will facilitate providing notice of the availability of the draft MFL technical assessment report and notification of the availability of proposed rule language.

9.1.5 Support development of public notices

Public notices will be used to inform the community of public meetings and rule development activities. Notices of Governing Board meetings are published in the Florida Administrative Register and Governing Board agendas are posted on the District website prior to the meeting date. The District will publish notices pertaining to rule development activities in the Florida Administrative Register as required by Florida Statutes. These notices are anticipated to include a Notice of Rule Development, Notice of Rule Development Workshop(s), and Notice of Proposed Rule. Notices for public meetings and workshops will also be published in the Florida Administrative Register and posted on the District's website.

Notices will include dates, times, and locations of public meetings or workshops, as well as the name, address, and telephone number of the primary contact person. Notices may also indicate the availability of the draft MFL technical assessment report or draft rule language for public review. Instructions for accessing copies of these documents and the location of a hard copy for review will be provided. The District's Communications Office will also use traditional media activities (press releases, etc.) to inform the media and the public of upcoming workshops.

9.2 Support development of materials for PIP

Public meetings will be conducted to inform the public of project activities and provide opportunities for public input. These meetings will be held in the community and will be facilitated by the District or their consultant. At least one public meeting will be scheduled subsequent to the completion of the draft MFL technical assessment report. Additional public workshops will be held during the rule development process, as required by Florida Statutes. Public meetings or workshops may be held during other stages of the study, if needed, to exchange information with the public. Updates regarding MFL activities will be provided as needed to the District's Governing Board. Assist the District with internal meetings as needed.

9.3 Attend two workshops in support of public involvement

At least one Atkins scientist will attend the public workshops in support of the District's MFL development efforts.

10. FINAL MFL REPORT PREPARATION

The Final MFL report will be submitted to the District and will comprise the Technical Assessments for the St. Marks River Rise, Wakulla, and Sally Ward springs MFLs. The MFL will be established only after peer review, public workshops, and rule adoption.

Task 10 *Prepare and submit a second draft and the final report, including review of the second draft document by District staff, the second round of comments and resolution (as necessary) of the comments, document revisions, and meetings with the District to ensure all comments are sufficiently addressed. Atkins staff will attend a Governing Board meeting in support of a presentation, as appropriate.*

Task 10.1 Complete revisions to first draft document (completed under Task 6). Submit a second draft document that will address (if available) peer review and public involvement issues and comments and comments from the District on the first draft prepared under Task 6

Task 10.2 Meet with District staff to resolve any remaining issues and comments for final resolution and incorporation into final document

Task 10.3 Complete any additional analyses necessary to address peer review, public input, or technical issues. Meet with District staff to ensure all comments are addressed.

Task 10.4 Attend Governing Board meeting or, alternatively, a District staff meeting, to support staff

Task 10.5 Prepare and submit final MFL document to the District. The final document will include resolution of peer review and public involvement issues, as appropriate, that were not available for the second draft document.

11. DELIVERABLES, SCHEDULES, AND COSTS

Deliverables for each of the MFLs and schedules for completion of the St. Marks River Rise, Wakulla, and Sally Ward springs, based on the District's 2014 Priority List, are presented here, along with other items for consideration in cost estimating and scheduling.

11.1 Deliverables

Deliverables are proposed to include the items listed below.

- All survey data (i.e. channel and floodplain cross section data, instrument and monitoring station surveys)
- Well construction and testing report
- All hydrologic, geologic, ecologic, and water quality and other collected data, in electronic format
- GIS data and files
- Model documentation and all input and output files for HEC-RAS, PHABSIM, the hydrodynamic model, and the integrated surface and groundwater model
- Materials prepared in support of the Public Involvement Plan
- Draft and final peer review reports
- Draft MFL report
- Final MFL report

For the each of the various models, the proposed deliverables are listed below.

- Draft and final databases containing all data used for model development and calibration
- All geospatially-referenced datasets and databases used for model development and calibration
- Model executable programs and final input files for model calibration and MFL scenarios
- Model output files for model calibration and MFL scenarios
- Draft and final model reports including description of model and data sources, skill assessments for calibrated model, tables and graphs for comparisons of benchmark and MFL model scenarios
- Transfer of all databases and model files on external hard drive
- Presentation of draft and final model calibration and MFL scenario results at meetings, if requested by the District

Deliverables for the groundwater and surface water model may include:

- Interim Technical Memorandum – Groundwater and Surface Water Data Interpretation
- Interim Technical Memorandum – Conceptual Groundwater Model
- Interim Report – Proposed Integrated Modeling Approach and Model Selection
- Interim Technical Memorandum – Integrated Model Development and Calibration
- HEC-RAS Model Documentation Report and Digital Model Files

- Other data analysis or model results, as requested by the District

11.2 Schedule

The District's *2014 Minimum Flows and Levels Priority Watebody List and Schedule* (November 2013) lists the MFL initiation, technical assessment, and rule adoption dates for designated water bodies. The technical assessment for St. Marks River Rise is currently scheduled for completion in 2018. Completion of the technical assessment for Wakulla Springs and Sally Ward Spring are currently scheduled for 2021. The priority list is updated annually and may be found on the District's website.

Historical data available for development of these MFLs is limited (as described in the work plan); as a result, the schedules include approximately 18 months of data collection for all three water bodies to supplement existing information. The data collection effort will be followed by data analysis, model development, quantification of relationships among spring flows, withdrawals, and water resource values (WRVs), and development of the proposed MFLs. Voluntary peer review of MFLs and stakeholder involvement are also included in the schedules. Development and approval of the final MFL technical reports are consistent with the *2014 Minimum Flows and Levels Priority Waterbody List and Schedule*.

Two schedules are provided here: one for developing MFLs for the St. Marks River Rise (Figure 11), and a second for Wakulla and Sally Ward springs (Figure 12). These schedules are based on the current approved priority list time table; however, the District is exploring opportunities to complete the MFLs for Wakulla and Sally Ward springs at an earlier date.

Data collection and compilation are critical first steps to both schedules, while other tasks (e.g. model development, peer review, report preparation) are sequenced to reflect the scheduled completion of the MFL technical assessment for the St. Marks River Rise in 2018 and the assessment for Wakulla and Sally Ward springs in 2021. The groundwater data collection has been initiated with groundwater flow modeling to be implemented predominantly during development of the St. Marks River Rise MFL. Similarly, the surface water data collection network must be established for portions of the groundwater model, requiring a large initial effort. These considerations are reflected in the schedules.

11.3 Cost Estimates

Planning level cost estimates were prepared based on previous MFL and similar efforts completed by Atkins team members as well as potential local subcontractors. Cost estimates are for development of MFLs for the St. Marks River Rise and Wakulla and Sally Wards springs, inclusive of the downstream and estuarine portions of the system, as described in the work plan. Cost estimates are presented in Table 4. Combined costs to develop MFLs for the St. Marks River Rise, Wakulla Springs, and Sally Ward spring total $2,475,000. Costs for MFL development for the St. Marks River Rise total $1,850,000, and include hydrological data collection and groundwater model development needed to develop MFLs for Wakulla Springs and Sally Ward Spring. Costs for data collection and technical assessments unique to Wakulla Springs and Sally Ward Spring total an additional $625,000.

Annual costs associated with each system have been estimated. These are planning level estimates only; however, actual costs will be determined when future task orders are issued. Similarly, the schedules may vary as individual task orders are generated; specific tasks may be moved from one year to another to accommodate data, staffing or funding constraints.

Elevations surveys are also critical to the development of MFLs (e.g., HEC-RAS modeling). However, elevation surveys for the Wakulla and Sally Ward springs can be performed separately at a later date than elevations surveys for the St. Marks River Rise, as can surveys for floodplain WRVs. Modeling for the estuarine portion of the St. Marks River Rise, Wakulla, and Sally Ward springs system has also been sequenced to reduce initial costs associated with the MFL development. Cost estimates have taken into consideration local costs where possible, for example, well construction estimates from local drillers. In addition, the District has contracted with the Florida Geologic Survey (FGS) for some of the groundwater monitoring well construction.

Table 4. Annual planning level cost estimates for the St. Marks River Rise, Wakulla and Sally Ward Springs MFL development.

MFL Waterbodies	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	Total
ST. MARKS / WAKULLA MFLs									
St. Marks River Rise (supports Wakulla/ Sally Ward hydrologic data collection and analyses)	$ 300,000	$ 550,000	$ 500,000	$ 325,000	$ 175,000				$ 1,850,000
Wakulla/Sally Ward (completes data collection and technical assessment)		$ -	$ -	$ 50,000	$ 150,000	$ 175,000	$ 100,000	$ 150,000	$ 625,000
Total - St. Marks/Wakulla	**$300,000**	**$550,000**	**$500,000**	**$375,000**	**$325,000**	**$175,000**	**$100,000**	**$150,000**	**$2,475,000**

Notes:

[1]Combined costs to develop MFLs for the St. Marks River Rise, Wakulla Springs, and Sally Ward spring total $2,475,000.

[2]MFL development costs for the St. Marks River Rise total $1,850,000, and include hydrological data collection and groundwater model development needed to develop MFLs for Wakulla Springs and Sally Ward Spring.

[3]Costs for tasks unique to Wakulla Springs and Sally Ward Spring total $625,000.

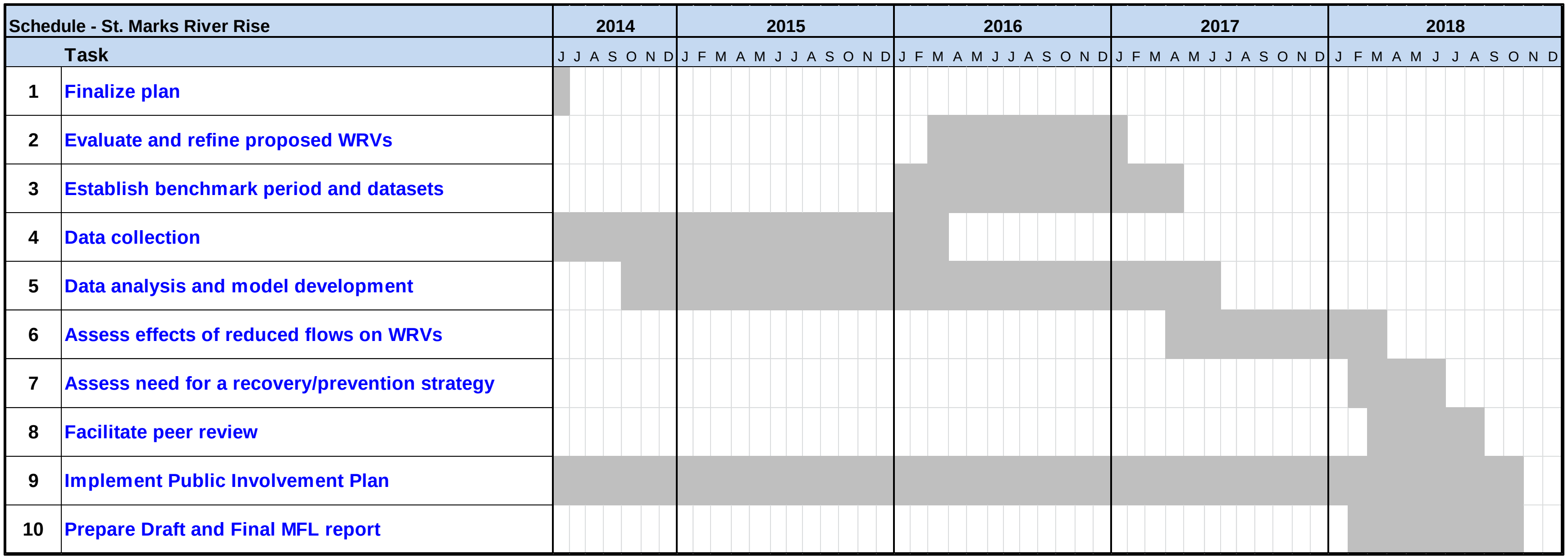


Figure 11. Proposed schedule for MFL technical assessment development for the St. Marks River Rise.

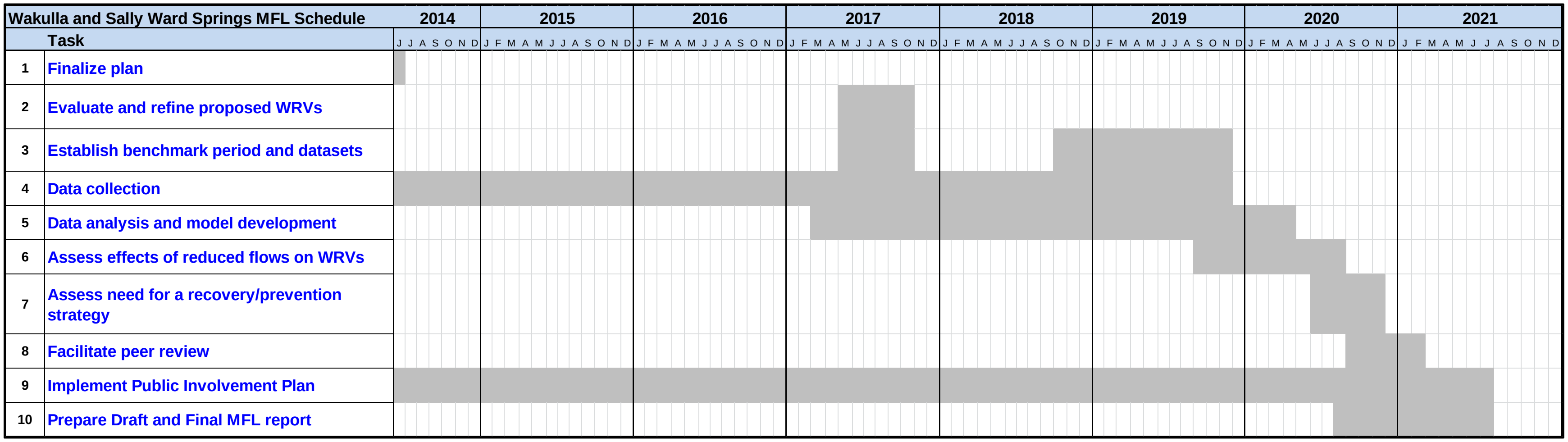


Figure 12. Proposed schedule for MFL technical assessment for Wakulla and Sally Ward springs to be completed in sequence after the St. Marks River Rise (see Figure 11). This schedule depicts completion of the Wakulla/Sally Ward springs assessments by 2021.

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