Proposed Minimum Flows and Levels for the Gum Slough Spring Run Final Report

Revised October 2011

Ron Basso
Southwest Florida Water Management District
Brooksville, Florida

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Jason Hood, Marty Kelly, Jonathan Morales, Tammy Hinkle
Formerly with the Southwest Florida Water Management District

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Appendix D - Vegetation Appendix. PBS&J. 2010. Characterization of Woody Wetland Vegetation Communities along Gum Slough. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

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Appendix F - Peer Review Report and District Response. Dahm, C.N., C. Hackney, and J.B. Martin. 2011. A Review of "Proposed Minimum Flows and Levels for the Gum Slough Spring Run, May 26, 2011, Peer Review Draft." Prepared for the Southwest Florida Water Management District, Brooksville, Florida and Peer Review with District Responses. Prepared by the Southwest Florida Water Management District, Brooksville, Florida.

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EXECUTIVE SUMMARY

The Gum Slough Spring Run is located in northwest Sumter and southern Marion Counties. The run discharges into the Withlacoochee River approximately mid-way between SR 44 and Hwy 200. The system lies in a primarily undeveloped area with the majority of land adjacent to the run being composed of intact wetland forests. Although much of the northern portion of the watershed is urban land use, the Marion Oaks subdivision, which was sub-divided in the 1960s, contains many undeveloped lots and parcels of vacant land.

The Gum Slough Springs Group is made up of numerous springs including Gum Spring Main, Gum Spring 1, and Alligator Spring in the headwaters, and Gum Springs 2, 3, and 4 as you proceed downstream. The combined discharge from the entire system, which includes overland flow, has a mean daily discharge of 98 cubic feet per second (cfs) making it a large second magnitude system.

Due to the low intra-annual variation in discharge, seasonal blocks typically utilized by the SWFWMD for river MFLs were not used. The average intra-annual variation is approximately 40 cfs for the short period of record. The MFLs include prescribed flow reductions based on limiting potential changes in aquatic habitat availability. A low flow threshold, based on fish passage depth and wetted perimeter inflection points is also incorporated into the MFL.

The low flow threshold is defined to be a flow that serves to limit surface water withdrawals, with no surface water withdrawals permitted when the threshold is exceeded. For the USGS Gum Springs near Holder, the low flow threshold was determined to be 35 cfs and was based on the lowest wetted perimeter inflection point and fish passage.

A prescribed flow reduction for the entire year was calculated to be 9%. The prescribed flow reduction was based on Physical Habitat Simulation Modeling.

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CHAPTER 1 – MINIMUM FLOWS AND LEVELS

1.1 Overview and Legislative Direction

The Southwest Florida Water Management District (District or SWFWMD), by virtue of its responsibility to permit the consumptive use of water and a legislative mandate to protect water resources from “significant harm”, has been directed to establish minimum flows and levels (MFLs) for streams and rivers within its boundaries (Section 373.042, Florida Statutes). As currently defined by statute, “the minimum flow for a given watercourse shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area” (see Glossary). Development or adoption of a minimum flow or level does not in itself protect a water body from significant harm. However, protection, recovery or regulatory compliance can be gauged and achieved once a standard has been established. The District's purpose in establishing MFLs is to create a yardstick against which permitting and/or planning decisions regarding water withdrawals, either surface or groundwater, can be made. Should an amount of withdrawal requested cause “significant harm”, then a permit cannot be issued. If it is determined that a system is either not in compliance, or expected not to be in compliance during the next 20 years, as a result of withdrawals, then a recovery plan is developed and implemented.

According to state law, minimum flows and levels are to be established based upon the best available information (Section 373.042, F.S.), and shall be developed with consideration of “...changes and structural alterations to watersheds, surface waters and aquifers and the effects such changes or alterations have had, and the constraints such changes or alterations have placed, on the hydrology of the affected watershed, surface water, or aquifer...” (Section 373.0421, F.S.). Changes, alterations and constraints associated with water withdrawals are not to be considered when developing minimum flows and levels. Because minimum flows are used for long-range planning and since the setting of minimum flows can potentially impact (restrict) the use and allocation of water, establishment of minimum flows will not go unnoticed or unchallenged. The science upon which a minimum flow is based, the assumptions made, and the policy used must, therefore, be clearly defined as each minimum flow is developed. It has been noted:

> *"There is no universally accepted method or combination of methods that is appropriate for establishing instream flow regimes on all rivers or streams. Rather, the combination or adaptation of methods should be determined on a case-by-case basis; . . . In a sense, there are few bad methods – only improper applications of methods. In fact, most . . . assessment tools . . . can afford adequate instream flow protection for all of a river's needs when they are used in conjunction with other techniques in ways that provide reasonable answers to specific questions asked for individual rivers and river segments. Therefore, whether a particular method 'works' is not based on its acceptance by all parties but whether it is based on sound science, basic ecological principles, and documented logic that address a specific need"* (Instream Flow Council 2002).

However, according to the State Water Resources Implementation Rule (Chapter 62-40.473, Florida Administrative Code), "consideration shall be given to the protection of water resources, natural seasonal fluctuations in water flows or levels, and environmental values associated with coastal, estuarine, aquatic and wetlands ecology, including:

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; and
10) Navigation.

1.2 Historical Perspective

For freshwater streams and rivers, the development of instream flow legislation can be traced to recent work by fisheries biologists, dating back not much more than 35 to 40 years. Florida has had minimum flow and levels incorporated into its Water Resource Act since its enactment in 1972. However, it was not until 1997 that the role of minimum flows and levels were clearly defined by the state (Munson et al. 2005). A survey completed in 1986 (Reiser et al. 1989) indicated that at that time only 15 states had legislation explicitly recognizing that fish and other aquatic resources required a certain level of instream flow for their protection. Nine of the 15 states were western states "where the concept for and impetus behind the preservation of instream flows for fish and wildlife had its origins" (Reiser et al. 1989). Stalnaker et al. (1995) have summarized the minimum flows approach as one of standards development, stating that, "[following the large reservoir and water development era of the mid-twentieth century in North America, resource agencies became concerned over the loss of many miles of riverine fish and wildlife resources in the arid western United States. Consequently, several western states began issuing rules for protecting existing stream resources from future depletions caused by accelerated water development. Many assessment methods appeared during the 1960s and early 1970s. These techniques were based on hydrologic analysis of the water supply and hydraulic considerations of critical stream channel segments, coupled with empirical observations of habitat quality and an understanding of riverine fish ecology. Application of these methods usually resulted in a single threshold or 'minimum' flow value for a specified stream reach."

1.3 The Flow Regime

The idea that a single minimum flow is not satisfactory for maintaining a river ecosystem was most emphatically stated by Stalnaker (1990) who declared that "minimum flow is a myth". The purpose of his paper was to argue "multiple flow regimes are needed to maintain biotic and abiotic resources within a river ecosystem" (Hill et al. 1991). The logic is that "maintenance of stream ecosystems rests on streamflow management practices that protect physical processes which, in turn, influence biological systems." Hill et al. (1991) identified four types of flows that should be considered when examining river flow requirements, including:

1) flood flows that determine the boundaries of and shape floodplain and valley features;
2) overbank flows that maintain riparian habitats;
3) in-channel flows that keep immediate stream banks and channels functioning; and
4) in-stream flows that meet critical fish requirements.

As emphasized by Hill et al. (1991), minimum flow methodologies should involve more than a consideration of immediate fish needs or the absolute minimum required to sustain a particular species or population of animals, and should take into consideration “how streamflow affect channels, transport sediments, and influence vegetation.” Although not always appreciated, it should also be noted, “that the full range of natural intra- and inter-annual variation of hydrologic regimes is necessary to [fully] sustain the native biodiversity” (Richter et al. 1996). Successful completion of the life-cycle of many aquatic species is dependent upon a range of flows, and alterations to the flow regime may negatively impact these organisms as a result of changes in physical, chemical and biological factors associated with particular flow conditions.

More recently, South African researchers, as cited by Postel and Richter (2003), listed eight general principles for managing river flows:

1) "A modified flow regime should mimic the natural one, so that the natural timing of different kinds of flows is preserved.
2) A river's natural perenniality or non-perenniality should be retained.
3) Most water should be harvested from a river during wet months; little should be taken during the dry months.
4) The seasonal pattern of higher baseflows in wet season should be retained.
5) Floods should be present during the natural wet season.
6) The duration of floods could be shortened, but within limits.
7) It is better to retain certain floods at full magnitude and to eliminate others entirely than to preserve all or most floods at diminished levels.
8) The first flood (or one of the first) of the wet season should be fully retained."

Common to this list and the flow requirements identified by Hill et al. (1991) is the recognition that in-stream flows and out of bank flows are important for ecosystem functioning, and that seasonal variability of flows should be maintained. Based on these concepts, the preconception that minimum flows (and levels) are a single value or the absolute minimum required to maintain ecologic health in most systems has been abandoned in recognition of the important ecologic and hydrologic functions of streams and rivers that are maintained by a range of flows. And while the term “minimum flows” is still used, the concept has evolved to one that recognizes the need to maintain a “minimum flow regime”. In Florida, for example, the St. Johns River Water Management District typically develops multiple flow requirements when establishing minimum flows and levels (Chapter 40-C8, F.A.C) and for the Wekiva River noted that, “[s]etting multiple minimum levels and flows, rather than a single minimum level and flow, recognizes that lotic [running water] systems are inherently dynamic” (Hupalo et al. 1994). Also, in 2005, changes that acknowledge the importance of retaining the hydrologic regime were made to the Florida Administrative Code. Specifically, Chapter 62-40.473(2) of the State Water Resources Implementation Rule currently directs that "minimum flows and levels should be expressed as multiple flows or levels defining a minimum hydrologic regime". This change was intended to protect variation in water flows and levels that contributes to significant functions of ecosystems.

An alternate approach which also maintains a flow regime is to develop MFLs using a 'percentage of flow approach' as discussed in Flannery et al. (2002) and has been incorporated into several SWFWMD surface water use permits and existing MFLs in the SWFWMD.

1.4 Ecosystem Integrity and Significant Harm

"A goal of ecosystem management is to sustain ecosystem integrity by protecting native biodiversity and the ecological (and evolutionary) processes that create and maintain that diversity. Faced with the complexity inherent in natural systems, achieving that goal will require that resource managers explicitly describe desired ecosystem structure, function, and variability; characterize differences between current and desired conditions; define ecologically meaningful and measurable indicators that can mark progress toward ecosystem management and restoration goals; and incorporate adaptive strategies into resource management plans" (Richter et al. 1996). Although it is clear that multiple flows are needed to maintain the ecological systems that encompass streams, riparian zones and valleys, much of the fundamental research needed to quantify the ecological links between the instream and out of bank resources, because of expense and complexity, remains to be done. This research is needed to develop more refined methodologies, and will require a multi-disciplinary approach involving hydrologists, geomorphologists, aquatic and terrestrial biologists, and botanists (Hill et al. 1991).

To justify adoption of a minimum flow for purposes of maintaining ecologic integrity, it is necessary to demonstrate with site-specific information the ecological effects associated with flow alterations and to also identify thresholds for determining whether these effects constitute significant harm. As described in Florida's legislative requirement to develop minimum flows, the minimum flow is to prevent "significant harm" to the state's rivers and streams. Not only must "significant harm" be defined so that it can be measured, it is also implicit that some deviation from the purely natural or existing long-term hydrologic regime may occur before significant harm occurs. The goal of a minimum flow would, therefore, not be to preserve a hydrologic regime without modification, but rather to establish the threshold(s) at which modifications to the regime begin to affect the aquatic resource and at what level significant harm occurs. If recent changes have already "significantly harmed" the resource, or are expected to do so in the next twenty years, it will be necessary to develop a recovery or prevention plan.

1.5 Summary of the SWFWMD Approach for Developing Minimum Flows

As noted by Beecher (1990), "it is difficult [in most statutes] to either ascertain legislative intent or determine if a proposed instream flow regime would satisfy the legislative purpose", but according to Beecher as cited by Stalnaker et al. (1995), an instream flow standard should include the following elements:

1) a goal (e.g., non-degradation or, for the District's purpose, protection from "significant harm");
2) identification of the resources of interest to be protected;
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);
4) a benchmark period; and
5) a protection standard statistic.

In addition to Beecher's requirements, researchers (Seerley et al. 2006) at the University of Georgia Carl Vinson Institute Government, have identified the following seven guiding principles for instream flow protection:

1) Preserving whole functioning ecosystems rather than focusing on a single species.
2) Mimicking, to the greatest extent possible, the natural flow regime, including seasonal and inter-annual variability.
3) Expanding the spatial scope of instream flow studies beyond the river channel to include the riparian corridor and floodplain systems.
4) Conducting studies using an interdisciplinary approach.
5) Using reconnaissance information to guide choices from among a variety of tools and approaches for technical evaluations in particular river systems.
6) Practicing adaptive management, an approach for recommending adjustments to operational plans in the event that objectives are not achieved.
7) Involving stakeholders in the process.

The District's approach for minimum flows development incorporates the five elements listed by Beecher (1990). The goal of a MFLs determination is to protect the resource from significant harm due to withdrawals and was broadly defined in the enacting legislation as "the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." What constitutes "significant harm" was not defined. Impacts on the water resources or ecology are evaluated based on an identified subset of potential resources of interest. Ten potential resources are: recreation in and on the water; fish and wildlife habitats and the passage of fish; estuarine resources; transfer of detrital material; maintenance of freshwater storage and supply; aesthetic and scenic attributes; filtration and absorption of nutrients and other pollutants; water quality and navigation. The approach outlined in this report identifies specific resources of interest.

While the main unit of measure used by the District for defining minimum flows is flow or discharge (in cubic feet per second), it will become evident that several different measures of habitat, along with elevations in feet above the National Geodetic Vertical Datum of 1929 (NGVD 1929) or the North American Vertical Datum of 1988 (NAVD1988) associated with these habitats were employed. Ultimately, however, these different measures of habitat and inundation elevations were related to flows in order to derive the minimum flow recommendations.

Fundamental to the approach used for development of minimum flows and levels is the realization that a flow regime is necessary to protect the ecology of the river system. The initial step in this process requires an understanding of historic and current flow conditions to determine if current flows reflect past conditions. If this is the case, the development of minimum flows and levels becomes a question of what can be allowed in terms of withdrawals before significant harm occurs. If there have been changes to the flow regime of a river, these must be assessed to determine if significant harm has already occurred. If significant harm has occurred, recovery becomes an issue. The SWFWMD has adopted an approach for establishing benchmark flow periods that involves consideration of the effects of climatic changes on river flow patterns. The approach, which led to identification of separate benchmark periods for flow records collected prior to and after 1970, is now routinely used to develop MFLs for the freshwater segments of rivers within the SWFWMD.

Following assessment of historic and current flow regimes and the factors that have affected their development, the District develops protection standard statistics or criteria for preventing significant harm to the water resource. Criterion associated with fish passage in the river channel and maximization of the wetted perimeter are routinely used in the establishment of freshwater MFLs in the SWFWMD. Criterion associated with medium and high flows that result in the inundation of woody habitats associated with the river channel and vegetative communities on the floodplain are also used. The District routinely uses fish passage, wetted perimeter and other criteria to protect low flows and applied approaches associated with development of medium to high flow criteria per recommendations contained in the peer review of the proposed upper Peace River minimum flows (Gore et al. 2002). These efforts have included collection and analyses of in-stream fish and macroinvertebrate habitat data using the Physical Habitat Simulation (PHABSIM) model, and evaluation of inundation characteristics of floodplain habitats.

1.5.1 A Building Block Approach

The peer-review report on proposed MFLs for the upper segment of the Peace River (Gore et al. 2002) identified a "building block" approach as "a way to more closely mirror original hydrologic and hydroperiodic conditions in the basin". Development of regulatory flow requirements using this type of approach typically involves description of the natural flow regime, identification of building blocks associated with flow needs for ecosystem specific functions, biological assemblages or populations, and assembly of the blocks to form a flow prescription (Postel and Richter 2003). As noted by the panelists comprising the Upper Peace River MFLs review panel, "assumptions behind building block techniques are based upon simple ecological theory; that organisms and communities occupying that river have evolved and adapted their life cycles to flow conditions over a long period of pre-development history (Stanford et al. 1996). Thus with limited biological knowledge of flow requirements, the best alternative is to recreate the hydrographic conditions under which communities have existed prior to disturbance of the flow regime." Although in most cases, the District does not expect to recreate pre-disturbance hydrographic conditions through MFLs development and implementation, the building block approach is viewed as a reasonable means for ensuring the maintenance of similar, although dampened, natural hydrographic conditions.

Due to very low intra-annual variation (Figure 1-1) in discharge, the District has forgone the building block approach for the analyses of the Gum Slough Spring Run (Gum Slough). The high spike in flow around day 271 is due to the short period of record and the multiple hurricanes of 2004 having a major influence on the mean daily flow for that period. On September 9, 2004 there was 7.42 inches of rain at the nearby Inverness rain gauge. Two days later, flow at the Gum Springs near Holder gage exceeded 500 cfs. Although discharge exhibits seasonal variations, it was determined that the fluctuations are too small to benefit from the use of seasonal blocks and that a year-round flow prescription would be more applicable. This dampened annual hydrograph is similar to and similar decisions have been made on other spring fed systems including Homosassa River and Rainbow River.

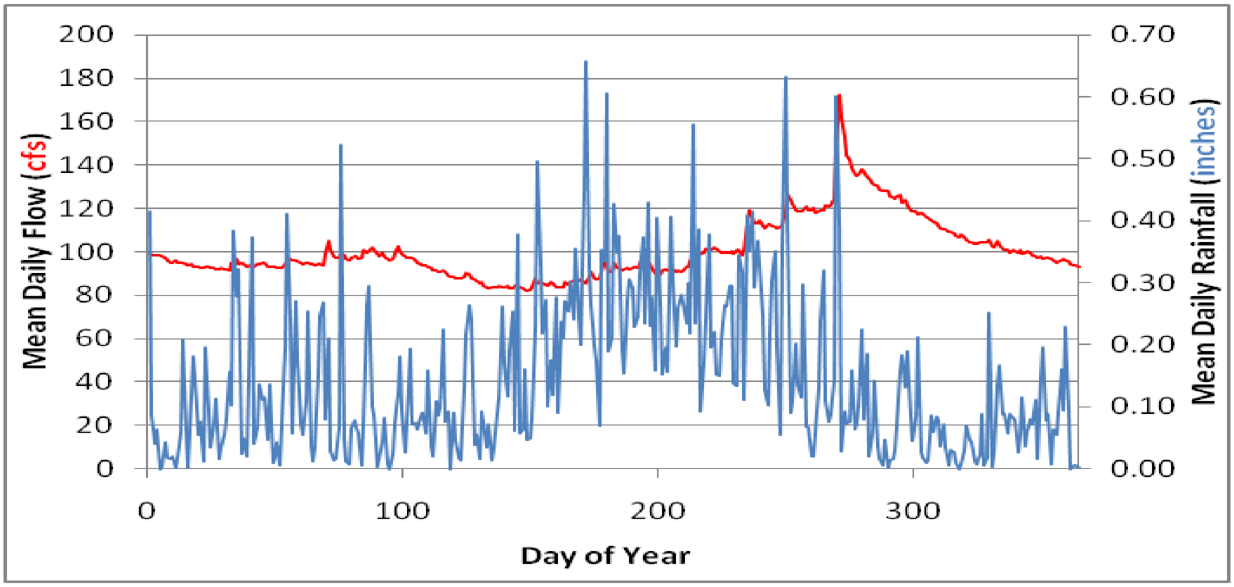


Figure 1-1. Mean daily flows (October, 2003 through September, 2010) and mean daily rainfall (January, 2003 through December, 2010) for Gum Springs near Holder.

1.6 Flows and Levels

Although somewhat semantic, there is a distinction between flows, levels and volumes that should be appreciated when considering MFLs development. The term "flow" may most legitimately equate to water velocity; which is typically measured by a flow meter. A certain velocity of water may be required to physically move particles heavier than water; for example, periodic higher velocities will transport sand from upstream to downstream; higher velocities will move gravel; and still higher velocities will move rubble or even boulders. Flows may also serve as a cue for some organisms; for example, certain fish species search out areas of specific flow for reproduction and may move against flow or into areas of reduced or low flow to spawn. Certain macroinvertebrates drift or release from stream substrates in response to changes in flow. This release and drift among other things allows for colonization of downstream areas. One group of macroinvertebrates, the caddisflies, spin nets in the stream to catch organisms and detritus carried downstream, and their success in gathering/filtering prey is at least partially a function of flow. Other aquatic species have specific morphologies that allow them to inhabit and exploit specialized niches located in flowing water; their bodies may be flattened (dorsally-ventrally compressed) to allow them to live under rocks or in crevices; they may have special holdfast structures such as hooks or even secrete a glue that allows them to attach to submerged objects.

Discharge refers to the volume of water moving past a point per unit time, and depending on the size of the stream (cross-sectional area), similar volumes of water can be moved with quite large differences in the velocity. The volume of water moved through a stream can be particularly important to an estuary. It is the volume of freshwater that mixes with salt water that determines, to a large extent, what the salinity in a fixed area of an estuary will be. This is especially important for organisms that require a certain range of salinity. The volumes of fresh and marine water determine salinity, not the flow rate per se; therefore, volume rather than flow is the important variable to this biota. For the purpose of developing and evaluating minimum flows, the District identifies discharge in cubic feet per second for field-sampling sites and specific streamflow gaging stations.

In some cases, the water level or the elevation of the water above a certain point is the critical issue to dependent biota. For example, the wetland fringing a stream channel is dependent on a certain hydroperiod or seasonal pattern of inundation. On average, the associated wetland requires a certain level and frequency of inundation. Water level and the duration that it is maintained will determine to a large degree the types of vegetation that can occur in an area. Flow and volume are not the critical criteria that need to be met, but rather water surface elevation or level.

There is a distinction between volumes, levels and velocities that should be appreciated. Although levels can be related to flows and volumes in a given stream (stream gaging, in fact, often depends on the relationship between stream stage or level and discharge), the relationship varies between streams and as one progresses from upstream to downstream in the same system. Because relationships can generally be empirically determined between levels, flows and volumes, it is possible to speak in terms of, for example, minimum flows for a particular site (discharge in cubic feet per second); however, one needs to appreciate that individual species and many physical features may be most dependent on a given flow, level or volume or some combination of the three for their continued survival or occurrence. The resultant ecosystem is dependent on all three.

CHAPTER 2 – BASIN DESCRIPTION

This chapter includes a brief description of the Gum Slough Spring Run (Gum Slough) watershed including location and climate. A complete description of physiography and hydrogeology are included in Section 4.2.

2.1 Geographic Location

Gum Slough, which is designated as an "Outstanding Florida Waters" by the Department of Environmental Protection, originates along the boundary of Sumter and Marion counties and flows into the Withlacoochee River. The run travels west and southwest approximately five miles before reaching the Withlacoochee River. Figures 2-1 and 2-2 illustrate the location of the Gum Slough and the location of study sites along the run. For the purpose of this report, the Gum Slough watershed boundaries were those delineated by the United States Geological Survey (Sepulveda 2002).

The Gum Slough watershed is approximately 51 square miles or 32,500 acres. Currently, the dominant land use in the watershed is urban and built-up. Although developed in the 1960's, much of this urban area is low density due to the Marion Oaks residential development being largely composed of vacant lots. The Marion Oaks subdivision (Figure 2-3) is approximately 16,000 acres and has an estimated population of 15,000 (GIS Associates 2010). The Florida Land Use, Cover and Forms Classifications for this area is Residential, Low Density indicating that there are fewer than two dwelling units per acre. Although the Land Use is classified as urban and Built-up, much of the Land Cover remains Upland Forest.

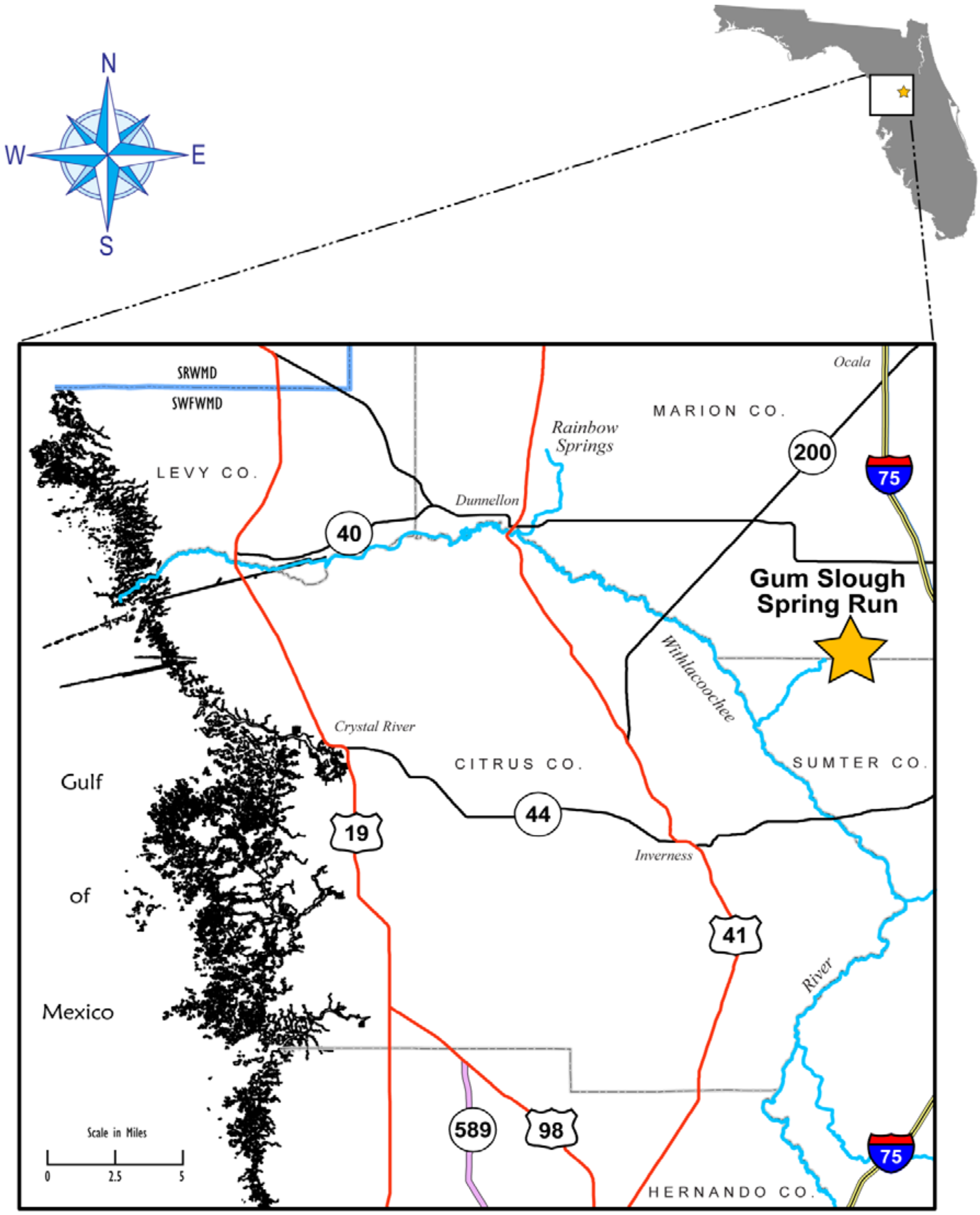


Figure 2-1. Map of the location of the Gum Slough Spring Run.

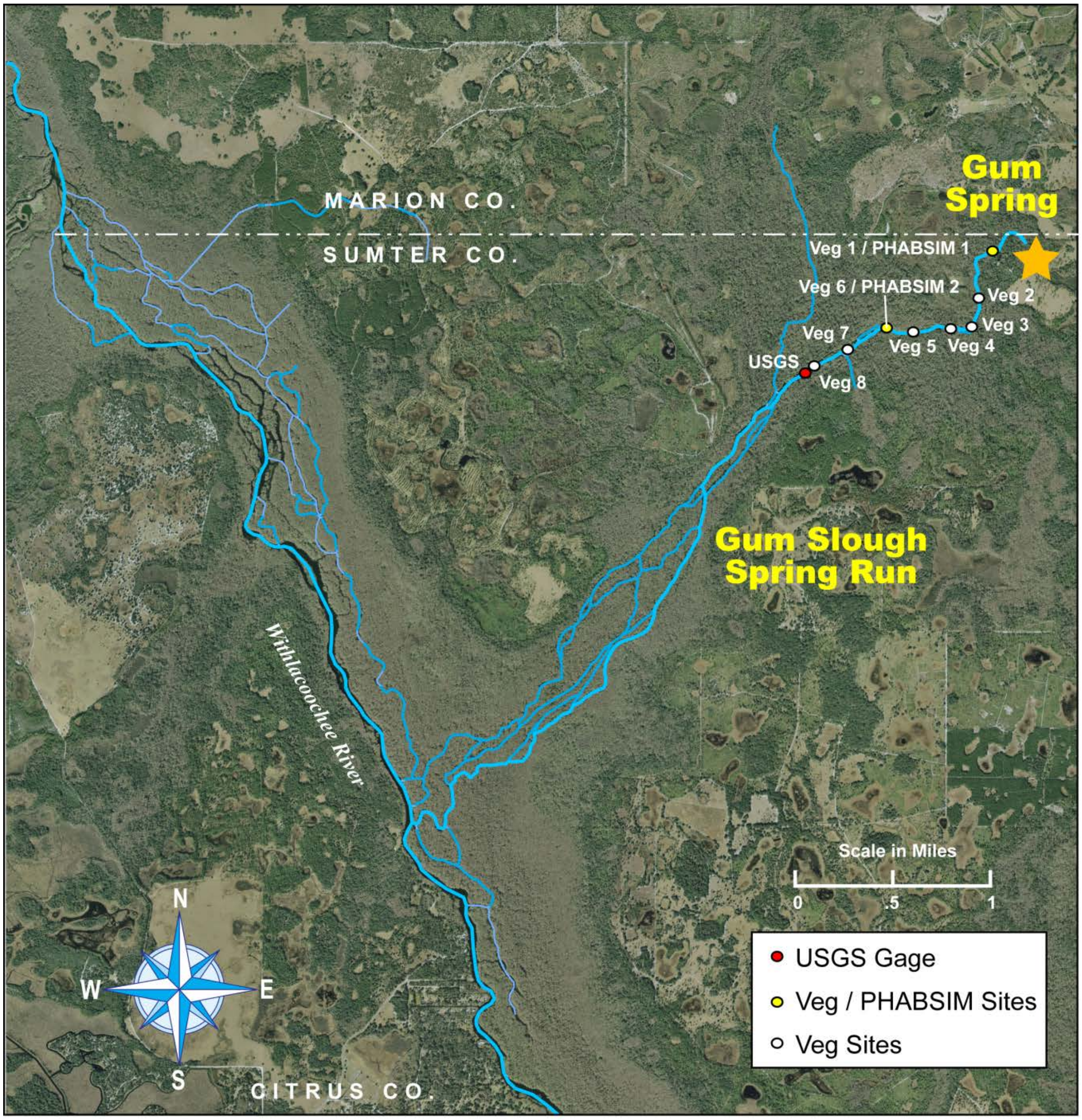


Figure 2-2. Location of the Gum Slough Spring run and study sites.

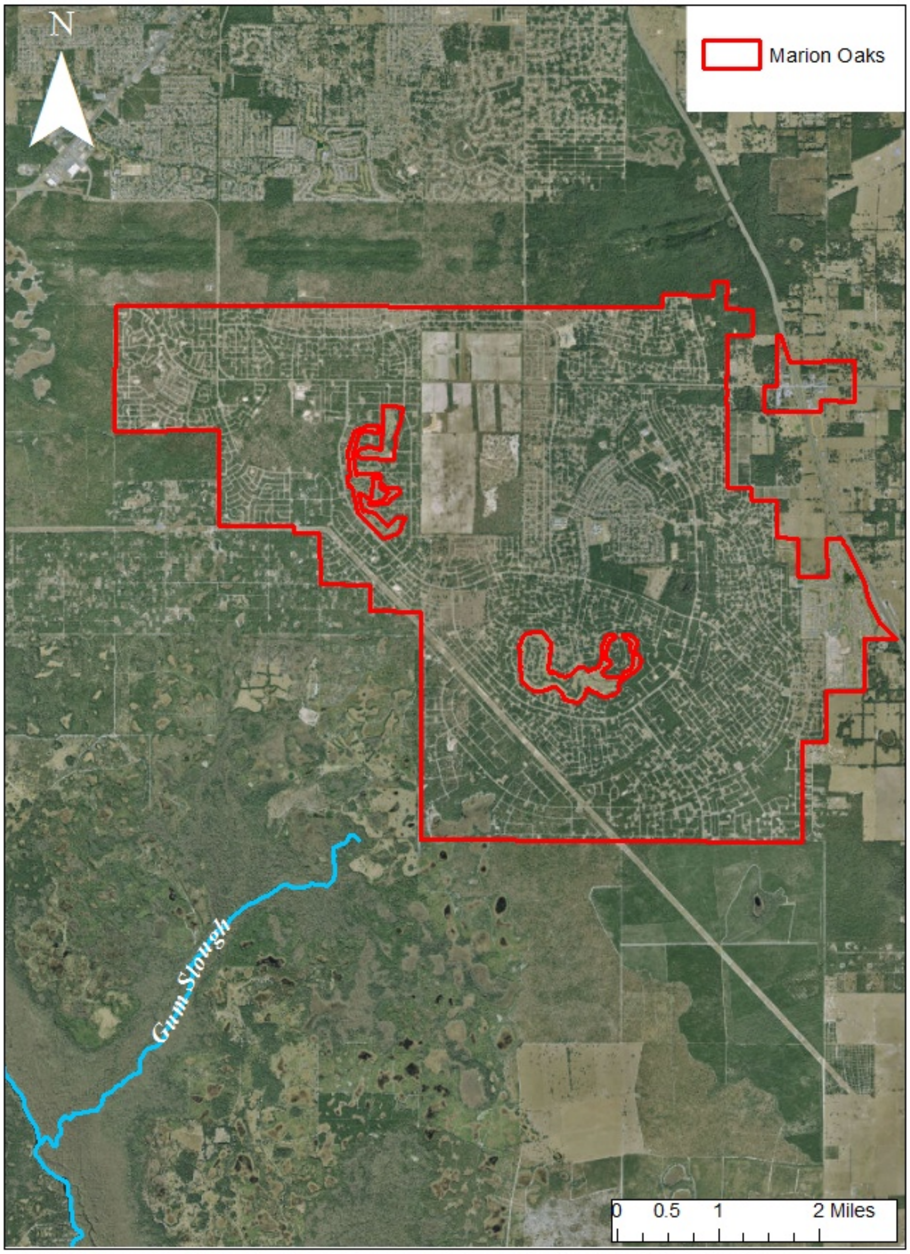


Figure 2-3. Location and size of Marion Oaks subdivision.

Much of the land surrounding the run is public ownership or privately owned conservation land (Figure 2-4). The remainder of land adjacent to the river is owned by two private owners.

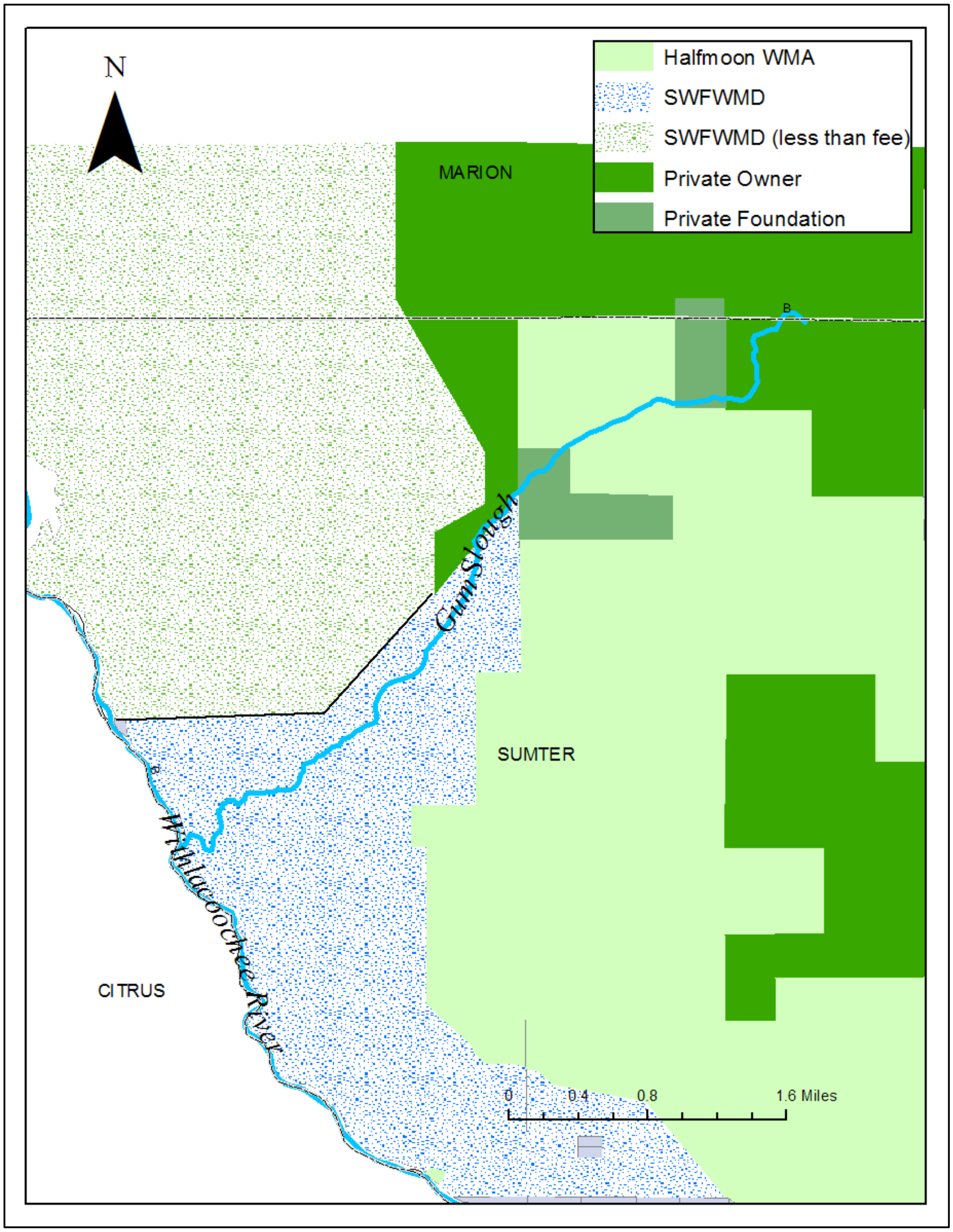


Figure 2-4. Land ownership adjacent to the Gum Slough Springs Run.

2.2 Climate

The Gum Slough watershed lies within the subtropical climatic zone. Average rainfall is approximately 54 inches but varies widely from season to season and year to year. A large portion of the rainfall in the watershed occurs between June and September (Figure 1-1). Dry season flows are almost entirely baseflow from the various springs along the run. The average mean daily temperature is approximately 72^{o} F (22^{o} C). Mean summer temperatures are in the low 80's (^{o}F) and the mean winter temperatures are in the upper 50's (^{o}F).

CHAPTER 3 – LAND USE

This chapter includes a presentation and discussion of land use data. These data are evaluated to examine the potential impact of land use changes on river flow volumes and water quality trends.

3.1 Land Use Changes in the Gum Slough Watershed

A series of maps, tables and figures were generated for the Gum Slough watershed for four specific years (1974, 1990, 1995 and 2004) for purposes of considering land use changes that have occurred over the last several decades (Figure 3-1 through 3-4). The 1974 maps, tables and figures represent land use and cover generated using the USGS classification system (Anderson et al. 1976). The USGS classification has a minimum mapping unit of 10 acres for man-made features with a minimum width of 660 feet. The minimum mapping unit for non-urban and natural features is 40 acres with a minimum width of 1320 feet. The 1990, 1995 and 2004 maps represent land use and land cover information from the Florida Department of Transportation (FDOT). The FDOT (1999) developed the Florida Land Use, Cover and Forms Classification System (FLUCCS) using the USGS classification system as its basis. Unlike the USGS classification system, the FLUCCS is a hierarchical system with four different levels of classification. Each level contains information of increasing specificity to describe land cover conditions. Minimum mapping units are also smaller. The minimum mapping unit for uplands is 5 acres; for wetlands the minimum mapping unit is 0.5 acres.

The 1990, 1995 and 2004 land use/land cover maps are more detailed than the 1974 maps due to the higher resolution of the latter maps and differences in land use categories. As a result, some of the changes in land uses between the USGS and FLUCCS derived maps are likely the result of differences in methodologies rather than actual land use changes. However, for presentation and discussion purposes, we combined numerous land use types into fairly broad categories, and thereby eliminated much of the error associated with the use of the two classification systems. Land use/cover types identified for our analysis included: Urban and Built-up, Rangeland, Pasture and Other Agriculture, Wetlands (forested and non-forested), Water, Uplands, and Other.

The Gum Slough watershed is approximately 50 square miles or 32,650 acres. From inspection of percentage changes as shown in either Table 3-1 or Figure 3-5, several land use/cover changes are readily apparent. There has been a noticeable increase in the urban land use. As of 2004, 47% of the watershed was categorized as urban land use. In 1974, urban land was approximately 0% of the watershed, which amounts to the urbanization of 15,400 acres over a 30 year period. This was primarily a shift from upland forest as there were approximately 11,000 fewer acres in this land cover in 2004 as compared to 1974. Although developed in the 1960s, much of this urban area is low density due to the Marion Oaks Sub-division being largely composed of vacant lots (Figure 2-3). The remaining land use categories remained fairly stable with the exception of a few changes between 1974 and 1990 which may be attributable to mapping differences and improvements.

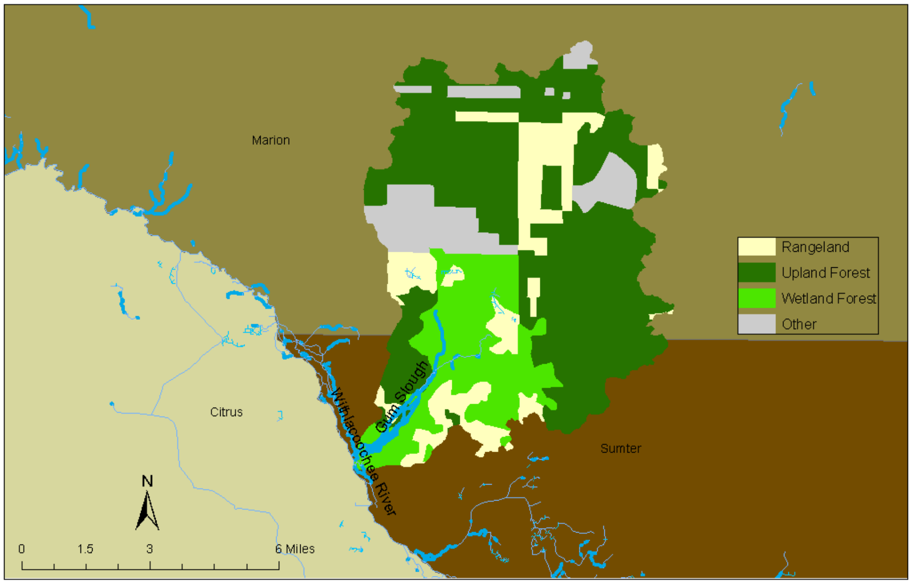


Figure 3-1. 1974 Land Use/cover maps of the Gum Slough watershed, Florida.

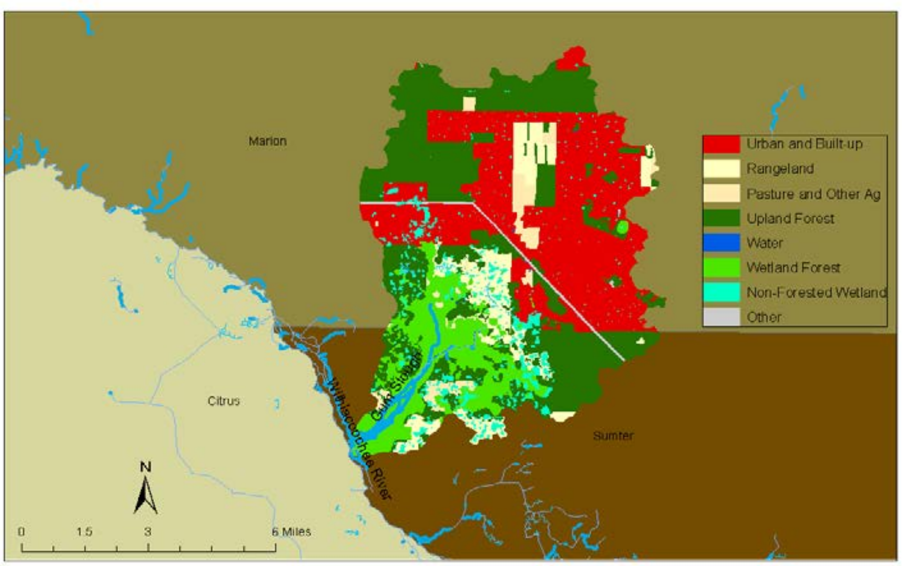


Figure 3-2. 1990 Land Use/cover maps of the Gum Slough watershed, Florida.

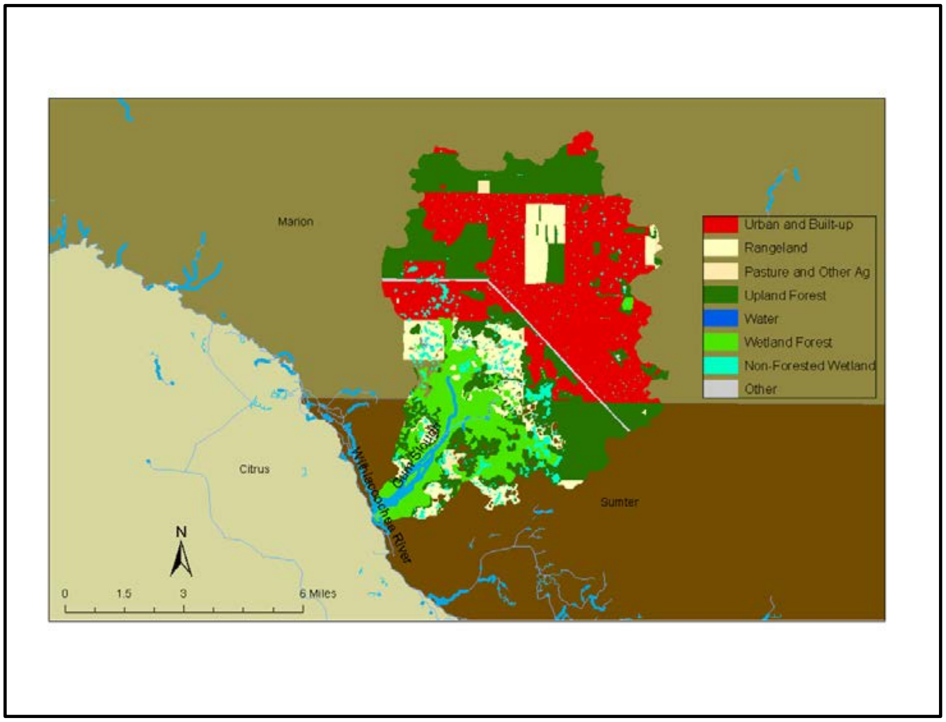
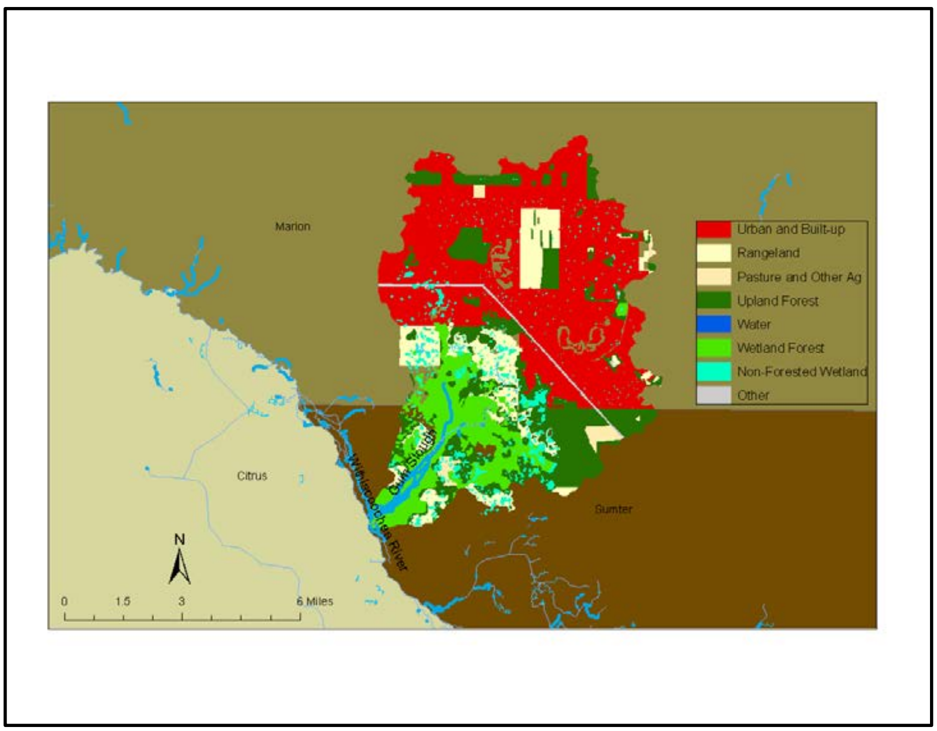


Figure 3-3. 1995 Land Use/cover maps of the Gum Slough watershed, Florida.



. **Figure 3-4. 2004 Land Use/cover maps of the Gum Slough watershed, Florida.**

Table 3-1. Land use and land cover (by percentage) changes in the Gum Slough Watershed (51 acres) for four time periods; 1974, 1990, 1995 and 2004.

Gum Springs Watershed	1974(%)	1990(%)	1995(%)	2004(%)
Urban and Built-up	0	35	37	47
Rangeland	16	8	10	10
Pasture and Other Ag	0	3	1	2
Upland Forest	54	35	32	22
Water	0	0	1	0
Wetland Forest	19	14	13	13
Non-Forested Wetland	0	5	4	5
Other	11	1	1	1

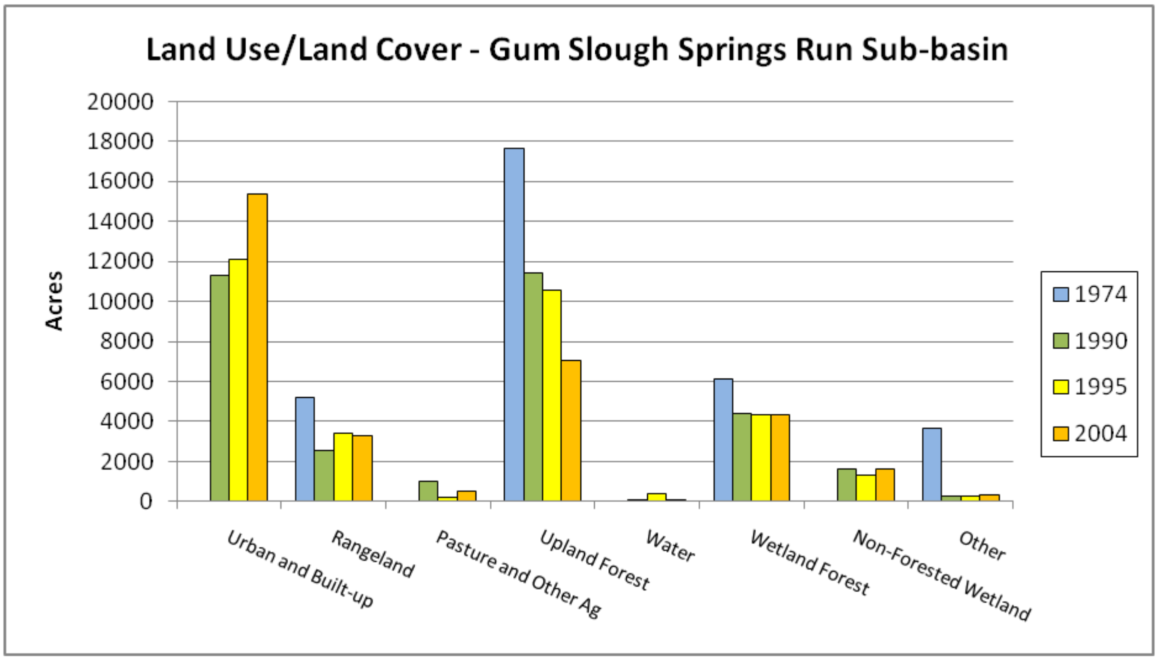


Figure 3-5. Comparison of land use and land cover changes in the Gum Slough watershed.

CHAPTER 4 - HYDROLOGY

4.1 Overview

The Gum Slough Spring Run originates from numerous spring vents near the Sumter/Marion county line. The run travels west and southwest approximately five miles before entering the Withlacoochee River. The upper half of the run is generally one channel but becomes highly braided on the lower half as it approaches the Withlacoochee River. For the purpose of establishing the MFL for the Gum Slough, the study reach is from the headspring to the USGS gage (Figure 2-2).

The average flow for the USGS gage Gum Springs near Holder (02312764) is 98 cfs for the period of record (October, 2003 through September, 2010 (Figure 4-1). Although the period of record is considerably shorter than that of other rivers that the SWFWMD has established MFLs for, anecdotal evidence suggests that, although average flows have been lower in more recent years, the extreme high and low flows seen since 2003 are representative of the full range of flows for the past fifty years (Judy Smith, personal communication, July 2010).

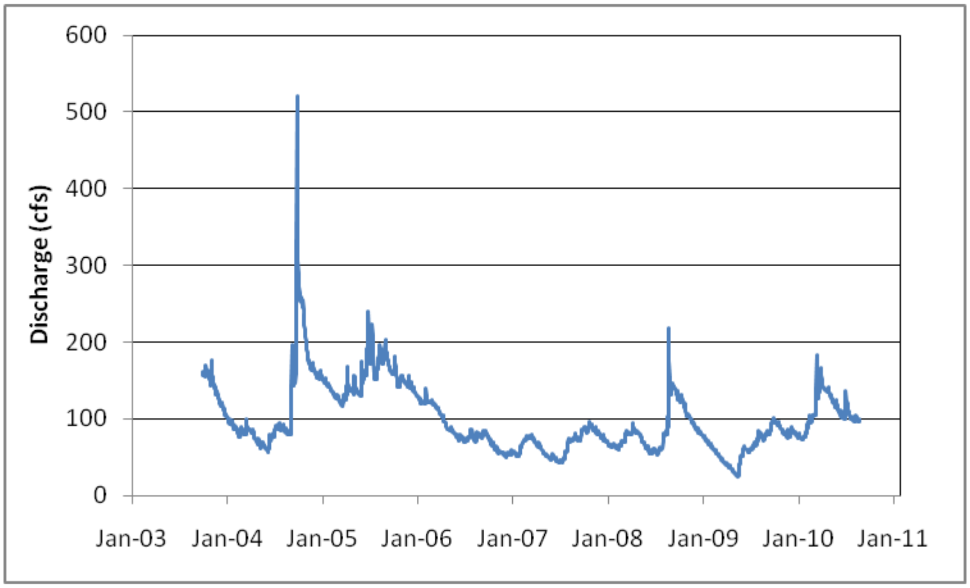


Figure 4-1. Period of record discharge (October 2003 through September 2010) as measured at the USGS gage Gum Springs near Holder (02312764).

4.2 <u>Hydrologic Analysis of Flow Decline</u>

4.2.1 Introduction

Gum Slough is located in northwest Sumter County about six miles northeast of the Withlacoochee River (Figure 4-2). The main spring pool measures 69 ft. north to south and 81 ft. east to west (FGS 2001). The depth measured over the vent is 9.8 ft. The head spring vent is located just 5 ft. north of an old wooden dock on the south side of the spring (see Figure 7-3 for location of vents). The spring pool water color is bluish green with suspended algal mats and particles. Gum Springs forms the headwaters of Gum Slough, which flows southwest into the Withlacoochee River. There are at least six individual springs along Gum Slough located up to 0.8 miles from the head spring (Rosenau et al. 1977). Champion and Starks (2001) termed this collection of springs as the Gum Slough Springs Group. Individual springs that make up the group include Gum Spring Main, Gum Slough numbers 1-4, and Alligator Spring.

Prior to establishment of a Minimum Flow (MF), an evaluation of hydrologic changes in the vicinity of the spring is necessary to determine if the water body has been significantly impacted by existing groundwater withdrawals. This section describes the hydrogeologic setting near the spring and provides the results of a numerical model simulation of predicted springflow change due to existing groundwater withdrawals.

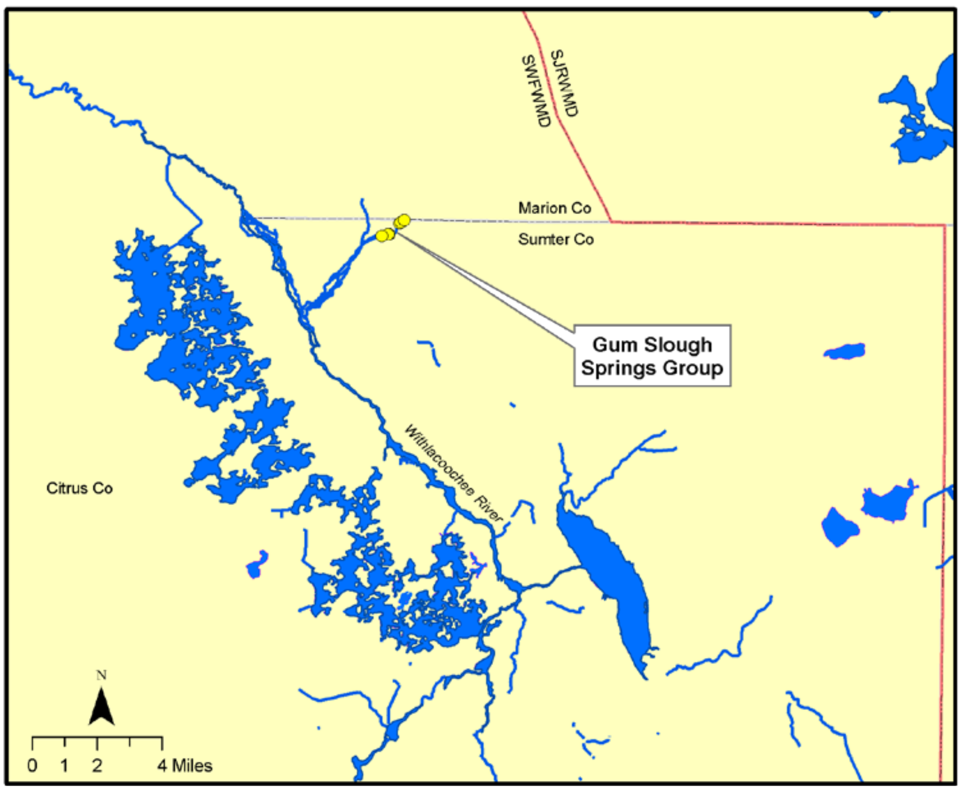


Figure 4-2. Location of the Gum Slough Springs Group.

4.2.2 Hydrogeologic System

The hydrogeologic framework in the Gum Springs area includes a surficial aquifer, a discontinuous intermediate confining unit, and a thick carbonate rock sequence named the Floridan aquifer system. At land surface and extending several tens of feet deep are generally fine-grained quartz sands that grade into clayey sand just above the contact with limestone. A thin, sometimes absent, sandy clay layer forms the intermediate confining unit (ICU) and overlies the limestone units of the Upper Floridan Aquifer (UFA). In general, a regionally extensive surficial aquifer is not present because the clay confining unit is thin, discontinuous, and breeched by numerous karst features. Because of this geology, the UFA is mostly unconfined in the Gum Springs area.

The geologic units, in descending order, that form the UFA include the Oligocene Suwannee Limestone, the upper Eocene Ocala Limestone, and the middle Eocene Avon Park Formation. In northern Pasco and Hernando counties, the Suwannee Limestone is the uppermost unit. Further north in Citrus and Sumter Counties, the Ocala Limestone forms the top of the Upper Floridan aquifer, except in extreme southern Levy County where the Avon Park Formation is exposed near land surface. The entire carbonate sequence of the UFA thickens and dips toward the south and southwest. Average thickness of the UFA ranges from 500 feet in southern Levy County to 1,000 feet in central Pasco County (Miller 1986).

Two aquifers are recognized in the Gum Springs area within the Floridan aquifer system: the Upper Floridan and Lower Floridan (Hill and Basso 2005). Both the Upper Floridan and Lower Floridan aquifers are highly productive and provide the primary source of groundwater in the area. The Upper Floridan Aquifer (UFA) occupies the saturated portion of the Ocala Limestone and extends from about twenty feet below land surface to approximately 250 feet (Fredericks 2010; AEI 2003). The Ocala Limestone has been extensively exposed to solutional processes and consequently the top of the unit is highly karstified. Underlying the UFA is Middle Confining Unit 1 (MCU 1) (Miller 1986). In the Gum Springs area, this unit occurs in the upper part of the Avon Park Formation. It is generally comprised of dolostone and dolomitic limestone that is lower in permeability than the overlying Upper Floridan aquifer and underlying Lower Floridan aquifer.

The Lower Floridan aquifer (LFA) generally occurs at depths below 500 feet and extends to approximately 2,000 feet (Campbell 1989). The LFA lies within the Avon Park and Oldsmar Formations, which consists of interbedded limestone and dolostone with minor components of gypsum and anhydrite (Campbell 1989). The basal confining unit of the LFA occurs at the top of the Cedar Keys Formation which is composed of massive anhydrites interbedded with limestone (Miller 1986). The largely freshwater LFA below MCU 1 is only found in portions of Marion and Sumter County within the District. MCU 1 does not exist in the remainder of the District and the LFA lies below the gypsum-anhydrite dominated Middle Confining Unit 2 (MCU 2) unit. The LFA below MCU 2 generally contains poor quality, highly-mineralized water.

Gum Springs is located in a transition zone between where the MCU 1 and MCU 2 units exist as described by Miller (1986). Since deep exploratory drilling has not occurred near Gum Springs, it is presumed that the hydrogeology of this area is similar to northeast Sumter County. It is just as plausible, however, that MCU 1 does not exist at this location and the LFA is contained below the gypsum-anhydrite dominated MCU 2 unit at this site.

Dissolution of limestone is an active process via infiltration of rainwater, because the limestone units of the UFA are close to land surface and poorly confined. Numerous sinkholes, internal drainage, and undulating topography that are typical of karst geology dominate the landscape. These active karst processes lead to enhanced permeability within the Upper Floridan aquifer. The median transmissivity value of the UFA based on six aquifer performance tests in southwest Marion and northern Sumter Counties is 325,000 ft^2/day (SWFWMD 2006).

There are two first-magnitude springs (flow greater than 100 cubic feet per second discharge) found near the Gum Slough Springs Group: the Rainbow Springs group and Silver Springs. Both major springs are located in Marion County. These two springs together discharge approximately one billion gallons (1,547 cfs) per day of water from the UFA. The Rainbow Springs group discharges approximately 600 cubic feet per second (388 mgd) to the Rainbow River which provides tributary inflow to the Withlacoochee River just east of Lake Rousseau. In addition, very high recharge rates to the UFA occur in west-central Marion, eastern Citrus and northern Sumter Counties with values ranging between 10 and 25 inches per year (Sepulveda 2002).

4.2.2.1 Groundwater Withdrawals in the Vicinity of Gum Springs

The District currently maintains a database of metered and estimated water use for the period from 1992 through 2006. Figure 4-3 shows the groundwater withdrawals in the vicinity of Gum Springs for 2005 based on District data and 2002 water use estimates from the St. Johns River Water Management District. Groundwater use in 2005 within the immediate vicinity of Gum Springs is low. Groundwater withdrawn within two, five, and ten miles of the Gum Slough Springs Group was 0, 1.5, and 11.2 million gallons per day (mgd), respectively Most of the individual groundwater withdrawals are small and dispersed in the Gum Springs area except within the Villages Development in northeast Sumter County and the City of Ocala in Marion County.

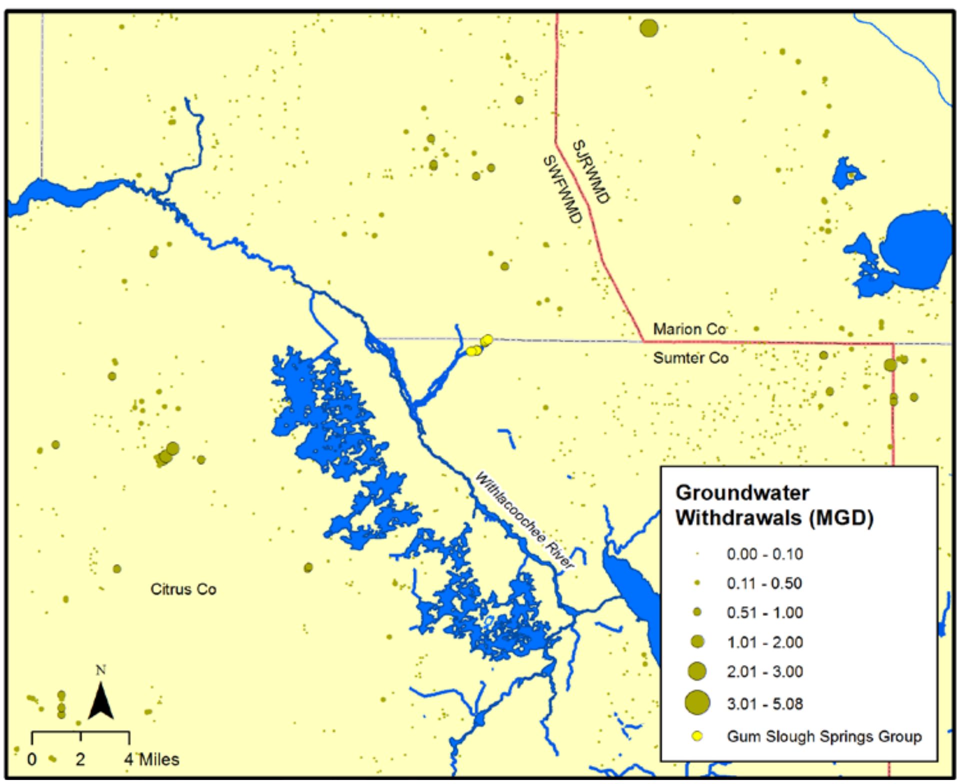


Figure 4-3. UFA groundwater withdrawals near Gum Springs during 2005.

4.2.2.2 Gum Slough Discharge History

Streamflow history at Gum Slough is only available since 2003 when the USGS installed a gage approximately 1.5 miles downstream of the Gum Springs Main Spring (Figure 4-4). During the approximate seven years of record, median daily flow was 84 cfs (54.3 mgd). The maximum and minimum daily recorded flows were 520 (336 mgd) and 24 (15.5 mgd) cfs, respectively (Figure 4-5). The maximum recorded flow occurred as Hurricane Jeanne crossed the state in late September 2004. Hurricane Frances also contributed heavy rainfall in early September 2004. The lowest recorded discharge was measured following a prolonged drought during May 2009.

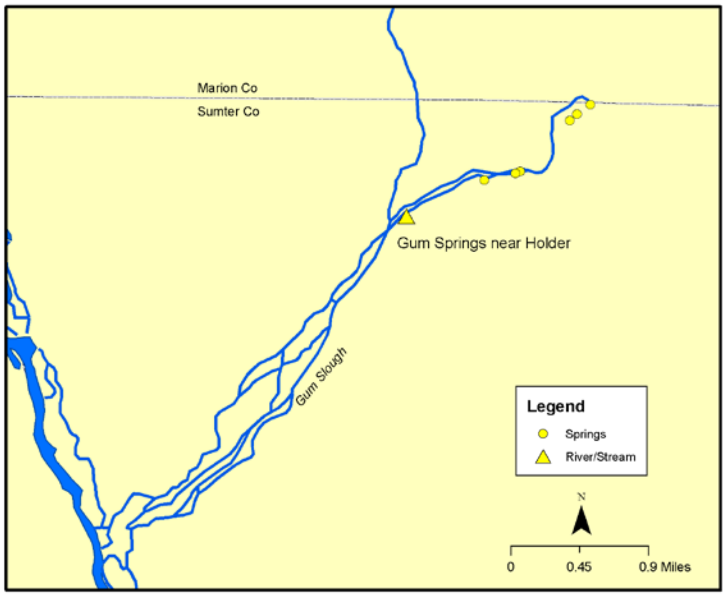


Figure 4-4. Location of the USGS 02312764 Gum Springs near Holder FL streamflow measuring station on Gum Slough.

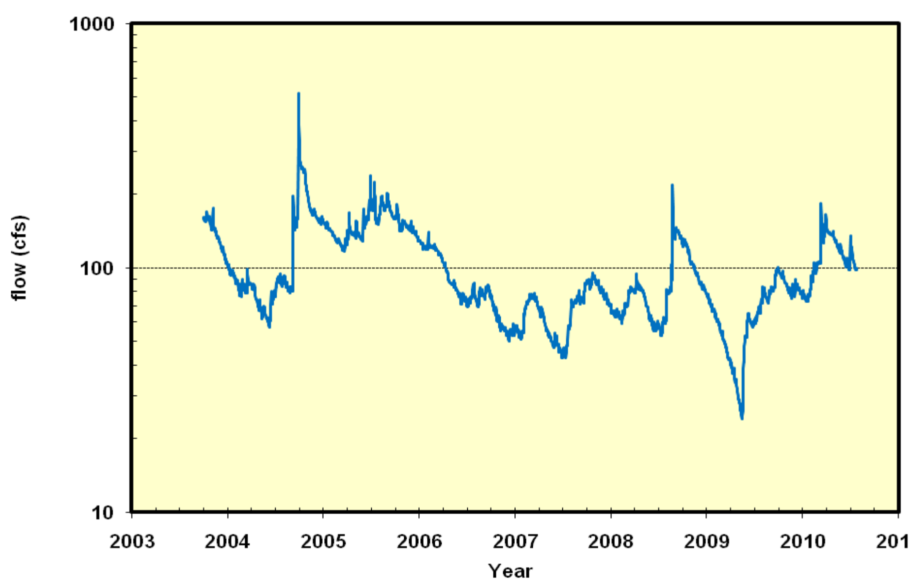


Figure 4-5. Flow history at the USGS Gum Springs near Holder station.

4.2.2.3 Gum Slough Baseflow Separation

Review of the Gum Slough flow hydrograph indicates that there is a stormwater runoff contribution to Gum Slough flow that is independent of baseflow contribution from the springs. During September 2004, flow reached 520 cfs and during the summer rainy season flow can typically exceed 200 cfs (Figure 4-5). Since the MF will be established based on total streamflow, it is necessary to separate out runoff and groundwater contributions (baseflow) so that impacts to flow can be properly assessed.

Baseflow separation is a process that estimates the groundwater contribution to the total streamflow. Baseflow contributions to the stream from the groundwater system were examined using a separation technique developed by Perry (1995). This method has been utilized extensively in west-central Florida by the University of South Florida in developing estimates of baseflow for a regional surface water model (Geurink and others, 2000). Hydrogeologic (2008, 2010) utilized this approach in development of baseflow estimates for calibrating groundwater seepage to streams in their Northern District groundwater flow model versions 1.0 and 2.0. The method was employed to develop streamflow calibration targets for the Northern District groundwater flow model for the 1995 steady-state and 1996-2006 transient simulations.

The technique is a low-pass filter and works with a specific time-window, in this case 121 days. The 121-day period represents a time span of 60 days prior to a specified date, the specified date, and 60 days after the specified date. The minimum daily flow recorded for a 121-day period is recalculated on a daily basis by moving the window forward one day at a time. Another time series is then created, also using a 121-day moving window, which averages the minimum flows generated from the initial time-series of 121-day lowest daily flows. The result is a smoothed time series of minimum flows, which is the assumed baseflow. This method was utilized to calculate average baseflow for the long-term USGS gaging station at Gum Slough for the period of record (Figure 4-6). Based on this technique for the period of record from October 2003 through July 2010, average streamflow was 98 cfs with a baseflow contribution of 73 cfs. For Gum Slough, baseflow contributes approximately 75 percent of streamflow volume as measured at the Gum Springs near Holder gage using this baseflow separation technique.

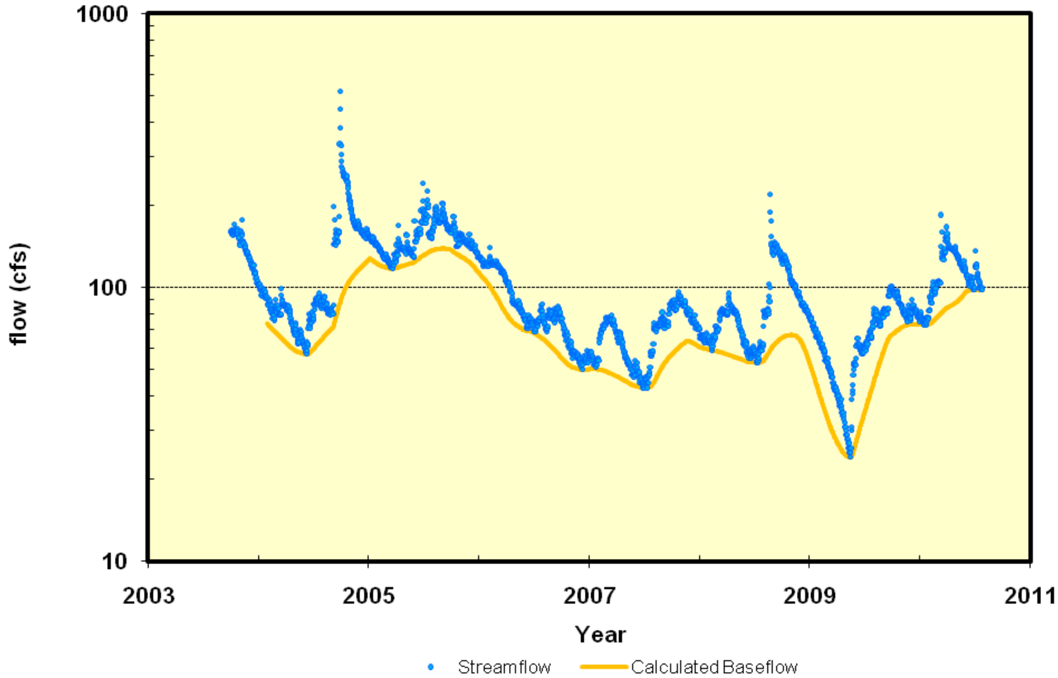


Figure 4-6. Streamflow and estimated baseflow at the Gum Springs near Holder station.

4.2.2.4 Long-Term Rainfall Changes

Analysis of rainfall averaged from the Brooksville, Inverness, and Ocala National Oceanic and Atmospheric Administration (NOAA) stations from 1930 through 2008 shows a declining trend after 1970, especially pronounced after 1989. Cumulative departure from mean annual rainfall for the 1970 to 2008 period is -71.2 inches. In contrast, the cumulative departure from mean rainfall from 1931-1969 is +74 inches (Figure 4-7). Annual departure in mean rainfall shows that 27 out of 39 years since 1970 have recorded below average rainfall (Figure 4-8).

The rainfall record was also parsed into 3, 6, and 10-year average periods from 1901 through 2009. Rainfall data from the SWFWMD headquarters, Inverness Pool, and Ocala Airport was used in 2009 since the NOAA station data was unavailable. Each period was compared to the highest ten percent (P10), the median, and the lowest ten percent (P90) values for each period's rainfall (Figures 4-9 through 4-11). The 3-year, 6-year, and 10-year values ending in 2009 were near or at the 85 percent exceedance rainfall for each period. The majority of values for the 3, 6 and 10-year periods were substantially below median rainfall after 1970.

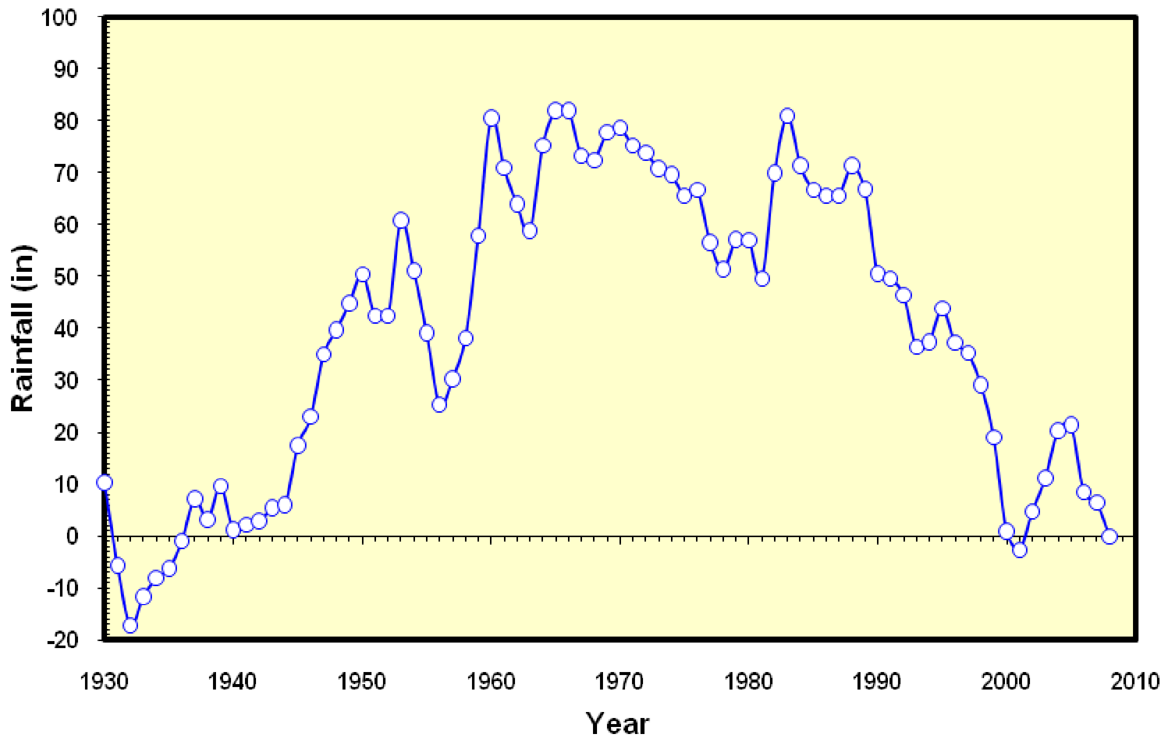


Figure 4-7. Cumulative departure in mean annual rainfall from 1930 through 2009 based on average rainfall values for the Inverness, Ocala, and Brooksville NOAA rainfall stations (Note: 2009 data from nearby SWFWMD rainfall stations).

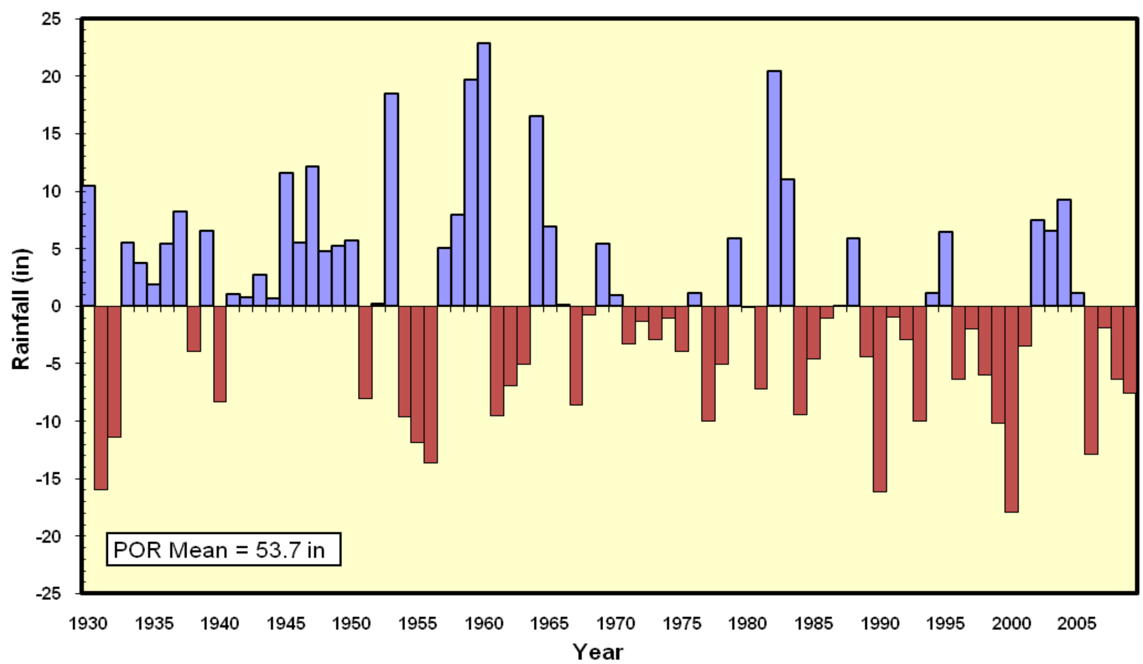


Figure 4-8. Annual departure in mean rainfall from 1930 through 2009 based on rainfall averaged from the Inverness, Ocala, and Brooksville NOAA rainfall stations (Note: 2009 data from nearby SWFWMD rainfall stations).

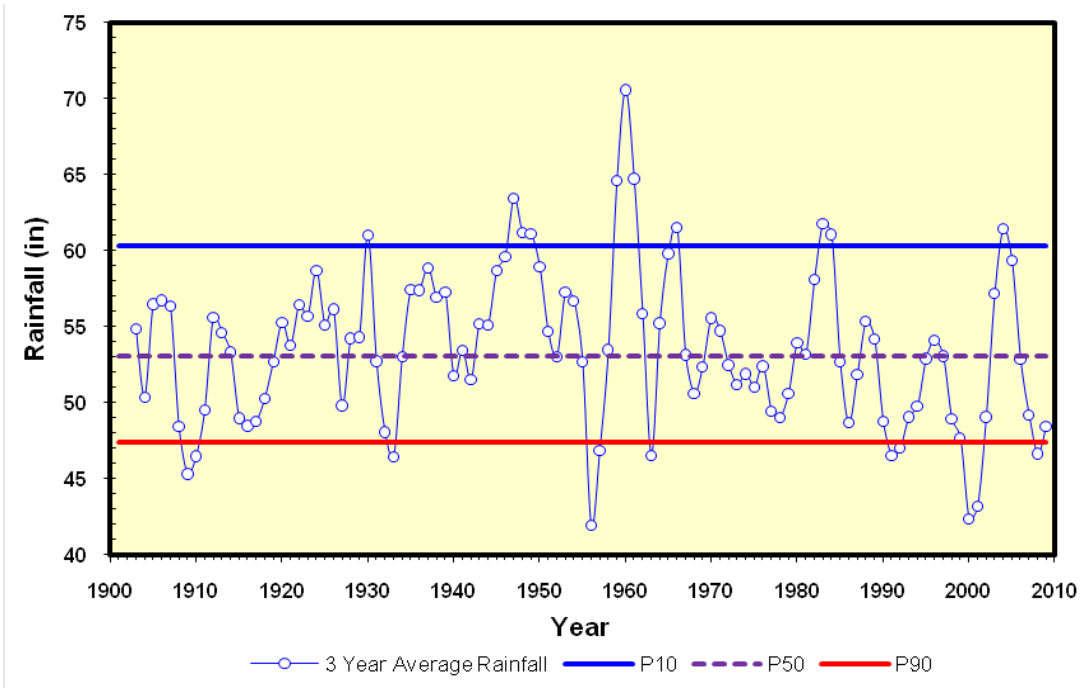


Figure 4-9. Three-year average rainfall compared to the P10, P50, and P90 percentiles (1901-2009). Average rainfall based on records for the Inverness, Ocala, and Brooksville NOAA rainfall stations (Note: 2009 data from nearby SWFWMD rainfall stations).

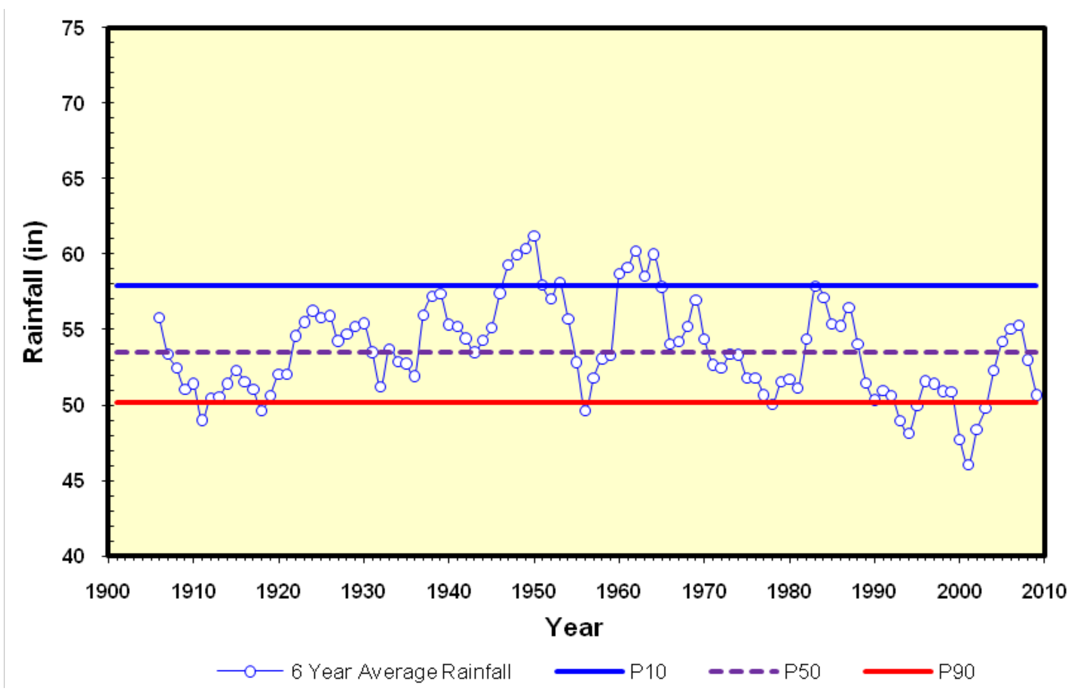


Figure 4-10. Six-year average rainfall compared to the P10, P50, and P90 percentiles (1901-2009). Average rainfall based on records for the Inverness, Ocala, and Brooksville NOAA rainfall stations (Note: 2009 data from nearby SWFWMD rainfall stations).

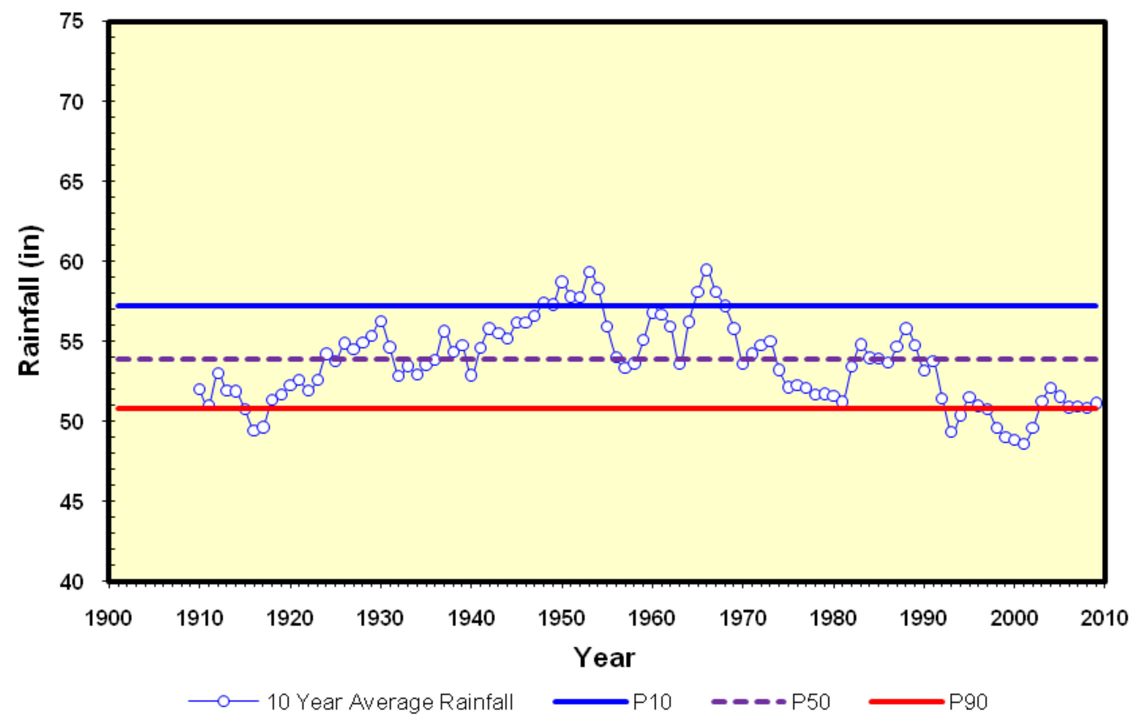


Figure 4-11. Ten-year average rainfall compared to the P10, P50, and P90 percentiles (1901-2009). Average rainfall based on records for the Inverness, Ocala, and Brooksville NOAA rainfall stations (Note: 2009 data from nearby SWFWMD rainfall stations).

4.2.3 Numerical Model Results

A number of regional groundwater flow models have included the Gum Springs area. Ryder (1982) simulated the entire extent of the SWFWMD. In 2002, the USGS simulated the entire Florida peninsula in their "Mega Model" of regional groundwater flow (Sepulveda 2002).

4.2.3.1 Northern District Model

The SWFWMD Northern District groundwater flow model (NDM) was completed in May 2008 by the consulting firm HGL, Inc. (Hydrogeologic, Inc. 2008). The domain of the NDM includes portions of the SWFWMD, the St. Johns River Water Management District (SJRWMD), and the Suwannee River Water Management District (SRWMD). The flow model encompasses the entire extent of the Central West-Central Florida Groundwater Basin (CWCFGWB) and the Northern West-Central Florida Groundwater Basin (NWCFGWB). The eastern boundary of the regional groundwater flow model extends just east of the Lake County/Orange County line. The western boundary of the model domain extends approximately five miles offshore of the Gulf of Mexico.

The regional model finite-difference grid consists of 182 columns and 275 rows of 2,500 ft. uniform grid spacing (Refer to Figure 4-12 for the geographical distribution of NDM). The NDM is fully 3-Dimensional with top and bottom elevations specified for each model layer. Topographic elevations were assigned to the top of model layer 1 from a digital elevation model provided by SWFWMD, based on the USGS 30m National Elevation Dataset (NED). The Florida Geological Survey supplied elevation data for all other layers in the model.

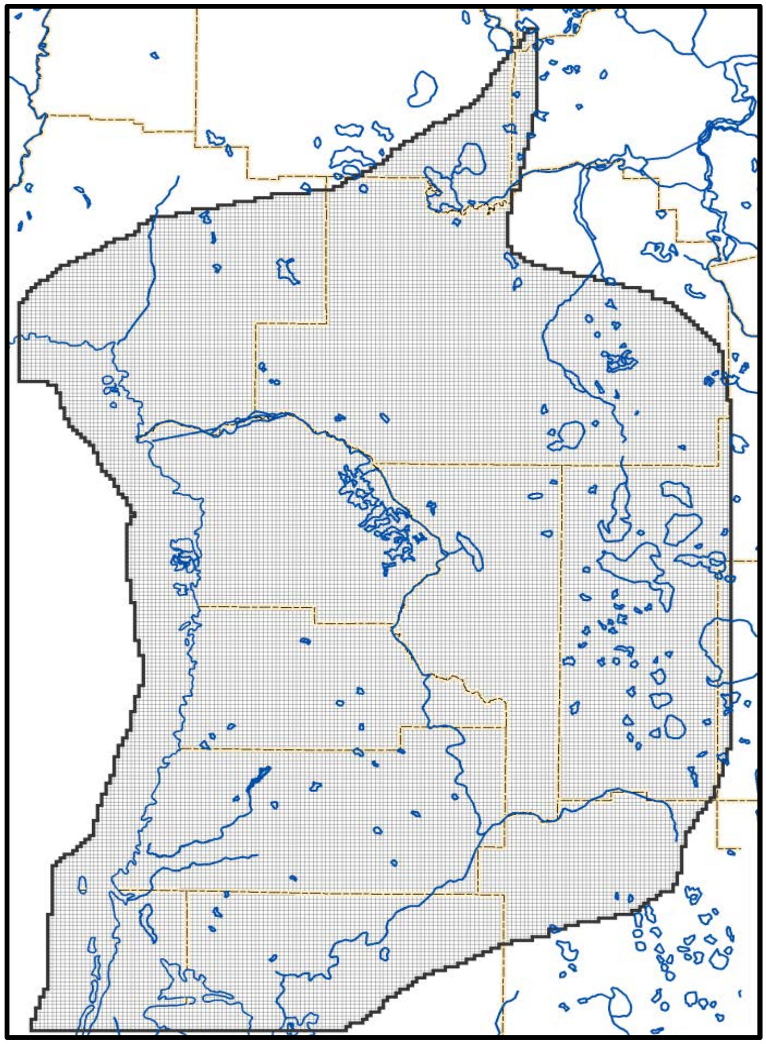


Figure 4-12. Groundwater grid in the Northern District model.

The NDM consists of seven layers that represent the primary geologic and hydrogeologic units including: 1. Surficial Sands; 2. Intermediate Confining Unit (ICU); 3. Suwannee Limestone; 4. Ocala Limestone; 5. Upper Avon Park Formation; 6. Middle Confining Unit (MCU) I and MCU II; and 7. Lower Avon Park Formation or Oldsmar Formation. The UFA is composed of the Suwannee Limestone, Ocala Limestone, and upper Avon Park; the Lower Floridan aquifer (LFA) is composed of the permeable parts of both the Avon Park and the Oldsmar Formation. Due to the permeability contrasts between the units, each unit is simulated as a discrete model layer rather than using one model layer to represent a thick sequence of permeable units (e.g., UFA).

In regions where the UFA is unconfined, the second model layer represents the uppermost geologic unit in the UFA. The Suwannee Limestone is absent over a large part of the model domain. Where the Suwannee is absent, model layers 3 and 4 represent the Ocala Limestone. The Ocala Limestone is absent in some local areas in the northernmost region of the model domain. In those areas, model layers 3 through 5 represent the Avon Park Formation. With the exception of the eastern part of the domain, the Oldsmar Formation is assumed to have a relatively low permeability being similar to the permeability of the overlying MCU II, which includes the lower Avon Park. Consequently, with the exception of the eastern part of the model domain, the finite-difference cells representing the LFA (model layer 7) are inactive and groundwater flow is not simulated.

The NDM was calibrated to steady-state 1995 calendar year conditions and transient conditions from 1996 through 2002 using monthly stress periods. This model is unique for west-central Florida in that it is the first regional flow model that represents the groundwater system as fully three-dimensional. Prior modeling efforts, notably Ryder (1985), Sepulveda (2002), and Knowles et al (2002), represented the groundwater system as quasi-three-dimensional.

The groundwater flow and solute transport modeling computer code MODFLOW-SURFACT was used for the groundwater flow modeling (Hydrogeologic, Inc. 2008). MODFLOW-SURFACT is an enhanced version of the USGS modular three-dimensional groundwater flow code (McDonald and Harbaugh 1988).

4.2.3.2 2005 Scenario

To determine drawdown in the UFA and potential impacts to Gum Springs flow, 2005 groundwater withdrawals were simulated in the NDM under long term transient conditions (five years) and compared to pre-pumping conditions (zero withdrawals). UFA heads and Gum Springs discharge generated at the end of the 2005 simulation were subtracted from UFA heads and Gum Springs discharge at the end of the pre-pumping simulation to determine aquifer drawdown and springflow impacts. Total groundwater withdrawals in 2005 were 438.1 mgd over the NDM domain.

The model predicts UFA drawdown of less than 0.25 feet from pre-pumping to 2005 conditions near Gum Springs (Figure 4-13). The predicted reduction in Gum Springs flow was 5.3 percent or 3.2 cfs based on a simulated pre-pumping springflow of 61.1 cfs. Gum Springs discharge is represented in the model as the total of Gum Main Spring and Alligator Spring. The other springs of the Gum Slough Group were not simulated in the NDM. The period-of-record (POR) estimated mean baseflow for Gum Slough is 73 cfs so a 5.3 percent reduction due to groundwater withdrawals would equal 3.9 cfs. The POR mean streamflow for Gum Slough is 98 cfs. Adjusting the impact based on Gum Slough discharge would equate to about a four percent reduction based on mean streamflow for the period 2003 through 2010.

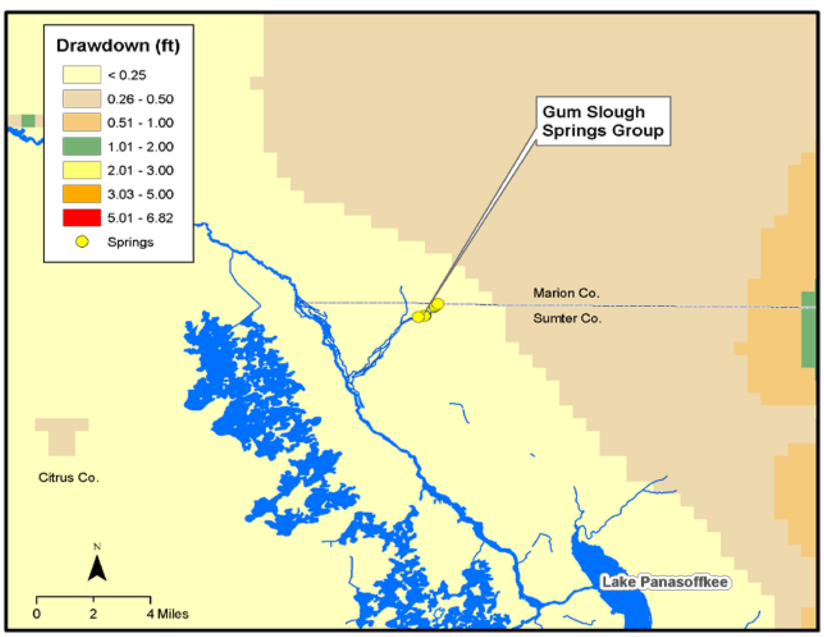


Figure 4-13. Predicted drawdown in the UFA due to 2005 groundwater withdrawals.

4.2.4 Summary

Gum Springs is located in northwest Sumter County about six miles northeast of the Withlacoochee River. Gum Springs forms the headwaters of Gum Slough, which flows southwest into the Withlacoochee River. There are at least six individual springs along Gum Slough. Champion and Starks (2001) termed this collection of springs as the Gum Slough Springs Group. Near Gum Springs, a regionally extensive surficial aquifer is not present because the clay confining unit is thin, discontinuous, and breeched by numerous karst features. Because of this geology, the UFA is mostly unconfined in the Gum Springs area. Baseflow contribution from spring discharge comprises about 75 percent of Gum Slough streamflow volume.

Analysis of rainfall data indicates a decline in rainfall after 1970 with the pre-1970 period much wetter than the post-1970 period. The change in rainfall that occurred in 1970 corresponds to the transition from a warm (wet) Atlantic Multidecadal Oscillation (AMO) cycle to a cool (dry) one (Kelly 2004). Groundwater withdrawals in 2005 were simulated under transient conditions using the NDM. Aquifer heads and Gum Springs discharge quantities were subtracted from a separate run of the NDM under non-pumping conditions. The model results indicate that predicted drawdown within the Upper Floridan aquifer near Gum Springs is less than 0.25 feet. Predicted streamflow decline for Gum Slough (Gum Springs near Holder station) under current pumping conditions is approximately four percent. As a result, 3.9 cubic feet per second was added to the daily USGS record for the Gum Springs near Holder gage to correct for the impact attributable to groundwater pumping. This corrected record was utilized for all analyses.

CHAPTER 5 – WATER CHEMISTRY

This chapter includes a presentation of available water quality data for the Gum Spring Main.

5.1 Overview

Although flow can affect water quality, it is not expected that the adoption and achievement of minimum flows in the Gum Slough Springs System will necessarily lead to substantial changes in water quality. However, it is appropriate to review the water quality to document current status.

Water quality data are not available from the USGS for this system. Data, only extending back to 1998, are available from SWFWMD's Water Quality Monitoring Program (WQMP). Due to the short period that water quality data are available, trend analyses were not performed. The following is a presentation of the current water quality status for Gum Springs Main (headspring). These data were collected on a quarterly basis directly from the spring vent.

5.2 Macronutrients: Phosphorus and Nitrogen

Concentrations of the two major macronutrients, phosphorus and nitrogen, have been monitored for 12 years on Gum Slough Spring Run.

5.2.1 Phosphorus

Phosphorus has been measured by WQMP for 12 years as total phosphorous in mg/L. Friedemann and Hand (1989) determined the typical ranges of various constituents found in Florida lakes, streams and estuaries. Based on their finding, 90% of all Florida streams exhibited total phosphorus concentrations less than 0.87 mg/l P. Phosphorus concentrations in Gum Springs Main were well below this level for the entire period of record with a mean value of 0.03 mg/L. This concentration is the same as that found in Rainbow Springs which also has a mean of 0.03 mg/L for the same period (1998 through 2010).

The United States Environmental Protection Agency recently compiled water quality data for streams of Florida considered to be minimally impacted from anthropogenic sources and biologically healthy for the proposal of their numeric nutrient criteria. Analyzing those data, the 90th percentile of reference streams in the peninsular region of Florida had total phosphorous values of 0.107 mg/L or less. No values for Gum Slough Spring Run exceed this threshold.

5.2.2 Nitrogen

Nitrogen has been reported by the WQMP in various forms. For this report, total nitrogen and dissolved nitrogen were analyzed and, due to overlapping data being equal, considered equal. With a mean of 1.36 mg/L, Gum Springs Main headspring has N values well in excess of background conditions (0.05 mg/L) established by the Florida Department of Environmental Protection. This is slightly higher than the mean of 1.17 mg/L for the Rainbow Springs for the same period.

5.3 Selected Chemical Constituents

Below is a presentation of other chemical constituents and physical parameters for Gum Springs Main (Table 5.1). All parameters appear to be comparable to springs in the region.

Table 5-1. Water Quality of Gum Springs Main

Parameter	Mean	Median	Min	Max	N
Alkalinity (mg/L)	115.94	123.10	59.50	132.00	42
NH3 (N) (Dissolved) (mg/L)	0.04	0.01	0.00	0.62	34
Ca (Dissolved) (mg/L)	52.73	52.55	45.60	57.50	41
C (Total Organic) (mg/L)	0.53	0.30	0.17	3.90	41
Chloride (Dissolved) (mg/L)	6.60	6.54	5.21	7.70	42
D.O. (mg/L)	3.11	3.29	0.30	4.84	29
Fl (Dissolved) (mg/L)	0.14	0.13	0.04	0.52	31
Hardness (Total) (ug/L)	161	162	154	166	40
Iron (Dissolved) (ug/L)	19.37	12.50	2.50	70.00	41
Mg (Dissolved) (mg/L)	6.78	6.86	5.44	7.39	41
Nitrate (N) (Dissolved) (mg/L)	1.02	1.02	0.01	2.28	29
Nitrate-Nitrite (N) (Total) (mg/L)	1.43	1.41	1.33	1.53	36
N - Total (mg/L)	1.36	1.26	0.84	4.00	30
OPO4 (mg/L)	0.04	0.03	0.02	0.04	31
P - Total (mg/L)	0.032	0.029	0.019	0.087	42
pH (SU)	7.62	7.66	6.93	7.95	41
Potassium (Dissolved) (mg/L)	0.42	0.41	0.09	1.30	42
TDS (mg/L)	194	192	166	237	42
SiO2 (Dissolved) (mg/L)	8.52	8.55	8.10	9.30	32
Sodium (Dissolved) (mg/L)	3.83	3.78	3.42	4.35	33
Sp. Cond (uS/cm)	324.14	320.50	294.00	361.50	42
Sulfate (Dissolved) (mg/L)	26.68	27.10	3.11	35.60	41
Temperature (deg C)	23.17	23.03	21.70	27.00	42
Turbidity (NTU)	0.70	0.13	0.08	21.00	40

CHAPTER 6 – GOALS, ECOLOGICAL RESOURCES OF CONCERN, AND KEY HABITAT INDICATORS

6.1 Goal – Preventing Significant Harm

The goal of a MFLs determination is to protect the resource from significant harm due to withdrawals and was broadly defined in the enacting legislation as "the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." What constitutes "significant harm" was not defined. The District has identified loss of flows associated with fish passage and maximization of stream bottom habitat with the least amount of flow as potentially significantly harmful to river ecosystems. Also, based upon consideration of a recommendation of the peer review panel for the upper Peace River MFLs (Gore et al. 2002), significant harm in many cases was defined as quantifiable reductions in habitat.

In their peer review report on the upper Peace River, Gore et al. (2002) stated, "[i]n general, instream flow analysts consider a loss of more than 15% habitat, as compared to undisturbed or current conditions, to be a significant impact on that population or assemblage." This recommendation was made in consideration of employing the Physical Habitat Simulation Model (PHABSIM) for analyzing flow, water depth and substrate preferences that define aquatic species habitats. With some exceptions (e.g. loss of fish passage or wetted perimeter inflection point), there are few "bright lines" which can be relied upon to judge when "significant harm" occurs. Rather loss of habitat in many cases occurs incrementally as flows decline, often without a clear inflection point or threshold.

Based on Gore et al. (2002) comments regarding significant impacts of habitat loss, we recommend use of a 15% change in habitat availability as a measure of significant harm for the purpose of MFLs development. Although we recommend a 15% change in habitat availability as a measure of unacceptable loss, it is important to note that percentage changes employed for other instream flow determinations have ranged from 10% to 33%. For example, Dunbar et al. (1998), in reference to the use of PHABSIM, noted, "an alternative approach is to select the flow giving 80% habitat exceedance percentile," which is equivalent to a 20% decrease. Jowett (1993) used a guideline of one-third loss (i.e., retention of two-thirds) of existing habitat at naturally occurring low flows, but acknowledged that "[n]o methodology exists for the selection of a percentage loss of "natural" habitat which would be considered acceptable."

6.2 Resources and Area of Concern

The resources addressed by the District's minimum flows and levels analyses include the surface waters and biological communities associated with the river system, including the river channel and its floodplain. A river system is physiographically complex, with a meandering channel and associated floodplain wetlands. This hydrologic and physical setting provides habitat for a diverse array of plant and animal populations. Because "[a]quatic species have evolved life history strategies primarily in direct response to the natural flow regimes" (Bunn and Arthington 2002), a primary objective of minimum flows and levels analysis is to provide for the hydrologic requirements of biological communities associated with the river system. Human uses of the natural resources are also an important consideration for the establishment of minimum flows and levels. Such uses include fishing, swimming, wildlife observation, aesthetic enjoyment, and boating.

6.3 Resource Management Goals and Key Habitat Indicators

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

Resource management goals for the Gum Slough Spring Run addressed by our minimum flows analysis include:

1) Maintenance of minimum water depths in the river channel for fish passage and recreational use;
2) Maintenance of water depths above inflection points in the wetted perimeter of the river channel to maximize aquatic habitat with the least amount of flow;
3) Protection of in-channel habitat for selected fish species and macroinvertebrate assemblages; and
4) Inundation of woody habitats including snags and exposed roots in the stream channel.

These goals are consistent with management goals identified by other researchers as discussed in Chapter 1. The rationale for identifying these goals and the habitats and ecological indicators associated with the goals are addressed in subsequent sections of this chapter. Field and analytical methods used to assess hydrologic requirements associated with the habitats and indicators are presented in Chapter 7, and results of the minimum flows and levels analyses are presented in Chapter 8.

6.3.1 Fish Passage and Recreational Use

Ensuring sufficient flows for the passage or movement of fishes is an important component of the development of minimum flows. Maintenance of these flows is expected to ensure continuous flow within the channel or river segment, allow for recreational navigation (e.g., canoeing), improve aesthetics, and avoid or lessen potential negative effects associated with pool isolation (e.g., high water temperatures, low dissolved oxygen concentrations, localized phytoplankton blooms, and increased predatory pressure resulting from loss of habitat/cover). Tharme and King (1998, as cited by Postel and Richter 2003), in developing a "building block" approach for South African rivers, listed the retention of a river's natural perenniality or non-perenniality as one of eight general principles for managing river flows. For many rivers within the District, flows and corresponding water depths adequate for fish passage are currently or were historically maintained by baseflow during the dry season (Figure 6-1). For example, in the upper Peace River, historical flows were sufficient for maintaining a naturally perennial system and flow was sufficiently high during the low-flow season to permit passage of fish along most of the river segment (SWFWMD 2002). Recent flows in the upper Peace River have not, however, been sufficient for fish passage much of the time. Historic flows in other District rivers, such as the Myakka River were probably intermittent, historically, but have increased in recent years. Evaluation of flows sufficient for fish in support of minimum flows development may, therefore, involve consideration of historic or recent flow conditions with respect to perenniality and the likelihood of fish passage being maintained naturally (i.e., in the absence of consumptive water use).

Figure 6-1. Example of low flow at a riffle or shoal area. Many potential in-stream habitats such as limerick, snags, sandbars, and exposed roots are not inundated under low flow conditions.

6.3.2 Wetted Perimeter Inflection Point

A useful technique for evaluating the relation between the quantity of stream habitat and the rate of streamflow involves an evaluation of the "wetted perimeter" of the stream bottom. Wetted perimeter is defined as the distance along the stream bed and banks at a cross-section where there is contact with water. According to Annear and Conder (1984), wetted perimeter methods for evaluating streamflow requirements assume that there is a direct relationship between wetted perimeter and fish habitat. Studies on streams in the southeast have demonstrated that the greatest amount of macroinvertebrate biomass per unit reach of stream occurs on the stream bottom (e.g., Benke et al. 1985). Although production on a unit area basis may be greater on snag and root habitat, the greater area of stream bottom along a reach makes it the most productive habitat under low flow conditions. By plotting the response of wetted perimeter to incremental changes in discharge, an inflection can be identified in the resulting curve where small decreases in flow result in increasingly greater decreases in wetted perimeter. This point on the curve represents a flow at which the water surface recedes from stream banks and fish habitat is lost at an accelerated rate. Stalnaker et al. (1995) describe the wetted perimeter approach as a technique for using "the break" or inflection point in the stream's wetted perimeter versus discharge relation as a surrogate for minimally acceptable habitat. They note that when this approach is applied to riffle (shoal) areas, "the assumption is that minimum flow satisfies the needs for food production, fish passage and spawning."

We view the wetted perimeter approach as an important technique for evaluating minimum flows and levels near the low end of the flow regime. The wetted perimeter inflection point in the channel provides for large increases in bottom habitat for relatively small increases of flow. This point is defined as the "lowest wetted perimeter inflection point". It is not assumed that flows associated with the lowest wetted perimeter inflection point meet fish passage needs. However, identification of the lowest wetted perimeter inflection point permits evaluation of flows that provide the greatest amount of inundated bottom habitat in the river channel on a per-unit flow basis.

6.3.3 In-Channel Habitats for Fish and Macroinvertebrates

Maintenance of flows greater than those allowing for fish passage and maximization of wetted perimeter are needed to provide aquatic biota with sufficient resources for persistence within a river segment. Feeding, reproductive and cover requirements of riverine species have evolved in response to natural flow regimes, and these life history requirements can be used to develop protective minimum flows.

To achieve this goal, Physical Habitat Simulation (PHABSIM) protocols are included in the District's approach for establishing minimum flows for river systems. PHABSIM provides a means to quantify changes in habitat that are associated with changes in stream flow. PHABSIM is the single most widely used methodology for establishing "minimum flows" on rivers (Postel and Richter 2003), and its use was recommended in the peer review of proposed MFLs for the upper Peace River (Gore et al. 2002). The technique has, however, been criticized, because it is based on the specific requirements of a few select species (typically fish of economic or recreational value), and it is argued that such an approach ignores many ecosystem components. This criticism is overcome in the current District approach for MFLs development, since PHABSIM represents only one of several tools used to evaluate flow requirements. Results of PHABSIM analyses are used to assess flow needs during periods of low to medium flows.

6.3.4 Woody Habitats

Stream ecosystem theory emphasizes the role of instream habitats in maintaining ecosystem integrity. These habitats form a mosaic of geomorphically defined substrate patches (Brussock et al. 1985), each with characteristic disturbance regimes and macroinvertebrate assemblages (Huryn and Wallace 1987). For instance, invertebrate community composition and production in a Blackwater river varies greatly among different habitat types, where the habitats are distinguished by substrates of different stability (e. g. , sand, mud and woody debris) (Benke et al. 1984, Smock et al. 1985, Smock and Roeding 1986). Ecosystem dynamics are influenced by the relative abundance of these different habitat types. Changes in community composition and function occurring along the river continuum are in part a consequence of the relative abundance of different habitat patches, which are under the control of channel geomorphology and flow. For determining MFLs, we identify key habitats and features that play a significant role in the ecology of a river system using a habitat-based approach that includes a combination of best available data and site-specific field work.

Among the various instream habitats that can be influenced by different flow conditions, woody habitats (snags and exposed roots) are especially important. In low-gradient streams of the southeastern U.S.A. coastal plain, wood is recognized as important habitat (Cudney and Wallace 1980; Benke et al. 1984, Wallace and Benke 1984; Thorp et al. 1990; Benke and Wallace 1990). Wood habitats harbor the most biologically diverse instream fauna and are the most productive habitat on a per unit area basis (Benke et al. 1985). Comparisons of different instream habitats in a southeastern stream indicate that production on snags is at least twice as high as that found in any other habitat (Smock et al. 1985).

Wood provides advantages as habitat, as it is relatively stable and long lived compared to sand substrata, which constantly shift (Edwards and Meyer 1987). Even bedrock substrates, though the most stable of all, are susceptible to smothering by shifting sand and silt. Wood is a complex structural habitat with microhabitats (such as interstices that increase surface area) that provide cover for a variety of invertebrates. As an organic substrate, wood is also a food resource for utilization by microbial food chains, which in turn supports colonization and production of macroinvertebrates. As physical impediments to flow, woody structures enhance the formation of leaf packs and larger debris dams. These resulting habitats provide the same functions as woody substrata in addition to enhancing habitat diversity instream. Organisms in higher trophic levels such as fish have been shown to also depend on woody structures either for cover, as feeding grounds, or as nesting areas.

Since woody habitats are potentially the most important instream habitat for macroinvertebrate production, inundation of these habitats for sufficient periods is considered critical to secondary production (including fish and other wildlife) and the maintenance of aquatic food webs. Not only is inundation considered important, but sustained inundation prior to colonization by invertebrates is necessary to allow for microbial conditioning and periphyton development. Without this preconditioning, the habitat offered by snags and wood is essentially a substrate for attachment without associated food resources. The development of food resources (microbes) on the substrate is needed by the assemblage of macroinvertebrates that typically inhabit these surfaces. After the proper conditioning period, continuous inundation is required for many species to complete development. The inundated woody substrate (both snags and exposed roots) within the stream channel is viewed as an important riverine habitat and it is assumed that withdrawals or diversions of river flow could significantly decrease the availability of this habitat under medium to high flow conditions.

CHAPTER 7 – TECHNICAL APPROACH FOR ESTABLISHING MINIMUM FLOWS AND LEVELS FOR GUM SLOUGH SPRING RUN

7.1 Overview

For most surface water dominated systems the MFL methodology employed by the SWFWMD utilizes a seasonal approach which involves identification of a low flow threshold and development of prescribed flow reductions for periods of low, medium and high flows, sometimes termed Blocks 1, 2 and 3. Due to very low intra-annual variation (Figure 1-1) in discharge, the District has forgone the building block approach for the analyses of Gum Slough. Although discharge exhibits seasonal variations, it was determined that the fluctuations are too small to benefit from the use of seasonal blocks and that a year-round flow prescription would be more applicable. This dampened annual hydrograph and similar decisions have been made on other spring fed systems including Chassahowitzka, Homosassa, and Rainbow rivers.

The prescribed flow reductions are based on limiting potential changes in aquatic and wetland habitat availability that may be associated with changes in river flow. All analyses were performed on the period of record flows for the USGS Gum Springs near Holder gage. It should be noted that the entire period of record occurs during a predominantly dry period (see Rainfall Appendix) including the most severe drought on record.

7.2 HEC-RAS Cross-Sections

The entire Hydrologic Engineering Centers River Analysis System (HEC-RAS) model development and calibration report is contained in Appendix HEC-RAS. An internal review was conducted of the model and model report and the associated memo is contained in Appendix Review of HEC-RAS model.

Elevation data for the Gum Slough were compiled from surveyed transects by the SWFWMD survey section conducted in support of minimum flows and levels and Light Detection and Ranging (LiDAR) data, available from the District's Geographic Information System (GIS) and Mapping Department for the Gum Slough watershed. Figure 7-1 illustrates the locations of the cross-sections generated from the elevation data.

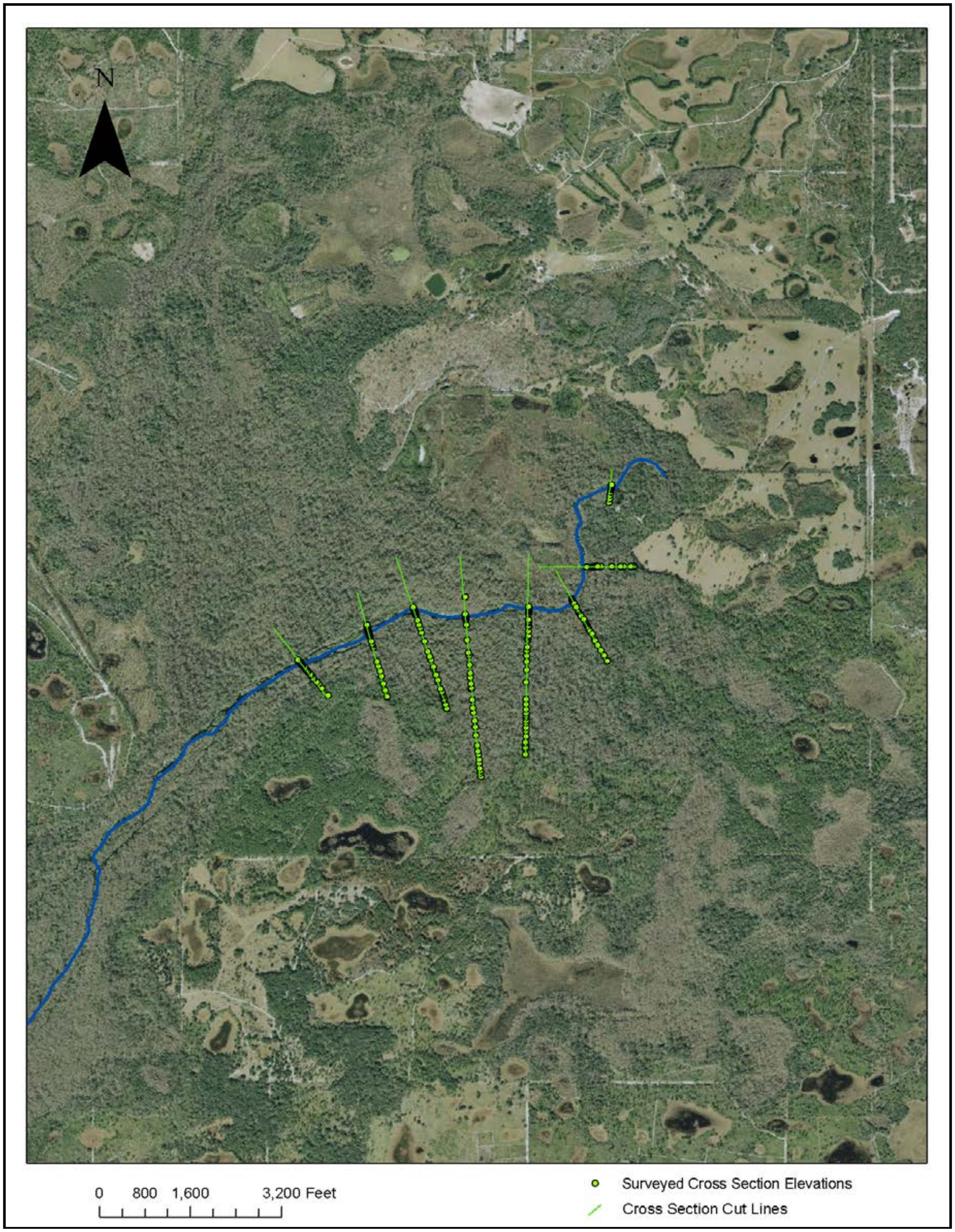


Figure 7-1. Location of HEC-RAS cross-sections in the Gum Slough (Map produced by Intera, Inc.).

7.2.1 PHABSIM Cross-Sections

Physical Habitat Simulation (PHABSIM) cross-sections, designed to quantify specific habitats for fish and macroinvertebrates at differing flow conditions, were established at four representative (see Figure 7-2) sites. Bottom substrata consist mainly of sand, bedrock or muck. Various densities of submersed vegetation (primarily *Vallisneria americana* and *Sagittaria kurziana*) were observed at the sites.

Identification of shoal locations in the study reach was important for PHABSIM analyses because these features represent hydraulic controls used in developing hydraulic simulation models with PHABSIM software. The shoals restrict flow and can be sites where loss of hydraulic connection may occur or may present barriers to fish migration or hamper canoeing. Field reconnaissance of shoals in the entire study reach was conducted for selection of the two PHABSIM data collection cross-sections.

PHABSIM analysis required acquisition of field data concerning channel habitat composition and hydraulics. At each PHABSIM site, tag lines were used to establish three cross-sections across the channel to the top of bank on either side of the river. Water velocity was measured with a Sontek Streampro Acoustic Doppler Current Profiler and/or a Sontek Flow Tracker Handheld Acoustic Doppler Velocimeter at intervals determined for each site, based on the criteria of obtaining a minimum of 20 measurements per cross-section. Stream depth, substrate type and habitat/cover were recorded along the cross-sections. Other hydraulic descriptors measured included channel geometry (river bottom-ground elevations), water surface elevations across the channel and water surface slope determined from points upstream and downstream of the cross-sections. Elevation data were collected relative to temporary bench marks that were subsequently surveyed by District surveyors to establish absolute elevations. Data were collected at each site under three different flow conditions (low, medium and high flows) to provide the necessary information needed to run the PHABSIM model for each stream reach.

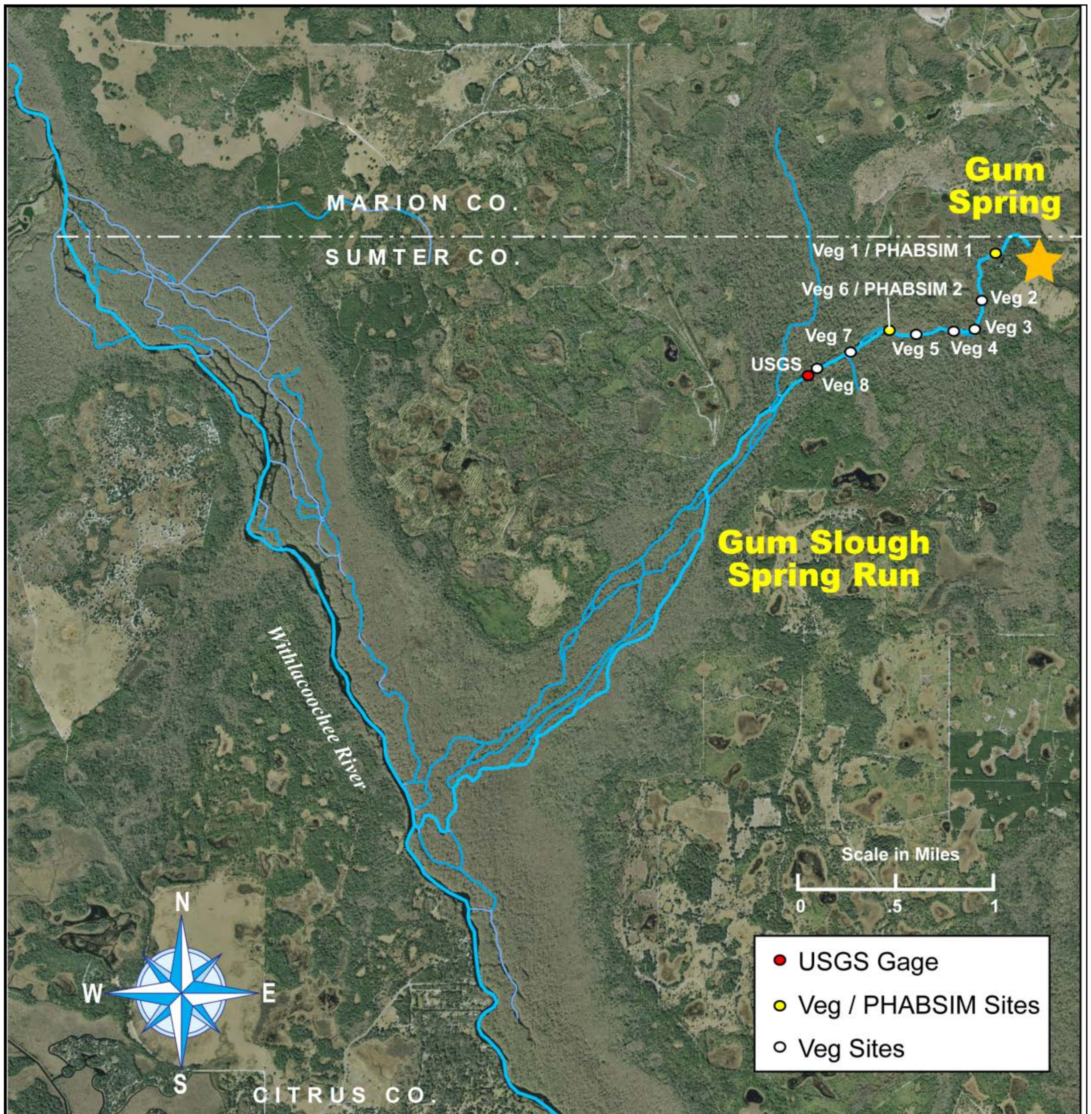


Figure 7-2. Data collection sites on the Gum Slough.

7.2.2 Instream Habitat Cross-Sections

Cross-sections for assessing instream habitats were examined at eight sites on Gum Slough. These sites were utilized in assessing floodplain vegetation and in PHABSIM analyses (6 vegetation-only and 2 PHABSIM / vegetation). Triplicate instream cross-sections, from the top of bank on one side of the channel through the river and up to the top of bank on the opposite channel, were established at each site perpendicular to flow in the channel. Typically, one of the three instream cross-sections at each site were situated along the floodplain vegetation transect line, and the other two replicate cross-sections were located 50 ft. upstream and downstream. A total of 24 instream cross-sections were sampled (8 cross-sections x 3 replicates at each site).

For each instream habitat cross-section, the range in elevations (in feet above the North American Vertical Datum of 1988) and linear extent (along the cross-section) for the following habitats were determined:

- bottom substrates (such as sand, mud, clay or bedrock);
- exposed roots;
- woody debris or snags;
- wetland (herbaceous or shrubby) vegetation;
- wetland trees;
- submersed aquatic vegetation;
- floating aquatic vegetation; and
- emergent aquatic vegetation.

Following the collection of cross-sectional habitat data, additional elevations of woody habitats were also collected longitudinally at each instream habitat site. Belt transects along the banks of the run were used to document the elevational distribution of woody habitats such as snags or exposed roots. Belt transects include the collection and analyses of woody debris data 50-ft upstream and downstream of the centerline transect rather than strictly along a transect.

Live (exposed roots) and dead (snag) woody habitats were measured along both river banks from the center cross-section upstream to the upstream cross-section. Elevations for up to 15 samples of exposed root and snag habitat were collected from each bank between the center and upstream cross-sections. Measured woody habitats are representative of the vertical distribution of woody habitats in the sample corridor (between the two instream cross-sections). The upper and lower vertical extent of each encountered woody habitat sample (referred to as High and Low front shots, respectively) were measured using survey equipment.

7.2.3 Floodplain Vegetation/Soils Cross-Sections

Eight transect locations were identified along the Gum Slough study corridor (Figure 7-3) using criteria such as the location of dominant wetland communities identified from National Wetlands Inventory maps consistent with aerial photography, soils maps, and field observations. Other criteria related to transect selection are described in PBS&J (2010).

Among the eight locations, which were also HEC-RAS transects, two of them were utilized for PHABSIM analyses. Each transect was oriented perpendicular to the river channel and extended across the river corridor and floodplain in order to identify and to characterize elevations, soils, physical features, and vegetation. Due to private land ownership limiting access privileges and the orientation of the floodplain, cross sections extended from the right bank of the run, through the channel to left bank, and continued to the extent of the floodplain on the left bank side. The topography is such in the study corridor that very little floodplain occurs outside the right bank. Cross-sections were established out to the 0.5 percent exceedance flow based on previous determinations of the landward extent of floodplain wetlands in the river corridor.

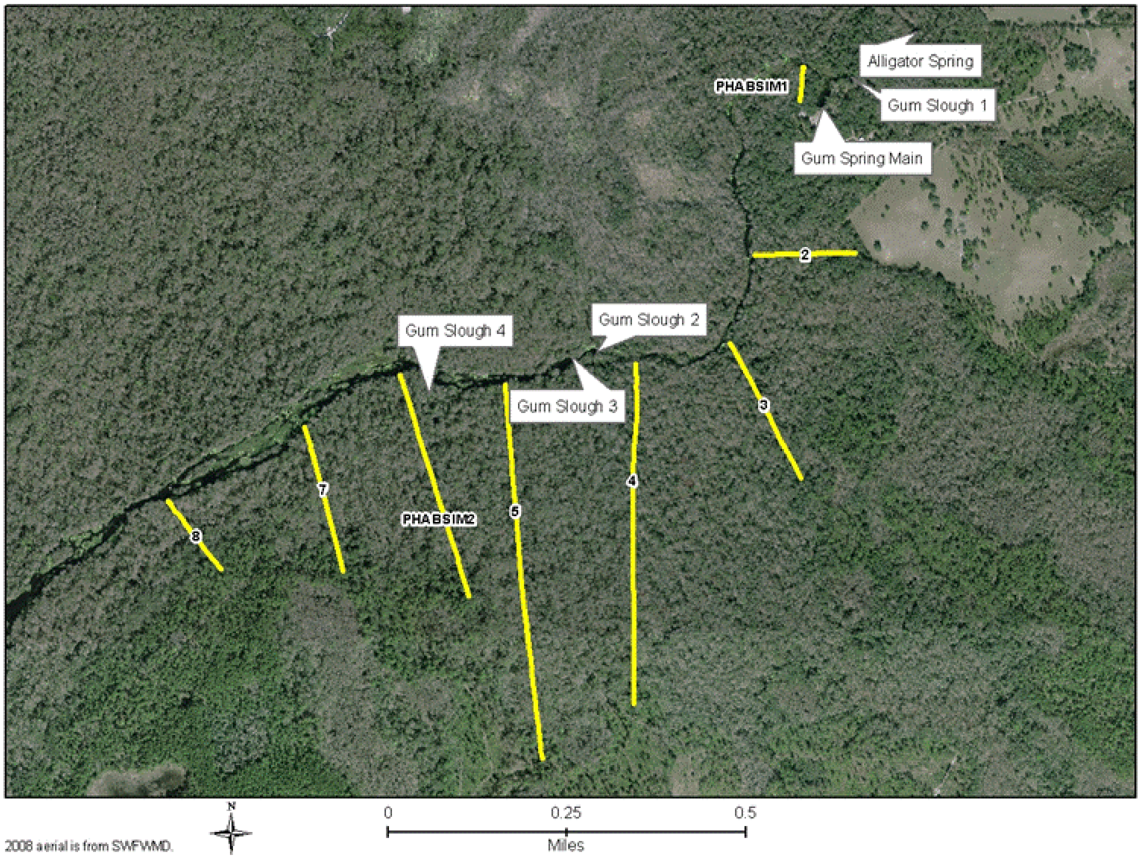


Figure 7-3. Location of vegetation transects and their extents are indicated along the Gum Slough study corridor. Vegetation transects 1 and 6 were also utilized for PHABSIM analyses and are labeled as such in the figure above. Map as referenced in PBS&J (2010).

7.3 Vegetation Characterization

To characterize forested vegetation communities along each cross-section, changes in dominant vegetation communities were located and used to delineate boundaries between vegetation zones. Trees, rather than shrubs and herbaceous species, were used to define vegetation communities, because relatively long-lived tree species are better integrators of long-term hydrologic conditions. At least three samples located within each vegetation zone were collected using the Point Centered Quarter method (see Cottam and Curtis 1956, as cited in PBS&J 2010). Shrubs and ground cover plant species were also noted. Sampling points were distributed along transects to capture conspicuous changes in topography, soils, or vegetative composition. Sampling points were between 50 and 200 feet apart, depending on the length of the communities within transects and every attempt was made to overlap sampling points with existing survey stakes for ease of surveying. At each sampling point, four quadrants were established using two, 1-meter PVC rods at right angles to each other. In each quadrant, the closest tree and shrub were identified. Data collected included the distance from the center point, species identification, and the diameter at breast height (dbh) of recorded trees.

7.4 <u>Soils Characterization</u>

Soils along the floodplain vegetation cross-sections were evaluated for the presence of hydric or flooding indicators, as well as saturation and/or inundation condition. At least three soil cores were examined to a minimum depth of 20 inches within each vegetation zone at each cross-section. Soils were classified as upland (non-hydric), hydric or non-hydric with the presence of flooding indicators. Special consideration was placed on locating elevations of the upper and lower extent of muck soils (> 12 inches in thickness) at cross-sections where they occurred.

7.5 <u>Hydrologic Indicators and Floodplain Wetted Perimeter</u>

Key physical indicators of historic inundation were identified, including: cypress buttress inflection elevations; cypress knees; lichen lines and/or moss collars; hypertrophied lenticels; stain lines; and scarps (Gilbert et al. 1995). The number of physical indicators of historic inundation varied by transect, depending on availability and reproducibility.

Ground elevation data were used to compare vegetation and soils within and among cross-sections. For some comparisons, vegetation elevations were normalized to the lowest channel elevations at the cross-section to account for differences in absolute elevations among the cross-sections. Wetted perimeter was calculated for vegetation classes in the study corridor to evaluate the potential change in inundated habitat that may be anticipated due to changes in river stage. The wetted perimeter for a vegetation class is the linear distance inundated along transects below a particular elevation or water level (river stage). Consequently, as distance from the river channel increases, the total wetted perimeter also increases, but can vary among vegetation classes. The HEC-RAS floodplain model (see Section 0) was used to determine corresponding flows at the USGS gage Gum Springs near Holder that would be necessary to inundate specific floodplain elevations (e. g., mean vegetation zone and soils elevations).

7.6 <u>Modeling Approaches</u>

A variety of modeling approaches were used to develop minimum flows and levels for the Gum Slough Spring Run. A HEC-RAS model was developed to characterize flows at all study sites. Physical Habitat Simulation (PHABSIM) modeling was used to characterize potential changes in the availability of fish habitat and macroinvertebrate habitat. Long-term inundation analysis was used to examine inundation durations for specific habitats or floodplain elevations and to also examine changes in inundation patterns that could be expected with changes to the flow regime.

7.6.1 HEC-RAS Modeling

This description of the HEC-RAS modeling for the Gum Slough Spring Run is largely excerpted from Intera, Inc. (2010; Appendix HEC-RAS). HEC-RAS is a one-dimensional hydraulic model that can be used to analyze river flows. Version 4.0 of the HEC-RAS model was released by the U. S. Army Corps of Engineers Hydrologic Engineering Center in March 2008 and supports water surface profile calculations for steady and unsteady flows, including subcritical, supercritical, or mixed flows. Model geometry was obtained by overlaying existing hydrography with the DEM and the surveyed cross sections. Cross sections were placed at each vegetative cross section location. Using GEO-RAS, the DEM was intersected with the cross sections to produce the cross section geometry. The cross sections were imported into HEC-RAS, and the DEM data was replaced in each cross section with all available survey data.

The model was calibrated with the most complete stage-flow record available. In order to calibrate each cross section accurately, it is desirable to have stage and flow measurements at each cross section measured at the same time. While the high, medium, and low flow measurements recorded by the District provided good flow information, they lacked stage and flow measurements at each cross section. Additionally, for some flow regimes (such as the low flows) data was recorded on several days, which could necessitate the use of an average downstream boundary condition and increase model uncertainty. The best available calibration dataset was measured by the District on February 26, 2010, and was provided to Intera, Inc. in a spreadsheet. Since no measurements were taken at Vegetation cross section #8, the USGS gauge data was applied to this station. This is an appropriate estimation since this cross section is located approximately 92 feet upstream from the USGS gauge. Flow change locations were placed at each vegetative cross section based on the flow rates (Intera, Inc. 2010).

In summary, Intera, Inc. noted that;

The calibrated model has an absolute maximum error of 0.27 feet, which is well within the 0.5 feet desired by the District. The average error for the calibrated model was 0.0025 feet, indicating very little bias in the model. The model also performed well during the validation phase, with an average error of 0.055 feet.

Although a lower error is always desirable, the quantity of data required to significantly improve the error was not feasible. With very little bias detected in the errors it is felt that the model provides a very good representation of the system from which to conduct other analyses. The complete HEC-RAS model report from Intera, Inc. is included in the HEC-RAS Appendix and includes more detail about model development and calibration.

7.6.2 Physical Habitat Simulation (PHABSIM) Modeling

In their review of the District's minimum flow methods, Gore et al. (2002) suggested the use of procedures that link biological preferences for hydraulic habitats with hydrological and physical data. Specifically, Gore et al. (2002) endorsed use of the Physical Habitat Simulation (PHABSIM), a component of the Instream Flow Incremental Methodology (Bovee et al. 1998), and its associated software for determining changes in habitat availability associated with changes in flow. Following this recommendation, the PHABSIM system was used to support development of minimum flows for the Gum Slough Spring Run.

PHABSIM analysis requires acquisition of data concerning channel composition, hydraulics, and habitat suitability or preferences for individual species or groups of organisms. Required channel composition data includes dimensional data, such as channel geometry and distance between sampled cross-sections, and descriptive data concerning substrate composition and cover characteristics. Hydraulic data requirements include measurement of water surface elevations and discharge at each cross-section. These data are collected under a range of flow conditions for model calibration. Habitat suitability criteria are required for each species or group of interest. Criteria may be empirically derived or developed using published information.

Hydraulic and physical data are utilized in PHABSIM to predict changes in velocity in individual cells of the channel cross-section as water surface elevation changes. Predictions are made through a series of back-step calculations using either Manning's equation or Chezy's equation. Predicted velocity values are used in a second program routine (HABTAT) to determine cell-by-cell the amount of weighted usable area (WUA) or habitat available for various organisms at specific life history stages or for spawning activities (Figure 7-4). The WUA/discharge relationship can then be used to evaluate modeled habitat gains and losses with changes in discharge. Once the relationships between hydraulic conditions and WUA are established, they are examined in the context of historic flows, and altered flow regimes. This process is accomplished using the Time Series Library time series analysis routine (Milhous et al. 1990) and historic/altered flow records.

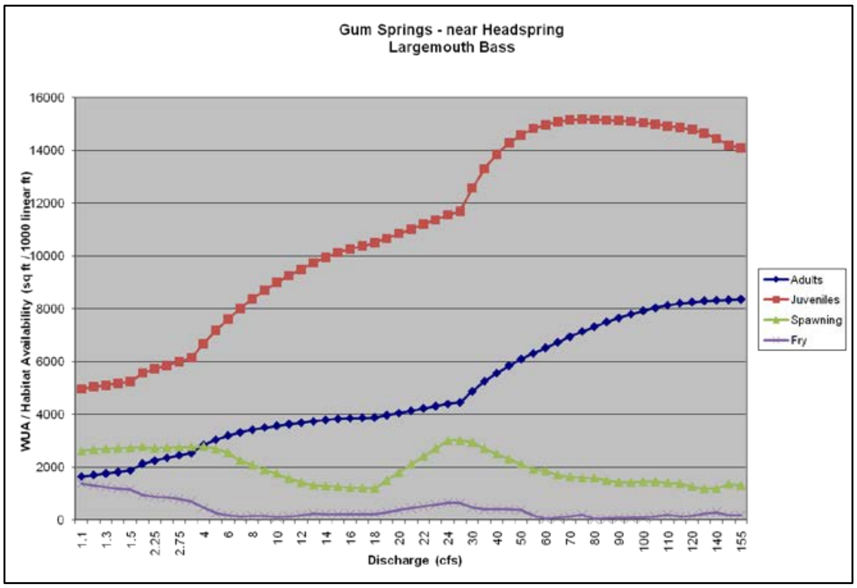


Figure 7-4. Weighted usable area (WUA) versus discharge for three life history stages (fry, juvenile, adult) and spawning activity of Largemouth Bass Fry at the PHABSIM 1 site in the Gum Slough Spring Run.

PHABSIM analysis does not prescribe an acceptable amount of habitat loss for any given species or assemblage. Rather, given hydrologic data and habitat preferences, it establishes a relationship between hydrology and WUA and allows examination of habitat availability in terms of the historic and altered flow regimes. Determining from these data the amount of loss, or deviation from the optimum, that a system is capable of withstanding is based on professional judgment. Gore et al. (2002) provided guidance regarding this issue, suggesting that "most often, no greater than a 15% loss of available habitat" is acceptable. For the purpose of minimum flows and levels development, we have defined percent-of-flow reductions that result in greater than a 15% reduction in available habitat from historic conditions as limiting factors. This is calculated by combining the WUA for all PHABSIM sites for each species, life stage, or guild. The assumption is made that the entirety of the study reach is represented equally by the selected PHABSIM sites, as was the goal during the site selection process. Figure 7-5 shows an example of habitat gain/loss plots, which display changes in WUA (habitat) relative to flow reductions of 10, 20, 30, and 40%.

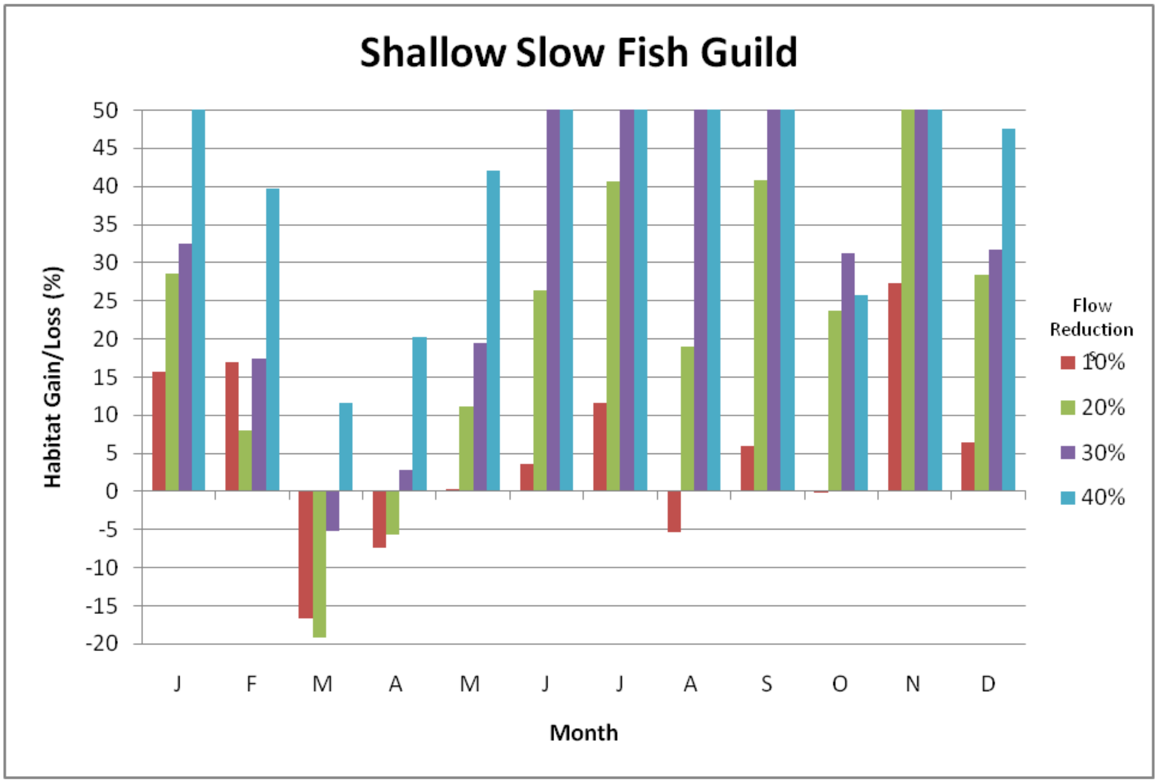


Figure 7-5. Example plot of habitat gain/loss relative to flow reductions of 10, 20, 30, and 40%. Habitat gain/loss is shown for the Shallow Slow Fish Guild (habitat for all sites combined) in the Gum Slough Spring Run based on corrected flow records from 2003 to 2009.

7.6.2.1 Development of Habitat Suitability Curves

Habitat suitability criteria used in the PHABSIM model include continuous variable or univariate curves designed to encompass the expected range of suitable conditions for water depth, water velocity, and substrate/cover type and proximity. There are three types of suitability curves.

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

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

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

Based on dominance of the spotted sunfish (*Lepomis punctatus*) in rivers within the District, a habitat suitability curve was created for this species. Since most of the regional experts in fish ecology were unfamiliar with development of habitat suitability criteria, a hybrid of the roundtable and Delphi techniques was used to develop a Type I curve. For this effort, a proposed working model of habitat suitability criteria was provided to 14 experts for initial evaluation. The proposed suitability curves were based on flow criteria for redbreast sunfish (*Lepomis auritus*) (Aho and Terrell 1986) modified according to published literature on the biology of spotted sunfish. Respondents were given approximately 30 days to review the proposed habitat suitability criteria and to suggest modifications. Six of the 14 experts provided comments. In accordance with Delphi techniques, the suggested modifications were incorporated into the proposed curves. Suggested modifications that fell outside of the median and 25% interquartile range of responses were not considered unless suitable justification could be provided.

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

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

Per recommendation of the peer review panel for the middle Peace River, the District developed additional habitat suitability curves for species of interest. Type III curves have been refined for the spotted sunfish and new Type III curves have been developed for species representative of various fish guilds including shallow-fast (SF), shallow-slow (SS), deep-fast (DF), and deep slow (DS) guilds. The curves for these four guilds were developed by Don Orth and Paul Leonard for fish in the southeastern United States, not specifically for Florida. The break points between the various curves are quite arbitrary as the analyses are utilized primarily to indicate gain or loss of habitat types more than for a specific fish or life stage.

7.6.3 Long-Term Inundation Analyses

Long-term inundation analysis is used to identify the number of days during a defined period of record that a specific flow or level (elevation) was equaled or exceeded at individual river cross-sections, including streamflow gaging sites. For the analyses, spreadsheets and associated plots are developed using measured elevations for habitats or other features (that were converted from a NGVD29 to a NAVD88 standard), HEC-RAS model output and adjusted flow records. The SWFWMD has transitioned away from NGVD29 for the following reasons:

- This datum was created using surveying technologies that were available in the early twentieth century. Its accuracy is limited when compared to the current state of the art in surveying and mapping.

- Nationally, many of the NGVD29 physical benchmarks have been destroyed or have invalid elevations because of ground subsidence, crustal deformation or glacial rebound.

- New surveying technologies such as global position systems (GPS) cannot effectively utilize NGVD29.

For the purpose of developing minimum flows and levels, percent-of-flow reductions that result in greater than a 15% reduction in the number of days of inundation from historic conditions are determined. Utilizing this tool, we identify flow reduction thresholds for mean elevations of live or dead woody habitats. These flow reductions identify potentially acceptable temporal habitat losses and also provide for woody habitat protection on a spatial basis (Munson and Delfino 2007).

7.7 Low-Flow Threshold

Protection of aquatic resources associated with low flows is an important component of minimum flows and levels implementation. To accomplish this goal, it is necessary to develop a low-flow threshold, which identifies flows that are to be protected in their entirety (i.e., flows that are not available for consumptive-use). To determine this threshold, two low-flow criteria are developed. One is based on the lowest wetted perimeter inflection point; the other is based on maintaining fish passage along the river corridor. The low-flow threshold is established at the higher of the two low-flow criteria, provided that comparison of that criterion with historic flow records indicates that the criterion is reasonable.

7.7.1 Wetted Perimeter

Output from multiple runs of the HEC-RAS model was used to generate a wetted perimeter versus flow plot for each of the HEC-RAS cross-sections of the Gum Slough Spring Run (Wetted Perimeter Appendix). Plots were visually examined for lowest wetted perimeter inflection points (LWPIP), which identify flow ranges that are associated with relatively large changes in wetted perimeter for relatively small increases in flow (e.g., Figure 7-6). The lowest wetted perimeter inflection point was identified for each cross-section. Higher inflection points were disregarded, since the goal was to identify the lowest wetted perimeter inflection point for flows contained within the stream channel. Most cross-section plots displayed no apparent LWPIPs, because they occurred below the lowest modeled flow. For cross-sections that displayed no distinct break or where the majority of the wetted perimeter is inundated below the lowest modeled flow, the LWPIP was established at the lowest modeled flow. The LWPIP flow at each HEC-RAS cross-section was used to develop a wetted perimeter criterion for the Gum Springs near Holder gage.

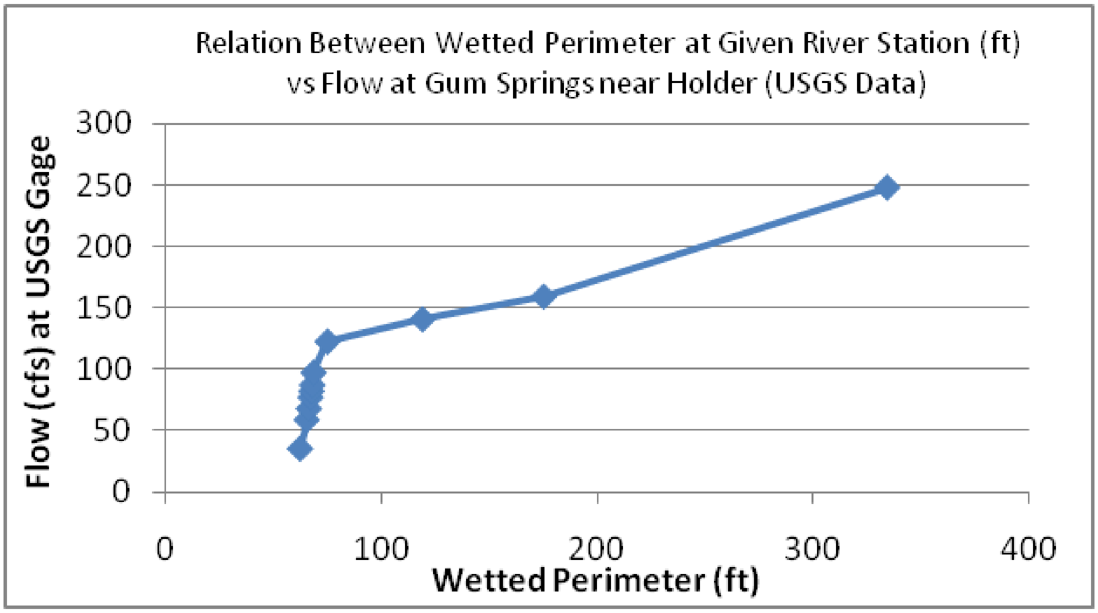


Figure 7-6. Wetted perimeter versus discharge at HEC-RAS station number 7063 (G1-PHAB 1) in the Gum Slough Spring Run. In this example, the LWPIP was below the lowest modeled flow of 35 cfs.

7.7.2 Fish Passage

For development of minimum flows, it is desirable to maintain longitudinal connectivity along a river corridor, to the extent that this connectivity has historically occurred. To secure the benefits associated with connectivity and sustained low flows, a 0.6-ft fish-passage criterion was used to develop a low flow standard for the Gum Slough Spring Run. The fish-passage criterion is routinely used by the District for development of MFLs and was found to be acceptable by the panel that reviewed the proposed upper Peace River flows (Gore et al. 2002) as well as subsequent peer review panels. Further, Shaw et al. (2005) also found that "the 0.6-ft standard represents best available information and is reasonable".

Flows necessary for fish-passage at each HEC-RAS cross-section were identified using output from multiple runs of the HEC-RAS model. The flows were determined by adding the 0.6 foot depth fish-passage criterion to the elevation of the lowest spot in the channel cross-section and determining the flow necessary to achieve the resultant elevations. The flow necessary to meet fish passage criteria were interpolated from the modeled flows that bracketed the required fish passage depth of 0.6 feet.

7.8 <u>Prescribed Flow Reduction</u>

7.8.1 PHABSIM Modeling

The PHABSIM model was used to evaluate potential changes in habitat associated with variation in instream flows. For the analyses, adjusted time series data from the Gum Springs near Holder gage site was used to model changes in habitat at two representative sites.

Simulations were conducted for various life-history stages of spotted sunfish, largemouth bass, bluegill, shallow-fast (SF) fish guild, shallow-slow (SS) fish guild, deep-fast (DF) fish guild and deep-slow (DS) fish guild, and for macroinvertebrate diversity at all four sites on the Gum Slough Spring Run. Flow reductions that resulted in no more than a 15% reduction in available habitat from simulated unimpacted conditions were determined to be limiting factors. These factors were used to identify acceptable flow reductions for the Gum Springs gage.

7.8.2 Snag and Exposed Root Habitat Analyses

Mean elevations of snag and exposed root habitats were determined for eight instream habitat cross-section sites. Flows at the cross-section sites and corresponding flows at the Gum Springs gage that would result in inundation of the mean habitat elevations at each cross-section were determined using the HEC-RAS model. The daily flow records for the period of record were used to determine the number of days that the mean elevations for snag and exposed root habitat were inundated in each block. These flow records were examined to identify percent-of-flow reductions that would result in no more than a 15% reduction in the number of days of inundation from direct river flow. Although we acknowledge that a 15% change in habitat availability based on a reduction in spatial extent of habitat may not be equivalent to a 15% change in habitat availability based on number of days a particular habitat is inundated (Munson and Delfino 2007), the peer review panel for the middle Peace River MFLs noted, “that the 15% threshold selected for preventing significant harm is appropriate” (Shaw et al. 2005).

7.8.3 Floodplain Connection Analyses

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

The intra-annual variation in flow in the Gum Slough Spring Run is generally 40 cfs or less. For this reason, Blocks were not used in the MFL development process. This, combined with the very short period of record of flow data for this system, lead us to only discuss the flows necessary to inundate various floodplain features. Attempting to determine allowable flow declines that would not cause significant harm would not be statistically defensible.

CHAPTER 8 – RESULTS AND RECOMMENDED MINIMUM FLOWS

8.1 Overview

Results from modeling and field investigations on the Gum Slough Spring Run were assessed to develop minimum flow criteria/standards for ensuring that ecological functions are protected from significant harm. All analyses were performed on period of record (2003 to 2010) flow records corrected by 3.9 cubic feet per second for groundwater pumping.

8.2 Low-Flow Threshold

The low-flow threshold (LFT) defines flows that are to be protected from surface water withdrawals throughout the year. The low-flow threshold is established at the higher of two flow criteria, which are based on maintaining fish passage and maximizing wetted perimeter for the least amount of flow in the river channel. For the Gum Slough Spring Run, a low-flow threshold was developed for the Gum Springs near Holder gage site.

8.2.1 Fish Passage

Flows necessary to maintain a minimum water depth of 0.6 foot to allow for fish passage at each cross-section in the HEC-RAS model are shown in Figure 8-1. At all cross-sections, the minimum water surface elevation that would allow for fish passage was equal to or lower than the elevation associated with the lowest modeled flow.

The flow necessary to maintain fish passage was at or below the lowest modeled flow (35 cfs as measured at the Holder gage). A flow of 35 cfs at the Holder gage was used to define the fish passage criterion.

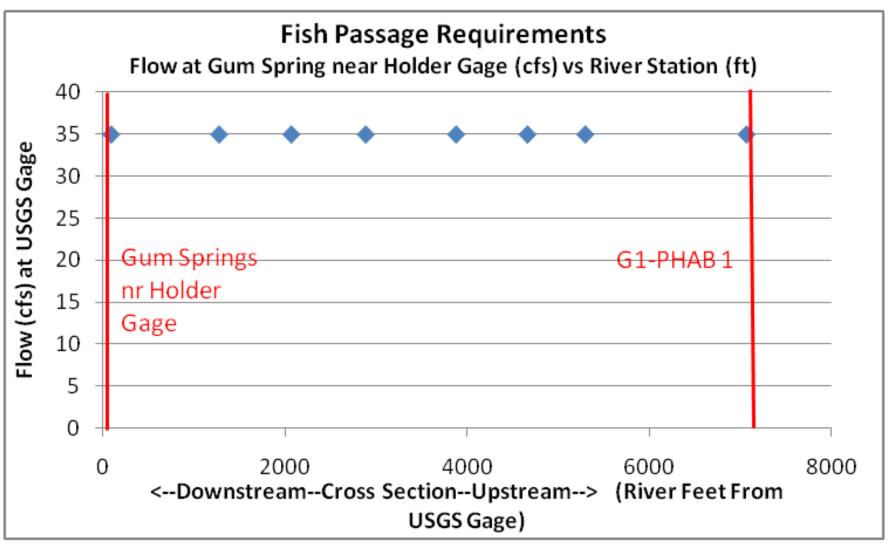


Figure 8-1. Plot of flow required at the Holder gage to inundate the deepest part of the channel at HEC-RAS cross-sections in the Gum Slough Spring Run to a depth of 0.6 ft. Lowest modeled flow was 35 cfs.

8.2.2 Lowest Wetted Perimeter Inflection Point (LWPIP)

Wetted perimeter plots (wetted perimeter versus flow at the Holder gage) were developed for each HEC-RAS cross-section of the Gum Slough Spring Run (Figure 8-2). From these plots, it was determined that the LWPIP was below the lowest modeled flow for all of the sites. A flow of 35 cfs at the Holder gage was used to define the LWPIP criterion.

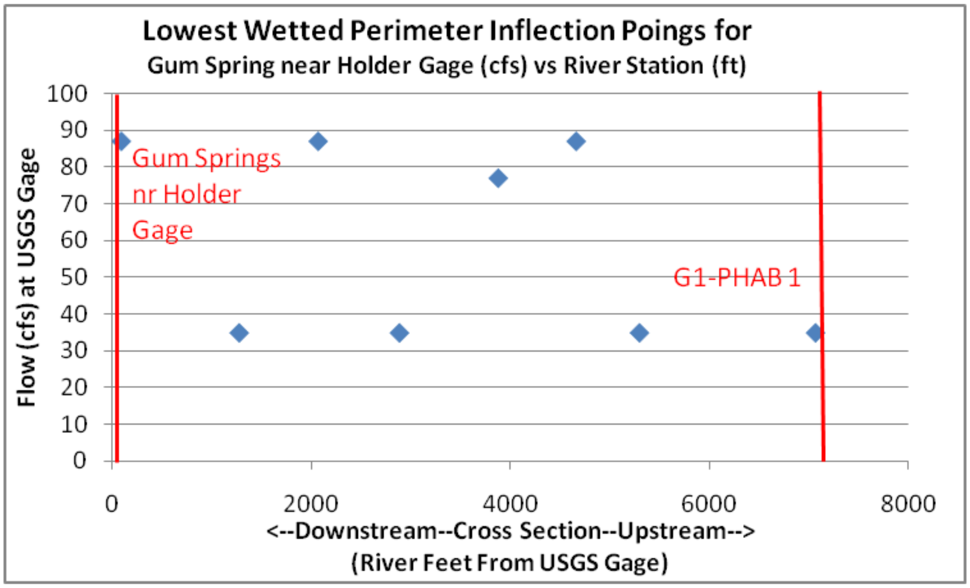


Figure 8-2. Plot of flow at the Holder gage required to inundate the lowest wetted perimeter inflection point at HEC-RAS cross-sections.

8.2.3 Low-Flow Threshold Results

The low-flow threshold (LFT) was established at the higher of the fish passage and wetted perimeter criteria and is, therefore, expected to provide protection for ecological and cultural values associated with both criteria. Therefore, LFT was set at 35 cfs at the Holder gage. Although flows in the river may be expected to drop below the LFT naturally, the threshold is defined to be a flow that serves to limit surface water withdrawals.

8.3 <u>PHABSIM Model Flow Reduction</u>

Prescribed flow reductions at the Holder gage site was developed based on the use of PHABSIM model to model potential changes in habitat availability for several fish species, fish guilds, and macroinvertebrate diversity at four representative sites.

8.3.1 PHABSIM Model Results

PHABSIM model analyses were conducted for two representative sites on the Gum Slough Spring Run. The PHABSIM sites were routinely co-located with vegetative cross-sections as shown in Figure 7-3. The TSLIB (time-series library) from the USGS Mid-Continent Research Laboratories was used to conduct the analysis.

Monthly discharge files were created for estimated historic conditions, 10% monthly flow reductions, 20% monthly flow reductions, 30% monthly flow reductions, and 40% monthly flow reductions. These monthly discharge files were then used for duration analyses to determine the percentage of time that the average and median habitat values were met or exceeded for each month for each calculated period of record. Comparisons to existing conditions were made to evaluate the amount of habitat gain or loss under conditions of reduced flow. It is noted that these analyses could be greatly improved by a longer flow.

The percent allowable reduction that would result in no more than a 15% loss of available habitat for each life stage, species, or guild was calculated for the entire reach. The shallow slow fish guild and macroinvertebrates were the most restrictive. To calculate the withdrawal limitation, the total WUA was calculated for the entire study reach (all sites combined) for each species, life stage, or fish guild. The percent flow reduction resulting in a 15% loss of available habitat was calculated for each species, life stage, or fish guild (Table 8-1). Wet season months were not considered for this analysis. During these months (August, September, October, and November) base flows are augmented by overland flows. Staff considers the baseflow that feeds Gum Slough Spring Run the resource susceptible to groundwater withdrawal impacts, not overland flows. In addition, PHABSIM is typically utilized by the District to determine allowable flow reductions for Blocks 1 and 2, utilizing inundation of floodplain features for Block 3 analyses. Graphs of all WUA are available in the PHABSIM Appendix.

Based on the most restrictive species, life stage, or fish guild (Table 8-1), the resulting allowable percent reduction for the Holder gage was 9 percent. Because Blocks were not used for this system, this allowable reduction is applicable all year.

Table 8-1. PHABSIM percent flow reduction calculations based on 15% flow reduction.

Species	Allowable % Reduction
SHALLOW-SLOW FISH GUILD	9%
Benthic Macros	9%
LMB Fry	10%
LMB Spawing	16%
DEEP-FAST FISH GUILD	21%
Bluegill Fry	21%
Bluegill Adult	23%
Spotted Sunfish Adult	26%
DEEP-SLOW FISH GUILD	31%
SHALLOW-FAST FISH GUILD	40%
LMB Adult	40%
LMB Juvenile	40%
Bluegill Juvenile	40%
Bluegill Spawning	40%
Spotted Sunfish Juvenile	40%
Spotted Sunfish Spawning	40%
Spotted Sunfish Fry	40%
Cyprinidae	40%

8.4 Inundation/Connection of Floodplain Features

Although it is generally appreciated that the river-floodplain connection is important to riverine ecology (see Section 7.8.3), few environmental flows have been based on a quantitative assessment of this feature. The District commonly conducts long term inundation analyses to determine maximum allowable flow reduction that will protect against greater than a 15% reduction in the number of days that various floodplain features are inundated as a result of river-floodplain connection. However, due to the very short period of record and the decision not to use the seasonal Block system, inundation analyses were not performed on these floodplain features. However, a discussion and presentation of the elevations and flows necessary to inundate these floodplain features follows.

8.4.1 Inundation of Floodplain Geomorphological Features

The text, tables, and figures presented in this section were taken largely verbatim from PBS&J (2010).

There was an overall increase in elevations along the channel of Gum Slough from downstream to upstream (see Table 8-2 and Figure 8-3). Increases ranged from as much as 3.5 feet (from downstream-most transect to Transect 4) to as little as 1 foot (from downstream-most transect to PHABSIM1, the most upstream transect).

Elevation increases along transects were greater than increases along the channel. The floodplain, or extent of wetlands, was broadest along Transects 4 (2,494 feet) and 5 (2,762 feet) in the mid-reaches of Gum Slough and elevation changes were greatest along these same transects (Figure 8-4). Transects 3, PHABSIM2, and 7 ranged from 1,091 to 1,709 feet in length, and Transects PHABSIM1 and 2 (most upstream reaches) and 8 (most downstream) ranged from 246 to 739 feet in length. The wettest vegetation communities (bay and cypress swamps) occurred at Transects 4, 5, and 7.

Elevation changes along transects were evaluated using relative elevations (elevations above, or normalized to, the channel bottom) and ranged from channel bottom (0 feet) to 3.0 feet at Transect 4 to a change of 7.1 feet at PHABSIM1. Elevations and distances along the 8 transects are listed in Table 8-2 and graphed in Figure 8-3. The elevation profile, associated vegetation communities, and locations of hydric soils along transects are graphed in Figure 8-4. Elevation profiles for other remaining transects are in the Appendix Vegetation Report.

Table 8-2. Elevation and distance along Gum Slough transects.

Transect		Transect Distance (feet)*	Transect Maximum Elevation (NAVD)*	Channel Elevation (NAVD)	Maximum Elevation Change	Median Elevation (NAVD)*	Median Relative Elevation	N*
Downstream ⇩	**PHABSIM1**	246	44.5	36.2	8.3	43.3	7.1	6
	2	739	44.8	38.6	6.2	43.1	4.5	13
	3	1,173	43.8	38.6	5.2	42.3	3.8	23
	4	2,494	47.8	38.7	9.1	41.9	3.0	35
	5	2,762	45.2	35.8	9.4	41.7	6.0	27
	PHABSIM2	1,709	44.9	38.1	6.8	41.5	3.4	20
	7	1,091	45.6	37.6	8.0	41.5	4.0	12
	8	636	46.4	35.2	11.2	40.6	5.6	15

*excludes the channel

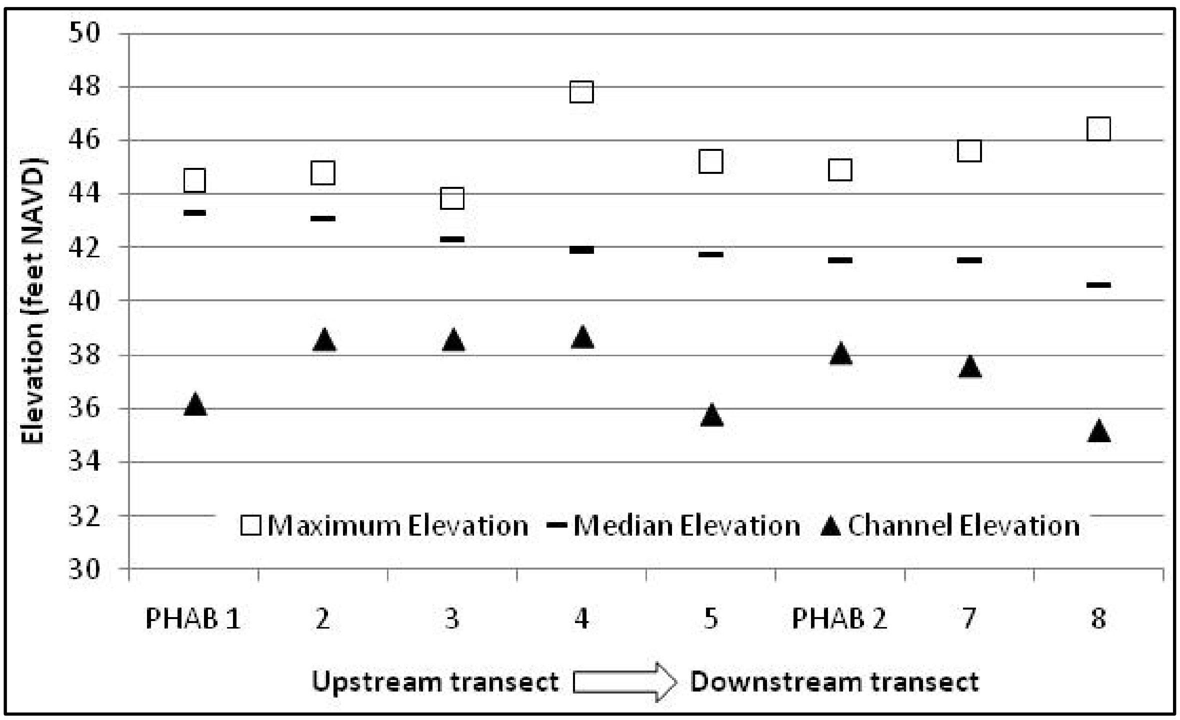


Figure 8-3. Channel bottom, maximum, and median elevations along Gum Slough transects.

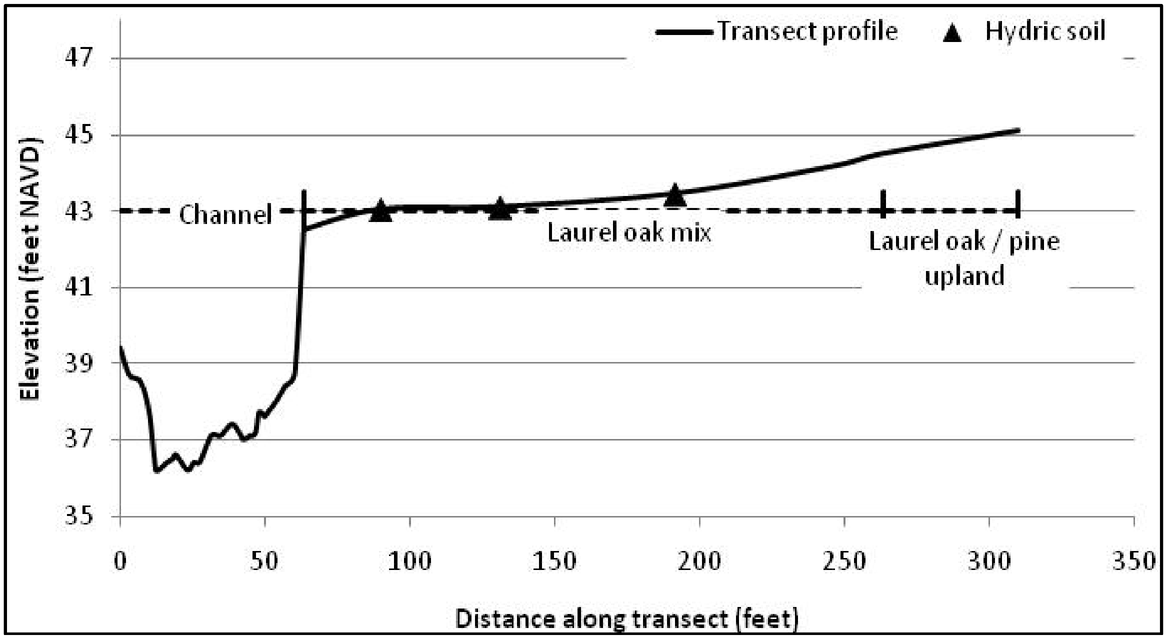


Figure 8-4. Elevation, vegetation, and hydric soil profile along Transect PHABSIM1.

Floodplain wetted perimeter plots (patterned after the wetted perimeter plots used for identification of the lowest wetted perimeter inflection point) were developed for each floodplain vegetation cross-section (see Appendix Vegetation Report). The plots were developed to show the linear extent of inundated floodplain (wetted perimeter) associated with measured floodplain elevations, including the mean elevations of the floodplain vegetation communities and some hydrologic indicators. For example, Figure 8-5 shows a floodplain wetted perimeter plot for floodplain vegetation along Transect 2. Based on the plot, approximately 400-600 linear feet of floodplain bottom would be inundated when the river is staged near the median elevation of maple hardwood hammock community. This flow would be equivalent to 140 cfs as measured from Gum Springs near Holder USGS gauge. This is in contrast to approximately 600-800 linear feet of floodplain that would be inundated at the median elevation of the ironwood hardwood hammock community. Flow would have to exceed 250 cfs to exceed the median elevation of this ironwood hardwood hammock community.

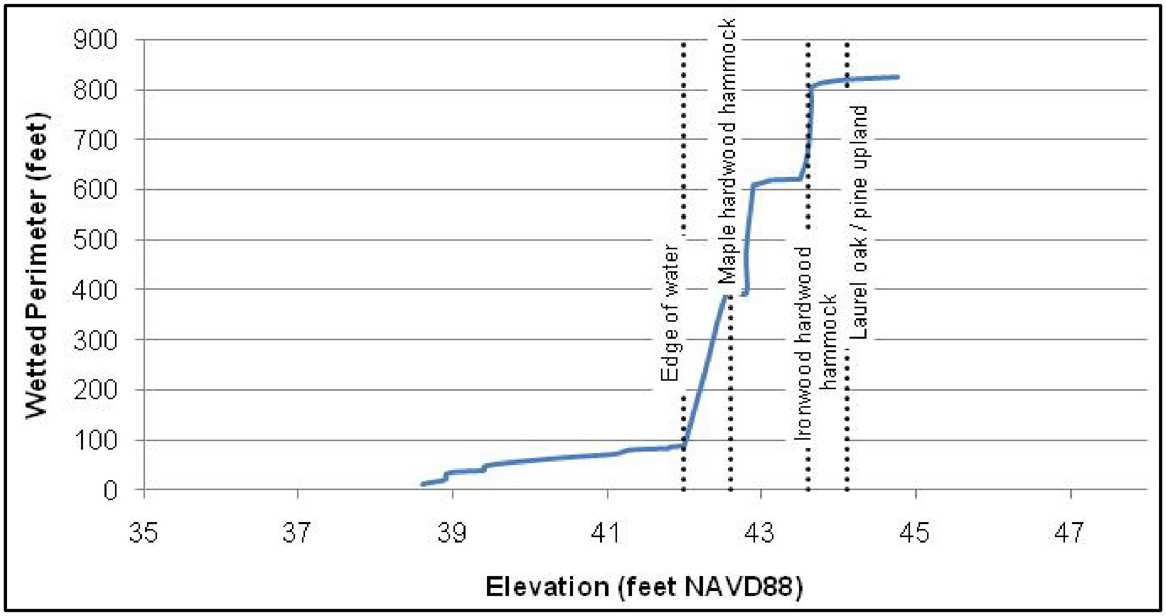


Figure 8-5. Floodplain wetted perimeter and median vegetation class elevations along Transect 2.

8.4.2 Inundation of Floodplain Vegetation Classes and Soils

8.4.2.1 Vegetation Classes

The text, tables, and figures presented in this section was taken largely verbatim from PBS&J (2010).

Vegetation community types were characterized as wetland classes along the Gum Slough study corridor according to PBS&J (2010). Six vegetation classes were characterized as wetland classes, including bay swamp and cypress swamps and four "hammocks." A single upland class was identified. The wetland classes included obligate and facultative wetland tree species, including bald cypress (*Taxodium distichum*), dahoon holly (*Ilex cassine*), swamp bay (*Persea palustris*), sweet bay magnolia (*Magnolia virginiana*) tupelo (*Nyssa sylvatica*), red maple (*Acer rubrum*), and ironwood (*Carpinus caroliniana*). The six wetland classes could be differentiated based on dominance of cypress, sweetgum (*Liquidambar styraciflua*), swamp bay, ironwood, laurel oak (*Quercus laurifolia*), and water oak (*Q. nigra*). Importance values (IVs) subtotaled by obligate, facultative, and other wetland status for each vegetation class are listed in Table 8-3. The vegetation classes were named according to the conspicuous canopy species observed along transects during sampling (species IVs were calculated after sampling). In the bay swamp and maple hardwood hammock classes the highest IV values were not swamp bay or red maple, but sweetgum and swamp bay, respectively. Differences between vegetation classes along the Gum Slough study transects were significant (Wilcoxon Signed Rank test, $p < 0.01$) based on IVs and provided a relative measure of species dominance (no units). For example, species IVs were consistently different between the cypress swamp and the bay swamp, as well as between these two classes and any of the five remaining vegetation classes.

Table 8-3. Importance values for tree species in vegetation classes along the Gum Slough Study Corridor.

Wetland Status[2]	Species	Vegetation Class[1] Cypress Swamp	Bay Swamp	Maple Hardwood Hammock	Laurel Oak Mix Hammock	Ironwood Hardwood Hammock	Water Oak/ Sweetgum Hammock	Laurel Oak/ Pine Upland	Total IV
OBL	*Cephalanthus*	3.9	0	3.3	0	0	20.3	0	27.6
OBL	*Fraxinus*	4.4	0	15.0	12.7	0	0	0	32.1
OBL	*Ilex cassine*	0	43.0	40.8	26.0	10.5	0	0	120.3
OBL	*Magnolia*	0	0	10.9	0	0	0	0	10.9
OBL	*Nyssa*	18.2	0	23.2	0	19.2	0	0	60.7
OBL	*Persea*	35.8	57.9	63.8	56.7	31.3	19.7	0	265.1
OBL	*Taxodium*	65.2	0	5.7	29.0	30.1	0	0	130.1
FACW[3]	*Persea*	0	0	0	0	0	13.4	0	13.4
FACW	*Acer rubrum*	25.8	54.7	27.7	26.3	7.6	0	0	142.0
FACW	*Carpinus*	7.9	0	19.5	0	70.4	22.4	23.2	143.6
FACW	*Celtis*	0	0	6.0	11.2	0	0	0	17.2
FACW	*Gordonia*	4.0	0	0	0	0	0	5.7	9.7
FACW	*Liquidambar*	49.2	69.4	7.3	0	35.3	39.4	42.3	242.9
FACW	*Quercus*	41.5	23.8	33.7	100.8	45.1	0	68.7	313.7
FACW	*Quercus nigra*	0	0	6.3	0	0	149.2	28.5	184.0
FACW	*Ulmus*	38.5	51.3	36.5	37.3	29.6	12.4	5.7	211.2
FAC[3]	*Magnolia*	0	0	0	0	0	0	7.0	7.0
FAC[3]	*Pinus taeda*	0	0	0	0	0	13.0	87.5	100.6
FAC	*Myrica*	0	0	0	0	0	0	11.0	11.0
FAC	*Sabal*	0	0	0	0	20.8	0	7.0	27.8
FAC[3]	*Carya glabra*	5.7	0	0	0	0	10.1	5.5	21.3
FACU[3]	*Quercus*	0	0	0	0	0	0	7.9	7.9

[1] Vegetation class columns total 300. [2] Wetland status according to FDEP unless noted otherwise. [3] Wetland status according to NWI. OBL = Obligate, FACW = Facultative Wet, FAC = Facultative, FACU = Facultative Upland.

Additional descriptions of major communities are described below:

Swamps. The swamp vegetation classes were characterized by a large component of obligate and facultative wetland species, for which IVs totaled 294 out of total 300 possible. Swamp species differ from other species in their extreme flood tolerance. For example, cypress trees can tolerate up to 3 meters of water for periods of time and can typically tolerate 1 meter of inundation for more than 10 years, while 30 days of inundation will kill seeds (Harms et al. 1980; Souther and Shaffer 2000; Mattson and Krummrich 1995; DuBarry 1963; Loucks and Keen 1973). Cypress, tupelo, and ash are the most tolerant of inundation and can tolerate up to a meter of inundation for up to 10 years.

- Cypress swamp. Twelve species total. IVs for obligate wetland species totaled 127.5 (out of the total possible 300) and included cypress, swamp bay, and tupelo. Dominant species (IV> 50) included cypress (IV = 65.2), followed by sweetgum (IV=49.2) and laurel oak (IV=41.5). Minor (10< IV < 50) components: swamp bay, red maple (Acer rubrum), tupelo, and American elm (Ulmus americana). Very small (IV< 10) components: pignut hickory (Carya glabra), buttonbush (Cephalanthus occidentalis), popash (Fraxinus caroliniana), and ironwood.

- Bay Swamp. Six species total. IVs for obligate wetland species totaled 100.8. Dominant species: sweetgum (IV=69.4), swamp bay (IV=57.9), red maple (IV=54.7), and American elm (IV=51.3). Minor components: dahoon holly and laurel oak. No species with IV<10.

Hammocks. These vegetation classes, like the swamp classes, were characterized by large obligate and facultative wetland species components, including cypress. However, many of these species, while tolerant of temporary flooding, may be less tolerant of prolonged flooding. Obligate and facultative wetland species totaled more than 275 of a total 300 possible.

- Maple hardwood hammock (14 species). Dominant components: swamp bay (IV=63.8). Minor components: dahoon holly (IV=40.8), American elm (IV=36.5), laurel oak (IV=33.7), red maple (IV=27.7), tupelo (IV=23.2), popash (IV=15.0), and sweet bay magnolia (IV=10.9). Small components: buttonbush, cypress, hackberry (Celtis laevigata), sweetgum, and water oak.

- Ironwood hardwood hammock (10 species). Dominant component: ironwood (IV=70.4), laurel oak (IV=45.1), sweetgum (IV=35.3), swamp bay (IV=31.3), cypress (IV=30.1), American elm (IV=37.3), tupelo (IV=19.2), and dahoon holly (IV=10.5). Small component: red maple.

- Laurel oak hammock (8 species) was dominated by laurel oak (IV=100.8) and swamp bay (IV=56.7). Minor components included cypress (IV=29.0), red maple (IV=26.3), American elm (IV=37.3), dahoon holly (IV=26.0), popash (IV=12.7), and hackberry (IV=11.2). No minor components.

- Water oak / sweetgum hammock (9 species). Dominant components: water oak (IV=149.2). Smaller components: buttonbush (IV=20.3), swamp bay (IV=19.7), red bay (Persea borbonia, IV=13.4), ironwood (IV=22.4), loblolly pine (Pinus taeda, IV=13.0), and pignut hickory (IV=10.1). No minor components. Obligate wetland species IVs totaled only 40.

Laurel oak / pine upland. The single upland class included 12 species. Dominants: loblolly pine (IV=87.5) and laurel oak (IV=68.7). Lesser components: hackberry, sweetgum, water oak, wax myrtle. Minor components: sweet bay, southern magnolia (Magnolia grandiflora), cabbage palm (Sabal palmetto), pignut hickory, and live oak. IVs for obligate (zero) and facultative wetland species totaled 174.1.

8.4.2.2 Soils

Alfisols and ultisols form the central ridge where the Gum Slough study corridor is located, although spodosols, or flatwoods soils are the dominant soil order throughout Florida. Alfisols and ultisols are gently sloping and well drained sandy soils with loamy subsoils layered over phosphatic limestone (Fernald 1981). Natural systems associated with these soils are generally mixed hardwood forests (Myers and Ewel 1990). Sand, limestone, and clay (NRCS 1988) components dominate these soils rather than organic materials. In spite of the relative absence of peat soils in alfisols and ultisols, there are adequate organic peat deposits to support horticultural peat mining in the Holocene deposits east of Oxford and southwest of Tarrytown in Sumter County (NRCS 1988).

Hydric soils were found along all 8 study transects (Table 8-4) and all hydric soils were also characterized by the presence of muck. Soils were examined for other hydric indicators such as organic bodies, oxidized rhizospheres, and stripped matrix, but no other indicators were noted.

Elevations of hydric soils ranged from 40.5 to 43.1 feet NAVD and consistently increased from downstream Transect 8 to upstream Transect PHABSIM1.

Median elevations of nonhydric soils were consistently greater than hydric soils and ranged from 43.5 feet NAVD at Transect 3 to 46.6 feet NAVD at Transect 4. Differences in median elevations between hydric and nonhydric soils ranged from nearly 5 feet at Transect 4 to just over 1 foot higher at Transect 3. With the exception of Transect 4, differences between hydric and nonhydric soils elevations increased downstream. Median elevations of hydric soils were lower when compared with nonhydric soils (Wilcoxon Signed Rank test, $p < 0.01$).

Table 8-4. Median elevations (feet NAVD) of hydric and nonhydric soils along Gum Slough study transects.

Transect		**Hydric* (N)**	**Nonhydric (N)**
	PHABSIM1	43.1 (3)	
Upstream	2	42.9 (6)	
	3	42.4 (5)	43.5 (1)
	4	41.9 (13)	46.6 (3)
	5	41.6 (12)	44.6 (3)
	PHABSIM2	41.5 (6)	44.9 (3)
	7	41.3 (5)	45.3 (3)
Downstream	8	40.5 (8)	4.8 (3)

*All hydric soils included presence of muck.

8.4.3 Critical Elevation of Floodplain Features and Flow Requirements for Inundation

Table 8-5 summarizes the various floodplain features described in the Gum Slough study transects, specifically the various vegetation classes, hydric mucky soils, and geomorphological aspects of the floodplain as depicted by the floodplain wetted perimeter as well as top of bank features where water could either inundate one side or both sides of the channel. Range of mean elevations of these features is reported as well as the flow range required to inundate them (Table 8-5).

Among the various floodplain vegetation community classes, the lower end of their elevations varied from 40.5-41.7 ft. requiring flows from the river of about 115 to 148 cfs to inundate up to their mean elevations. In contrast, the upper range of occurrences of these vegetation classes, require up to 215 cfs. Three transects inhabited by an ironwood hardwood hammock, water oak/sweet gum hammock and a cypress swamp occurred at higher elevations exceeding the modeled flow range (>248 cfs). All the upland communities observed in this study site occupied a higher elevation range which expectedly exceeded the modeled flow range. Among the mucky hydric soils sampled, inundation of these areas requires 115 cfs from the river. One exception, as exemplified by a >248 cfs flow requirement to inundate, suggests a seepage wetland in the vicinity that helps maintain the mucky hydric soil horizon. Flows required to inundate a broad segment of the floodplain range from 106-200 cfs. However, based on the topography of the terrain, further inundation higher up in the floodplain results in higher flows that exceed the modeled flow range. If the river provides the inundation required to flood the riparian communities, most of that flow would occur along one bank side, the left bank, which occurs at a much lower elevation compared to the right bank. This is also consistent with the floodplain topography in this river where the floodplain extends along a southeast trending direction.

Table 8-5. Summary of floodplain hydrologic indicators.

Floodplain Feature	Number of Floodplain Transects Containing Feature and Number of Floodplain Transects Containing Feature that Exceeded Modeled Flow Range (n)	Mean Elevation Range among Floodplain Transects Containing Feature (in feet NAVD88)	Corresponding Guage	Flow Range Required for Inundation (cfs)
Laurel Oak Mix Hammock	2	41.7 - 43.3	Gum Springs near Holder	147 - 215
Maple Hardwood Hammock	4	41.5 - 42.6	Gum Springs near Holder	140 - 145
Ironwood Hardwood Hammock	3 (1)	40.8 - 43.6	Gum Springs near Holder	148 - > 248
Cypress Swamp	3 (1)	41.5 - 42.2	Gum Springs near Holder	132 - > 248
Bay Swamp	1	41.7	Gum Springs near Holder	155
Water Oak/Sweetgum Hammock	2 (1)	40.5 - 44.5	Gum Springs near Holder	115 - > 248
Laurel Oak Pine Upland	6 (6)	43.7 - 46.6	Gum Springs near Holder	> 248
Mucky Hydric Soils	8 (1)	40.5 - 43.1	Gum Springs near Holder	115 - > 248
Low Floodplain Wetted Perimeter	8	40.6 - 42.6	Gum Springs near Holder	106 - 200
High Floodplain Wetted Perimeter	8 (3)	41.2 - 43.5	Gum Springs near Holder	165 - > 248
Top of Bank - One Side	8 (1)	39.4 - 42.8	Gum Springs near Holder	< 35 - 240
Top of Bank - Two Sides	8 (4)	41.2 - 43	Gum Springs near Holder	118 - > 248

8.5 Instream/Woody Habitat Protection

A prescribed flow reduction for criterion based on long-term inundation analyses to specifically evaluate changes in inundation patterns of woody habitats was also used to evaluate habitat loss. The prescribed flow reductions were established by calculating the percent-of-flow reduction, which would result in no more than a 15% reduction in the number of days of inundation of woody habitat.

8.5.1 Instream Habitats

Instream habitats found in Gum Slough as they occurred along the eight instream cross-sections are shown in Figures 8-6 and 8-7. These habitats were divided into two groups; those having vertical relief (e.g., various macrophyte types such as wetland WV, emergent EV, floating FV, submersed vegetation SAV, woody habitats such as woody debris WD and exposed roots ER) and those that adhere to the bottom (e.g., sand S, mud M, bedrock R, shell SH, algal mats AL and leaf packs LL).

Among the bottom substrates, consisting of inorganic and organic components, mud, sand and algal mats appear to be dominant among the sampled transects (Figure 8-7). Leaf packs came second and mainly occurred along the edges of the waterline. Less represented were exposed bedrock and shell bottom substrates. Among those instream habitats that exhibit greater vertical relief, submersed aquatic vegetation, emergent vegetation and woody debris (snags) dominated. Exposed roots were also well represented throughout the various transects, followed by wetland vegetation which also tend to occupy the bank edges. *Sagittaria kurziana*, *Najas guadalupensis* and *Vallisneria americana* were among the major submersed aquatic plants noted. *Pistia stratiotes* was a dominant floating macrophyte while *Lobelia cardinalis* (a listed species) and *Pontedaria cordata* were dominant emergent macrophytes seen in Gum Slough. Emergent, floating and submersed aquatic vegetation seems to be more dominant in extent of linear habitat in the lower third of the study area where the channel widens into several braided channels.

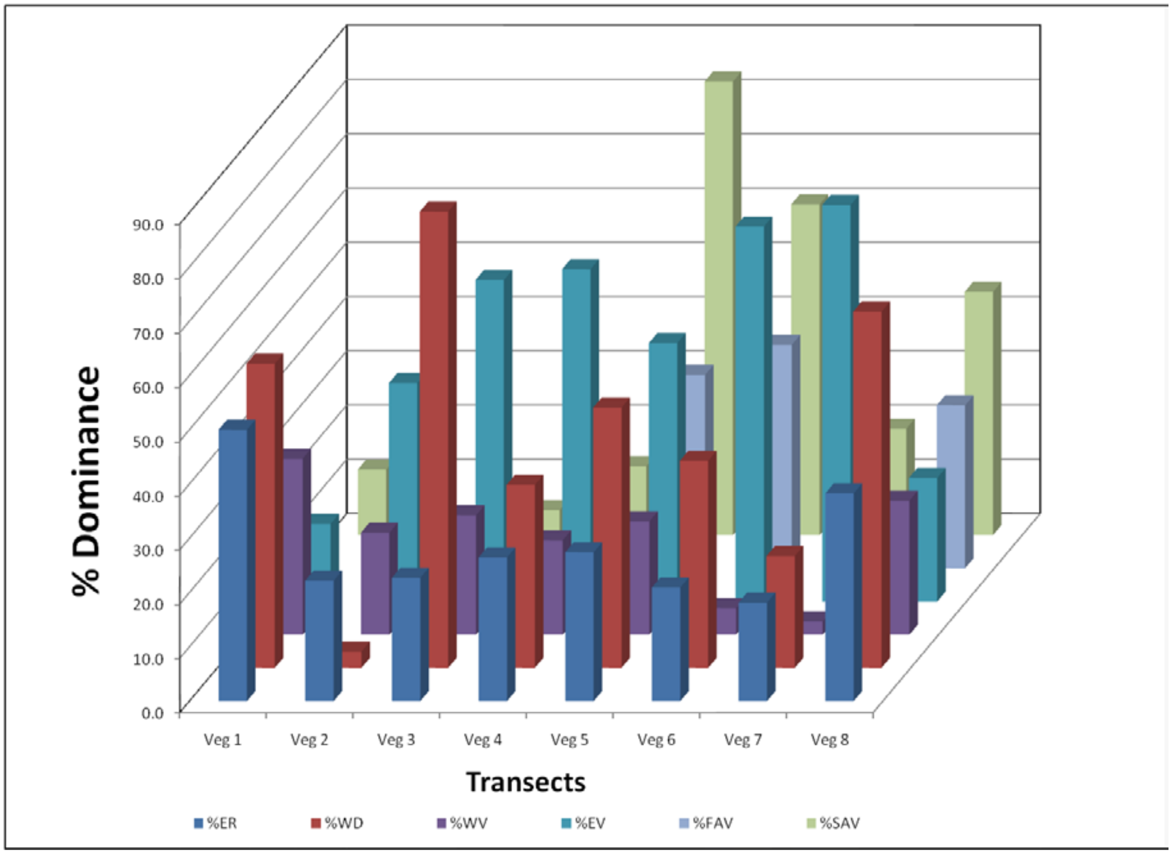


Figure 8-6. Percent dominance of instream habitats (excluding bottom habitats) based on linear extent of these habitats along eight cross-sections on Gum Slough Spring Run.

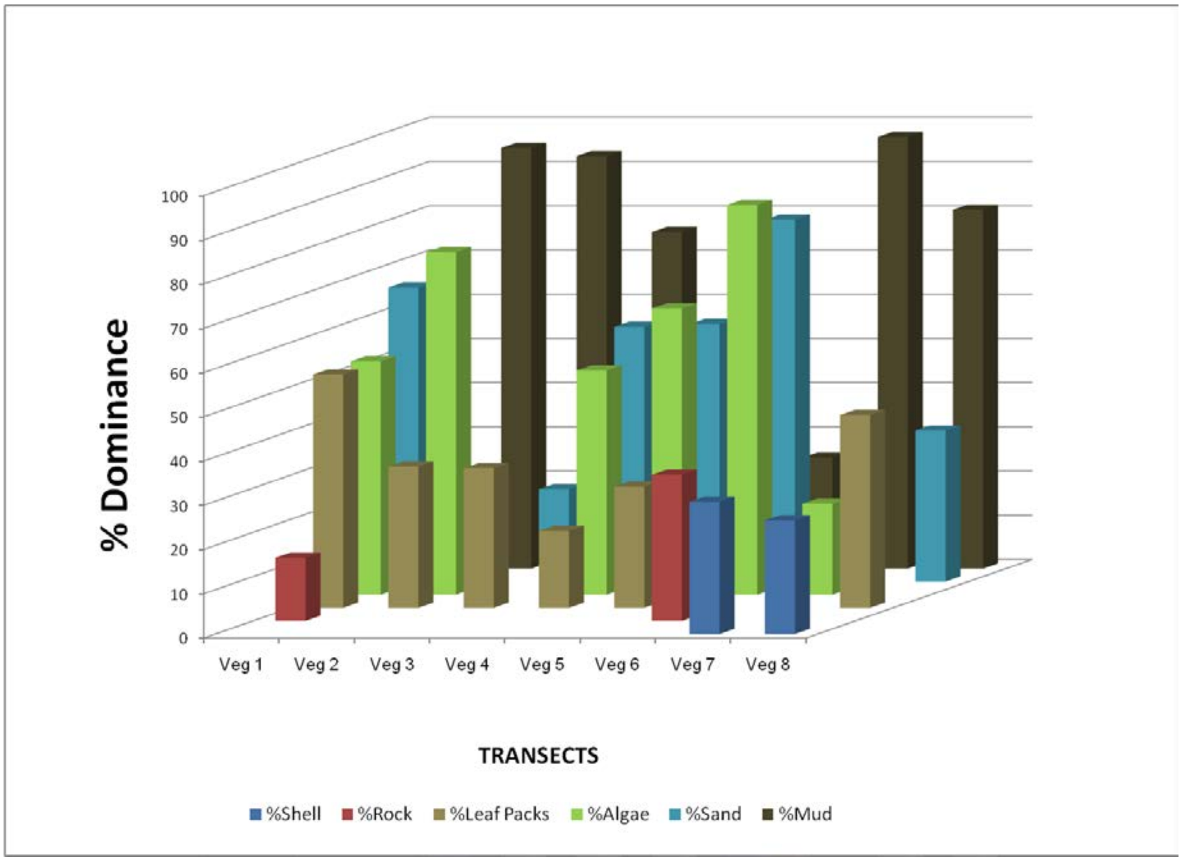


Figure 8-7. Percent dominance of bottom instream habitats based on linear extent of these habitats along eight cross-sections on Gum Slough Spring Run.

Relative elevations of the habitats were consistent among the cross-sections (Figure 8-8). Wetland vegetation was typically situated near the top of the banks with woody debris and exposed roots occurring at slightly lower elevations. In some sites (Transects 2, 3 and 4), emergent vegetation was associated with bank features as well. Predictably, submerged aquatic plants were found in association with the bottom substrates. The occurrence of exposed roots at relatively high elevations is important because inundation of this habitat results in inundation of habitats located at lower elevations. Maintaining a mosaic of aquatic and wetland habitats provides the greatest potential for stream productivity and ecosystem integrity (Pringle et al. 1988). As each point in the figure represent an average elevation for a particular item, some appear to be out of place (e.g. floating vegetation below the bottom habitats).

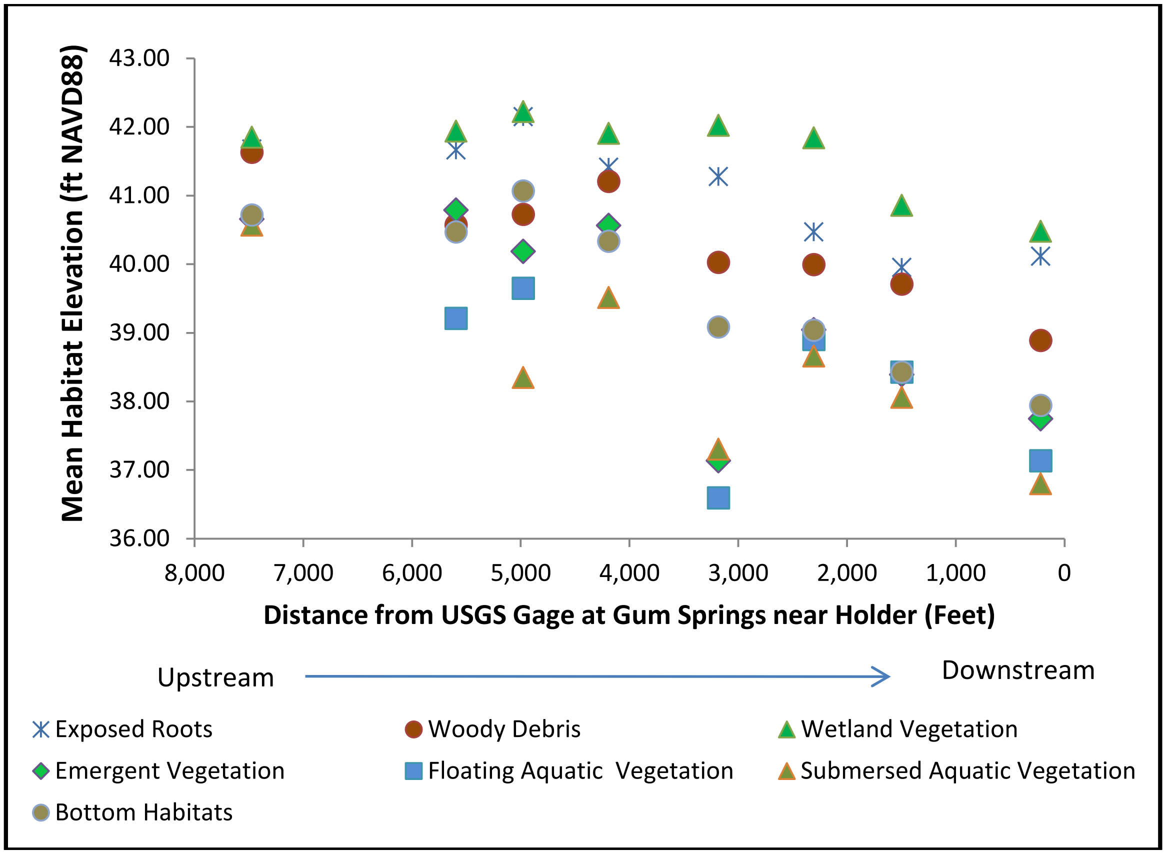


Figure 8-8. Mean elevations of instream habitats at twenty-six cross-section sites on Gum Slough.

8.5.2 Flow Relationships with Woody Instream Habitats

Based on the ecological importance of woody habitat, and its potential for use in development of a medium flow standard, inundation patterns were examined for exposed root and snag habitats at eight Gum Slough Spring Run instream habitat cross-sections. Based on HEC-RAS output, flows at the respective Gum Springs near Holder USGS gage that are sufficient for inundation of the mean elevation of exposed root habitat as measured using the combined data from the cross-section method and the belt transect method at the 8 sites ranged from 35 to 122 cfs at the Gum Springs near Holder gage (Table 8-6). Similarly, when snag habitats were characterized via a longitudinal belt method combined with a cross-section method, flows at 8 sites ranged from 35 to 110 cfs (Table 8-6). Based on historic flow records, inundation of exposed roots and snag habitat occurs regularly during the entire year. This is common on spring runs that are adapted to relatively muted hydrographs.

Table 8-6. Mean elevation of instream woody habitats (exposed roots and snags) at various instream habitat sites, corresponding flows at the Gum Springs near Holder USGS gage required for inundation of the mean elevations, and maximum percent-of-flow reductions associated with less than a 15% reduction in the number of days flow sufficient to inundate the mean habitat elevations.

Habitat	Site	Mean Elevation (ft NAVD)	S.D.	Flow (cfs) at Gage Required for Inundation	Gage	Allowable Percent of Flow Reduction
Exposed Roots	Veg 1	37.98	1.06	35	Gum Springs near Holder	42
Exposed Roots	Veg 2	41.66	0.97	87	Gum Springs near Holder	8
Exposed Roots	Veg 3	42.15	0.74	115	Gum Springs near Holder	7
Exposed Roots	Veg 4	41.42	1.18	122	Gum Springs near Holder	5
Exposed Roots	Veg 5	41.28	1.93	120	Gum Springs near Holder	5
Exposed Roots	Veg 6	40.47	1.73	77	Gum Springs near Holder	5
Exposed Roots	Veg 7	39.96	1.10	60	Gum Springs near Holder	15
Exposed Roots	Veg 8	40.12	1.19	86	Gum Springs near Holder	8
Mean				**88**		**12**
Snags	Veg 1	37.93	1.01	35	Gum Springs near Holder	42
Snags	Veg 2	40.57	1.46	49	Gum Springs near Holder	22
Snags	Veg 3	40.73	1.63	59	Gum Springs near Holder	15
Snags	Veg 4	41.21	1.31	110	Gum Springs near Holder	9
Snags	Veg 5	40.03	2.61	47	Gum Springs near Holder	22
Snags	Veg 6	40.00	1.68	57	Gum Springs near Holder	15
Snags	Veg 7	39.71	1.19	50	Gum Springs near Holder	22
Snags	Veg 8	38.89	2.12	35	Gum Springs near Holder	42
Mean				**55**		**24**

8.5.3 Results of Woody Habitat Protection Criteria

The goal of the woody habitat protection criteria is to limit the reduction in number of days that the mean elevation of woody habitat is inundated to 15% for all sites combined. This best represents a 15% loss in woody habitat inundation for the entire spring run. The resulting allowable percent withdraw for exposed roots and snags are 12 and 24 percent at the Gum Springs near Holder gage, respectively. The woody habitat inundation criterion is therefore defined as the more conservative, 12 percent maximum allowable flow reduction.

8.6 Proposed Minimum Flows for Gum Slough Spring Run

For Gum Slough Spring Run the minimum flow recommendation is stated as a percent of flow reduction at the USGS Gum Springs near Holder gage. Reductions and the low flow threshold apply to the entire year.

A number of different flow reduction criteria were analyzed during the development of the minimum flow. The results of these criteria are summarized in Table 8-7 and in the text below.

Table 8-7. Flow reduction recommendations for each individual criterion based on a composite of all individual criterion for each analysis.

Analysis Name	Measure / Goal	Maximum Allowable Flow Reduction
Fish Passage	Maintain depth of 0.6' across shoals	35 cfs
Wetted Perimeter	Maximize inundated river channel	35 cfs
PHABSIM	Avoid reductions >15% for various species	9%
Snags	Avoid reductions >15% in snag availablility	24%
Exposed Roots	Avoid reductions >15% in exposed root availablility	12%

Utilizing the most restrictive flow reduction criteria and low flow threshold, the minimum flows for Gum Slough Springs Run are as follows. Figure 8-9 illustrates the flow prescription criteria for the period of record. The SWFWMD will reevaluate this MFL in approximately ten years when a more appropriate flow dataset is available.

At the Gum Springs near Holder gage, the proposed MFL allows removal of 9 percent of flows for the entire year. Surface water withdrawals are prohibited from depressing flows below 35 cfs for the entire year.

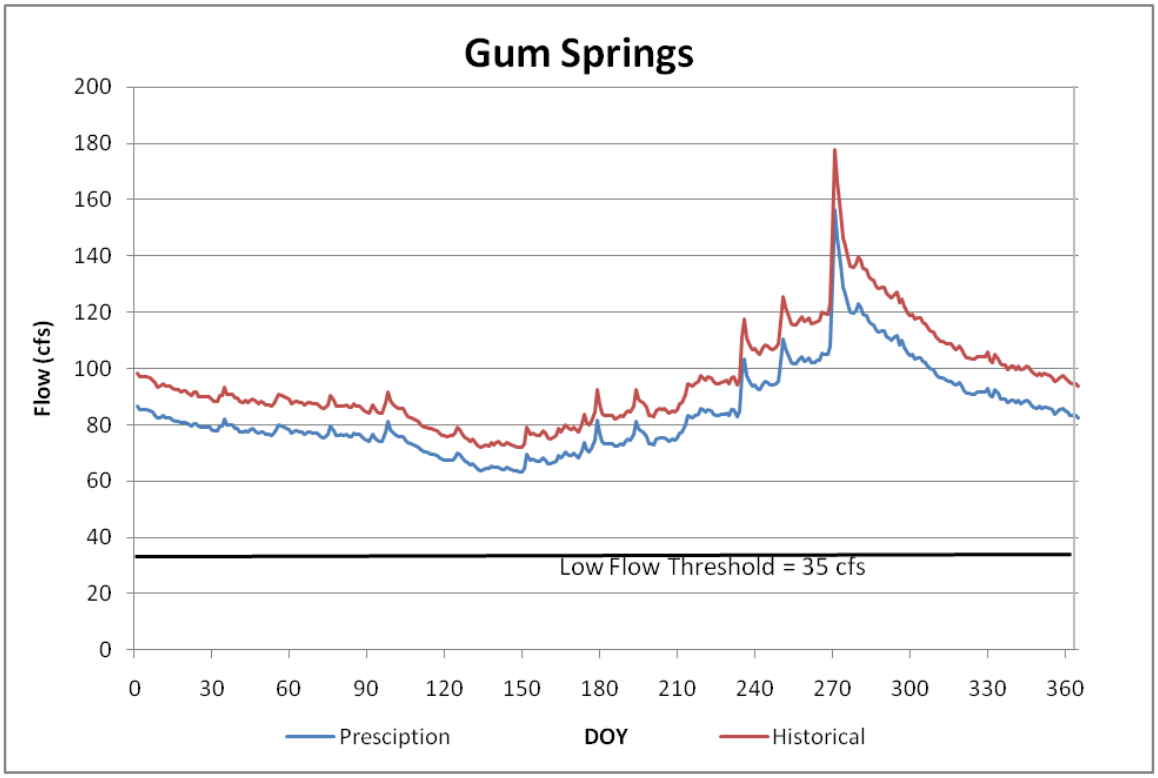


Figure 8-9. Flow prescription for the Gum Spring near Holder USGS gage.

CHAPTER 9 – LITERATURE CITED

Aho, J.M. and J.W. Terrell. 1986. Habitat Suitability Index Models and Instream Flow Suitability Curves: Redbreast Sunfish. U.S. Fish and Wildlife Service Biological Report 82 (10.119).

Ainsle, W.B., B.A. Pruitt, R.D. Smith, T.H. Roberts, E.J. Sparks, and M. Miller. 1999. A Regional Guidebook for Assessing the Functions of Low Gradient Riverine Wetlands in Western Kentucky. U.S. Army Corps of Engineers Waterways Experiment Station. Technical Report WRP-DE-17. Vicksburg, Mississippi.

Anderson, J., E. Hardy, J. Roach, and R. Witmer. 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data. Geological Survey Professional Paper 964. U.S. Government Printing Office, Washington, D.C.

Andreyev Engineering, Inc. 2003. Hydrogeology of the Villages. Update to December 23, 2002 Report. The Villages, Florida.

Annear, T.C. and A.L. Condor. 1984. Relative bias of several fisheries instream flow methods. North American Journal of Fisheries Management 4:531-539.

Basso, R. and R. Schultz. 2003. Long-Term Variation in Rainfall and its Effect on Peace River flow in West-Central Florida. Hydrologic Evaluation Section, Southwest Florida Water Management District. Brooksville, Florida. 33 pp.

Beecher, H. 1990. Standards for instream flows. Rivers 1(2):97-109.

Benke, A.C., R.L. Henry III, D.M. Gillespie, and R.J. Hunter. 1985. Importance of the snag habitat for animal production in a southeastern stream. Fisheries 10:8-13.

Benke, A.C. and J.B. Wallace. 1990. Wood dynamics in coastal plain blackwater streams. Canadian Journal of Fisheries and Aquatic Sciences 47:92-99.

Benke, A.C., T.C. Van Arsdall, Jr., D.M. Gillespie, and F.K. Parrish. 1984. Invertebrate productivity in a subtropical blackwater river: the importance of habitat and life history. Ecological Monographs 54:25-63.

Berryman and Henigar. 2005. Characterization of Wetland Vegetation Communities and Hydric Soils along the Upper Hillsborough River. Berryman and Henigar, Tampa, Florida.

Bovee, K.D., B.L. Lamb, J.M. Bartholow, C.B. Stalnaker, J. Taylor, and J. Hendrickson. 1998. Stream Habitat Analysis Using the Instream Flow Incremental Methodology. U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD-1998-0004.

Brinson, M.M., B.L. Swift, R.C. Plantico, and J.S. Barclay. 1981. Riparian Ecosystems: Their Ecology and Status. U.S. Fish and Wildlife Service, Biological Services Program Report FWS/OBS-81/17. Washington, D.C.

Brown, M.T., J.M. Schaefer, and K.H. Brandt.1990. Buffer Zones for Water, Wetlands and Wildlife in East Central Florida. CFW Publication #89-07. Florida Agricultural Experiment Stations Journal Series No. T-00061. East Central Florida Regional Planning Council.

Brussock, P.P., A.V. Brown and J.C. Dixon. 1985. Channel form and stream ecosystem models. Water Resources Bulletin 21:859-866.

Bunn, S.E. and A.H. Arthington. 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental Management 30:492-507.

Campbell, K. 1989. Geology of Sumter County, Florida. Report of Investigation No. 98. Florida Geological Survey, Tallahassee, Florida.

Champion, K.M. and R. Starks. 2001. The Hydrology and Water Quality of Springs in West-Central Florida. Water Quality Monitoring Program. Southwest Florida Water Management District, Brooksville, Florida.

Conner, W.H. and J.W. Day. 1976. Productivity and composition of a bald cypress-water tupelo site and a bottomland hardwood site in a Louisiana swamp. American Journal of Botany 63:1354-1364.

Cottam, G. and J.T. Curtis. 1956. The use of distance measures in phytosociological sampling. Ecology 37(3):451-460.

Crance, J.H. 1988. Relationships Between Palustrine Forested Wetlands of Forested Riparian Floodplains and Fishery Resources: A Review. Biological Report 88(32). U.S. Fish and Wildlife Service. Washington, D.C.

Cudney, M.D. and J.D. Wallace. 1980. Life cycles, microdistribution and production dynamics of six net-spinning caddisflies in a large southeastern (USA) river. Holartic Ecology 3:169-182.

Dinkins, L.J. 1969. Dunnellon, Boomtown of the 1890s. Great Outdoors Publishing Company. 215 pp.

Dunbar, M.J., A. Gustard, M.C. Acreman, and C.R. Elliott. 1998. Overseas Approaches to Setting River Flow Objectives. Institute of Hydrology. R&D Technical Report W6-161. Oxon, England. 83 pp.

DuBarry, A.P., Jr. 1963. Germination of bottomland tree seeds while immersed in water. Journal of Forestry 61:225-226.

EAS, Inc. 2010. HEC-RAS Modeling of the Withlacoochee River. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Edwards, R.T. and J.L. Meyer. 1987. Metabolism of a sub-tropical low gradient blackwater river. Freshwater Biology 17:251-263.

Enfield, D., A. Mestas-Nunez, and P. Trimble. 2001. The Atlantic Multidecadal Oscillation and its relation to rainfall and river flows in the continental U.S. Geophysical Research Letters 28(10):2077-2080.

Flannery, M.S., E.P. Peebles, and R.T. Montgomery. 2002. A percent-of-flow approach for managing reductions to freshwater inflow from unimpounded rivers to Southwest Florida estuaries. Estuaries 25:1318-1332.

Florida Department of Transportation (FDOT). 1999. Florida Land Use, Cover and Forms Classification System Handbook, Third Edition. Florida Department of Transportation, Surveying and Mapping Office, Geographic Mapping Section, Tallahassee, Florida. 93 pp.

Florida Geological Survey (FGS). 2001. Springs of Florida, FGS Bulletin No. 66, 342 pp.

Florida Geological Survey (FGS). 2007. Florida Springsheds. Geographical information system data file. Florida Department Environmental Protection/Florida Geological Survey. Tallahassee, Florida.

Florida Geological Survey (FGS). 2009. Regional and Statewide Trends in Florida's Spring and Well Groundwater Quality (1991-2003), Draft. Bulletin Number 69. Tallahassee, Florida.

Fredericks, J. 2010. Well Construction and Hydrogeology of the Gum Springs Well Site in Sumter County, Florida (Draft), Southwest Florida Water Management District, 8 pp.

Friedemann, M. and J. Hand. 1989. Typical Water Quality Values for Florida's Lakes, Streams, and Estuaries. Standards and Monitoring Section. Bureau of Surface Water Management, Florida Department of Environmental Regulation, Tallahassee, Florida.

FNAI. 2005. http://www. fnai. org/descriptions. cfm.

Gilbert, K.M., J.D. Tobe, R.W. Cantrell, M.E. Sweeley, and J.R. Cooper. 1995. The Florida Wetlands Delineation Manual. Florida Department of Environmental Protection, Tallahassee, and Florida Water Management Districts, 197 pp.

GIS Associates. 2010. The Small Area Population Projection Methodology of the Southwest Florida Water Management District. Brooksville, Florida.

Gore, J.A., C. Dahm, and C. Klimas. 2002. A review of "Upper Peace River: an analysis of minimum flows and levels." Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Gore, J.A., J.B. Layzer, and J. Mead. 2001. Macroinvertebrate instream flow studies after 20 years: a role in stream and river restoration. Regulated Rivers 17:527-542.

Gore, J.A. and R.D. Judy, Jr. 1981. Predictive models of benthic macroinvertebrate density for use in instream flow studies and regulated flow management. Canadian Journal of Fisheries and Aquatic Science 38:1363-1370.

Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins. 1991. An ecosystem perspective on riparian zones. Bioscience 41:540-551.

Geurink, J., M. Nachabe, M. Ross, and P. Tara. 2000. Development of Interfacial Boundary Conditions For the Southern District Ground Water Model of the Southwest Florida

Water Management District, Water Resource Report No. MHAS.SWFWMD.00.03, 34 pp.

Hammett, K. 1990. Land Use, Water Use, Streamflow Characteristics, and Water-Quality Characteristics of the Charlotte Harbor Inflow Area, Florida. U.S. Geological Survey Water-Supply Paper 2359. Prepared in cooperation with the Florida Department of Environmental Regulation, Tallahassee, Florida. 64 pp.

Harms, W.R., H.T. Schreuder, D.D. Hook, C.L. Brown, F.W. Shropshire. 1980. The effects of flooding on the swamp forest in Lake Ocklawaha, Florida. Ecology 61(6):1412-1421.

Hickey, J. 1998. Analysis of Stream Flow and Rainfall at Selected Sites in West-Central Florida. SDI Environmental Services, Tampa, Florida. 53 pp.

Hill, M. and R. Basso. 2005. Hydrogeologic Conceptual Model of the Villages Area, Sumter County, Florida (Draft). Southwest Florida Water Management District, Brooksville, Florida. 15 pp.

Hill, J.E. and C.E. Cichra. 2002. Minimum Flows and Levels Criteria Development. Evaluation of the Importance of Water Depth and Frequency of Water Levels/Flows on Fish Population Dynamics, Literature Review and Summary: The Effects of Water Levels on Fish Populations. Institute of Food and Agricultural Sciences, Department of Fisheries and Aquatic Sciences, University of Florida, Gainesville, Florida. 40 pp.

Hill, M.T., W.S. Platts, and R.L. Beschta. 1991. Ecological and geological concepts for instream and out-of-channel flow requirements. Rivers 2:198-210.

Hood, J.L. 2007. Dissolved Oxygen as Related to Minimum Flows and Levels. Master’s Thesis, University of Florida, Gainesville, Florida.

Hook, D.D. and C.L. Brown. 1973. Root adaptations and relative flood tolerance of five hardwood species. Forest Science 19(3):225-229.

Hupalo, R., C. Neubauer, L. Keenan, D. Clapp, and E. Lowe. 1994. Establishment of Minimum Flows and Levels for the Wekiva River System. Technical Publication SJ94-1. St. Johns River Water Management District, Palatka, Florida.

Huryn, A.D. and J.B. Wallace. 1987. Local geomorphology as a determinant of macrofaunal production in a mountain stream. Ecology 68:1932-1942.

Hydrogeologic, Inc. 2008. Computer Flow and Saltwater Intrusion Model for the Northern District Water Resources Assessment Project, Version 1.0.

Hydrogeologic, Inc. 2010. Computer Flow and Saltwater Intrusion Model for the Northern District Water Resources Assessment Project, Version 2.0.

Instream Flow Council. 2002. Instream Flows for Riverine Resource Stewardship. Instream Flow Council. 411 pp.

Intera, Inc. 2010. Gum Springs Run: HEC-RAS Steady State Model Development. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 69:125-134.

Jones, G.W., E.C. DeHaven, L. Clark, J.T. Rauch, and C.G. Guillen. 1990. Groundwater Quality of the Southwest Florida Water Management District: Central Region. Southwest Florida Water Management District, Brooksville, Florida.

Jones, G.W., S.B. Upchurch, and K.M. Champion. 1996. Origin of Nitrate in Ground Water Discharging From Rainbow Springs, Marion County, Florida. Ambient Ground-Water Quality Monitoring Program, Southwest Florida Water Management District, Brooksville, Florida.

Jowett, I.G. 1993. Minimum Flow Requirements for Instream Habitat in Wellington Rivers. New Zealand Freshwater Miscellaneous Report No. 63. National Institute of Water and Atmospheric Research, Christchurch, New Zealand. 33 pp.

Junk, W.P., P.B. Bayley, and R.E. Sparks. 1989. The flood pulse concept in river-floodplain systems. pp. 110-127, In D.P. Dodge (ed.), Proceedings of the International Large River Symposium. Special Publication of the Canadian Journal of Fisheries and Aquatic Sciences 106.

Kelly, M.H. 2004. Florida River Flow Patterns and the Atlantic Multidecadal Oscillation. Draft Report. Ecologic Evaluation Section, Southwest Florida Water Management District. Brooksville, Florida. 80 pp. + appendix.

Kelly, M.H., A.B. Munson, J. Morales, and D.A. Leeper. 2005a. Proposed Minimum Flows for the Middle Segment of the Peace River, from Zolfo Springs to Arcadia. Ecologic Evaluation Section, Southwest Florida Water Management District, Brooksville, Florida. 165 pp + appendix.

Kelly, M.H., A.B. Munson, J. Morales, and D.A. Leeper. 2005b. Alafia River Minimum Flows and Levels, Freshwater Segment Including Lithia and Buckhorn Springs. Ecologic Evaluation Section, Southwest Florida Water Management District, Brooksville, Florida. 165 pp + appendix.

Kelly, M.H., A.B. Munson, J. Morales, and D.A. Leeper. 2005c. Proposed Minimum Flows and Levels for the Upper Segment of the Myakka River, From Myakka City to SR 72. Ecologic Evaluation Section, Southwest Florida Water Management District, Brooksville, Florida. 165 pp + appendix.

Knowles, Jr., L. 1996. Estimation of Evapotranspiration in the Rainbow Springs and Silver Springs Basins in North-Central Florida, U.S. Geological Survey Water-Resources Investigations Report 96-4024.

Knowles, Jr., L., A.M. O'Reilly, and J.C. Adamaski. 2002. Hydrogeology and Simulated Effects of Ground-Water Withdrawals From the Floridan Aquifer System in Lake County and the Ocala National Forest and Vicinity, North-Central Florida. U.S. Geological Survey Water-Resources Investigations Report 02-4207.

Kuensler, E.J. 1989. Values of forested wetlands as filters for sediments and nutrients. pp. 85-96, In D.D. Hook and R. Lea (eds.), Proceedings of the Symposium: The Forested Wetlands of the United States. U.S. Department of Agriculture, Forest Service, Southeastern Forest Experimental Station, General Technical Report SE-50.

Lewelling, B.R. 2003. Extent of Areal Inundation of Riverine Wetlands Along Cypress Creek, and the Peace, Alafia, North Prong Alafia, and South Prong Alafia Rivers, West Central Florida. U.S. Geological Survey Water Resources Investigations Report 02-4254. 91 pp.

Lewelling, B.R. 2004. Extent of Areal Inundation of Riverine Wetlands along Five River Systems in the Upper Hillsborough River Watershed, West-Central Florida. U.S. Geological Survey Water Resources Investigations Report 2004-5133. 76 pp.

Loucks, W.L. and R.A. Keen. 1973. Submergence tolerance of selected seedling trees. Journal of Forestry 71:496-497.

Manly, B.F.J., L.L. McDonald, and D.L. Thomas. 1993. Resource Selection by Animals: Statistical Design and Analysis for Field Studies. Chapman and Hall, London, England.

Mattson, R.A. and J. Krummrich. 1995. Determination of Salinity Distributions in the Upper Suwannee River Estuary: A Cooperative Project of the Florida Game and Fresh Water Fish Commission and Suwannee River Water Management District, Unpublished Final Report. 49 pp.

McCabe, G. and D. Wolock. 2002. A step increase in streamflow in the conterminous United States. Geophysical Research Letters 29:2185-2188.

McDonald, M.G. and A.W. Harbaugh. 1988. A Modular Three-Dimensional Finite-Difference Groundwater Flow Model, U.S. Geological Survey Techniques of Water-Resources Investigations Book 6, Chapter A1.

McKevlin, M.R., D.D. Hook, and A.A. Rozelle. 1998. Adaptations of Plants to Flooding and Soil Waterlogging. pp. 173-204, In Messina, M.G. and W.H. Conner (eds.), Southern Forested Wetlands: Ecology and Management. Lewis Publishers, Boca Raton, Florida.

Mertes, L.A.K. 1997. Documentation and significance of the perirheic zone on inundated floodplains. Water Resources Research 33(7):1749-1762.

Milhous, R.T., J.M. Bartholow, M.A. Updike, and A.R. Moos. 1990. Reference Manual for Generation and Analysis of Habitat Time Series – Version II. U.S. Fish and Wildlife Service, Biological Report 90(16).

Miller, J.A. 1986. Hydrogeologic Framework of the Floridan Aquifer System in Florida and in Parts of Georgia, Alabama, and South Carolina. U.S. Geological Survey Water-Resources Investigations Report 84-4135, 69 pp.

Mills, L.R. and C.P. Laughlin. 1976. Potentiometric Surface of the Floridan Aquifer May 1975, and Change of Potentiometric Surface 1969 to 1975, Southwest Florida Water Management District and Adjacent Areas. U.S. Geological Survey Water Resources Investigation No. 76-80.

Mumma, M. 1996. Effect of Recreation on the Water Chemistry and Submerged Plant Community of Rainbow River, Florida. Master's Thesis, University of Florida, Department of Fisheries and Aquatic Sciences, Gainesville, Florida.

Munson, A.B., J.J. Delfino, and D.A. Leeper. 2005. Determining minimum levels: the Florida experience. Journal of the American Water Resources Association 41(1):1-10.

Munson, A.B. and J.J. Delfino. 2007. Minimum wet-season flows and levels in Southwest Florida Rivers. Journal of the American Water Resources Association 43(2).

Myers, R.L. and J.J. Ewel. 1990. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida. 765 pp.

Natural Resources Conservation Service (NRCS). 1988. Soil Survey of Sumter County, Florida. U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C. 204 pp.

PBS&J. 2007.Rainbow River 2005 Vegetation Mapping and Evaluation Report. Southwest Florida Water Management District SWIM Project #W419.

PBS&J. 2010. Characterization of Woody Wetland Vegetation Communities along Gum Slough. PBS&J, Tampa, Florida.

Perry, R.G. 1995. Regional Assessment of Land Use Nitrogen Loading of Unconfined Aquifers. Ph.D. Dissertation, University of South Florida, Tampa, Florida.

Postel, S. and B. Richter. 2003. Rivers for Life: Managing Water for People and Nature. Island Press, Washington, D.C. 253 pp.

Pringle, C.M., R. Naiman, G. Bretchko, J. Karr, M. Oswood, J. Webster, R. Welcomme, and M.J. Winterbourn. 1988. Patch dynamics in lotic ecosystems: the stream as a mosaic. Journal of the North American Benthological Society 7:503-524.

Reiser, D.W., T.A. Wesche, and C. Estes. 1989. Status of instream flow legislation and practices in North America. Fisheries 14:22-29.

Richter, B.D., J.V. Baumgartner, J. Powell, and D.P. Braun. 1996. A method for assessing hydrologic alteration within ecosystems. Conservation Biology 10:1163-1174.

Rosenau, J.C., G.L Faulkner, C.W. Hendry, Jr., and R.W. Hull. 1977. Springs of Florida: Florida Geological Survey Bulletin 31 Revised. 461 pp.

Ryder, P. 1982. Digital Model of Predevelopment Flow in the Tertiary limestone (Floridan) Aquifer System in West-Central Florida. U.S. Geological Survey Water-Resources Investigations Report 81-54.

Sacks, L.A. and A.B. Tihansky. 1996. Geochemical and Isotopic Composition of Ground Water with Emphasis on Sources of Sulfate in the Upper Floridan Aquifer and Intermediate Aquifer System in Southwest Florida. U.S. Geological Survey WRI Report 96-4146. 54 pp.

Scheele, D.S. 1975. Reality Construction as a Product of Delphi Interaction. pp. 37-41, In H.A. Linstone and M. Turoff (eds.), The Delphi Method: Techniques and Applications. Addison-Wesley, Reading, Massachusetts.

Seeley, D.W., J.E. Kundell, and M. Myszewski. 2006. Balancing Instream and Offstream Uses: Instream Flows, Surface Storage and Aquifer Management, a Report to the Georgia Environmental Protection Division. Carl Vinson Institute of Government, University of Georgia, Athens, Georgia. 161 pp.

Sepulveda, N. 2002. Simulation of Ground-Water Flow in the Intermediate and Floridan Aquifer Systems in Peninsular Florida. U.S. Geological Survey WRI Report 02-4009. 130 pp.

Shaw, D.T., C.N. Dahm, and S.W. Golladay. 2005. A Review of "Proposed Minimum Flows and Levels for the Middle Segment of the Peace River, From Zolfo Springs to Arcadia." Southwest Florida Water Management District, Brooksville, Florida. 23 pp.

Smith, D.L. and P. Stopp. 1978. The River Basin: An Introduction to the Study of Hydrology. Cambridge University Press, London, England. 120 pp.

Smock, L.A., E. Gilinsky, and D.L. Stoneburner. 1985. Macroinvertebrate production in a southeastern U.S. blackwater stream. Ecology 66:1491-1503.

Smock, L.A. and C.E. Roeding. 1986. The trophic basis of production of the macroinvertebrate community of a southeastern U.S.A. blackwater stream. Holarctic Ecology 9:165-174.

Souther, R.F. and G.P. Shaffer. 2000. The effects of submergence and light on two age classes of baldcypress (*Taxodium distichum* (L.) Richard) seedlings. Wetlands 20(4).

Southwest Florida Water Management District. 1993. Computer Model of Ground-Water Flow in the Northern Tampa Bay Area. Southwest Florida Water Management District, Brooksville, Florida. 119 pp.

Southwest Florida Water Management District. 1994. Estimated Water Use in the Southwest Florida Water Management District: 1991 and 1992. Southwest Florida Water Management District, Brooksville, Florida. 109 pp.

Southwest Florida Water Management District. 1996. Northern Tampa Bay Water Resource Assessment Project, Volume 1, Surface Water/Groundwater Interrelationships. Southwest Florida Water Management District, Brooksville, Florida

Southwest Florida Water Management District. 1996. Origin of Nitrate in Ground Water Discharging From Rainbow Springs. Ambient Ground Water Monitoring Section. Southwest Florida Water Management District, Tampa, Florida.

Southwest Florida Water Management District, 1999, Aquifer Characteristics Within the Southwest Florida Water Management District. Southwest Florida Water Management District, Brooksville, Florida. 111 pp.

Southwest Florida Water Management District. 2000. Hillsborough River Watershed Management Plan. Southwest Florida Water Management District, Brooksville, Florida.

Southwest Florida Water Management District. 2001. Springs Coast Comprehensive Watershed Management Plan. Springs Coast Comprehensive Watershed Management Team. Brooksville, Florida.

Southwest Florida Water Management District. 2002. Upper Peace River: An Analysis of Minimum Flows and Levels, Draft. Ecologic Evaluation Section. Resource Conservation and Development Department. Brooksville, Florida.

Southwest Florida Water Management District. 2004. The Determination of Minimum Flows for the Sulphur Springs, Tampa, Florida. Ecologic Evaluation Section. Resource Conservation and Development Department. Brooksville, Florida.

Southwest Florida Water Management District. 2004. Rainbow River Surface Water Surface Water Improvement and Management (SWIM) Plan. SWIM Section, Tampa, Florida.

Southwest Florida Water Management District, 2006, Aquifer Characteristics within the Southwest Florida Water Management District, Brooksville, Florida. 28 pp.

Stalnaker, C.B. 1990. Minimum Flow is a Myth. pp. 31-33, In M. B. Bain (ed.), Ecology and Assessment of Warmwater Streams: Workshop Synopsis. Biological Report 90(5). U.S. Fish and Wildlife Service, Washington, D.C.

Stalnaker, C., B.L. Lamb, J. Henriksen, K. Bovee, and J. Bartholow. 1995. The Instream Flow Incremental Methodology: A Primer for IFIM. Biological Report 29. U.S. Department of the Interior, National Biological Service, Washington, D.C. 46 pp.

Stanford, J.A., J.V. Ward, W.J. Liss, C.A. Frissell, R.N. Williams, J.A. Lichatowich, and C.C. Coutant. 1996. A general protocol for restoration of regulated rivers. Regulated Rivers 12: 391-413.

Stanturf, J.A. and S.H. Schoenholtz. 1998. Soils and Landform. pp. 123-147, In M.G. Messina and W.H. Conner (eds.), Southern Forested Wetlands: Ecology and Management. Lewis Publishers, Boca Raton, Florida.

Stewart, J.W., L.R. Mills, D.D. Knochenmus, and G.L. Faulkner, 1971. Potentiometric Surface and Areas of Artesian Flow, May 1969, and Change of Potentiometric Surface 1964 to 1969, Floridan Aquifer, SWFWMD. U.S. Geological Survey Hydrologic Investigations Atlas HA-440.

Stuber, R.J., G. Gebhardt, and O.E. Maughan. 1982. Habitat Suitability Index Models: Largemouth Bass. U.S. Fish and Wildlife Service, FWS/OBS-82/10. 16 pp.

Tate, R.L. III. 1980. Microbial oxidation of organic matter in Histosols. Advances in Microbial Ecology 4:169-201.

Tetra Tech, Inc. 2004. Withlacoochee River Basin Feasibility Study: Hydrology and Hydraulics Data Collection and Review. 255 pp.

Thorp, J.H., E.M. McEwan, M.F. Flynn, and F.R. Hauer. 1990. Invertebrate colonization of submerged wood in a cypress-tupelo swamp and blackwater stream. American Midland Naturalist 113:56-68.

Trommer, J.T., D.K. Yobbi, and W.S. McBride. 2009. Surface-Water and Groundwater Interactions along the Withlacoochee River, West-Central Florida, U.S. Geological Survey Scientific Investigations Report 2009–5124. 47 pp.

U.S. Army Corps of Engineers 2001. HEC-RAS River Analysis System User's Manual. U.S. Army Corps of Engineers, Davis, California.

U.S. Geological Survey. 1999. Sources and Chronology of Nitrate Contamination in Spring Waters, Suwannee River Basin, Florida. Water-Resources Investigations Report 99-4252. Tallahassee, Florida.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.

Walbridge, M.R. and B.G. Lockaby. 1994. Effect of forest management of biogeochemical functions in southern forested wetlands. Wetlands 11:417-439.

Water Resource Associates. 2005. Marion County Spring Protection Program Strategies and Recommendations for Protecting Silver and Rainbow Springs. Marion, Florida.

Wallace, J.B. and A.C. Benke. 1984. Quantification of wood habitat in subtropical Coastal Plain streams. Canadian Journal of Fisheries and Aquatic Sciences 41:1643-1652.

Weber, K. and R. Perry. 2001. Impacts of Ground-Water Withdrawals in the Hillsborough River Region, Hillsborough, Pasco, and Polk Counties. Technical Services Department. Resource Regulation Division. Southwest Florida Water Management District. Report 99-2. Brooksville, Florida.

Weber, K. and R. Perry. 2006. Groundwater abstraction impacts on springflow and base flow in the Hillsborough River Basin, Florida, USA, International Hydrogeology Journal, December.

Wharton, C.H., W.M. Kitchens, E.C. Pendleton, and T.W. Sipe. 1982. The Ecology of Bottomland Hardwood Swamps of the Southeast: A Community Profile. U.S. Fish and Wildlife Service FWX/OBS-81/37. 133 pp.

White, W.A. 1970. The Geomorphology of the Florida Peninsula. Florida Bureau of Geology Bulletin No. 51. 164 pp.

Wolansky, R.M. and T.H. Thompson. 1987. Relationship Between Groundwater and Surface Water in the Hillsborough River Basin, West-Central Florida. Florida Bureau of Geology, Bulletin 51, U.S. Geological Survey Water-Resources Investigations Report 87-4010.

Zuboy, J.R. 1981. A new tool for fisheries managers: the Delphi technique. North American Journal of Fisheries Management 1:55-59.

CHAPTER 10 – GLOSSARY OF TERMS

Algae – Mostly single celled, colonial, or multi-celled plants containing chlorophyll and lacking roots, stems and leaves.

Atlantic Multidecadal Oscillation (AMO) – A natural multidecadal cyclic variation in large-scale atmospheric flow and ocean currents in the North Atlantic Ocean that combine to alternately increase and decrease Atlantic sea surface temperatures. The cool and warm phases last for 25-45 years at a time, with a difference of about 1°F (0. 6°C) between extremes.

Aquifer – An underground geologic formation that contains sufficient saturated permeable material to yield significant quantities of water to wells or springs.

Baseflow – Is flow in a channel sustained by ground-water discharge in the absence of direct runoff.

Benchmark Period – A fixed, more or less permanent reference point in time expressed as a period of years where flows are thought to reflect conditions in the absences of withdrawals.

Benthic – Associated with the bottom of a body of water.

Biotic – Of or pertaining to the living components of an ecosystem.

Block 1 – A time period in which recorded flows are at their lowest annually, defined as beginning when the average median daily flow falls below and stays below the annual 75% exceedance flow.

Block 2 – A time period in which recorded flows are at their medium level annually. Usually seen when mean annual exceedance flows range between 50-75% exceedance flows.

Block 3 – A time period in which recorded flows are at their highest annually, defined as beginning when the average median daily flow exceeds and stays above the mean annual 50% exceedance flow.

cfs – Cubic feet per second is a measure of streamflow or discharge.

Confined Aquifer – A term used to describe an aquifer containing water between relatively impermeable boundaries. The water level in a well tapping a confined aquifer stands above the top of the confined aquifer and can be higher or lower than the water table that may be present in the material above it.

Cross-section – A plane across the stream channel perpendicular to the direction of water flow.

Diameter at Breast Height (DBH) – The width of a plant stem as measured at 4. 5 ft. above the ground surface.

Discharge – The rate of streamflow or the volume of water flowing at a location within a specified time interval. Usually expressed as cubic meters per second (cms) or cubic feet per second (cfs).

Diversity – That attribute of a biotic (or abiotic) system describing the richness of plant or animal species or complexity of habitat.

Ecosystem – Any complex of living organisms interacting with non-living chemical and physical components that form and function as a natural environmental unit.

Emergent Plant – A rooted herbaceous plant species that has parts extending above a water surface.

Exceedance – That probability of at least a minimal expectation being met, often measured in terms of annual probability of occurrence.

Exposed Roots – Living root associated with riparian vegetation (shrubs and trees) exposed along stream banks that provide structural habitat to instream biota.

Fish Passage – Refers to a flow depth that is deep enough to allow for fish to migrate upstream and downstream in the river. The District has routinely used $6/10^{th}$ of one foot as the depth that allows for passage of most fish.

Floodplain – (1) The area along waterways that is subject to periodic inundation by out-of-bank flows. 2) Land beyond a stream channel that forms the perimeter for the maximum probability flood.

Floodplain Wetted Perimeter –The cross-sectional distance along the stream bed, its banks and adjacent floodplains that is in contact with water seen during flooding events where stream banks are breached by high water flow.

Flow Regime – The variable pattern (magnitude and frequency) of high and low flows exhibited by rivers and streams that are critical to the integrity of river ecosystems.

Gage Height – The water surface elevation referenced to the gage datum. Gage height is often used interchangeably with the more general term "stage". Although gage height is more appropriate when used with a reading of a gage.

Groundwater – In general, all subsurface water that is distinct from surface water, specifically, that part which is in the saturated zone of a defined aquifer.

Habitat – The physical and biological surroundings in which an organism or population (living and non-living) lives; includes life requirements such as food or shelter.

Habitat Suitability Curves – An input to the PHABSIM model where continuous variable or univariate curves designed to encompass the expected range of suitable conditions for water depth, water velocity and substrate/cover type unique to a given target species at a specific life stage is exhibited.

HEC-RAS – The model acronym for Hydraulic Engineering Center-River Analysis System. It is a water-surface profile model for river simulation. In this report it is utilized to evaluate steady, one-dimensional, gradually varied flow.

High Flow Step – The high flow step is designed to assure that when out-of-bank flows occur they are protected by criterion specific to high flow conditions, rather than by criterion developed to protect in-channel features. The high flow step is ,therefore, a flow above which the more restrictive of the seasonally specific percent-of-flow reduction is used, or the high flow percent-of-reduction, developed to protect floodplain inundation during block three.

Hydric Soils – Any one of a class of soils usually formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part that favor the growth and regeneration of hydrophytic vegetation.

Instream Habitats – A specific type of area bounded within a stream's banks and its' associated (i. e. , biological, chemical, or physical) characteristics used by an aquatic organism, population or community.

Inundation – A condition in which water from any source temporarily or permanently covers a land surface.

Invertebrate – All animals without a vertebral column or backbone; for example, aquatic insects.

Julian Day – Is the term for a day corresponding to the Julian calendar in which days are numbered consecutively. In the context of this report days are number from 1 to 356 (or 366) each year.

Life Stage – A qualitative age classification of an organism into categories related to body morphology and reproductive potential, such as spawning, larva or fry, juvenile, and adult.

Long-term Inundation Analyses – Process used to identify the number of days during a defined period of record that a specific flow or level (elevation) was equaled or exceeded at a specified location.

Low Flow Threshold (LFT) – The lowest flow that serves to limit surface water withdrawals.

Main stem – The main channel of the river as opposed to tributary streams and smaller rivers that feed into it.

Macroinvertebrates – Any of the various fauna characterized without a backbone that can be seen without magnification.

Mean Annual Flows – The arithmetic mean of the individual daily mean discharges for the year noted.

Median Daily Flow – The middle flow value in a sequence of daily flow values, having as many above and below a certain daily flow value. If there is an even number of flow values, the median is the average of the two middle flow values.

Minimum Flows – The point(s) or level(s) on a watercourse at which further withdrawals would be significantly harmful to the water resources or ecology of the area.

Muck Soils – Type of organic soil consisting mainly of highly decomposed remains of plant material and other organisms.

National Wetlands Inventory (NWI) – A research program of the U. S. Fish and Wildlife Service aimed at producing and providing information on the characteristics, extent and status of U. S. wetlands, deep water habitats and other wildlife habitats.

Natural Flow – A flow condition where variation in discharge (or river stage) exists in the absence of any human alteration or would occur under completely unregulated conditions; that is not subjected to reservoirs, diversions, or other human works, over a specific time period.

Non-hydric Soil – A soil that has developed under predominantly aerobic soil conditions.

Percent Dominance – A quantitative descriptor of habitat, expressed as a percent, of the relative size or cover of instream habitats in a cross-sectional transect.

Percent-of-Flow Reductions – The percent-of-flow approach is a means of regulation in which a percent of the previous days natural flow is allocated as available for use.

Period of Record – The length of time for which data for a variable has been collected on a regular and continuous basis.

Physical Habitat Simulation Model (PHABSIM) – (1) A specific model designed to calculate an index to the amount of microhabitat available for different faunal life stages at different flow levels. PHABSIM has two major analytical components: stream hydraulics and life stage-specific habitat requirements. (2) This extensive set of programs is designed to predict the micro-habitat (depth, velocities, and channel indices) conditions in rivers as a function of streamflow, and the relative suitability of those conditions to aquatic life.

Pool – Part of a stream with reduced velocity, often with water deeper than the surrounding areas, which is usable by fish for resting and cover.

Prescribed Flow Reduction – A set of minimum flow rules tailored to seasonal blocks that summarize the extent of allowable flow reductions based on ecological criteria and maximum extent of loss allowed before significant harm takes place.

Recharge – Process by which water is added to the zone of saturation as recharge of an aquifer.

Riffle – A relatively shallow reach of stream in which the water flows swiftly and the water surface is broken into waves by obstructions that are completely or partially submersed. In this report riffle is synonymous with the term shoal.

Riparian Vegetation – Vegetation that is dependent upon an excess of moisture during a portion of the growing season on a site that is perceptively moister than the surrounding areas.

Riparian Zone – The transitional zone or area between a body of water and the adjacent upland identified by soil characteristics and distinctive vegetation that requires an excess of water. It includes wetlands and those portions of floodplains that support riparian vegetation.

Run – A portion of a stream with low surface turbulence that approximates uniform flow, and in which the slope of the water surface is roughly parallel to the overall gradient of the stream reach.

Seasonal Blocks – Any one of three seasonal time periods where flow conditions among Southwest Florida rivers or streams exhibit similar frequency, duration and magnitude in flow patterns that typically are linked to prevailing annual precipitation patterns. Currently differentiated into low (Block 1), medium (Block 2) and high (Block 3) flows.

Snags – Dead or decaying woody debris material found lying along stream banks or in the channel and serve as structural habitats for instream biota.

Stage – The distance of the water surface in a river above a known datum.

Substrate – The material on the bottom of the stream channel, such as rock, sand, mud or vegetation.

Thalweg – A longitudinal profile of the lowest elevations of a sequential series of cross-sections.

Transect – A line on the ground along which observations are made at some interval.

Tributary – A stream that feeds, joins or flows into a larger stream (at any point along its course or into a lake).

Upper Floridan aquifer (UFA) – The Upper Floridan aquifer occupies the saturated portion of the Ocala Limestone and extends from about twenty feet below land surface to approximately 250 feet (Fredericks 2010; AEI 2003).

Upland – Any area that does not qualify as a wetland because the associated hydrologic regime is not sufficiently wet to elicit development of vegetation, soils and/or hydrologic characteristics associated with wetlands.

Watershed – The total topographic region or area bounded peripherally by a divide and draining ultimately to a particular watercourse or body of water; also called catchment area, drainage area, and basin.

Weighted Usable Area (WUA) – A component of PHABSIM which is an indicator of the net suitability of use of a given stream reach by a certain life stage of a certain species.

Wetlands – Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas.

Wetland Soils – A soil that has characteristics developed in a reducing atmosphere, which exists when periods of prolonged soil saturation results in anaerobic conditions.

Wetland Vegetation – The sum total of macrophytic plant life that occurs in areas where the frequency and duration of inundation or soil saturation produce permanently or periodically saturated soils of sufficient duration to exert a controlling influence on the plant species present.

Wetted Perimeter – The cross-sectional distance along the stream bed and banks that is in contact with water.

Wetted Perimeter Inflection Point – A point on a curve relating wetted perimeter vs. discharge at which the slope of the line changes from convex to concave or vice versa.

Woody Habitats – Any of the various living (e. g. , exposed roots) or dead/decaying (e.g., snags) substrata composed of wood, usually originating from riparian vegetation that serve as habitation for various instream biota.