Recommended Minimum Flows for the Homosassa River System

October 30, 2012

Southwest Florida Water Management District

Douglas A. Leeper, Michael S. Flannery, Michael G. Heyl, Ron Basso
Southwest Florida Water Management District
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and

Marty Kelly
Formerly with the Southwest Florida Water Management District

with contributions by

HSW Engineering, Inc.
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On the Cover: Aerial photograph of the Homosassa Main Springs pool and upper portion of the Homosassa River in 2001 (Southwest Florida Water Management District files).

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Executive Summary

The Southwest Florida Water Management District or the Florida Department of Environmental Protection are required by State law to establish minimum flows and levels for priority lakes, wetlands, rivers and aquifers. As defined in Section 373.042(1)(b), Florida Statutes (F.S.), “[t]he 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." Minimum flows and levels are established and used by the District for water resource planning and as one of the criteria used for evaluating water use permit applications.

This report summarizes the development of recommended minimum flows for the Homosassa River system, which is located along the Springs Coast in Citrus County within the Southwest Florida Water Management District. The river system includes the Homosassa River, Southeast Fork of the Homosassa River, Halls River, Hidden River and springs associated with the rivers, including at least 22 named springs. The Homosassa River originates in the Homosassa Main Springs Pool in the Ellie Schiller Homosassa Springs Wildlife State Park west of the community of Homosassa and flows 8 miles to the Gulf of Mexico. Halls River originates at Halls River Head Spring and flows 3.5 miles to join the Homosassa River about 7 miles upstream from the Gulf. Hidden River also originates from a spring pool and flows 1.3 miles towards the Gulf before disappearing into a sink that probably contributes discharge to the Homosassa River. The Homosassa and Halls Rivers receive a small amount of surface runoff from their 56 square mile watershed, and similarly Hidden River receives some runoff from its watershed. The majority of flow in the system arises from the continuous spring discharge derived from the approximate 270 square mile springshed. Spring discharge to the system exhibits moderate seasonal variation, with lower flows in summer when tidal stage is highest. Estimated combined discharge past U.S Geological Survey gages in the Homosassa Main Spring run and the Southeast Fork of the Homosassa River averaged 152 cubic feet per second (cfs) for the period from 1995 through 2009. Existing water withdrawals within the springshed and greater contributing groundwater basin are estimated to have reduced spring discharge to the river system by approximately 1 percent.

Initial, proposed minimum flows and the data, methodologies, models and assumptions used for their development were described in a draft technical report titled *Recommended Minimum Flows for the Homosassa River System, July 12, 2010 Peer-Review draft* (Leeper *et al.* 2010). In that report, an allowable 5 percent flow reduction was recommended as an appropriate minimum flow criterion for the Homosassa River system. This recommendation was based on consideration of flow-related changes in salinity-based habitats, abundances of various fish and invertebrate taxa, and the availability of thermally favorable refuge habitat for manatees during critically-cold periods. Statistical and hydrodynamic modeling of 5 to 30 percent flow reductions were used to develop the initial, proposed minimum flow recommendation identified in the 2010 draft technical report.

The 2010 draft report on proposed minimum flows for the Homosassa River system was presented to the District Governing Board (Board) for consideration in July 2010 and subsequently subjected to scientific peer review. The peer-review panel convened to review the District’s draft report concluded in their October 2010 report that *“[e]vidence presented by Leeper et al (2010) is adequate to conclude that the proposed maximum 5% reduction in Minimum Flow satisfies the language and intent of the Statute and will result in “no significant harm” to the flora and fauna of the Homosassa River System*” (Hackney *et al.* 2010). These and other findings of the peer-review panel were summarized for the Board in November 2010.

In addition to the scientific peer review completed in 2010, the District's proposed minimum flows for Homosassa River system were actively reviewed by a large number of stakeholders. This stakeholder review was supported through rule development public workshops associated with the proposed minimum flows that were hosted by the District in October 2010 and January 2011. Based on stakeholder interest in minimum flows development for the Homosassa River system and other nearby water bodies, the District also hosted a series of three public workshops and facilitated a fourth stakeholder workshop in 2011 for discussion of the data and methodologies that have been or could be used to develop or reevaluate minimum flows for the Homosassa River system and other spring-dominated tidal river systems of the Springs Coast. The rule development workshops and the 2011 series of workshops were well attended and information associated with the workshop series was posted on the District's Springs Coast Minimum Flows and Levels Working Group web page created specifically for exchange of information relevant to the minimum flows development process (Uniform Resource Locator - *http://www.swfwmd.state.fl.us/projects/mfl/springs-coast-mfl.php*). In addition to these workshops, District staff made numerous presentations concerning minimum flows for the system to interested stakeholder groups and conducted a vigorous outreach effort involving hundreds of communications with Federal, State and local government and agency staff, citizen-based groups, and individual stakeholders.

As a result of the extensive review of the initial, proposed minimum flows for the Homosassa River system, District staff and consultants to the District initiated additional analyses that led to the development of revised minimum flow recommendations for the system. The additional analyses included evaluation of the effects potential flow reductions on measures of system productivity and evaluation of the effects of low (1 to 4 percent) flow reductions on current salinity-based habitats, salinity-based habitats that could be expected for various future sea level rise scenarios, and salinity-based habitats that could be expected for current and future sea level rise scenarios with consideration of existing withdrawal impacts to spring discharge. These additional analyses and other updates to the presentation of information supporting development of minimum flows for the Homosassa River system are included in this revised minimum flows report.

Percent-of-flow reductions associated with significant harm thresholds based on a 15 percent reduction in sensitive salinity-based habitats were used to develop revised minimum flows for the Homosassa River system. The revised, recommended minimum flows correspond with an allowable 3 percent reduction in natural flow, or the maintenance of 97 percent of natural flow. In the context of minimum flows development and implementation, natural flow is defined as the flow that would exist in the absence of water withdrawal impacts. The revised, recommended minimum flows differ from the allowable 5 percent-of-flow recommendation associated with the proposed minimum flows included in the District's July 2010 draft report for the river system.

Compliance with the minimum flows that are adopted for the river system will be based on gaged flow measurements, application of numerical or statistical models and consideration of other appropriate information, including well water levels, reported and estimated water use, landscape alterations and rainfall. Based on the estimated withdrawal impacts on spring discharge to the river system, development of a preventative or recovery strategy in association with adoption of the revised, recommended minimum flows is not necessary. A three-component minimum flows and levels prevention strategy will be implemented to ensure that minimum flows established for the Homosassa River system will not be violated as a result of water withdrawals. The strategy includes ongoing monitoring of flows and water levels; assessment of potential impacts associated with water supply development through the regional water supply planning process and other planning and assessment activities, and implementation of a protective water-use permitting program.

Because climate change, structural alterations and other changes in the watershed and groundwater basin of the Homosassa River system could potentially affect surface water or groundwater flow characteristics, and because additional information relevant to minimum flows development may become available, the District is committed to periodic reevaluation and if necessary, revision of minimum flows for this priority water body. Also, given the relatively small magnitude of the allowable percent-of-flow reduction associated with the revised minimum flows recommendation and the relatively short period of available flow records for gage sites within the system, staff recommends that minimum flows established for the river system be reevaluated 10 years after they are adopted into rule. Finally, based on insight that may be gained from additional stakeholder and Governing Board review, staff notes that the revised, recommended minimum flows presented in this report may be modified prior to adoption of associated rule amendments into Rule 40D-8.041, F.A.C.

CHAPTER 1. MINIMUM FLOWS AND LEVELS AND PURPOSE OF THIS REPORT

1.1 Legal Directives and Use of Minimum Flows and Levels

Section 373.042, Florida Statutes (F.S.), directs the Department of Environmental Protection or the water management districts to establish minimum flows and levels for lakes, wetlands, rivers and aquifers. Development of minimum flows and levels are key components in supporting resource protection, recovery and regulatory compliance by establishing standards below which significant harm will occur in specific water bodies. Section 373.0421, F.S., requires development of a recovery or prevention strategy for water bodies if the "existing flow or level in a water body is below, or is projected to fall within 20 years below, the applicable minimum flow or level." Section 373.0421 (2), F.S., requires that recovery or prevention strategies be developed to: "(a) achieve recovery to the established minimum flow or level as soon as practicable; or (b) prevent the existing flow or level from falling below the established minimum flow or level." Periodic re-evaluation and as necessary, revision of established minimum flows and levels are required by Section 373.0421(3), F.S.

Section 373.0421, F.S., requires minimum flows and levels to be based upon the best available information with consideration given to "…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…", with the caveat that these considerations shall not allow significant harm caused by withdrawals. Rule 62-40.473, Florida Administrative Code (F.A.C.) provides additional guidance for the establishment of minimum flows and levels, requiring that "consideration shall be given to the protection of water resources, natural seasonal fluctuations in water flows, and environmental values associated with coastal, estuarine, aquatic and wetland ecology, including: a) recreation in and on the water; b) fish and wildlife habitats and the passage of fish; c) estuarine resources; d) transfer of detrital material; e) maintenance of freshwater storage and supply; f) aesthetic and scenic attributes; g) filtration and absorption of nutrients and other pollutants; h) sediment loads; i) water quality; and j) navigation." The Rule also indicates that "minimum flows and levels should be expressed as multiple flows or levels defining a minimum hydrologic regime, to the extent practical and necessary to establish the limit beyond which further withdrawals would be significantly harmful to the water resources or the ecology of the area".

1.2 Development of Minimum Flows and Levels in the Southwest Florida Water Management District

1.2.1 District Minimum Flows and Levels Rules and Documents

The Southwest Florida Water Management District has developed specific methodologies for establishing minimum flows or levels for lakes, wetlands, rivers, springs and aquifers, subjected the methodologies to independent, scientific peer-review, and in some cases, adopted the methods into its Water Level and Rates of Flow Rule (Chapter 40D-8, F.A.C). In addition, regulatory components of recovery strategies necessary for the restoration of minimum flows and levels that are not currently being met have been adopted into the District's Recovery and Prevention Strategies for Minimum Flows and Levels Rule (Chapter 40D-80, F.A.C.). A recent summary of efforts completed for the District's Minimum Flows and Levels Program is provided by Hancock *et al.* (2010).

Using peer-reviewed methodologies, the District has established and codified into rule (Chapter 40D-8, F.A.C.) minimum flows for 16 river segments, including: the upper and lower Alafia River; the upper and lower Anclote River; the lower Braden River; Cow Pen Slough/Shakett Creek; the upper and lower Hillsborough River; the upper Myakka River; the upper, and lower Peace River; three segments of the middle Peace River; the Tampa Bypass Canal; and the Weeki Wachee River. A total of nine springs have been afforded the protection of minimum flows based on the adopted river segment minimum flows or minimum flows identified for individual springs. Information pertaining to the adoption of these minimum flows, peer-review or minimum flows and levels and other related issues is available from the District's Minimum Flows and Levels (Environmental Flows) Program web page at: *http://www.swfwmd.state.fl.us/projects/mfl* and the Minimum Flows and Levels (Environmental Flows) Documents and Reports web page at*:* *http://www.swfwmd.state.fl.us/projects/mfl/mfl_reports.html*.

1.2.2 Conceptual Overview of Minimum Flows

Minimum flows that have been established by the District and other water management districts in the state (*e.g.,* South Florida Water Management District 2002, Water Resources Associates, Inc. *et al.* 2005, Mace 2007, Neubauer *et al.* 2008) have emphasized the maintenance of natural flow regimes, which include seasonal and inter-annual flow variations that reflect or integrate climatic and watershed characteristics. Consideration of hydrologic regimes when developing or managing for minimum or environmental flows is predicated on the concept that many important ecologic and hydrologic functions of streams and rivers are primarily dependant or supported by the range and pattern of flow conditions (Hill *et al.* 1991, Richter *et al.* 1996, Poff *et al.* 1997, Postel and Richter 2003, Annear *et al.* 2004, Olsen and Richter 2006).

Based on the importance of the flow regime to river system integrity, the District has employed a percent-of-flow method for determining minimum flows for freshwater and estuarine river segments and associated spring systems. The percent-of-flow method identifies flow reductions as percentages of flows that may be withdrawn directly from the system without causing significant harm. The percent-of-flow reductions similarly apply to flow reductions that may be caused by indirect flow impacts associated with groundwater withdrawals. In some cases, specific allowable percentage flow reductions may be developed for seasonal flow periods or flow ranges to reflect changes in system sensitivity to flows. By proportionally scaling water withdrawals to the rate of flow, the percent-of-flow method minimizes adverse impacts that could result from withdrawal of large volumes of water during low flow periods, when river systems may be especially vulnerable to flow reductions. Similarly, larger volumes may be available for withdrawal during periods of higher flows. A goal of the use of the percent-of-flow method for establishing minimum flows is that the natural flow regime of the river be maintained, albeit with some flow reduction for water supply. The utility of the percent of flow approach has recently been recognized in the development of presumptive, risk-based environmental flow standards that are recommended for river systems where data-intensive approaches to flow protection have not or are not likely to be implemented (Richter *et al.* 2011).

The development of minimum flows for coastal systems such as the Homosassa River necessarily involves the evaluation of flow effects on downstream estuaries. Estuaries account for approximately three-quarters of the Florida coastline (Kleppel *et al.* 1996a) and these habitats serve as spawning areas, nurseries or other habitat for more than 95 percent of Florida's recreationally and commercially harvested fish, shellfish and crustaceans (Florida Fish and Wildlife Conservation Commission 2007).

To support early water-use regulation decisions for coastal river systems that preceded the establishment of minimum flows, the District funded a literature review of the effects of freshwater inflow on estuarine systems (Snedaker *et al.* 1977) and subsequently sponsored a workshop on the role of freshwater in Florida coastal areas (Seaman and McLean 1977). Florida-specific efforts were followed by a national symposium on estuarine inflows in 1980 (Cross and Williams 1981) and a decade ago, the Estuarine Research Federation published a special issue of the journal *Estuaries* containing papers presented at an estuarine inflow symposium held in St. Petersburg in 2001 (issue overview provided by Montagna *et al.* 2002). The special issue of Estuaries includes a paper by Alber (2002) outlining a conceptual model of estuarine inflow management, summaries of estuarine inflow programs being implemented in California (Kimmerer 2002) and Texas (Powell *et al.* 2002), and a review of methodological approaches using biological parameters (Estevez 2002). The special issue also includes a paper describing the development and application of the percent-of-flow approach for establishing minimum flows in the Southwest Florida Water Management District (Flannery *et al.* 2002). Numerous additional paper and reports have been devoted to the development and implementation of minimum flows for estuarine system, as exemplified by the publications of Wade (1992), Drinkwater and Frank (1994), Longley (1994), Kleppel *et al.* (1996a, b), Sklar and Browder (1998), Pierson *et al.* 2002, Postel and Richter (2003) and Olsen and Richter (2006).

1.2.3 Significant Harm

While Section 373.042, F.S. requires establishment of minimum flows and levels as limits at which further withdrawals would be significantly harmful to water resources or ecology of an area, "significant harm" is not explicitly defined. In establishing minimum flows the District has identified flows associated with fish passage and maximization of stream bottom habitat with the least amount of flow and determined that loss of these threshold flows would be significantly harmful to river systems. The District has also used quantifiable reductions in potential habitat or resources to identify significant harm and develop minimum flow recommendations. This latter approach is complicated by the fact that many structural and functional components of river ecosystems vary incrementally with flow and do not exhibit clear thresholds or "break-points".

Given the incremental nature of much environmental change in riverine ecosystems, the District has used a 15 percent change criterion when evaluating flow-based changes in potential habitat or resource. The basis for this management decision lies, in part, with a recommendation put forth by the peer-review panel that considered the District's proposed minimum flows for the upper Peace River. In their report, the panelists note that "[*i]n general, instream flow analysts consider a loss of more than 15 percent habitat, as compared to undisturbed or current conditions, to be a significant impact on that population or assemblage*" (Gore *et al.* 2002). The panel's assertion was based on consideration of environmental flow studies employing the

Physical Habitat Simulation Model (PHABSIM) for analyzing flow, water depth and substrate preferences that define aquatic species habitats. Use of a 15 percent change in habitat or resources as constituting significant harm and therefore, for development of minimum flow recommendations, has been extended by the District to evaluate changes in freshwater fish and invertebrate habitat, days of inundation of floodplains, snag habitat and woody debris in freshwater river segments, changes in abundances or population center-location tendencies of planktonic (free-floating) and nektonic (actively swimming) fish and invertebrates in estuarine river segments, spatial decreases in the availability of warm-water refuges for manatees during critically cold periods, and decreases in the volume, bottom area and shoreline length associated with specific salinity zones in estuarine river segments.

Peer-review panels convened to evaluate District recommendations subsequent to the findings put forth by Gore *et al.* (2002) for the upper Peace River have generally been supportive of the use of a 15 percent change criterion for evaluating effects of potential flow reductions on habitats or resources when determining minimum flows (see peer-review reports at the District's Minimum Flows and Levels Documents and Reports web page). Recently, in response comments made by Cichra *et al.* (2007) in the peer review of the recommended minimum flows for the upper Hillsborough River, the District has sponsored a review of the percentage flow, habitat and resource changes documented in the environmental flows literature (Jones Edmunds & Associates 2012). The District has also initiated a long-term study to evaluate changes in habitat associated with flow variation.

Pending completion of the ongoing District-sponsored literature review of environmental flow studies or findings from other environmental flow studies, the District is continuing to utilize the 15 percent habitat or resource change criteria for developing recommended minimum flows, including for development of the minimum flow recommendations for the Homosassa River system outlined in this report. However, allowable percentage changes in habitat or resources other than 15 percent have been used by others for environmental flow determinations. For example, Dunbar *et al.* (1998) in reference to the use of PHABSIM notes, "…*an alternative approach is to select the flow giving 80 percent habitat exceedance percentile*," which is equivalent to an allowable 20 percent decrease from baseline conditions. For another habitat-based environmental flow study, Jowett (1993) used a one-third loss of existing habitat associated with naturally occurring low flows as a guideline for determining flow recommendations. In Texas, the state established environmental flows for Matagorda Bay based on modeling that limited decreases of selected commercially important species to no more than twenty-percent reductions from historical harvest levels (Powell *et al.* 2002).

1.3 <u>Purpose of this Report</u>

Recommended minimum flows were developed for the Homosassa River system using the best available information, including data that were obtained or developed specifically for the purpose of the minimum flows and levels determination. Although State law does not require additional studies or data collection when establishing minimum flows or levels, the District voluntarily supported an extensive and diverse data collection effort involving physical, chemical and biological aspects of the Homosassa River system. For this effort and implementation of the recommended minimum flows, the Homosassa River system is defined as the entire courses of the Homosassa River, Southeast Fork of the Homosassa River, Halls River, Hidden River and springs associated with these rivers.

The proposed minimum flows and the data, methodologies, models and assumptions used for their development were described in a draft technical report titled *Recommended Minimum Flows for the Homosassa River System, July 12, 2010 Peer-Review draft* (Leeper et al. 2010; included as Appendix P to this report). The 2010 report was presented to the District Governing Board (see Appendices Q and R), subjected to scientific peer-review and reviewed by numerous additional stakeholders. This review process led to the completion of additional analyses by District staff and ultimately to the development of revised minimum flow recommendations that are included in this current report. Based on insight gained from additional stakeholder review, the revised, proposed minimum flows may be modified prior to presentation to the Southwest Florida Water Management District Governing Board for consideration as rule amendments to Rule 40D-8.041, F.A.C.

Subsequent chapters to this Report address the specific information and approaches used for development of minimum flow recommendations for the Homosassa River system. The physical setting and descriptive information for the river system are provided in Chapter 2 and biological resources associated with the system are described in Chapter 3. In Chapter 4, we identify the resources of concern and approaches used for evaluating changes in the resources that were considered for development of minimum flow recommendations. Results from resource-change assessments are described in Chapter 5 along with initial minimum flow recommendations for the Homosassa River system. Scientific peer review and stakeholder input associated with the initial minimum flow recommendations are addressed in Chapter 6. In Chapter 7, results of additional analyses completed in response to review and comment on the initial minimum flow recommendations are summarized. Chapter 7 also includes revised minimum flow recommendations for the Homosassa River system. Documents cited in this report and other relevant publications used for the minimum flows assessment are listed in Chapter 8. Appendices, which include summary data and reports used for development of minimum flow recommendations, public comment and peer-review of the process and recommendations, are included on a compact disc attached to the inside back cover of this report and are also bound as a separate volume of the report.

CHAPTER 2. PHYSICAL SETTING AND DESCRIPTION OF THE HOMOSASSA RIVER SYSTEM

2.1 Location and General Description

The Homosassa River System is located in Citrus County within the Southwest Florida Water Management District (Figure 2-1). This portion of the District is included in a region known as the Springs Coast, which includes coastal areas of the state from the Pithlachascotee River in Pasco County north to the Waccasassa River in Levy County.

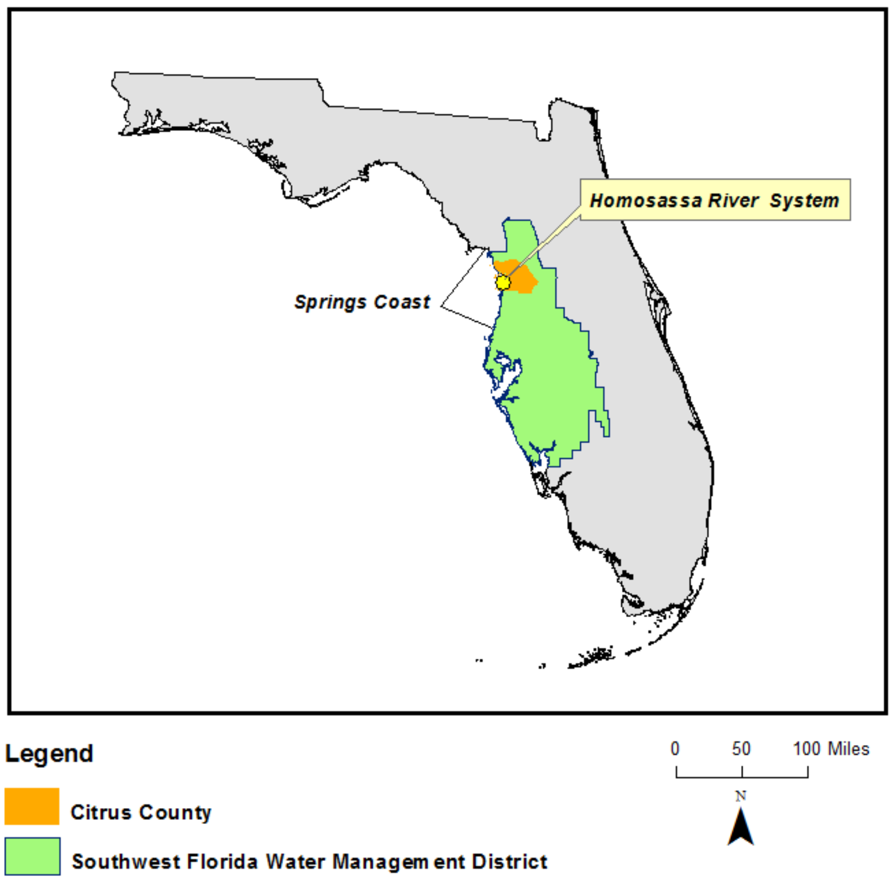


Figure 2-1. Location of the Homosassa River system in Citrus County, Florida, within the Springs Coast of portion of the Southwest Florida Water Management District (image data sources: Southwest Florida Water Management District 2003d, 2003e).

For the purpose of developing and implementing the minimum flows recommendations described in this report, the Homosassa River system includes the Homosassa River, Southeast Fork of the Homosassa River, Halls River, Hidden River and springs associated with these rivers (Figure 2-2). Named springs of the system include the Homosassa Main Springs, which includes three vents referred to as Main Spring Nos. 1, 2 and 3, Homosassa River No. 1 Spring (also referred to as Homosassa Unnamed Spring No. 1), Homosassa Unnamed Spring No. 2, Abdoney Spring, Alligator Spring, Banana Spring, Bear Spring, Belcher Spring, Blue Hole Spring, Bluebird Spring, McClain Spring, Otter Creek Spring, Pumphouse Spring, Southeast Fork Head Spring, Trotter Main Spring, Trotter No. 1 Spring, Halls River Head Spring, Halls River No. 1 Spring, Halls River Spring No. 2, Hidden River Head Spring, Hidden River No. 2 Spring and Hidden River Spring No. 6 (Figure 2-3).

The Homosassa River originates at the Homosassa Main Springs complex and flows approximately 8 miles to its mouth near Shell Island in the Homosassa Bay region of the Gulf of Mexico. General hydrography of the Homosassa River and surrounding area depicted in U.S. Geological Survey (USGS) topographic maps is shown in Figure 2-4. Yobbi and Knochemus (1989) report that the Homosassa River is approximately 200-700 feet wide and 5 feet deep in the upstream reach and about 1,000 feet wide and 15 to 20 feet deep at the mouth. Artificial channels associated with drainage and access improvement are common in the upper half of the river. The lower portion of the river is connected to a number of tidal creeks and bayous, including Price Creek, Salt River, Sams Bayou and False Channel to the north and Otter Creek, Battle Creek and Petty Creek to the south.

The Southeast Fork, which originates from several spring vents, extends about one quarter of a mile downstream to the bridge at West Fishbowl Drive and another 400 feet downstream to its confluence with the Homosassa River, about 0.15 miles downstream from the Homosassa Main Springs pool. The Southeast Fork is a shallow, narrow system, typically less than 100 feet in width in most areas. Halls River originates at Halls River Head Springs and flows approximately 3.2 miles to the bridge at Halls River Road and another 400 feet to join the Homosassa River approximately 0.2 miles downstream from the Homosassa Main Spring complex. The upper portion of Halls River includes several wide pools connected by narrow channels. The lower portion of the river is consistently broader, ranging between 200 and 750 feet in width. Hidden River is located about one and half miles south of the Homosassa River. The narrow river, with channel widths of 50 feet or less, originates at the Hidden River Head Springs and meanders westward for approximately one and a third miles before disappearing into a sink about 0.8 miles east of the headwaters of Mason Creek. Cherry *et al.* (1970) note that flows from Hidden River are ultimately discharged into the Homosassa River.

The Homosassa Main Springs includes three large vents (Nos. 1-3) within a collapsed-cavern feature that has been explored to a depth of about 70 feet (Karst Environmental Services, Inc. 1992, Jones *et al.* 2011, Champion and Starks 2001). Waters discharged from the three vents differ chemically, but may be collectively characterized as brackish (total dissolved solids between 1,000 and 10,000 mg/L at low tide) with water chemistry that may vary with the tidal cycle (Jones *et al*. 2011).

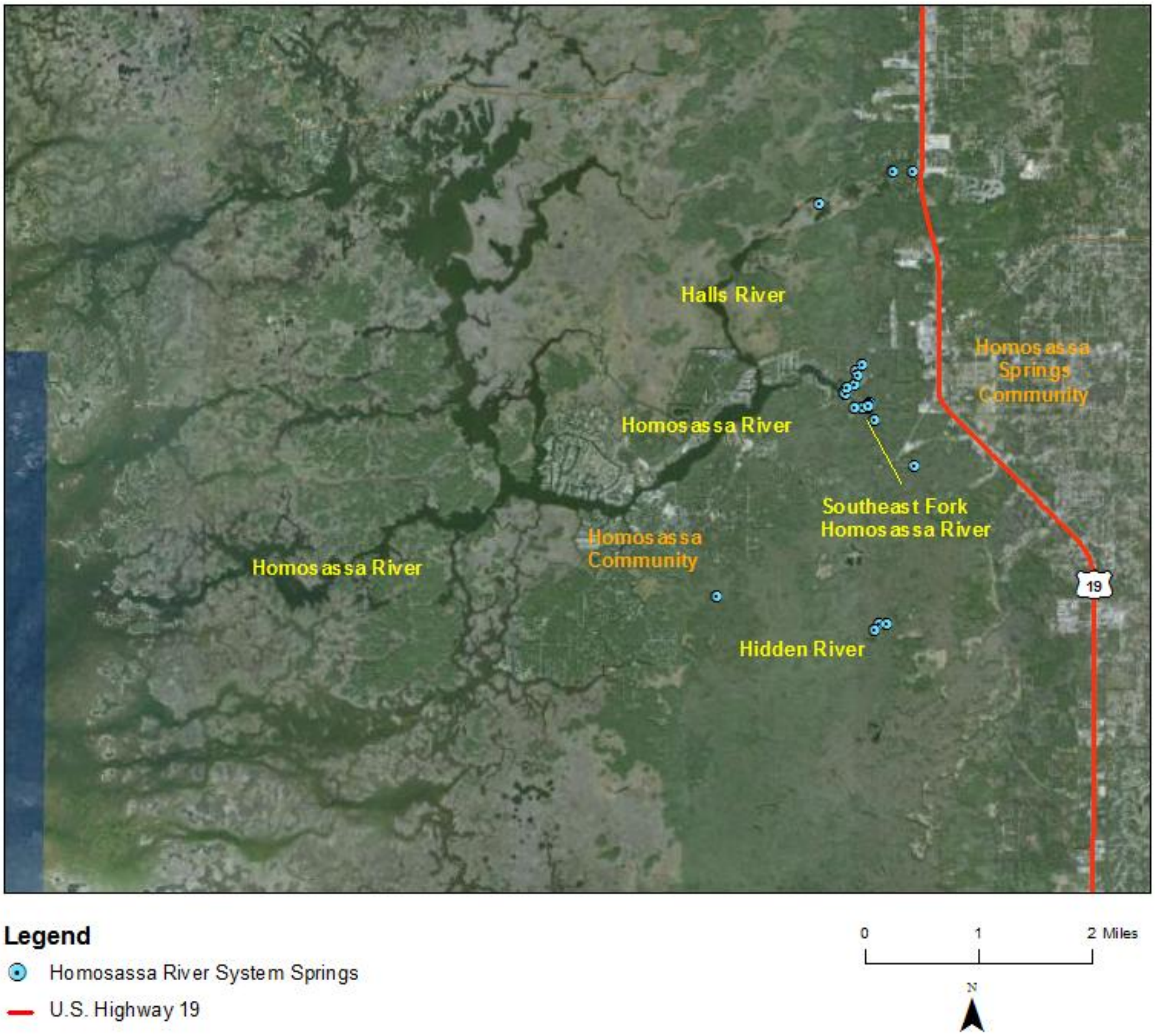


Figure 2-2. Aerial photograph showing the communities of Homosassa and Homosassa Springs and the Homosassa River system, which is defined for this report as the Halls River, Homosassa River, Southeast Fork of the Homosassa River, Hidden River and springs associated with these rivers (See Figure 2-3 for names of system springs) (photographic image source: Southwest Florida Water Management District 2003c and Woolpert, Inc. 2009).

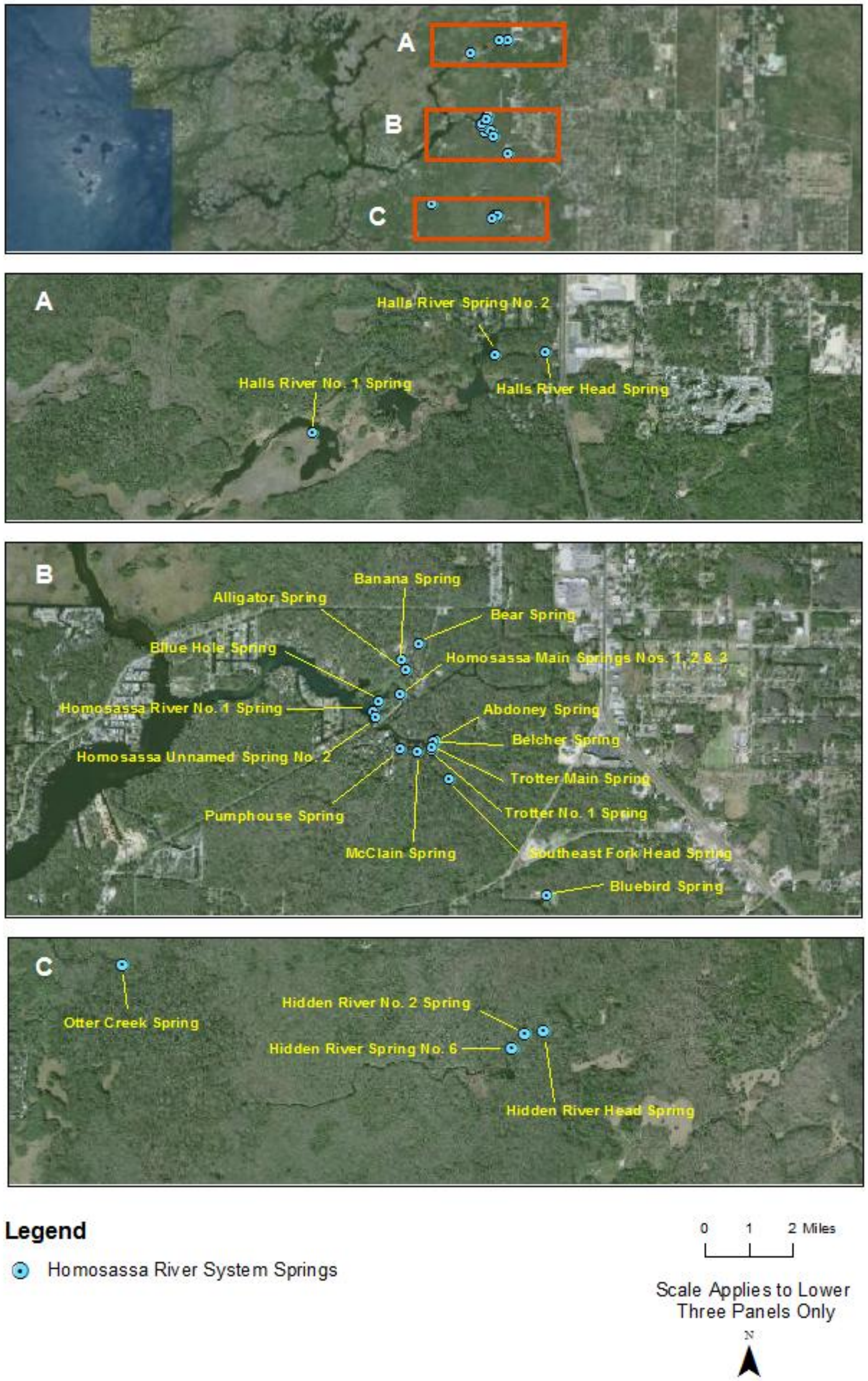


Figure 2-3. Named springs of the Homosassa River system. Upper panel shows relative location of areas shown in the lower three panels (image data sources: Southwest Florida Water Management District 2002a, 2003c and Woolpert, Inc. 2009).

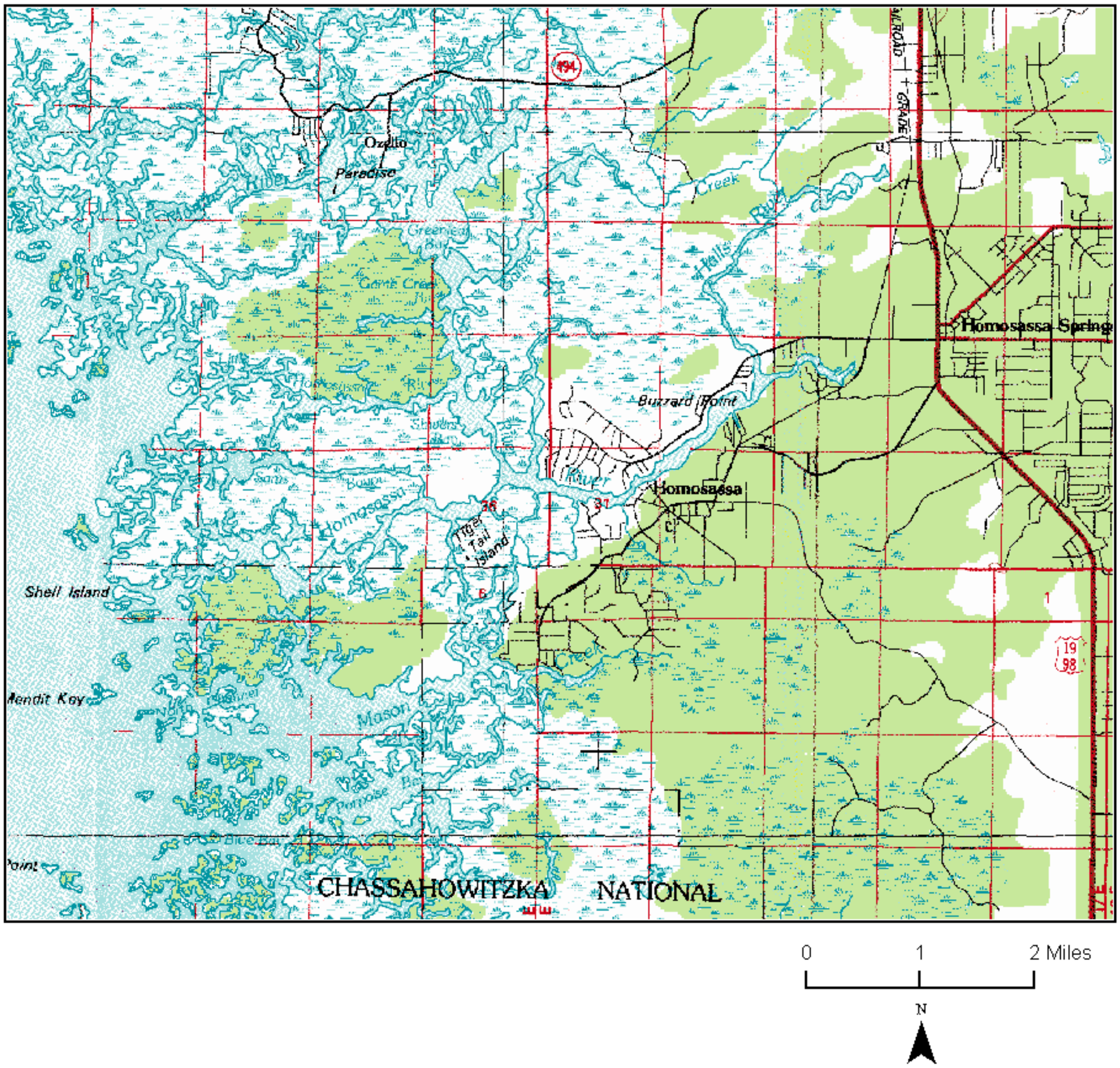


Figure 2-4. U.S. Geological Survey hydrography in the vicinity of the Homosassa River system (image source: Southwest Florida Water Management District 2002b).

Scott *et al.* (2004) identify three smaller springs that discharge to an approximate 900-foot long run which drains to the Homosassa River a few hundred feet downstream from the Homosassa Main Springs pool. The run originates at Bear Spring, in an approximate 20 by 60 foot pool with a depth of about five feet. Banana Spring discharges to the run from an excavated 40 by 60 foot pool. Downstream, Alligator Spring lies within a larger, 100 by 150 foot pool with an approximate depth between 5 and 8 feet. Blue Hole Spring is located adjacent to the south shore of the Homosassa River just upstream of the river's confluence with the Southeast Fork of the Homosassa River. Scott *et al.* (2004) estimate the spring vent lies under about 15 feet of water and discharges into a steep-sided pool approximately 25 by 75 feet in size.

Homosassa River No. 1 Spring, which may be the spring referred to as Homosassa Unnamed Spring No. 1 by Scott *et al.* (2004), is located along the east shore of the Southeast Fork of the

Homosassa River, near the confluence of the Southeast Fork and the Homosassa River. Jones *et al.* (2011) report that the vent for this spring lies under about ten feet of water in an approximated 50-feet diameter depression, and note that water quality of the limited discharge from the vent is probably influenced by the tidal cycle. Homosassa Unnamed Spring No. 2 is located in a cove off the east shore of the Southeast Fork of the Homosassa River. Scott et *al.* (2004) note that the spring pool is approximately 25 feet in diameter with a depth of about 3.1 feet.

Springs in the upper portion of the Southeast Fork of the Homosassa River include Abdoney Spring, Belcher Spring, McClain Spring, Pumphouse Spring, Southeast Fork Head Spring, Trotter Main Spring and Trotter No. 1 Spring. Collectively, the springs discharge fresh water with total dissolved solids < 1,000 mg/l (Jones *et al.* 2011) and their water quality is unaffected by tidal cycles (Yobbi 1992). Jones *et al.* (2011) note that some springs in the fork discharge tannin stained water derived from a nearby sunken spring-fed stream (referred to in this report as the Southeast Fork Head Spring and run) that is the likely source of discharge at Trotter Main Spring, Trotter No. 1 Spring and possibly Pumphouse Spring. Scott *et al.* (2004) report that Pumphouse Spring includes at least three vents in an approximate fifteen-foot deep pool. They also note that Trotter Main Spring includes an approximate five-foot long vent that lies under about ten feet of water.

Knochenmus and Yobbi (2001) describe the Halls River Head Spring as a sediment-filled vent in an approximate 200-foot wide pool. Jones *et al.* (2011) and Champion and Starks (2001) report that the pool contains a few sand boils, but not an obvious limestone vent. Yobbi (1992) notes that water discharged from the spring is brackish during low tide with variable water chemistry associated with the tidal cycle. Halls River Spring No. 2 lies about 900 feet downstream from the Head Spring, and discharges through an approximate 1.5-foot diameter vent into a 30 by 40 foot widened pool on the spring run. Approximately 0.7 miles downstream, Halls River No. 1 Spring discharges to the river.

Jones *et al.* (2011) note that Hidden River Head Springs and Hidden River Spring Number 2 consist of small, five-foot diameter circular depressions under about 4 feet of water. Knochenmus and Yobbi (2001) report that Hidden River Head Springs and another area spring referred to as Hidden River Spring Number 6 are small, sediment-filled vents under about five feet of water. The chemistry of water discharged from the Hidden River Head Spring varies with the tidal cycle (Champion and Starks 2001).

Otter Creek Spring is located approximately 1.2 miles upstream from the Homosassa River in Otter Creek. The relatively large headspring area receives surface inflow from the south and west, possibly from Hidden River (Dave DeWitt – Southwest Florida Water Management District, personal communication).

Bluebird Spring is located approximately 0.7 miles southeast of the Homosassa Main Springs Pool in Bluebird Springs Park, which is maintained by Citrus County. The spring discharges through a limestone vent under about 15 feet of water in an approximate 120 by 225 foot pool (Scott *et al.* 2004).

The Homosassa River system lies to the west of the community of Homosassa Springs and the river itself bisects the community of Homosassa (see Figure 2-2). Much of the land surrounding the Homosassa River and other components of the Homosassa River system is under public ownership. The Homosassa Main Springs are located in the Ellie Schiller Homosassa Springs Wildlife State Park and are used as a center for injured and orphaned Florida manatees

(*Trichechus manatus latirostris*). An underwater observatory located in the Main Springs pool affords park visitors with the opportunity to view manatees and other aquatic organisms in their element (Figure 2-5). The park also includes a dredged channel, known as Pepper Creek, which is used to convey park guests from the Visitor Center on U.S. Highway 19 to the west park entrance on Fishbowl Drive (Florida Department of Environmental Protection 2005).

In addition to the Ellie Schiller Homosassa Springs Wildlife State Park lands, much of the area surrounding Halls River and portions of the Homosassa River is included in the Crystal River Preserve State Park. A smaller unit of the State Park system, the Yulee Sugar Mill Ruins Historic State Park, is located near the south shore of the Homosassa River, and portions of the Withlacoochee State Forest are also situated in the vicinity of the Homosassa River system. Hidden River, Hidden River Head Spring and Hidden River No. 2 Spring are all located within the District-owned Chassahowitzka Riverine Swamp Sanctuary. In addition, portions of the Homosassa River are contained in the St. Martins Marsh Aquatic Preserve, the Homosassa River/Walker Tract, and the Chassahowitzka and Crystal River National Wildlife Refuges. The Homosassa River is classified as an Outstanding Florida Water (Florida Department of Environmental Protection 1996), a State designation associated with enhanced water quality protection criteria.

Figure 2-5. The fish bowl observatory and manatees at the Homosassa Main Springs pool in the Ellie Schiller Homosassa Springs Wildlife State Park in 2003 (image source: Southwest Florida Water Management District files).

2.2 Physiography, Watershed and Springshed

The Homosassa River system extends across three of the state's physiographic regions described by White (1970). Springs at the system headwaters lie within the Northern Gulf Coastal Lowlands, which includes sand covered scarps and terraces that reflect former marine shorelines and which rise from sea level to about 100 feet above sea level. Downstream, the system courses through the Coastal Swamps region, an area where land surfaces are typically less than ten feet above mean sea level. The lower reach of the system is included in the Drowned Karst region, an area of karst topography that has been inundated by rising sea level. Brooks (1981) categorized the area in which the Homosassa River system lies as the Chassahowitzka Coastal Strip of the Big Bend Karst in the Ocala Uplift Physiographic District, and described the region as "[*a] very low coastal strip of limestone rocklands mostly covered by hardwoods and swamps*" with some flatwoods. Brooks also notes that the Big Bend Karst area is an erosional limestone plain, with low sandy hills and few beaches.

The Homosassa, Southeast Fork of the Homosassa and Halls rivers lie within the Homosassa River drainage basin of the Upper Coastal Areas watershed, as delineated in accordance with the United States Geological Survey Hydrologic Unit Classification system (Florida Department of Environmental Protection 2004a, b). The drainage basin or watershed extends over approximately 55.6 square miles in Citrus County (Figure 2-6). Hidden River occurs within the Direct Runoff to Gulf drainage basin, an area that includes 61.5 square miles of Citrus County. Few surface water courses occur within the karst landscape of this region, so it is likely that surface runoff from only a small portion of the Homosassa River and Direct runoff to Gulf drainage basins makes its way directly to the channels of the Homosassa, Southeast Fork, Halls and Hidden Rivers.

Much of the flow in these rivers likely arises from spring discharge derived from the system's springshed. A springshed may be defined as an area of land where the water that falls on the landscape may eventually end up being discharged from a spring into a spring run. Groundwater withdrawals outside a springshed can lower water levels in the Upper Florida aquifer near a spring and contribute to diminished flow. Because discharge from a spring is based on the differential between the spring pool stage and nearby Upper Florida aquifer water level, withdrawals from areas outside of a springshed can affect spring discharge.

Knochenmus and Yobbi (2001) inferred ground-water flow patterns from potentiometric-surface maps of the Upper Floridan Aquifer system in the Springs Coast area and developed approximate ground-water basin boundaries for the region. The springshed for the Homosassa River system depicted in Figure 2-6 was developed based on figures presented in Knochenmus and Yobbi (2001) and extends over approximately 270 square miles in Citrus and Hernando counties. Basso (2010) developed a similar estimate of 292 square miles for the springshed based on approximation of the boundaries presented by Knochenmus and Yobbi. Geographic information system layers available from the Florida Department of Environmental Protection include an area of 289 square miles for the "Homosassa group" springshed. The springshed delineated by the Department is similar to the springshed depicted in Figure 2-6, although the northeast portion of the Department-delineated springshed extends under the City of Inverness and the lower two-thirds of the Tsala Apopka Lake chain, and into Sumter County to the south of the lake chain (Walrath *et al.* 2010).

The springshed for the Homosassa River system shown in Figure 2.6 is not the only region contributing groundwater to the system. Groundwater flows in aquifer systems throughout the much larger Central West-Central Florida and Northern West-Central Florida Groundwater Basins may to some degree, influence the volume of groundwater discharged from the Homosassa River system. This greater groundwater-basin area includes portions of the Southwest, St. Johns and Suwannee River Water Management Districts.

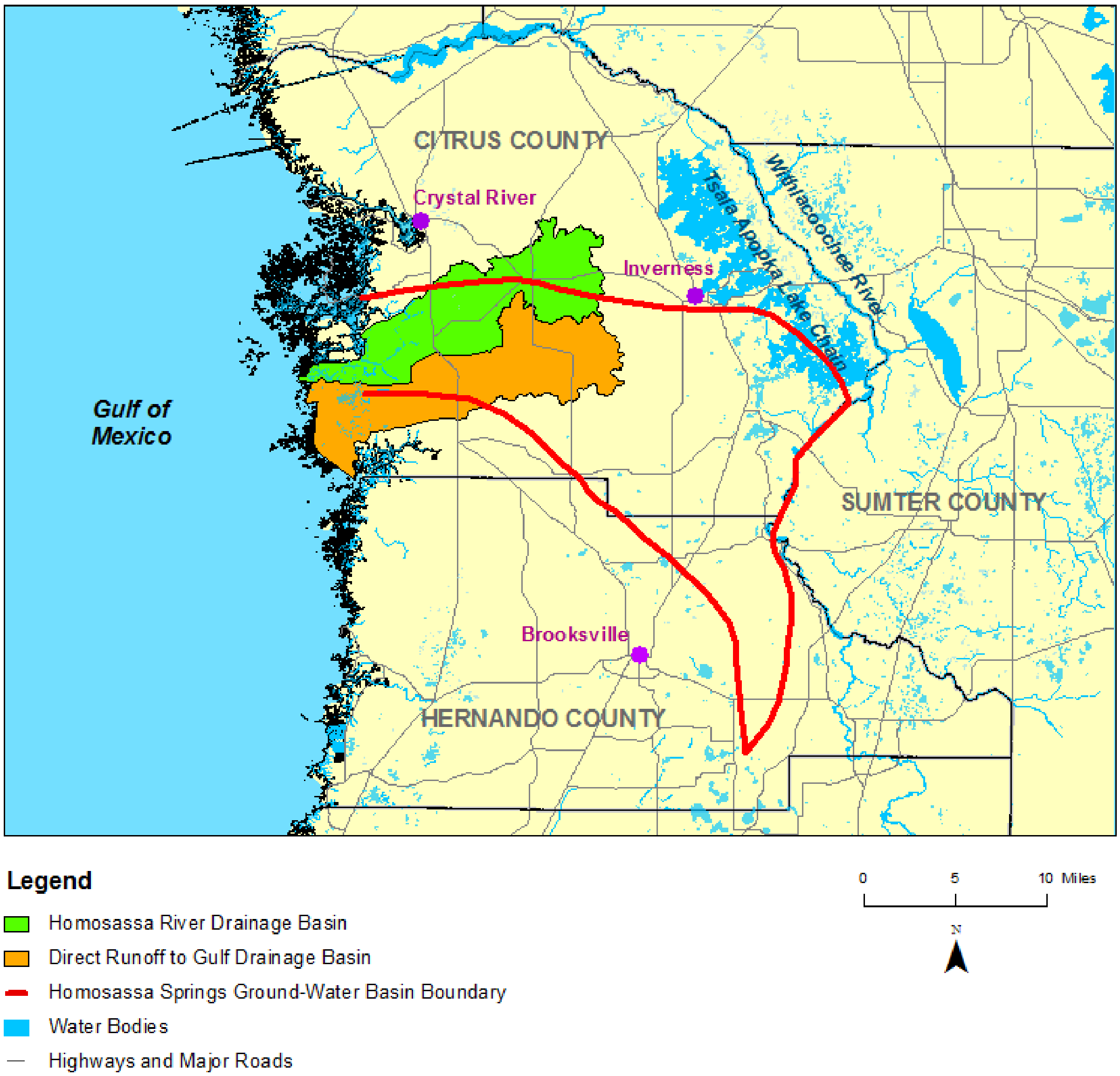


Figure 2-6. Homosassa River and Direct Runoff to Gulf drainage basins as delineated by the U.S. Geological Survey (Florida Department of Environmental Protection 2004a) and approximate location of the Homosassa Springs springshed boundary as adapted from Knochenmus and Yobbi (2001). The Homosassa, Southeast Fork of the Homosassa and Halls rivers lie within the Homosassa River Drainage Basin. Hidden River is located in the Direct Runoff to Gulf drainage basin.

2.3 Watershed Land Use and Cover

Land use and cover in the Homosassa River basin of the Homosassa River system currently includes a mix of urbanized or developed lands, agricultural lands, forested uplands, wetlands and water (Figure 2-7). Based on the Florida Land Use, Cover and Forms Classification System (Florida Department of Transportation 1999), urban and built-up lands and those used for transportation, communication and utilities in 2008 accounted for thirty-six percent of the 35,637 acres within the Homosassa River Basin (Table 2-1). Lands classified as upland forest accounted for twenty-nine percent of the basin area and water and wetlands accounted for twenty-six percent of the landscape. Urbanized areas include the community of Homosassa and other areas adjacent to the Homosassa River, the communities of Homosassa Springs, which is located primarily east of U.S. Highway 19, and an area of Citrus County northwest of the City of Inverness.

Table 2-1. Land use/cover by acre in the Homosassa River Drainage Basin, *i.e.*, watershed, for selected years based on Land use/cover classes of the Florida Land Use, Cover and Forms Classification System.

Land Use/ Cover Class	1990 Acres	1995 Acres	1999 Acres	2004 Acres	2005 Acres	2006 Acres	2007 Acres	2008 Acres
Urban and Built-Up	10,533	10,909	11,295	11,854	11,904	12,094	12,160	12,329
Agriculture	3,399	3,095	2,859	2,984	2,579	2,679	2,650	2,609
Rangeland	14	86	81	421	421	421	421	421
Upland Forest	12,089	11,954	11,646	10,584	10,884	10,640	10,592	10,475
Water	1,270	1,300	1,298	1,297	1,297	1,302	1,307	1,307
Wetlands	7,804	7,795	7,797	7,832	7,828	7,824	7,826	7,823
Barren Land	218	198	189	196	254	208	208	197
Transportation, Communication and Utilities	309	299	472	469	469	469	473	475
Total Acres	**35,637**							

Changes in land use and cover within the Homosassa River basin were evaluated using geographic information system layers representing land use/cover classifications for the area in 1990, 1995, 1999 and 2004 through 2008 (Southwest Florida Water Management District 2003a,b, 2004a, 2007a,b,c, 2008a, 2010). For the analyses, Esri ArcMap software was used to clip land use/cover layers to the boundaries delineated by the Homosassa River Drainage Basin. With the exception of the Urban and Built-Up and Upland Forest land use/cover classes, land use/cover in the watershed exhibited little change in the years examined between 1990 and 2008 (Table 2-1). Increases in urbanized lands have been associated primarily with decreases in forested uplands.

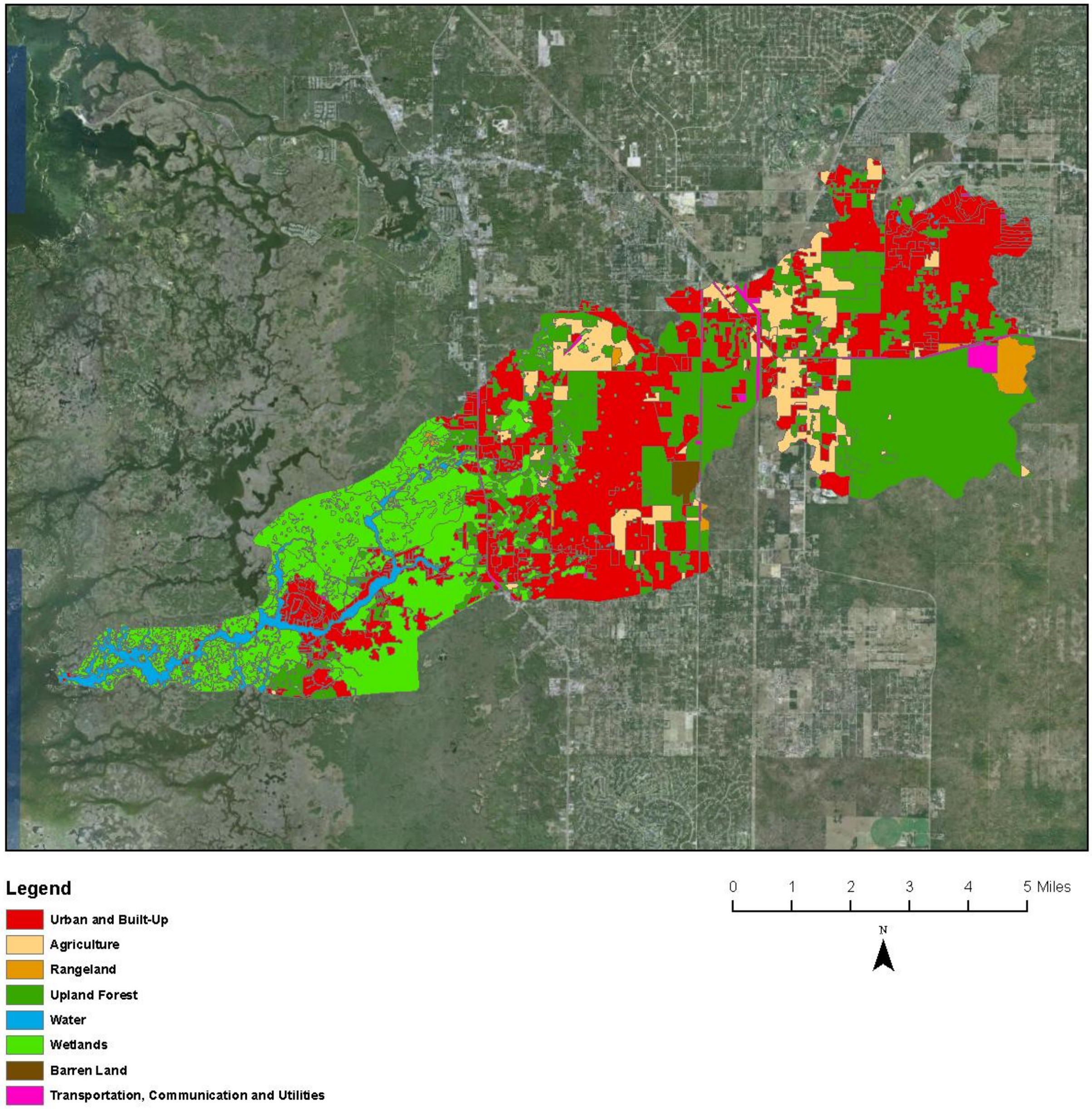


Figure 2-7. Land use–cover in the Homosassa River Drainage Basin in 2008, based on the Florida Land Use, Cover and Forms Classification System (image sources: Woolpert, Inc. 2009, Southwest Florida Water Management District 2010).

2.4 <u>Hydrology</u>

2.4.1 Data Sources for Hydrologic Information

Hydrologic information presented in this section is based on previously published reports and analyses completed specifically for development of minimum flow recommendations outlined in this report. Primary data sources for the analyses completed specifically for development of the recommend minimum flows included the District Water Management Information System, the U.S. Geological Survey National Water Information System, the National Weather Service and the Florida Automated Weather Network.

A number of agencies record and maintain rainfall and other meteorological records in the west-central Florida region. The Southwest Florida Water Management District currently tabulates rainfall summaries by specific geographic areas, including drainage basins and counties within the District, using NEXRAD (Next-Generation Radar) data obtained from the National Weather Service. Area-weighted monthly total rainfall values tabulated for Citrus County for the period from 1915 through 2009 were used for characterization of general rainfall patterns in the vicinity of the Homosassa River system. In addition, meteorological data used for modeling hydrologic conditions in the Homosassa River were obtained from the Florida Automated Weather Network (FAWN), which is maintained by the University of Florida Institute of Food and Agricultural Sciences (IFAS) and is supported, in part, by the District. Records used for the analyses included wind speed and direction information and air temperatures measured at the FAWN-IFAS Brooksville site, which is located at the United States Department of Agriculture Brooksville Subtropical Agricultural Station.

With support from the District and the Florida Department of Environmental Protection, the USGS maintains six surface-water gage sites where surface water levels, discharge and various water quality parameters are currently or have recently been monitored in the Homosassa River system (Table 2-2, Figure 2-8). Daily stage or gage height, *i.e.,* water level, records are available for each of the six sites, which are named Homosassa Springs at Homosassa Springs FL, Southeast Fork Homosassa Spring at Homosassa Springs FL, Halls River near Homosassa, FL, Homosassa River at Homosassa FL, Homosassa River at Shell Island near Homosassa FL, and Hidden River near Homosassa FL. Daily discharge estimates are available for four of the sites, including the gages at Homosassa Springs, the Southeast Fork, Homosassa River and Hidden River. Water quality parameters are currently or up until recently have been measured at all of the sites. In addition to the records for daily stage, discharge and other parameters, measurements of stage, specific conductance and water temperature collected at fifteen-minute intervals are available for five of the sites. Discharge estimates are also available for fifteen-minute intervals for the Homosassa Springs, SE Fork and Homosassa River sites.

Period of record daily parameter values for each of the six surface water gage sites were obtained from the USGS National Water Information System Web Interface in March 2010 and used to prepare much of the summary information presented in this minimum flows report. Some analyses and summary information presented in the report are based on fifteen-minute-interval data collected through September 30, 2008 that were obtained from the USGS by HSW Engineering, Inc.

Records or data available from the USGS include those that have been “approved” for publication, following agency processing and review, and those classified as “provisional” and subject to revision. Although both USGS approved and provisional data are presented in some portions or figures contained in this report, only approved data were used for data summaries and analyses associated with development of the recommended minimum flows for the Homosassa River system.

The USGS maintains two wells in the vicinity of the Homosassa River system that are used to monitor water levels in the Upper Floridan Aquifer and which are relevant to the information presented in this report. The Weeki Wachee Well near Weeki Wachee FL (Site Number 283201082315601) is used to estimate discharge at the Homosassa Springs at Homosassa Springs FL and Southeast Fork Homosassa Spring at Homosassa Springs FL gage sites. The well is located about 13 miles south of Homosassa Springs, near Weeki Wachee Springs in Hernando County (Figure 2-9). Water surface elevations are available for this well from June 15, 1966 through the current date, with USGS-approved data available through December 7, 2009. Records for the Weeki Wachee Well were obtained from the USGS by HSW Engineering, Inc. to support their hydrologic modeling efforts, which are described in HSW Engineering, Inc. (2010, 2011) and subsequent sections of this report. The second well of interest for development of minimum flows for the Homosassa River system is the Homosassa Well 3 near Homosassa FL (Site Number 284551082345301). This well is used to estimate discharge at the Hidden River near Homosassa FL site and is located approximately 0.4 miles southeast of the Hidden River gage site (Figure 2-9). The period of record for water levels in the well extends from January 25, 1967 to the current date, with approved data available through December 9, 2009.

Table 2-2. Summary information for daily records available for U.S. Geological Survey surface-water gage sites in the Homosassa River system. Periods of record are identified for Survey "approved" and "provisional" data. Additional site records may be available from Survey's "field measurement" or "field/lab samples" databases, but are not identified in this table. Information regarding availability of data collected for the sites at fifteen-minute intervals is provided in Appendix A of HSW Engineering, Inc. (2011).

Site Number and Name	Stage or Gage Height Periods of Record	Discharge Periods of Record	Specific Conductance or Salinity Periods of Record	Temperature Periods of Record	Comments
02310678 Homosassa Springs at Homosassa Spring FL	11/02/1988 – 03/16/2010 (provisional prior to 10/10/1996 and after 10/14/2009)	10/18/1995 – 03/16/2010 (provisional after 10/14/2009)	06/28/2004 – 03/16/2010 (provisional after 10/14/2009)	06/28/2004 – 03/16/2010 (provisional after 10/14/2009)	Gage height and discharge records sporadic prior to 01/09/1996. Gage height reported as mean, tidal high and tidal low. Discharge reported as mean. Specific conductance and temperature reported as bottom minimum and maximum.
02310688 SE Fork Homosassa Spring at Homosassa Springs FL	10/01/2002 – 12/28/2009 (provisional after 10/12/2009)	10/01/2000– 03/12/2010 (provisional after 10/12/2009)	05/03/2006 – 03/16/2010 (provisional after 10/12/2009)	05/03/2006 – 03/16/2010 (provisional after 10/12/2009)	Gage height reported as tidal high and tidal low. Discharge reported as mean. Specific conductance and temperature reported as near bottom minimum and maximum.
02310690 Halls River near Homosassa FL	10/27/2000 – 10/12/2009	NA	NA	NA	Gage height reported as mean, tidal high and tidal low.
02310700 Homosassa R at Homosassa FL	10/01/1970 – 01/03/2010 (provisional after 9/30/2009)	06/08/1984 – 03/12/2010 (not filtered for tide) (provisional after 12/12/2009) 05/20/2004 – 09/30/2009 (tidally filtered)	05/05/2006 – 03/16/2010 (top) (provisional after 12/12/2009) 05/18/2006 – 03/16/2010 (bottom) (provisional after 12/12/2009)	05/05/2004 – 03/16/2010 (top) (provisional after 12/12/2009) 05/18/2004 – 03/16/2010 (bottom) (provisional after 12/12/2009)	Gage height reported variously as mean, minimum, maximum and tidal high and low. Stage reported as tidal high and low. Discharge reported as mean. Specific conductance and temperature reported as top and bottom minimum and maximum.
02310712 Homosassa R at Shell Island near Homosassa FL	10/01/1984 – 10/06/2009	NA	09/15/2006 – 10/06/2009	09/15/2006 – 10/06/2009	Gage height reported variously as mean, tidal high and tidal low. Specific conductance and temperature reported as top, middle and bottom minimum and maximum.
02310675 Hidden River near Homosassa FL	NA	10/28/2003 – 03/16/2010 (provisional after 10/14/2009)	NA	NA	Discharge reported as mean.

NA = not available

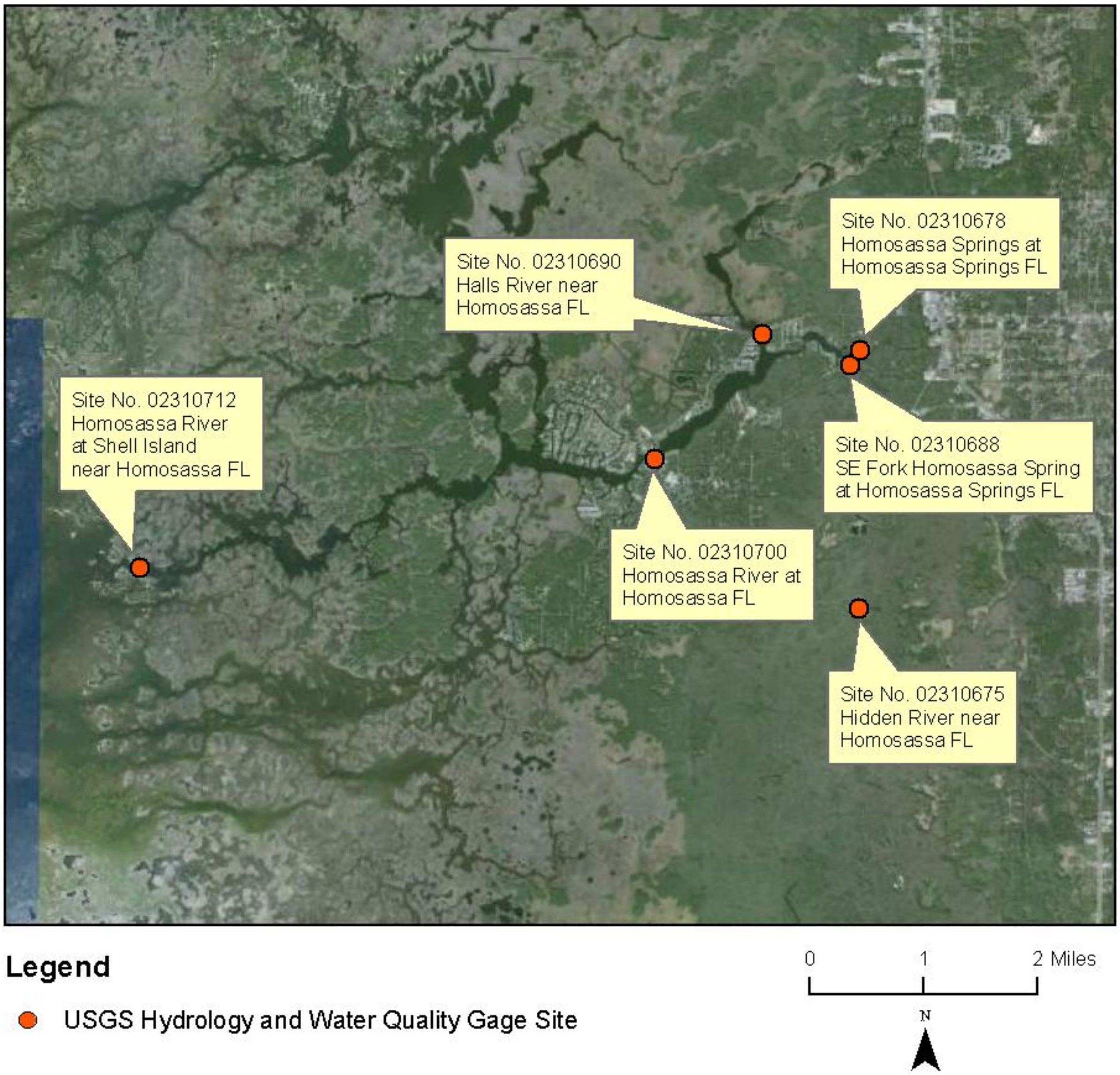


Figure 2-8. U.S. Geological Survey (USGS) surface-water gage sites in the Homosassa River system (photographic image sources: Southwest Florida Water Management District 2003c and Woolpert, Inc. 2009).

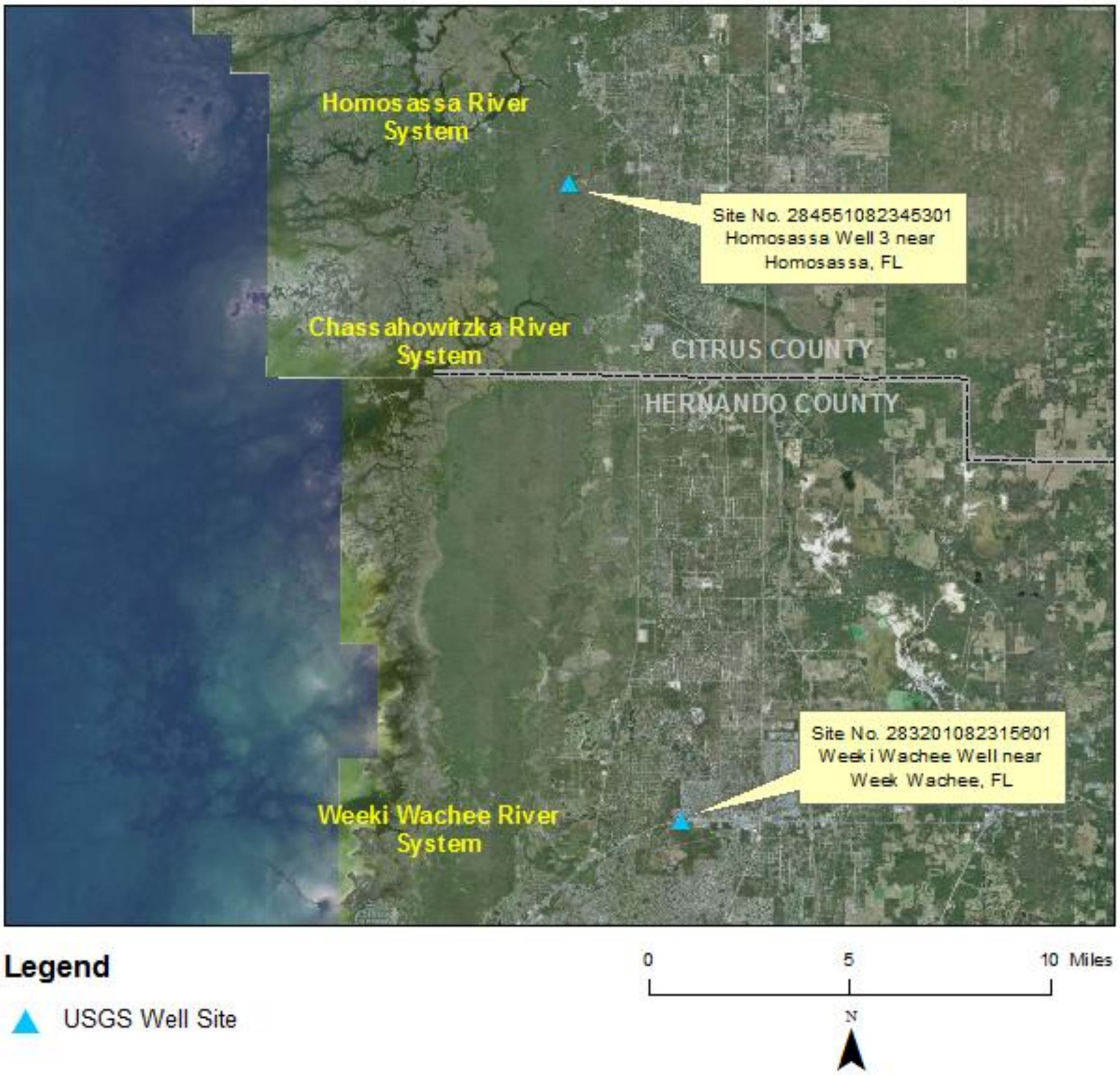


Figure 2-9. U.S. Geological Survey (USGS) well sites used to estimate discharge for gage sites in the Homosassa River system (photographic image sources: Southwest Florida Water Management District 2003c and Woolpert, Inc. 2009).

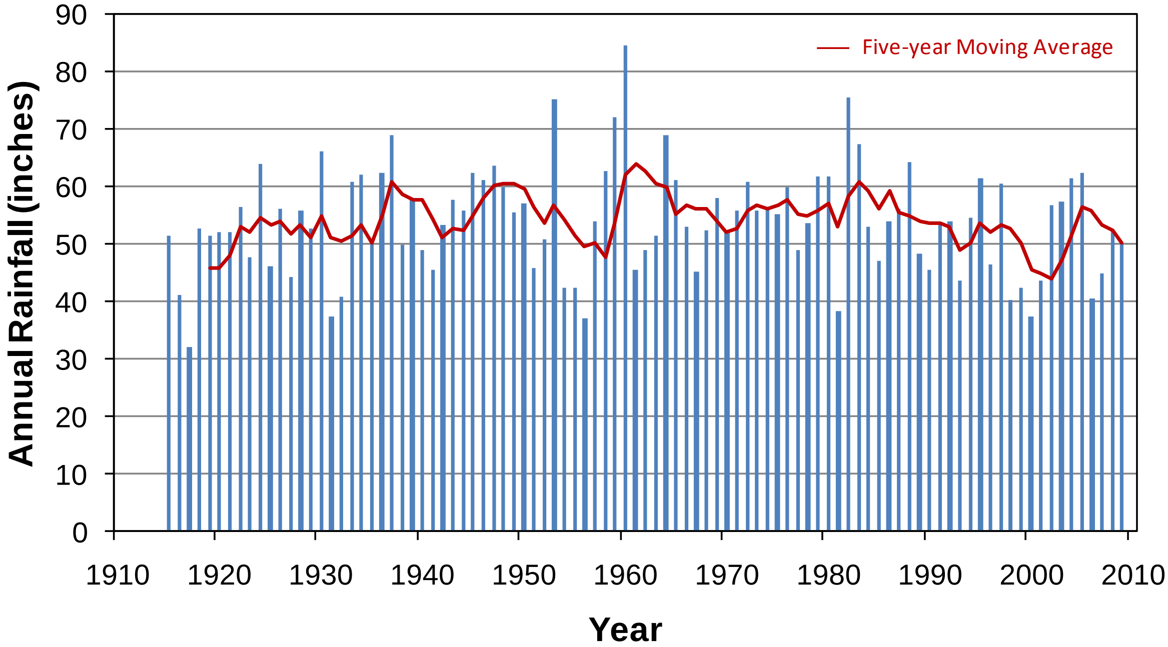
2.4.2 Climate and Rainfall

The climate of coastal Florida in the vicinity of the Homosassa Springs system may be characterized as humid subtropical. Local weather is strongly influenced by the Gulf of Mexico, which moderates winter and summer temperatures. Wolfe (1990b) notes that mean daily summer temperatures are typically in the low 80s (degrees Fahrenheit) along the Springs Coast. Wolfe also notes that daytime winter temperatures in the area often range into the upper 50s, although they may be considerably lower in response to passing cold fronts.

Based on area-weighted regional records, annual rainfall in Citrus County ranged from 32.1 to 84.6 inches and averaged 54.0 inches from 1915 through 2009 (Figure 2-10, upper panel). On an annual basis, rainfall has typically been highest during the months of June through September (Figure 2-10, lower panel), likely as a result of the significant rainfall events that may be associated with convective and tropical storms that occur during these wet-season months. Cherry *et al.* (1970) note that evaporation in the region is highest in May and June, prior to and during the early phase of the summer wet season. Knochenmus and Yobbi (2001) estimate that the annual average evapotranspiration rate from the Homosassa Springs ground-water basin is of 32 inches per year, based on a water budget developed for 1997 and 1998.

No statistically significant linear trend is evident for the full 95-year record for Citrus County rainfall, based on ordinary least squares regression analysis. Shorter-term trends are visually apparent in time-series plots, especially when annual values are aggregated as moving-average values. For example, a plot of five-year moving average values (see Figure 2-10, upper panel) clearly illustrates recent reductions in rainfall over the past twenty years, with the exception of the 2002 through 2005 period, when rainfall exceeded than the long-term average for four years in a row. Based on rainfall data from the Brooksville, Inverness and Ocala National Weather Service stations, Basso (2010) reports a declining trend in area rainfall for the past several decades, and notes that the regional decline in rainfall after 1970 corresponds to a change in the Atlantic Multidecadal Oscillation cycle from a warm (wet) to a cool (dry) period.

A plot of annual departure from the long-term average annual rainfall provides another means for identifying periods of above or below average rainfall. The latter two-thirds of the 1940s, for example, were relatively wet, as was the three year period from 1958 through 1960, when annual rainfall exceeded the long-term average by nine to 31 inches (Figure 2-11). In contrast, below average rainfall has been common during many of the past twenty years and rainfall in any given year during this period has not been more than 8.5 inches above average (Figure 2-11).



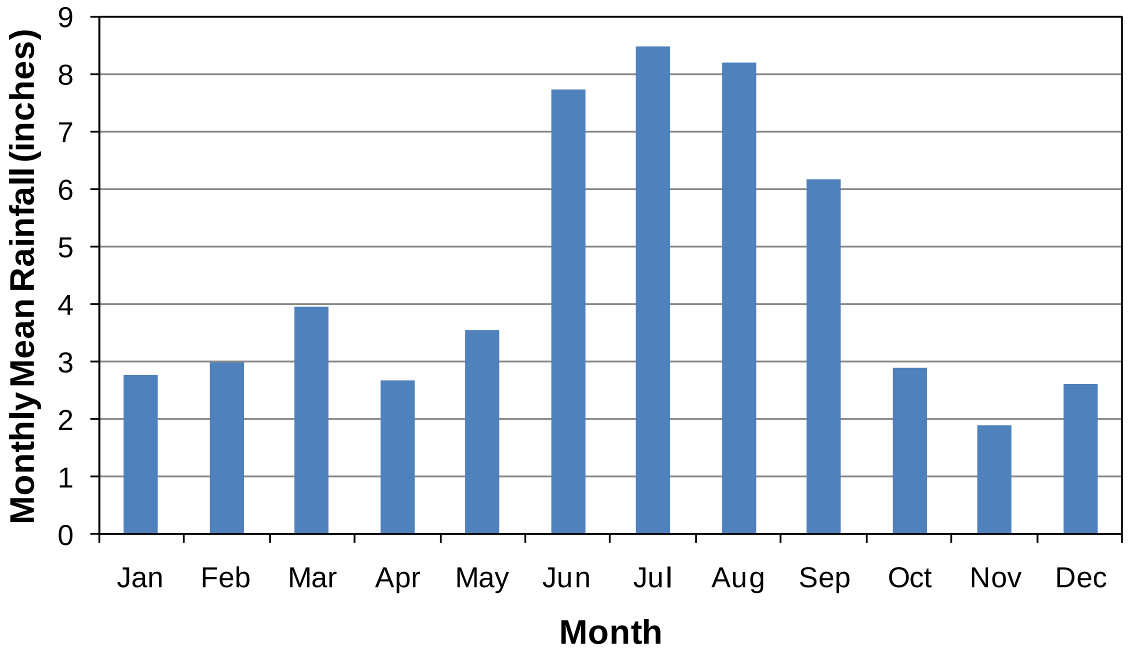


Figure 2-10. Area-weighted annual (upper panel) and monthly mean (lower panel) rainfall for Citrus County between 1915 and 2009 (data source: Southwest Florida Water Management District Rainfall Data Summaries web page at http://www. swfwmd state.fl.us /data/ wmdbweb/rainfall_data_summaries.php).

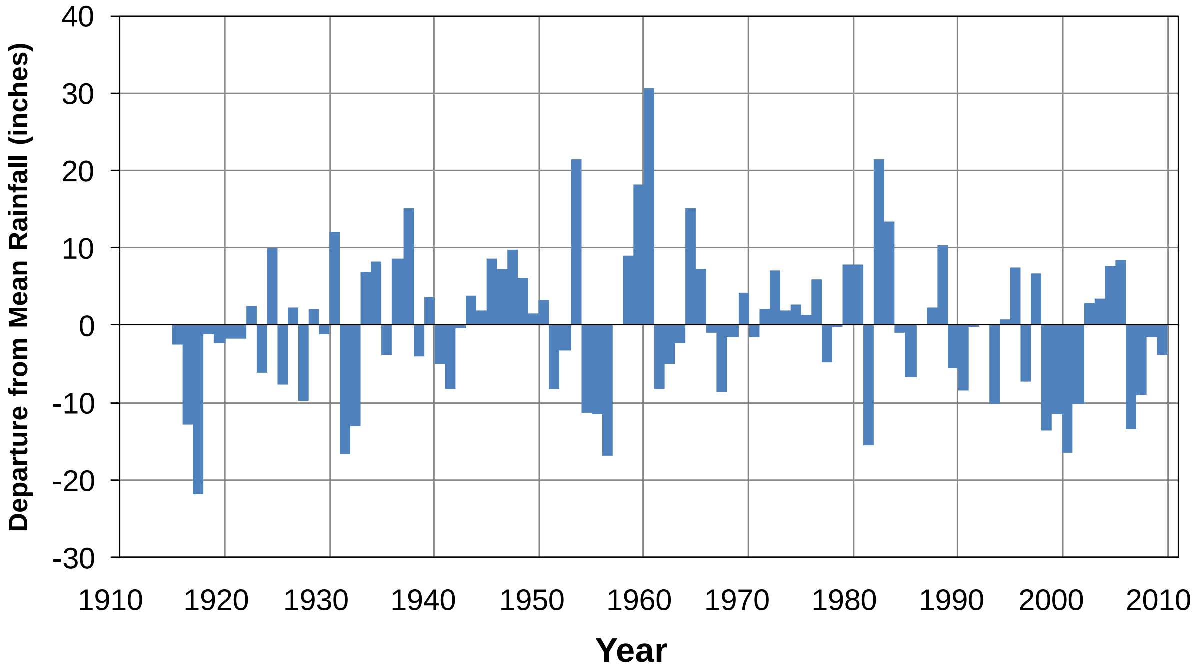


Figure 2-11. Annual departure from the mean annual rainfall of 54.0 inches for Citrus County from 1915 through 2009.

2.4.3 Stage and Tides

Tides in the vicinity of the Homosassa River system may be classified as mixed semidiurnal; higher and lower high tides and higher and lower low tides may occur in a single day. The diurnal tidal range is about two feet at the mouth of the Homosassa River near Shell Island (Yobbi and Knochenmus 1989) and tidal influence on stage or gage height is evident throughout the Homosassa River system (Figure 2-12). Daily high and low water levels at gage sites in the Homosassa River and Halls River are highly correlated (HSW Engineering, Inc. 2011; included in this report as Appendix A). Figure 2-13 provides an example of the relationship between gage heights at Shell Island and the upstream gage sites. These values were not converted to elevations relative to the North American Vertical Datum of 1988 (NAVD88) to ensure separation and improve visualization of the water level records shown in the figure.

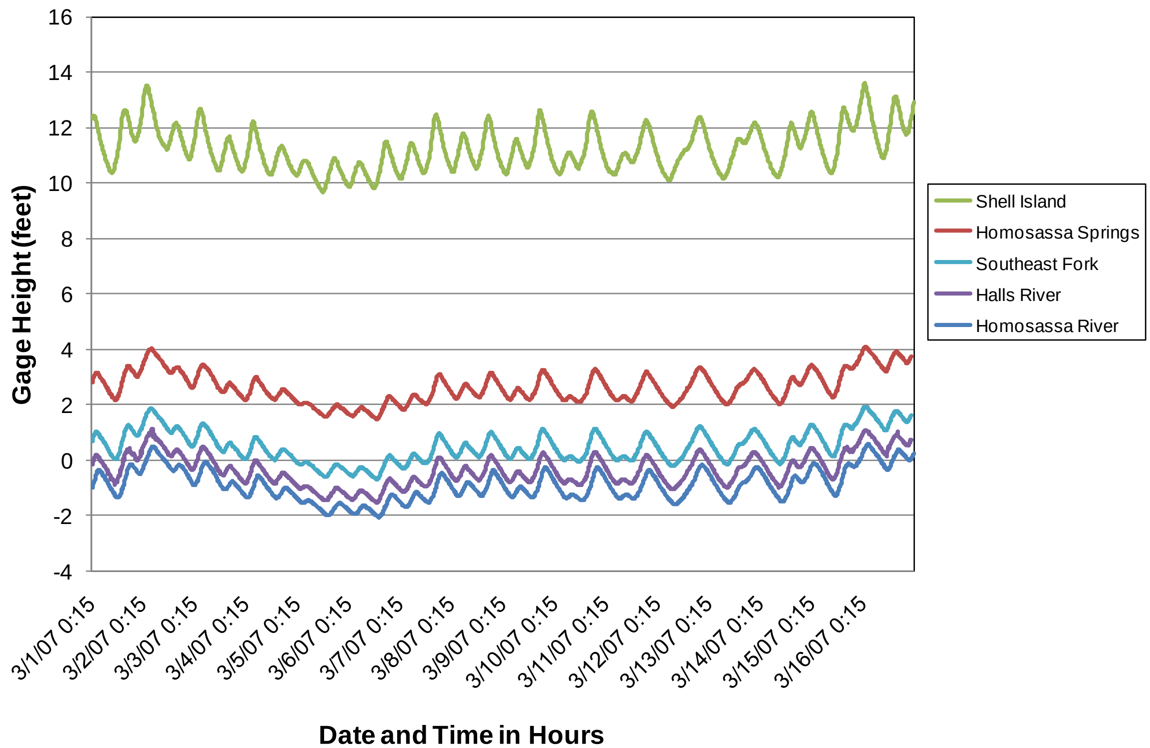
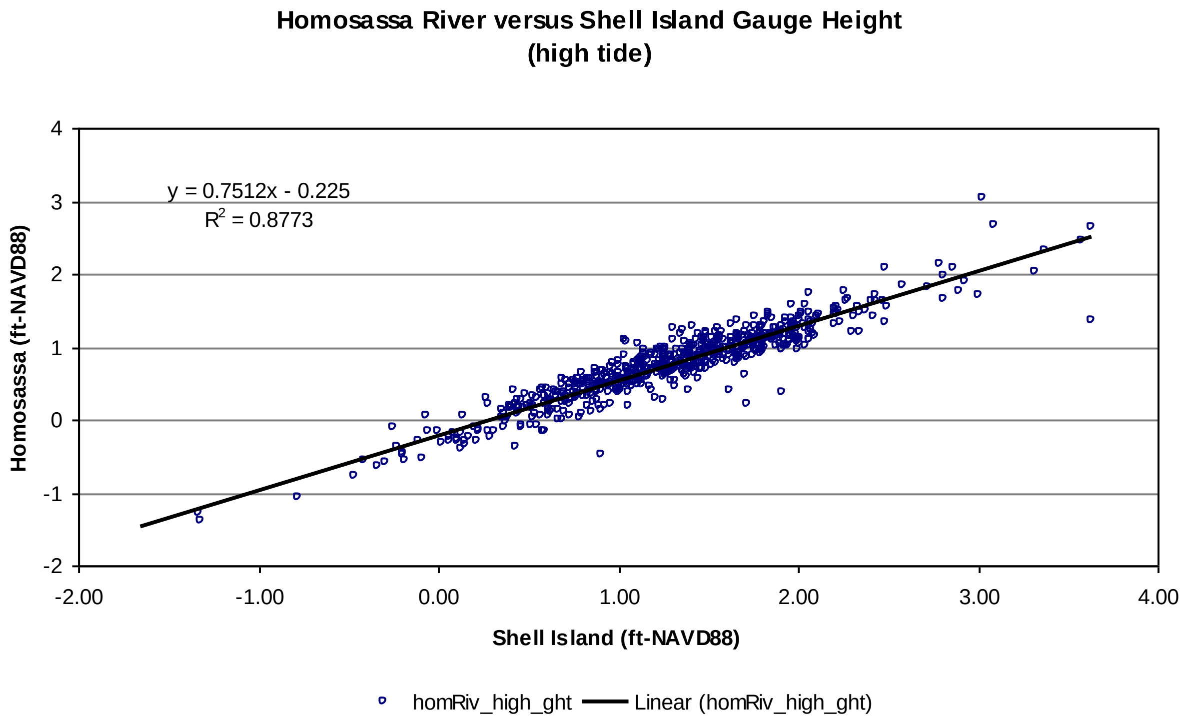


Figure 2-12. Time-series of fifteen-minute gage height records showing tidal influence at the U.S. Geological Survey Shell Island, Homosassa River, Halls River, Homosassa Springs and the Southeast Fork Homosassa Springs gage sites from March 1 through March 16, 2007. Gage datum values to convert gage heights to elevations relative to NAV88 vary among sites.



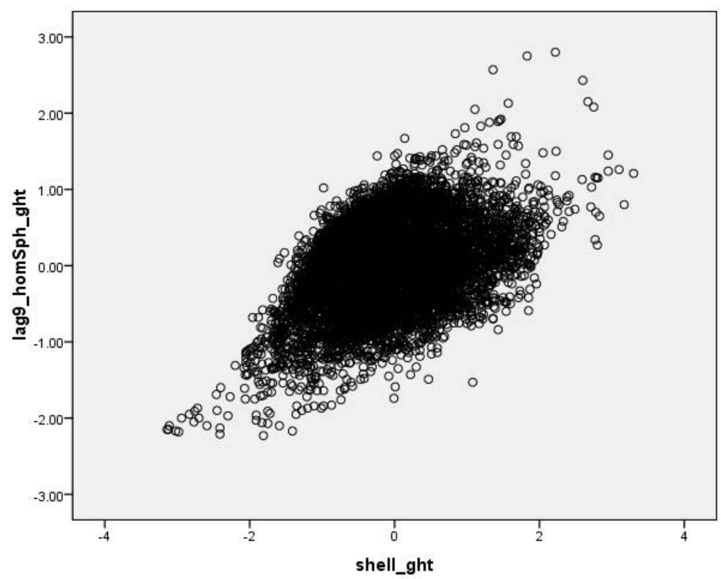


Figure 2-13. Relationship between gage heights for the U.S. Geological Survey Homosassa River at Shell Island near Homosassa FL, Homosassa Springs at Homosassa Springs FL, and Homosassa River at Shell Island near Homosassa FL gage sites. Upper panel shows the relationship for daily high tide gage heights; lower panel shows relationship for 15-minute gage heights with the spring gage height (y-axis) lagged 2.5 hours behind the Shell Island gage height (x-axis). Panels reproduced from HSW Engineering, Inc. (2011).

Tidal fluctuations in the vicinity of the Homosassa River system vary seasonally, with higher low and median tides occurring during late spring and summer, and lower low and median tides occurring in the winter (Figure 2-14). This typical seasonal shift in tides contributes to seasonal discharge patterns in the spring/river system (see next section). Some of the highest recorded high tides have, however, been observed during fall and winter months, likely due to wind driven tides associated with passing frontal systems

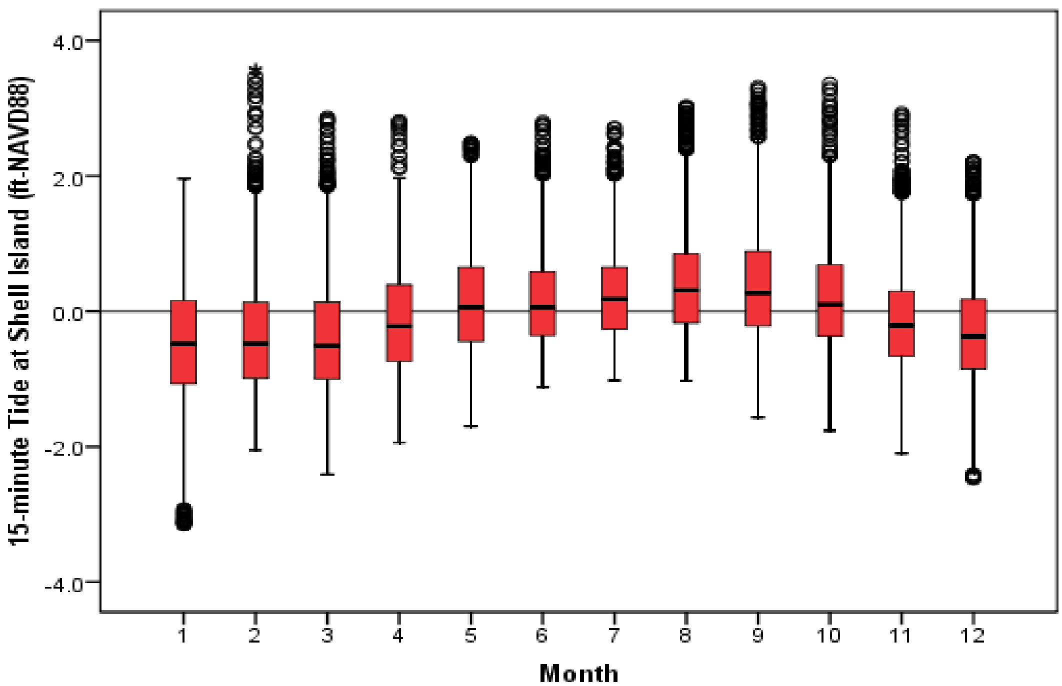


Figure 2-14. Box plot of fifteen-minute tidal stage at Shell Island for the period from September 14, 2006 through September 30, 2008, summarized by month (1-12). Plot reproduced from HSW Engineering, Inc. (2011). Boxes represent medians and first (Q1) and third (Q3) quartiles, whiskers correspond to the highest values within the upper (Q3+1.5(Q3-Q1) and lower (Q1-1.5(Q3-Q1)) limits, and circles or asterisks beyond the whiskers represent outliers or extremely high or low values, respectively.

2.4.4 Discharge – Mean Daily Records

Mean daily discharge reported by the USGS for the Homosassa Springs at Homosassa FL gage site is derived by averaging 96 daily discharge estimates based on fifteen-minute interval gage heights at the spring and hourly groundwater levels at the Weeki Wachee Well near Weeki Wachee FL site. Mean daily discharge at the Homosassa Springs gage site has varied only moderately during the period of record (Figure 2-15), with approved mean daily discharge values ranging from 34 to 141 cfs and average and median values of 89 and 88 cfs, respectively (Table 2-3).

Discharge from the main Homosassa Springs (and other system springs) tends to be lowest in late spring and early summer (Figure 2-16), likely as a result of the higher median and low tides during this period. Lower tides in the winter exert less hydraulic head pressure over the spring vents, thus allowing greater spring discharge relative to higher tide conditions. Simple linear regression of USGS approved daily discharge values indicates a significant negative linear trend ($p<0.001$) over the relatively short period of record (note that regression information is not shown in Figure 2-15). However, this trend appears to be influenced by low flows that were observed after the summer of 2006, when there was a period of deficit rainfall in the region (Southwest Florida Water Management District 2010b).

Using an approach similar to that used for the Homosassa Springs gage site, mean daily discharge at the Southeast Fork Homosassa Spring at Homosassa Springs FL gage site is calculated from fifteen-minute interval discharge estimates based on the gage height at the site and the water level in the Weeki Wachee well. Reported mean daily discharge at the Southeast Fork gage site has varied only moderately, ranging from 23 to 100 cfs, with average and median values of 61 and 60 cfs, respectively, for approved data (Figure 2-17, Table 2-3). The seasonal pattern of flows from the Southeast Fork gage is similar to the Homosassa Springs gage with the highest flows in the winter and lowest flows in the late spring and early summer.

Mean daily discharge at the Homosassa River at Homosassa FL gage site is calculated using fifteen-minute interval discharge estimates based on measured gage height and a rating curve for site. An Acoustic Doppler Current Profiler, which is effective at measuring downstream and upstream flow, is used to develop the streamflow rating relationships. Discharge estimates for the site are reported as unfiltered values and values that are filtered in an attempt to remove tidal influence (Figure 2-18). Approved, filtered mean daily discharge at the site ranged from -636 to 2,090 cfs; mean and median values for the period of record were 272 and 251 cfs, respectively. Negative values in the record suggest that tidal influences are not completely accounted for in the method used to transform the unfiltered records. However, prolonged onshore winds can contribute to upstream tidal flow and negative discharge values.

Mean daily discharge values are not reported by the USGS for the Halls River near Homosassa FL gage site. However, discharge may be approximated for Halls River by subtracting combined discharge from the Homosassa Springs and Southeast Fork sites from the reported filtered discharge at the Homosassa River gage. Calculated in this manner, the resulting mean daily discharge estimates include ungaged spring and diffuse groundwater discharge to the river above the Homosassa River gage, surface runoff to the river, and error associated with incomplete filtering of tidal influences on the Homosassa River discharge records (HSW Engineering, Inc. 2011). Mean daily discharge for the Halls River was estimated to range from -765 to 1,195 cfs with mean and median values of 129 and 108 cfs, respectively (Figure 2-19, Table 2-3).

Mean daily discharge at the Hidden River near Homosassa FL gage site is calculated using the daily maximum water level and a rating curve for the site and water level in the USGS Homosassa Well 3 near Homosassa FL. Approved, daily mean discharge at the site has ranged from 1.3 to 25 cfs, with a mean and median value of eight cfs (Figure 2-20, Table 2-3).

Table 2-3. Mean daily discharge statistics based on approved U.S. Geological Survey records for gage sites in the Homosassa River system. Statistics are expressed as cubic feet per second (cfs) unless specified. Periods of record for approved data are listed by gage site in Table 2-2.

Statistic (cfs or N)	Homosassa Springs at Homosassa Springs FL	SE Fork Homosassa Spring at Homosassa Springs FL	Combined Springs[a]	Halls River[b]	Homosassa River at Homosassa FL (tidally filtered)	Hidden River near Homosassa FL
Maximum	141	100	240	1,995	2,090	25.0
75th Percentile	98	68	165	200	350	11
Median	88	60	147	108	251	8.0
25th Percentile	79	53	131	28	167	4.6
Minimum	34	23	57	-765	-636	1.3
Mean	89	61	149	129	272	8.0
Standard Deviation	14	11	26	181	183	4.4
Number (N) of daily Records	4,975	3,123	3,102	1,662	1,774	2,063

[a] Combined Springs discharge determined as the sum of the Homosassa Springs at Homosassa FL and SE Fork Homosassa Spring at Homosassa Springs FL discharge for days when records were available for both sites.
[b] Halls River discharge estimated by subtracting combined springs discharge from tidally filtered Homosassa River at Homosassa FL discharge for days when records were available for the two spring sites and the Homosassa River site.

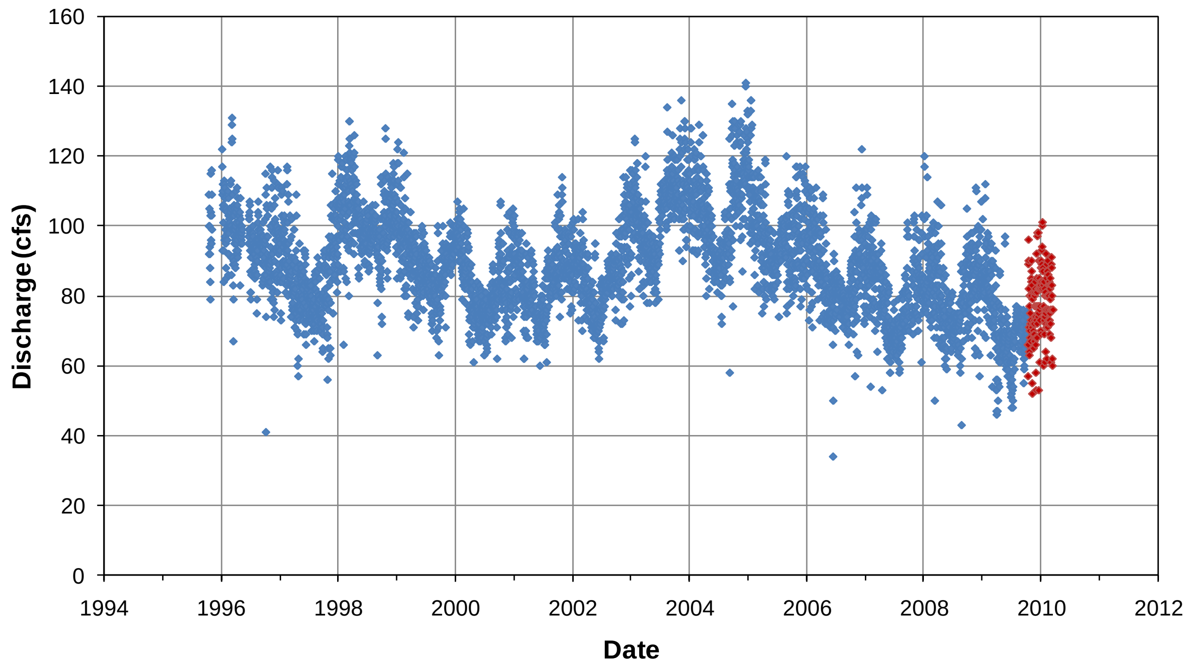


Figure 2-15. Period of record daily mean discharge time series for the U.S. Geological Survey Homosassa Springs at Homosassa Springs FL gage site (number 02310678). Values approved by the Survey are shown in blue; provisional values are shown in red.

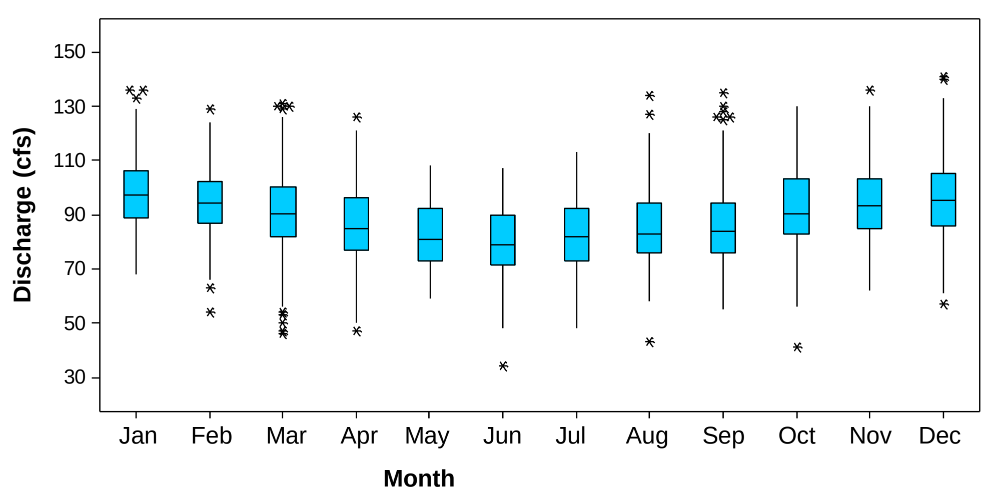


Figure 2-16. Box plot of monthly mean discharge values for the U.S. Geological Survey Homosassa Springs at Homosassa Springs FL gage site (number 02310678), based on compilation of approved period of record daily values. Boxes represent medians and first (Q1) and third (Q3) quartiles, whiskers correspond to highest values within the upper (Q3 + 1.5(Q3 – Q1)) and lower (Q1 – 1.5(Q3 – Q1)) limits, and asterisks beyond the whiskers represent extremely high or low values.

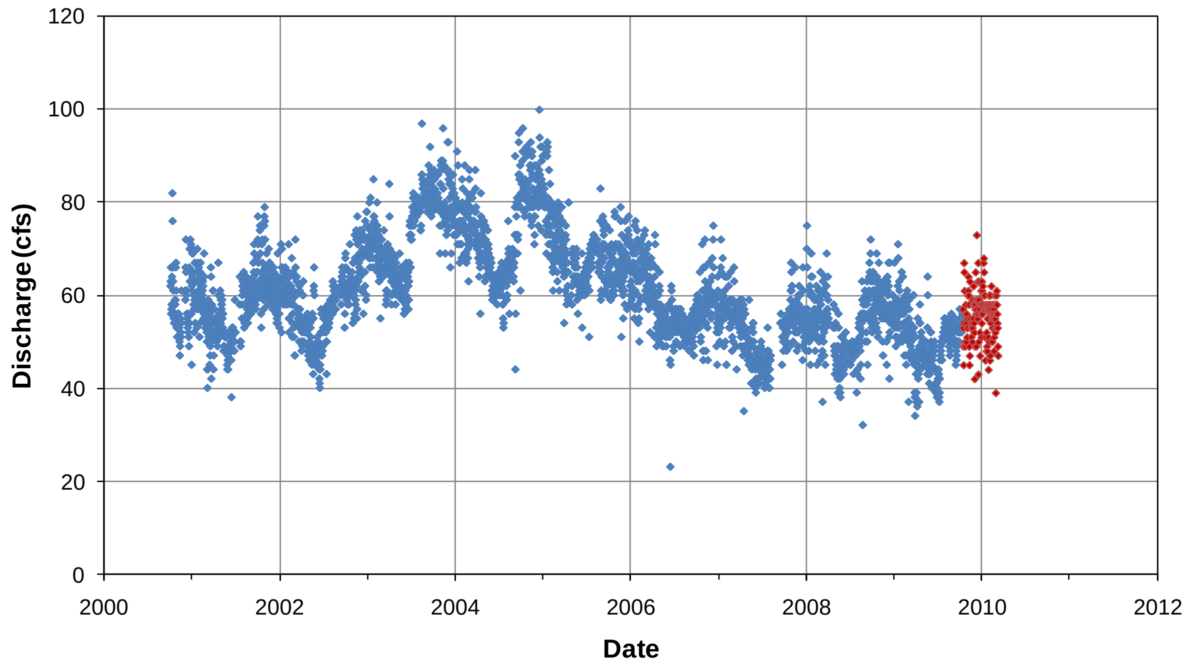


Figure 2-17. Period of record daily mean discharge time series for the U.S. Geological Survey SE Fork Homosassa Springs at Homosassa Springs FL gage site (number 02310688). Values approved by the Survey are shown in blue; provisional values are shown in red.

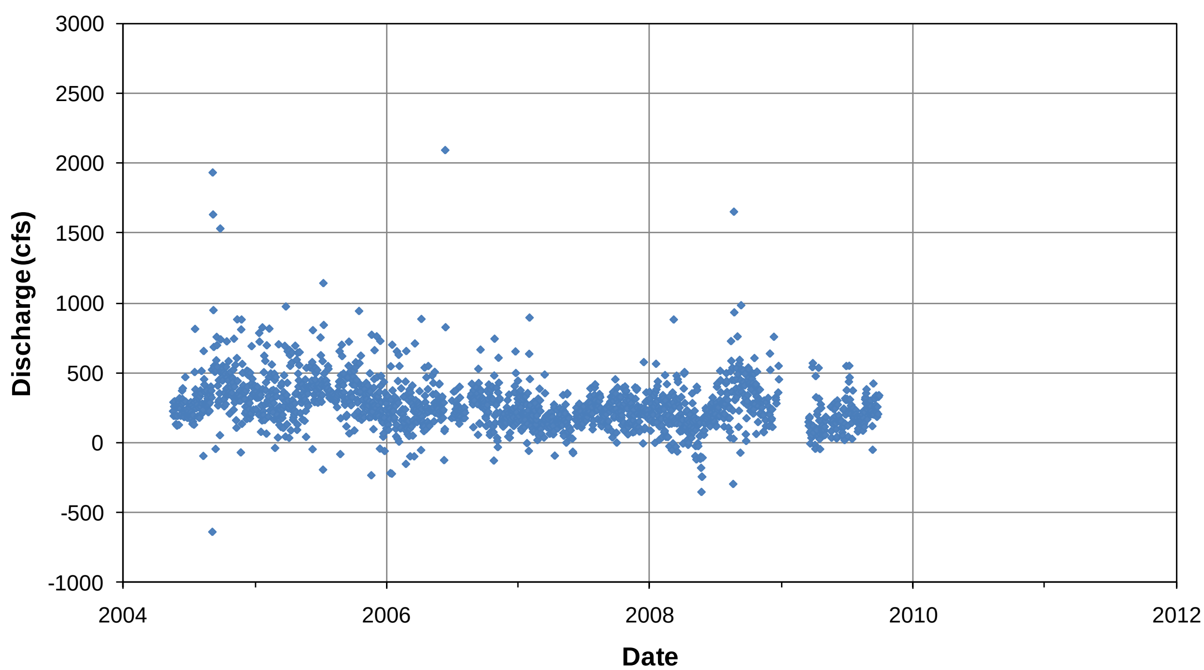


Figure 2-18. Period of record daily mean tidally-filtered discharge time series for the U.S. Geological Survey Homosassa River at Homosassa FL gage site (number 02310700). All values shown are approved by the Survey.

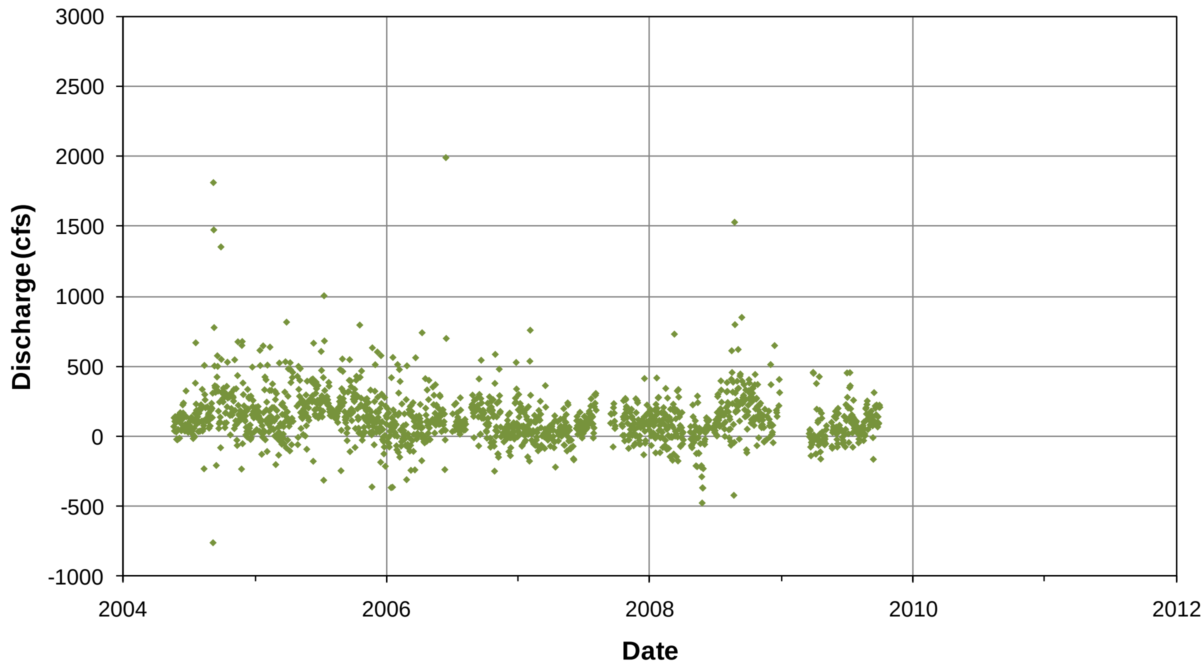


Figure 2-19. Estimated daily mean tidally-filtered discharge time series for Halls River. Values estimated by subtracting approved discharge records for the U.S. Geological Survey Homosassa Springs at Homosassa Springs FL and SE Fork Homosassa Springs at Homosassa Springs FL gage sites from the records for the Homosassa River at Homosassa FL gage site.

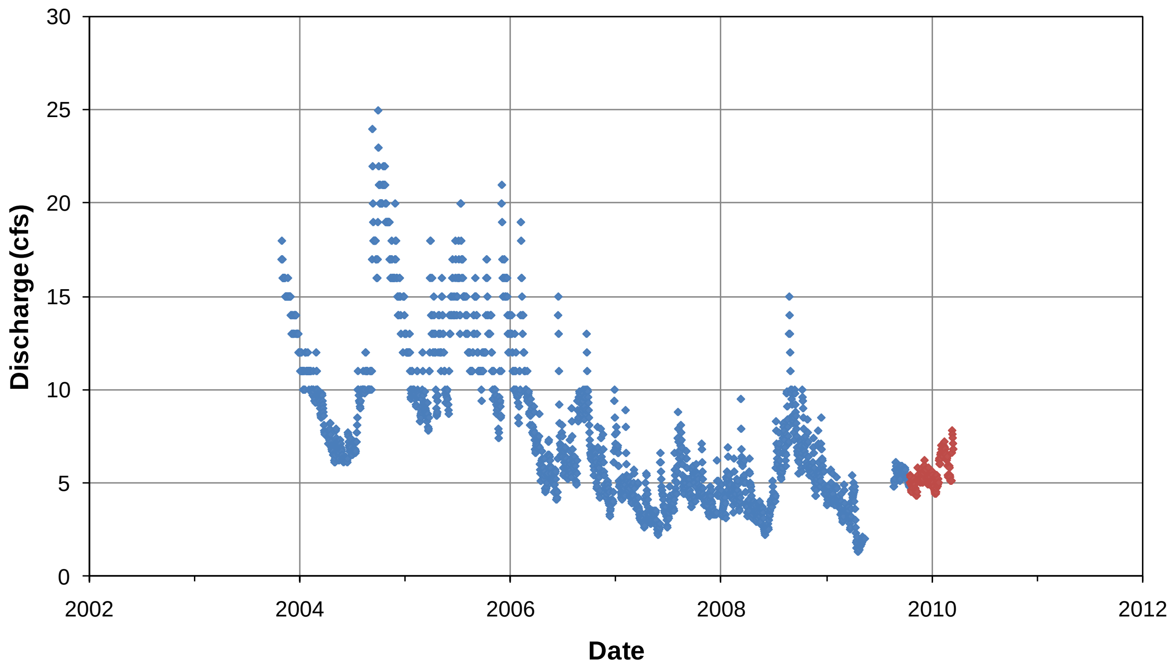


Figure 2-20. Period of record daily mean discharge time series for the U.S. Geological Survey Hidden River near Homosassa Springs FL gage site (number 02310675). Values approved by the Survey are shown in blue; provisional values are shown in red.

2.4.5 Discharge – Historical Instantaneous Records

In addition to daily mean discharge records for sites in the Homosassa River system, the U.S. Geological Survey maintains discrete or instantaneous discharge records for Homosassa Springs and Southeast Fork gage sites in their National Water Information System Water Quality and Surface-Water Field Measurement data sets. The records in the Survey's Water Quality database are coded as "historical" data and this descriptor is used in this report to differentiate discharge records from the Water Quality and Surface Water Field Measurement data sets from the daily mean records discussed in the preceding section of this report chapter. Historical records for the Homosassa and Southeast Fork gage sites have been used by others for characterization of discharge in the Homosassa River system (*e.g.*, Ferguson *et al.* 1947, Mann and Cherry 1969, Rosenau *et al.* 1977, Scott *et al.* 2002, 2004).

The U.S. Geological Survey Water Quality database includes 115 discharge measurements made between October 1930 and September 1978 at the Homosassa Springs at Homosassa Springs, FL gage site. The Surface-Water Field Measurements database includes 386 discharge measurements collected at the site between June 1984 and October 2009. One hundred eleven of the 115 records in the Water Quality database are reported as instantaneous measurements, meaning they were recorded at one time during the day. The discharge records in the Surface-Water Field Measurements data set are all instantaneous measurements.

The mean and median for the 501 discharge measurements in the "historical" Homosassa Springs at Homosassa Springs gage site record (which is shown in Figure 2-21) are 94.6 and

92.5 cubic feet per second (cfs), respectively. A composite discharge record that includes both “historical” and “daily means” discharge records (Figure 2-22) yields mean and median values of 89.5 and 89.0 cfs, which are similar to the mean (89.0 cfs) and median (88.0 cfs) values for the approved “daily means” record. The “historical” record with averaged values for the dates with multiple instantaneous discharge measurements includes a total of 177 records, with mean and median values of 107.8 and 104.0 cfs, respectively. Combination of this record with the “daily means” record (Figure 2-23) yields mean (89.6 cfs) and median (89.0 cfs) discharge values that are similar to the mean and median values for the approved “daily means” record. The minimal influence of the “historical” records on measures of central tendency for the composited flows at the Homosassa Springs at Homosassa gage site is not unexpected, given differences in the frequency of flow measurement for the “historical” and “daily means” data sets. The mean and median of annual average discharge values for the composite record were 105.9 and 101.6 cfs, respectively. These annual values are higher than the values based on the “daily means” discharge record, as a result of higher individual “historical” records in years with multiple records and years with only a single record.

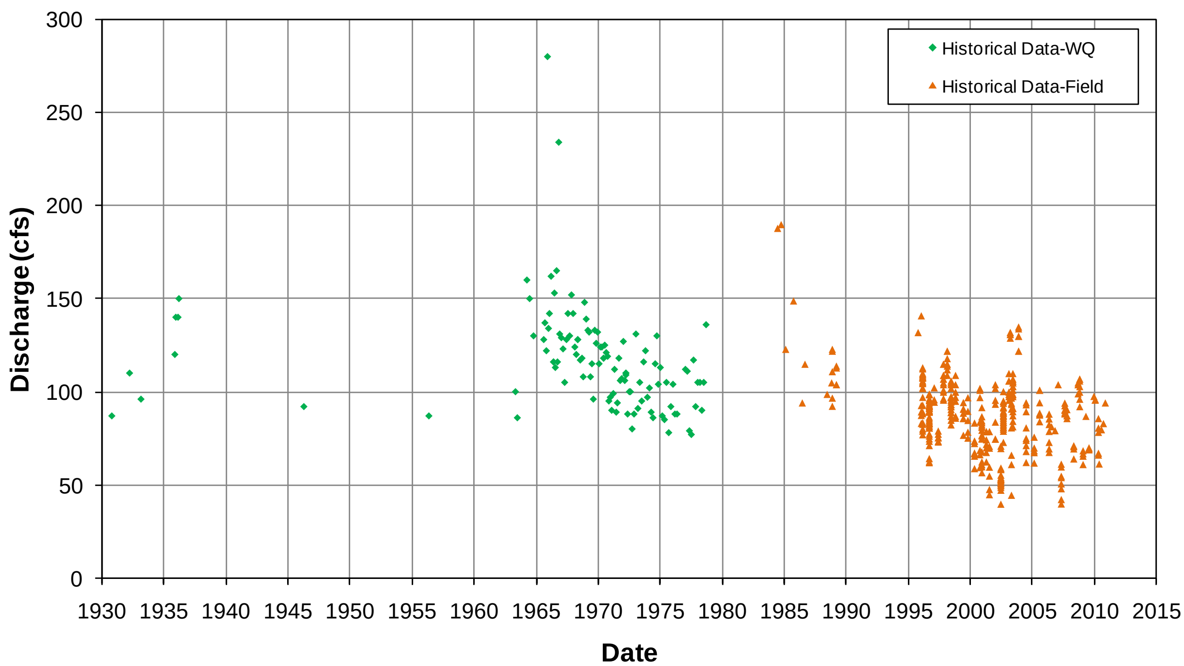


Figure 2-21. Period of record “historical” discharge time series for the U.S. Geological Survey Homosassa Springs at Homosassa Springs FL gage site (number 02310678). Historical values include records available from the Survey’s National Water Information System Water Quality (WQ) and Surface-Water Field Measurement data sets.

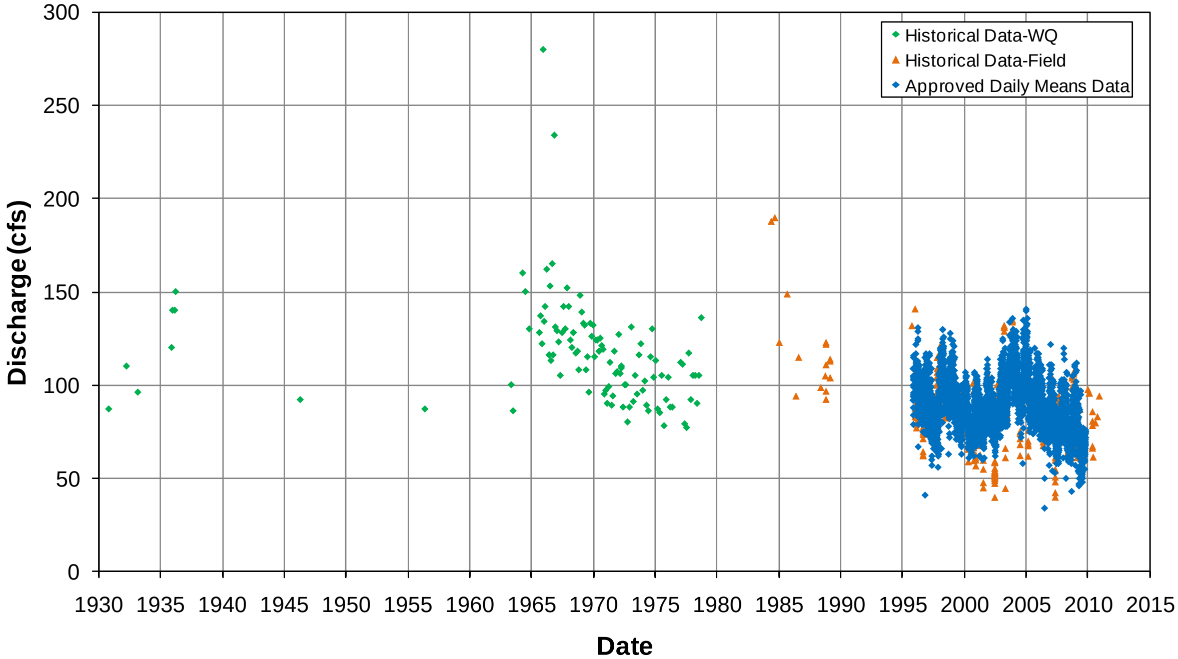


Figure 2-22. Period of record approved daily mean and "historical" discharge time series for the U.S. Geological Survey Homosassa Springs at Homosassa Springs FL gage site (number 02310678). Historical values include records available from the Survey's National Water Information System Water Quality (WQ) and Surface-Water Field Measurement data sets.

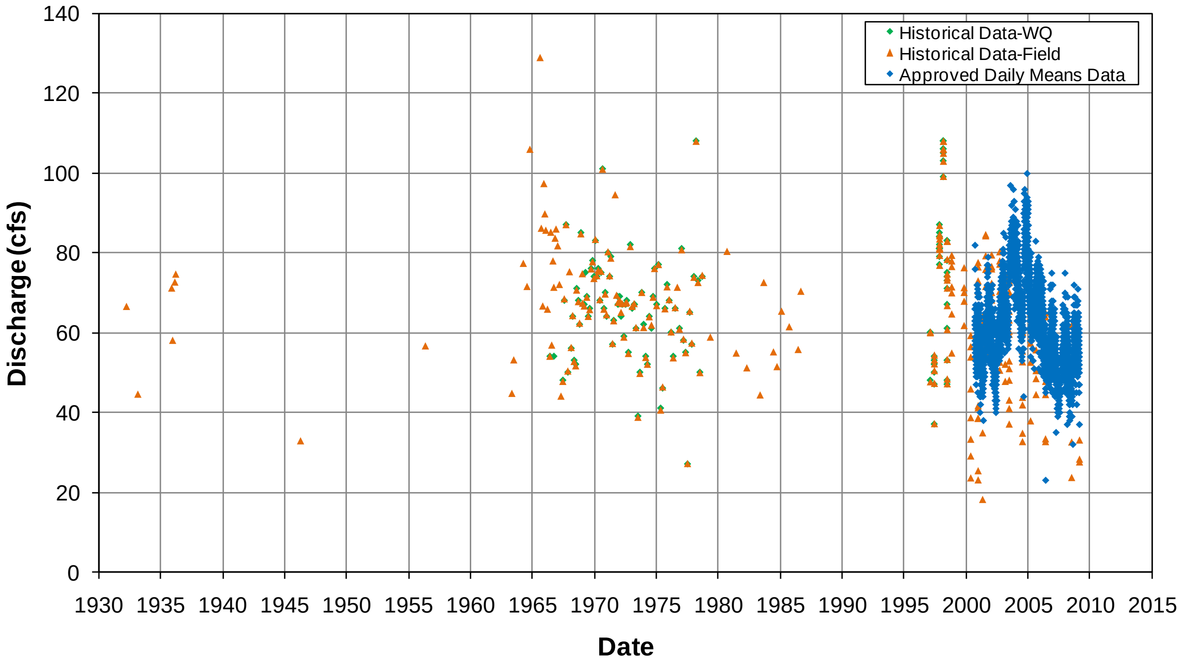


Figure 2-23. Period of record approved daily mean and daily average historical discharge time series for the U.S. Geological Survey Homosassa Springs at Homosassa Springs FL gage site (number 02310678). Historical values include records available from the Survey's National Water Information System Water Quality (WQ) and Surface-Water Field Measurement data sets, with daily replicates (Reps) averaged.

The USGS National Water Information System Water Quality and Surface-Water Field Measurement databases also include discharge records for the Southeast Fork Homosassa Spring at Homosassa Springs, FL gage site. A total of 123 records collected from May 1966 through June 1998 are currently available from the water quality database and 302 discharge records collected from March 1932 through December 2010 are available from the surface-water field measurement database. All but two of the records in the water-quality database, and all of the records in the surface-water database are reported as instantaneous measurements, meaning they were recorded at a single time during the day. Most of the records in these two data sets are single values recorded on individual dates, although 40 of the "water-quality" records are instantaneous measurements that were taken multiple times during the day on five separate dates in 1998, and 171 of the "surface-water" records are instantaneous measurements that were recorded on a total of 24 dates.

The mean and median for the 425 discharge measurements in the "historical" Southeast Fork Homosassa Springs gage site record (which is shown in Figure 2-24) are 65.4 and 66.0 cubic feet per second (cfs), respectively. A composite discharge record that includes both "historical" and "daily means" discharge records (Figure 2-25) yields mean and median values of 61.4 and 60.0 cfs, which are similar or the same as the mean (61.1 cfs) and median (60.0 cfs) values for the approved "daily means" record. The "historical" record with averaged values for the dates with multiple instantaneous discharge measurements includes a total of 243 records, with mean and median values of 65.7 and 66.6, respectively. Combination of this record with the "daily means” record (Figure 2-26) yields mean (61.4 cfs) and median (60.0 cfs) discharge values that are also similar or the same as the mean and median values for the approved “daily means” record. As noted for flow records for Homosassa Springs at Homosassa gage, the minimal influence of “historical” records on measures of central tendency for the composited flows at the Southeast Fork Homosassa gage site is not unexpected, given differences in the frequency of flow measurement for the “historical” and “daily means” data sets. The mean and median of annual average discharge values for the composite record were 63.3 and 62.9 cfs, respectively, and are similar to values calculated for the “daily mean” and “historical” records.

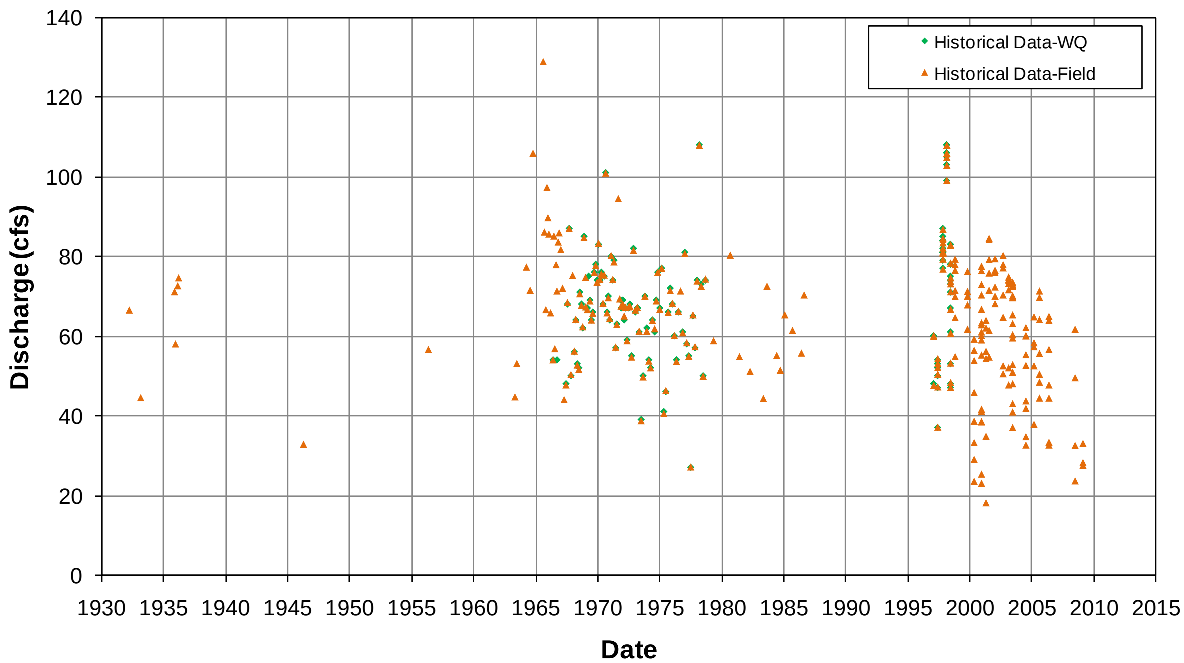


Figure 2-24. Period of record “historical” discharge time series for the U.S. Geological Survey SE Fork Homosassa Springs at Homosassa Springs FL gage site (number 02310688). Historical values include records available from the Survey’s National Water Information System Water Quality (WQ) and Surface-Water Field Measurement data sets.

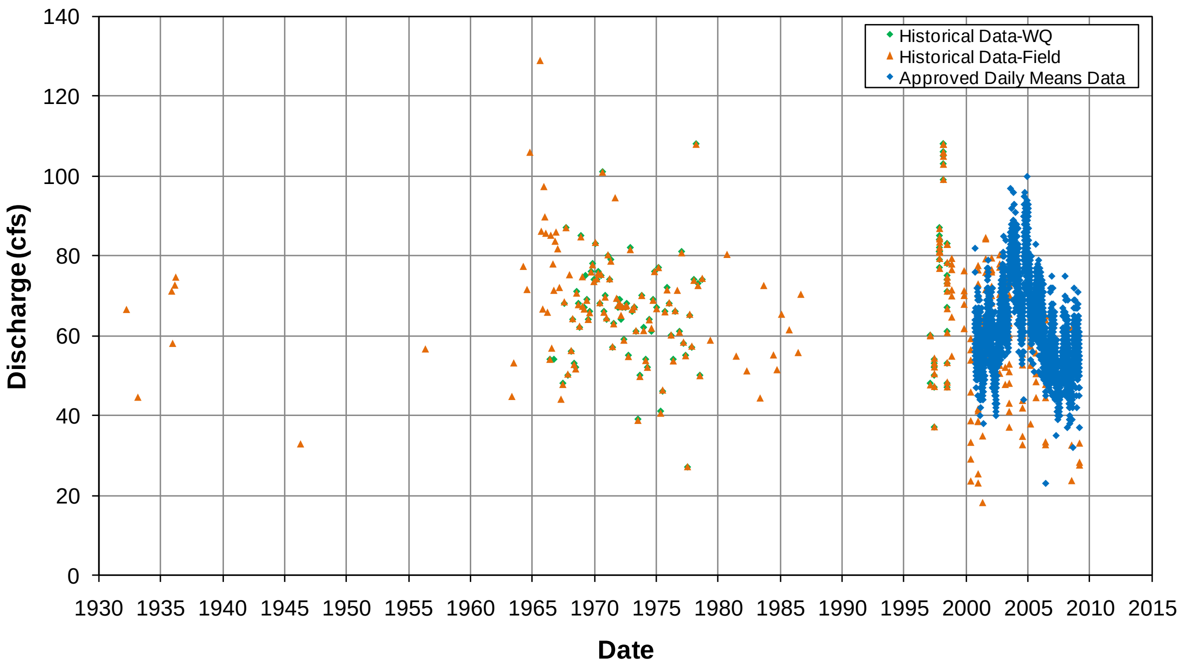


Figure 2-25. Period of record approved daily mean and historical discharge time series for the U.S. Geological Survey SE Fork Homosassa Springs at Homosassa Springs FL gage site (number 02310688). Historical values include records available from the Survey's National Water Information System Water Quality and Surface-Water Field Measurement data sets.

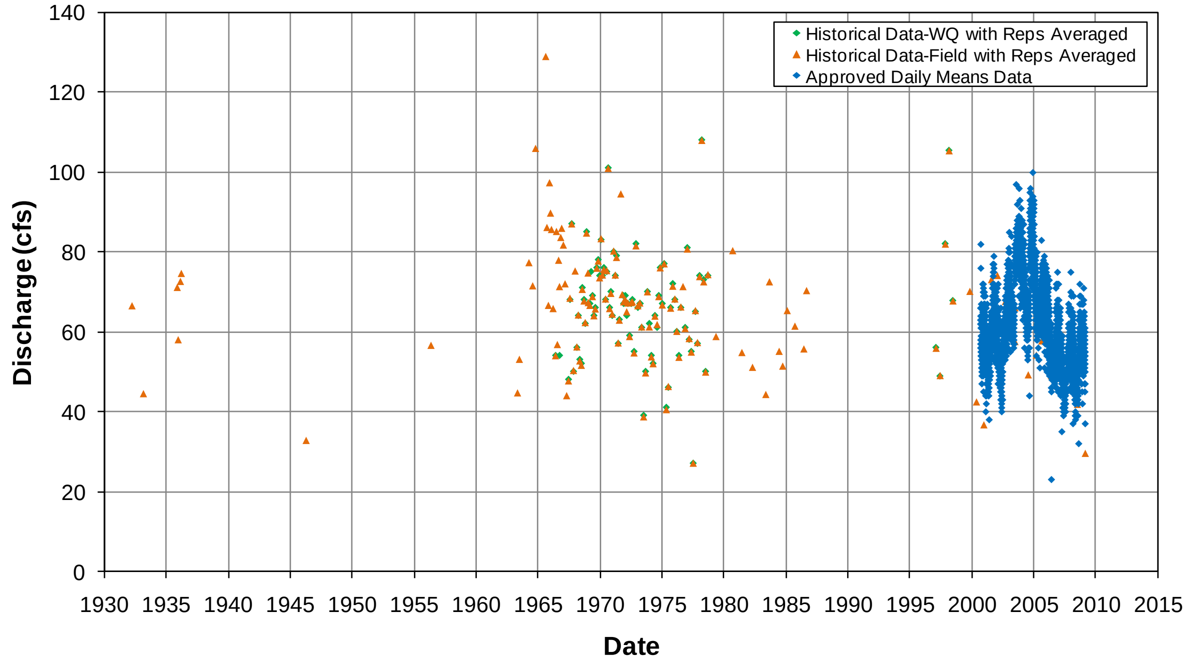


Figure 2-26. Period of record approved daily mean and daily average historical discharge time series for the U.S. Geological Survey SE Fork Homosassa Springs at Homosassa Springs FL gage site (number 02310688). Historical values include records available from the Survey's National Water Information System Water Quality and Surface-Water Field Measurement data sets, with daily replicates (Reps) averaged.

2.4.6 Discharge – Consideration of Mean Daily Records and Historical Instantaneous Records

It is well documented that discharge from most springs in the Homosassa River system is affected by tides, so instantaneous discharge measurements for the Homosassa Springs and Southeast Fork gage sites in the "historical" United States Geological Survey databases may be expected to vary considerably throughout any given day, depending on the tide stage at the time of measurement. In contrast, the daily mean discharge records reported by the United States Geological Survey are based on up to 96 discharge estimates for each day of record, and as such, better represent tidally-averaged values.

The daily-mean discharge records included in this draft report on recommended minimum flows for the Homosassa River system are classified by the United States Geological Survey as "approved" for publication, following agency processing and review, and "provisional", *i.e.*, subject to revision. Of these data, only approved values were used for the data summaries and analyses supporting development of minimum flow recommendations for the river system. In contrast to the daily-mean discharge values, records in the Survey's water quality database are coded as "historical" data rather than "reviewed and accepted" data. The differences in how the discharge records were derived, *i.e.*, as instantaneous or daily mean values, and the data quality coding attributed to the records by the United States Geological Survey suggest that the daily mean and "historical" discharge values may not be directly comparable. The "historical" discharge records included in the field-measurements database may similarly not be considered comparable to the daily mean discharge records. The discontinuous nature of the "historical" discharge values for the Homosassa Springs and Southeast Fork gage sites also limits the utility of these records for minimum flows development.

Based on the existence of tidal effects on spring discharge, the discontinuous nature of the "historical" discharge records, and the determination that observed variability in "historical" and more recent discharge records is consistent with available rainfall information and not indicative of a flow decline that may be attributed to anthropogenic activities (see next section of this report), staff elected to exclude "historical" discharge records from summary analyses used to develop minimum flow recommendations for the Homosassa River system.

2.4.7 Discharge – Relationships with Rainfall and Groundwater Levels

Observed variation in discharge measurements for the Homosassa Springs and other United States Geological Survey gage sites in the river system are consistent with long and short term regional rainfall patterns. For example, the period of relatively higher "historical" discharge around 1965 at the Homosassa Springs gage site (refer to Figure 2-21) corresponds with above average annual rainfall totals for 1965 and the preceding year (see Figure 2-10). Similarly, the apparent decrease from peak "historical" discharge values to the lower values measured at the site in the 1970s corresponds with a number of years in the late-1960s and early 1970s with below average annual rainfall. As expected, more recent discharge patterns also reflect rainfall conditions, with relatively lower discharge values corresponding with a period of generally below average rainfall, except for the period from 2002 through 2004, when rainfall was above average (see Figure 2-10) and discharge exhibited an increasing trend at both the Homosassa Springs and Southeast Fork gage sites (refer to Figures 2-15 and 2-17).

Water levels in the Upper Floridan aquifer in the vicinity of the Homosassa River system also show correspondence with rainfall patterns. Basso (2010, included as Appendix B to this report) reviewed water levels at the Lecanto 2 Upper Floridan Aquifer well based on the proximity of the well to the headwater springs of the river system and the length of the relatively continuous well water-level record, which includes measurements dating back to 1965. Simple linear regression of monthly water levels from September 1965 through January 2010 shows a statistically significant downward trend ($n = 534$; $p < 0.01$) (Figure 2-27). Much of the decline in water levels at this well is related to lower than average rainfall during the period. A cumulative sums graph of annual rainfall measured at the National Weather Service Brooksville station versus mean annual water level from the Lecanto 2 well (Figure 2-28) shows only minor deviation in slope over the period of record, suggesting that rainfall is a dominant factor in the water level fluctuations observed at the Lecanto 2 well.

Collectively, available "historical" and "daily means" discharge records for the Homosassa Springs and Southeast Fork gage sites, long-term rainfall and area well water level records are not suggestive of substantial anthropogenic reductions in historic spring flows in the Homosassa River system. This assertion is explored in greater detail in the subsequent section of this chapter and in Appendix B.

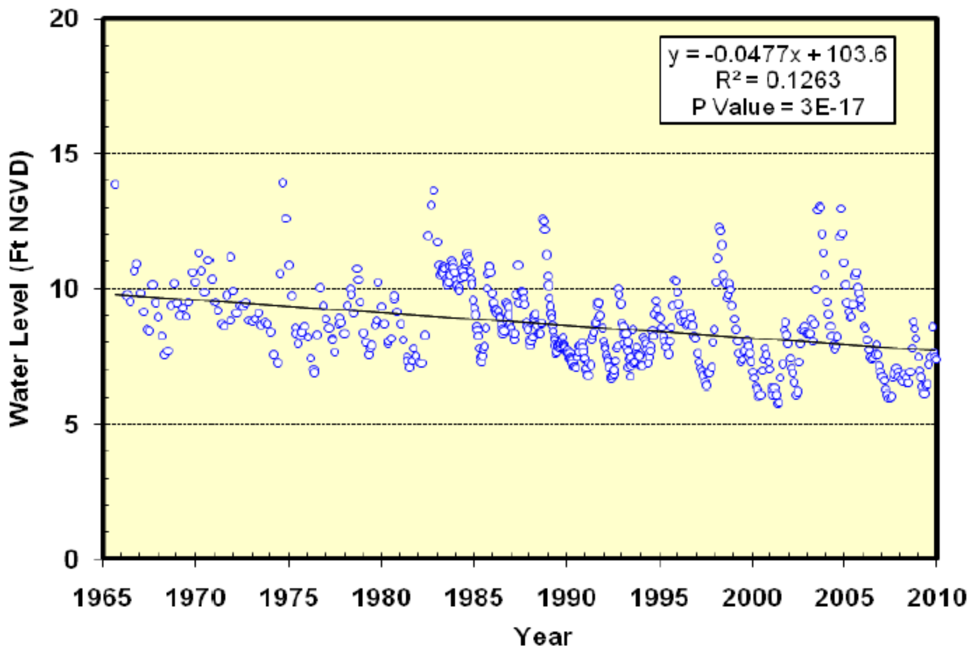


Figure 2-27. Monthly water levels at the Lecanto 2 Upper Floridan aquifer well from September 1965 through January 2010 (plot reproduced from Basso 2010).

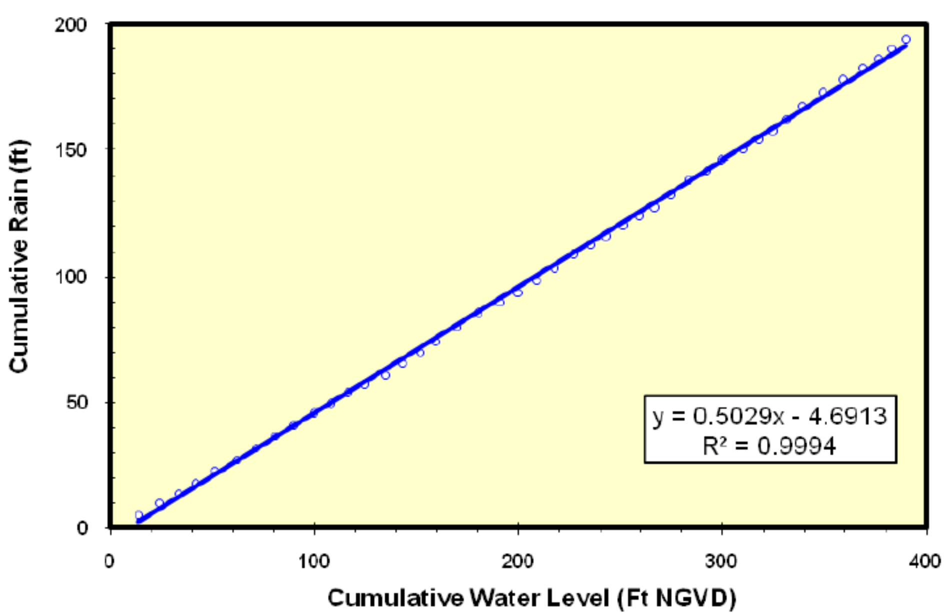


Figure 2-28. Cumulative sums of mean annual Lecanto 2 Upper Floridan aquifer well water levels and rainfall at the Brooksville National Weather Service gage site from 1965 through 2008 (plot reproduced from Basso 2010).

2.4.8 Discharge – Water Use Impacts on Spring Discharge

In the late 1980s, the United States Geological Survey developed a digital ground-water model of the Upper Floridan Aquifer system for the portion of west-central Florida that includes the Homosassa River system (Yobbi 1989). The model was used to evaluate changes in spring discharge associated with hypothetical withdrawals totaling 116 cfs (75 million gallons per day or mgd) from five wellfields distributed from Crystal River to a point south of the border between Citrus and Hernando counties. The model was also used to evaluate potential effects associated with individual 62 cfs (40 mgd) withdrawals located within four-square-mile model grids in the vicinity of major area springs. Results for the Homosassa River system indicate that discharge from Hidden River Springs and combined discharge from Homosassa Springs, the Southeast Fork Homosassa Springs and Halls River Springs would be reduced by eight percent in response to the simulated withdrawal of 75 mgd from hypothetical regional wellfields. Simulated withdrawals of 40 mgd in the vicinity of Hidden River and Homosassa Springs resulted in respective fourteen and thirteen percent decreases in spring discharge. Yobbi (1989) notes that his reported results should be considered speculative, because at the time of the USGS modeling effort, no appreciable ground-water withdrawals were occurring in the region and the modeled withdrawals in the proximity of individual springs would not likely be allowed under the then existing water-use regulations.

More recently, Knochenmus and Yobbi (2001) developed water budgets for a two-year period (January 1997 through December 1998) for ground-water basins associated with the Aripeka, Weeki Wachee, Chassahowitzka and Homosassa spring systems. Estimated ground-water withdrawals in the Homosassa Springs basin for the two year period totaled 0.6 inches per year and included permitted water-use in area counties and non-permitted use in Citrus County, where individual water-withdrawals less than the District's threshold requirement for issuance of a water-use permit are relatively common. Withdrawals accounted for 1.2 percent of the total combined outflow components of the water budget (evapotranspiration, spring discharge, ground-water flow and withdrawals). Knochenmus and Yobbi (2001) emphasize the minimal impact of water withdrawals on area water budgets, noting that *"…little if any of the ground water pumped from the Coastal Springs Ground Water Basin is exported from the area, and a portion of the pumped volume is returned to the basin*."

In support of the minimum flows development for the Homosassa River system, Basso (2010, see Appendix B) evaluated rainfall, Upper Floridian Aquifer levels, area water withdrawals, and modeled withdrawal impacts on ground-water levels and spring discharge in the Homosassa River system. As noted in the previous section of this report, Basso reports a statistically significant downward trend in water levels in the Lecanto 2 Upper Floridan Aquifer well (which is about 9.5 miles southeast of the Homosassa Main Springs complex) for the period from 1965 through 2009, but notes that this trend is consistent with regional rainfall patterns. He also notes that in 2005, groundwater withdrawals within five miles of the Homosassa Main Springs averaged 1.3 mgd, and averaged 8.2 mgd within ten miles of the spring complex. On a broader, regional scale, Basso reports that average annual groundwater withdrawals totaled 438.1 mgd in 2005 within the Northern District groundwater flow model (Northern District Model) domain (Figure 2-29), an area that includes all of Citrus, Hernando, Pasco and Sumter Counties and significant portions of adjacent counties.

For identification of potential effects of water withdrawals in the Homosassa River system, the Northern District Model was used to simulate spring discharge and the potentiometric surface of the Upper Floridan Aquifer system for scenarios with and without regional groundwater pumping. The Northern District Model is the first regional, west-central Florida model that represents the groundwater system as fully three-dimensional, with top and bottom elevations specified for each of the seven layers included in the model. The Northern District Model was calibrated to steady-state 1995 calendar-year conditions and transient conditions from 1996 through 2002 using monthly stress periods. Additional details regarding model development and use are available in HydroGeoLogic, Inc. (2008, 2010) and Basso (2010).

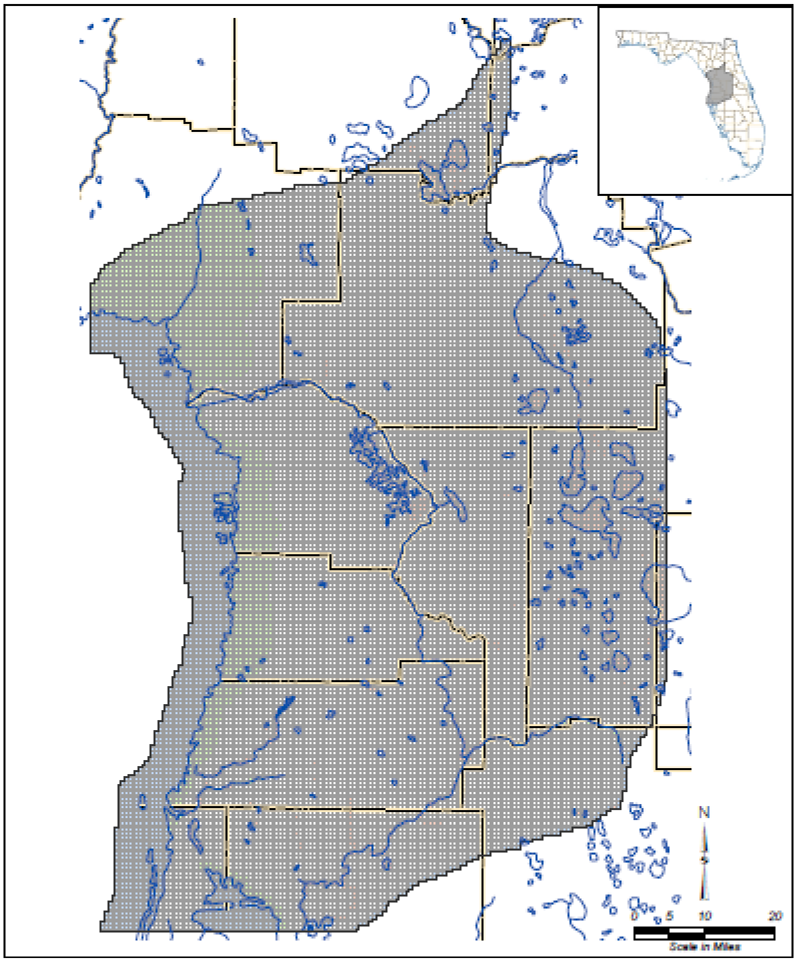


Figure 2-29. Domain and grid for the Northern District Model (image source: HydroGeoLogic, Inc. 2008).

To determine drawdown in the Upper Floridan aquifer and potential impacts to spring discharge in the Homosassa River system, the average annual groundwater withdrawals of 438.1 mgd in 2005 were simulated in the Northern District Model under long-term transient conditions (five years) to approximate steady-state conditions. Results from this scenario were compared with results from a non-pumping scenario that was simulated as described by Water Resources Associates, Inc. (2010) by running the model in transient mode for one year to match elevations for pre-development potentiometric surface contours of the Upper Floridan aquifer presented by Johnston *et al.* (1980). The difference in water levels in the Upper Floridan aquifer between the non-pumping and 2005 withdrawal scenario is the predicted drawdown under current conditions.

Flows were also simulated in the model for most of the springs within the Homosassa group. The difference in simulated flow between the non-pumping condition and 2005 withdrawals condition is the predicted springflow decline due to current water withdrawals.

In the Homosassa River system area, drawdown in the potentiometric surface of the Upper Floridan aquifer associated with the 438.1 mgd annual average withdrawal was less than 0.1 feet at the Homosassa Springs group. The predicted decrease in combined discharge from springs in the Homosassa River system included in the Northern District Model was 2.3 cfs, a value that represented a 1.1 percent decrease from the total combined discharge of 210 cfs predicted for the springs in the modeled scenario without withdrawals (Table 2-4). Predicted decreases associated with modeled withdrawals ranged from 0.9 to 4 percent, with the highest decrease predicted for Hidden River Head Spring. The predicted 4 percent decrease in discharge for Hidden River Head Spring, corresponded to a reduction of only 0.3 cfs.

Given the relatively minor (1.1 percent) potential impact of withdrawals on spring discharge in the Homosassa River system that were identified by Basso (2010), measured and modeled flows used for the initial minimum flow analyses presented in Chapters 3 through 5 of this report were not adjusted and were considered baseline flows. Flow adjustments based on estimated withdrawal impacts were, however, subsequently evaluated and used for analyses supporting development of revised minimum flow recommendations, as summarized in Chapter 7.

Table 2-4. Predicted discharge for selected springs in the Homosassa River system, based on the Northern District groundwater flow model for non-pumping and 2005 withdrawal scenarios (adapted from Basso 2010).

Spring	Spring Location	Discharge for Non-Pumping Scenario (cfs)	Discharge for 2005 Pumping Scenario (cfs)	Difference (cfs)	Percent Difference
Homosassa Main Springs	Homosassa River	71.65	70.98	0.67	0.9
Abdoney Spring	Southeast Fork	4.98	4.93	0.05	0.9
Belcher Spring	Southeast Fork	4.98	4.89	0.10	2.0
McClain Spring	Southeast Fork	4.98	4.93	0.05	0.9
Pumphouse Spring	Southeast Fork	4.97	4.92	0.05	0.9
Trotter No. 1 Spring	Southeast Fork	4.97	4.93	0.05	0.9
Halls River No. 1 Spring	Halls River	5.00	4.95	0.05	0.9
Halls River Head Spring	Halls River	102.11	101.06	1.05	1.0
Hidden River Head Spring	Hidden River	6.61	6.35	0.26	4.0
Total		**210.2**	**207.9**	**2.31**	**1.1**

Drawdown in the Upper Floridan aquifer and potential impacts to spring discharge in the Homosassa River system were also examined with the Northern District Model based on projected water demand for the year 2030. This year was selected to address a twenty-year water planning horizon for water supply purposes and coincides with a time-frame appropriate for implementing or evaluating future compliance with minimum flows and levels to be established for the Homosassa River system. The year 2030 withdrawal analyses were similar to those described for the 2005 conditions, with the exception that drawdown in the Upper Floridan aquifer and potential impacts to spring discharge in the Homosassa River system were based on estimated annual groundwater withdrawals of 576.1 mgd for year 2030. Withdrawals predicted for year 2030 were distributed or dispersed at current withdrawal points within the model domain. In the Homosassa River system area, drawdown in the potentiometric surface of the Upper Floridan aquifer associated with the predicted 2030 annual average withdrawal was less than 0.1 feet. The predicted decrease in combined discharge from springs of the Homosassa River system included in the Northern District Model was 5.1 cfs, a value that represented a 2.4 percent decrease from the total combined discharge of 210 cfs predicted for the springs in the modeled scenario without withdrawals (Table 2-5). Predicted decreases associated with modeled withdrawals ranged from 2.1 to 8.5 percent, with the highest decrease predicted for Hidden River Head Spring. The predicted 8.5 percent decrease in discharge for Hidden River Head Spring, corresponded to a reduction of 0.6 cfs.

Table 2-5. Predicted discharge for selected springs in the Homosassa River system, based on the Northern District groundwater flow model for non-pumping and 2030 withdrawal scenarios.

Spring	Spring Location	Discharge for Non-Pumping Scenario (cfs)	Discharge for 2030 Pumping Scenario (cfs)	Difference (cfs)	Percent Difference
Homosassa Main Springs	Homosassa River	71.65	70.16	1.49	2.1
Abdoney Spring	Southeast Fork	4.98	4.87	0.11	2.1
Belcher Spring	Southeast Fork	4.98	4.77	0.21	4.3
McClain Spring	Southeast Fork	4.98	4.87	0.11	2.1
Pumphouse Spring	Southeast Fork	4.97	4.87	0.10	2.1
Trotter No. 1 Spring	Southeast Fork	4.97	4.87	0.10	2.0
Halls River No. 1 Spring	Halls River	5.00	4.9	0.10	2.1
Halls River Head Spring	Halls River	102.11	99.76	2.35	2.3
Hidden River Head Spring	Hidden River	6.61	6.05	0.56	8.5
Total		**210.2**	**205.12**	**5.13**	**2.4**

Impacts associated with potential withdrawals for year 2030 have also recently been evaluated by Water Resource Associates, Inc. (2010) as part of a water-supply feasibility analysis completed for the Withlacoochee Regional Water Supply Authority. Using the Northern District Model, Water Resource Associates, Inc. report that year 2030 predicted withdrawals would be expected to decreased pre-development (no withdrawals) spring discharge in the Homosassa River system by 1.6 cfs, which corresponds to a 1.9 percent decrease in pre-development discharge.

2.5 Bathymetry and River-Kilometer System

To support development of minimum flows for the Homosassa River system, the District contracted with the University of South Florida to map shoreline and complete a bathymetric survey of the system and surrounding areas. For the survey, bottom substrate elevations in the Homosassa River, Halls River and tributary channels off the Homosassa River were measured near the shoreline, along the centerline of main channels and across 257 channel cross-sections spaced approximately 500 feet apart using a boat-mounted real-time kinematics global positioning system and a survey-grade Odom echo sounder (Wang 2007; included as Appendix C to this report). A survey of Hidden River was not included in this effort. The surveyed bottom elevation data were referenced to the North American Vertical Datum of 1988 (NAVD88). Data processing of the bathymetric data set with Esri ArcGIS software included creation of a triangulated integrated network of the river segment ground and river bottom elevations (Figure 2-30).

Mapped shoreline and bathymetric survey data were provided to HSW Engineering, Inc. by the District for development of bathymetric data sets used to support much of the analyses described in the remainder of this report, including the salinity and thermal modeling conducted to support minimum flow recommendations. As part of this effort, a river kilometer system (Figure 2-31) was developed to describe distances along the Homosassa River from a point near Shell Island (Rkm 0) to a point near the upstream terminus of the South Fork of the Homosassa River (Rkm 13). A river-kilometer system was also developed for the Halls River, from the river’s confluence with the Homosassa River (at Halls River Rkm 0) to the Halls River Head Spring at Rkm 5.6. Bathymetric data were processed by HSW Engineering, Inc. (2011) using Esri ArcGIS 9.2 and SURFER to develop stage-area-volume relationships for the Halls River and the main channel of the Homosassa River from Rkm 0 to approximately Rkm 12.5, near the confluence of the Homosassa River and Southeast Fork of the Homosassa River. Area and volume information were also estimated for individual 500-m to 100-m segments of the main Homosassa River channel. Area and volume were not estimated for the Southeast Fork of the Homosassa River or the approximate 300-m reach of the Homosassa River downstream from the Main Homosassa Spring complex.

At a reference elevation of 0.0 feet NAVD88, the main channel of the Homosassa River extends over 2.76 million square meters, or approximately 682 acres and contains approximately 3.68 million cubic meters, or 972 million gallons of water (Figure 2-32). Cumulative upstream inundated area and volume in the main channel of the Homosassa River at this same elevation by river kilometer are shown in Figure 2-33. In terms of area and volume, Halls River is much smaller than the Homosassa River. At 0.0 feet NAVD88, Halls River extends over approximately 341,000 square meters (84 acres) and includes approximately 269,000 cubic meters (71 million gallons) of water (Figure 2-34).

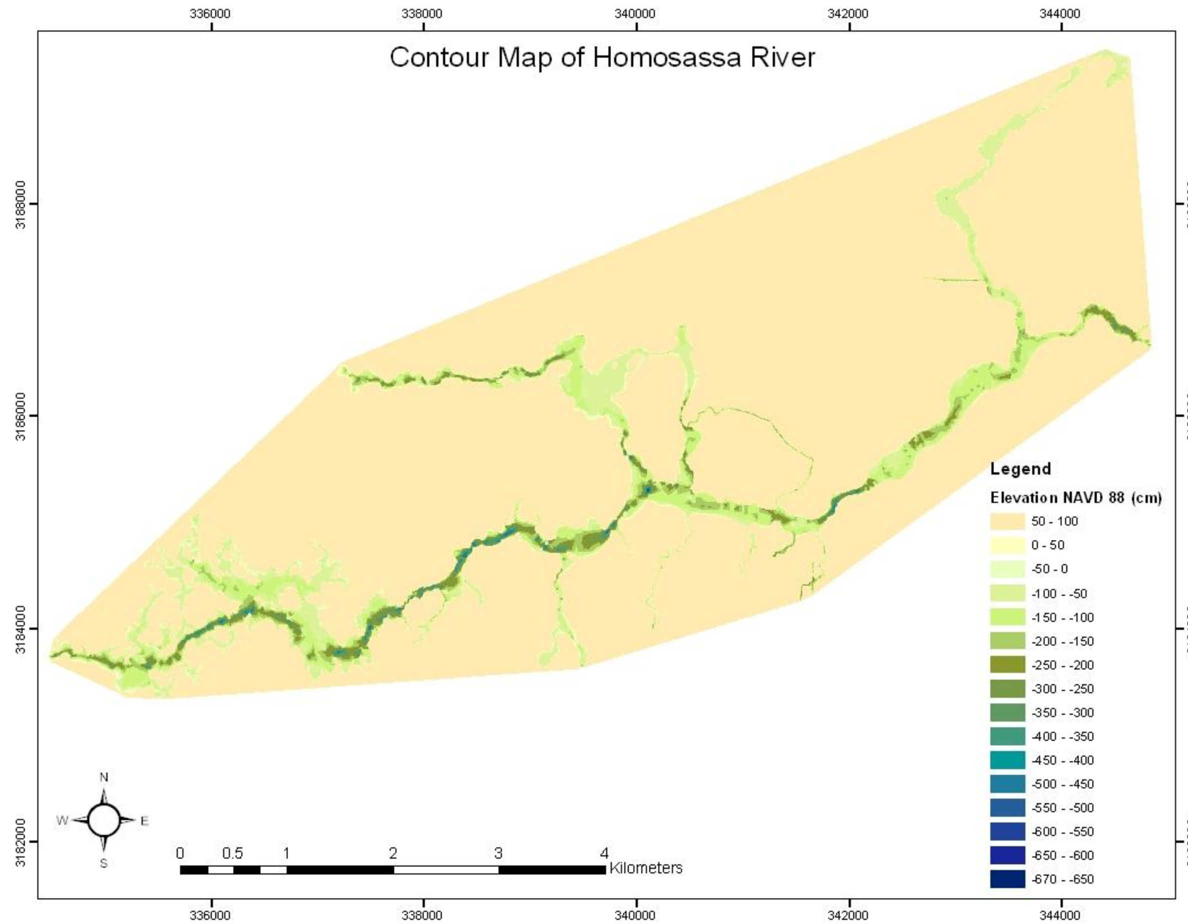


Figure 2-30. River bottom elevation contour map of the Homosassa and Halls Rivers and adjacent areas. Image provided by Ping Wang (University of South Florida).

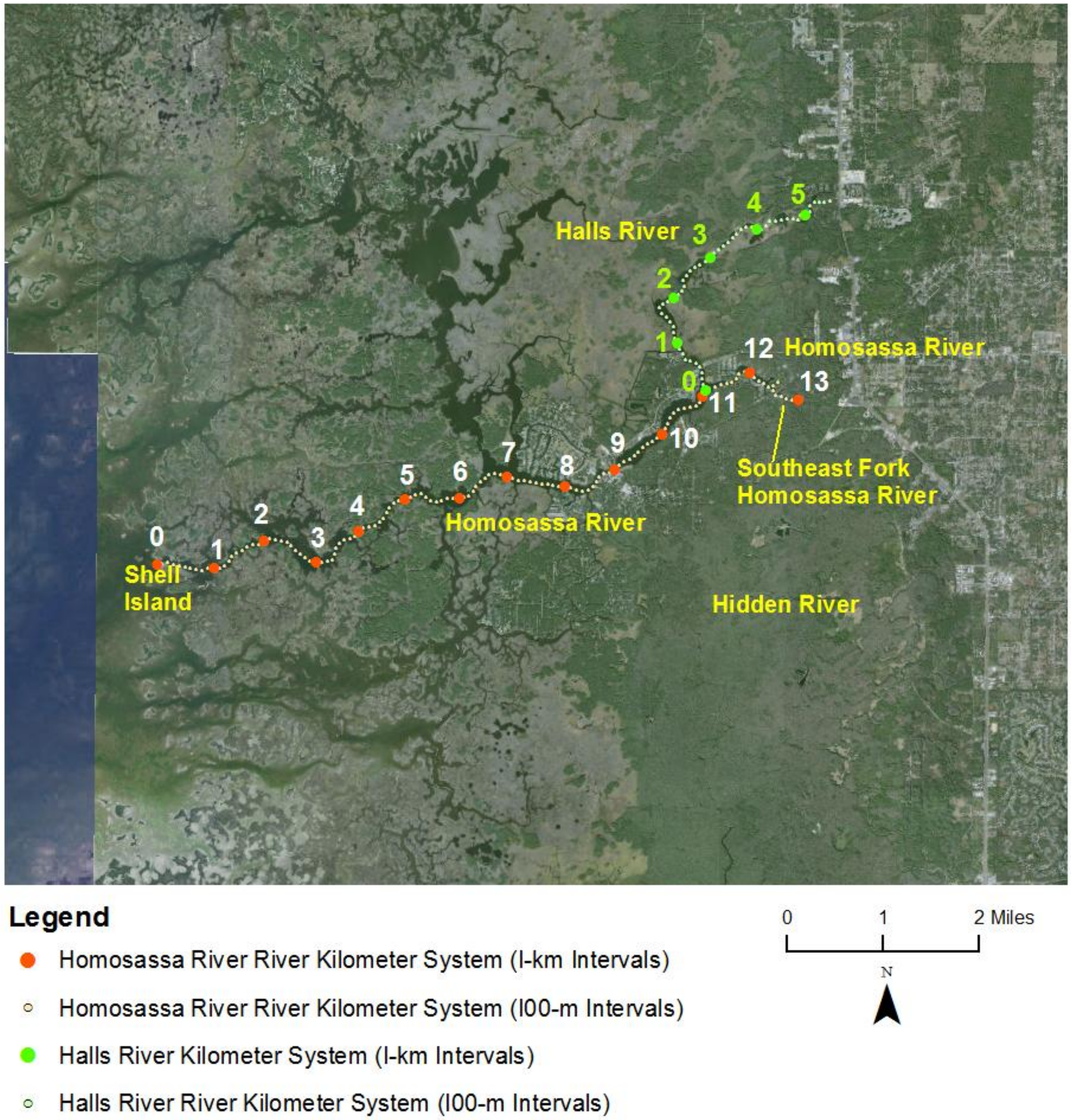


Figure 2-31. River-kilometer systems (with labeled 1-km locations) developed for the Homosassa River and Halls River to support minimum flows establishment. Note that a river-kilometer system was not developed for Hidden River (photo- graphic image sources: Southwest Florida Water Management District 2003c and Woolpert, Inc. 2009).

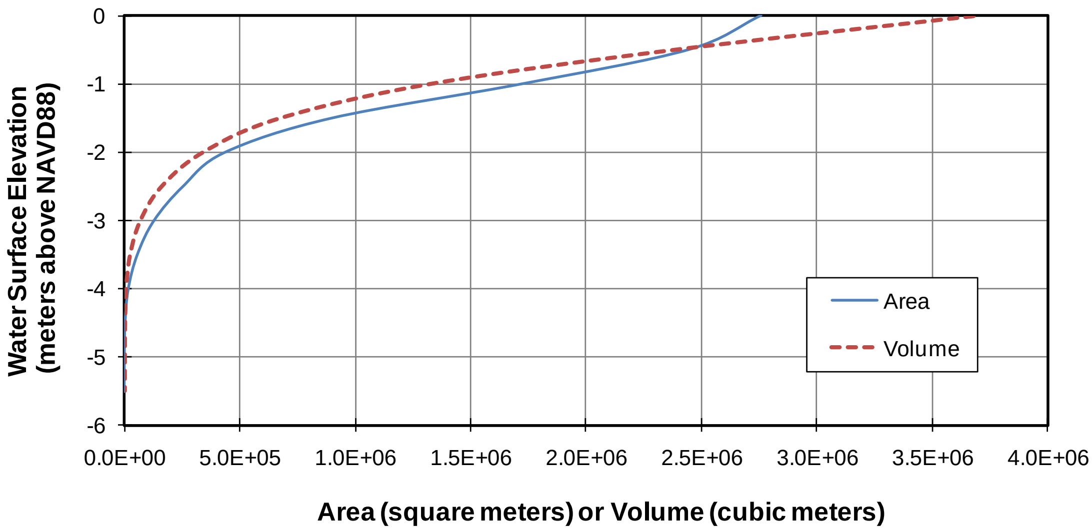


Figure 2-32. Stage-area-volume relationships for the main channel of the Homosassa River between river kilometers 0 and 12.5.

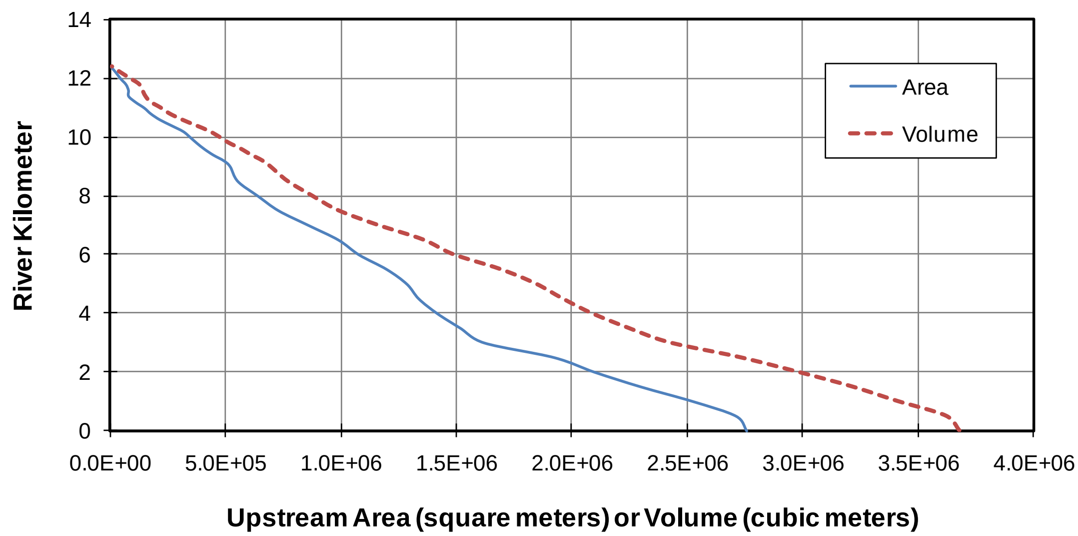


Figure 2-33. Upstream area and volume for the main channel of the Homosassa River by river kilometer from river kilometer 0 (near Shell Island) to river kilometer 12.5 (near the confluence of the Homosassa River and South Fork of the Homosassa River).

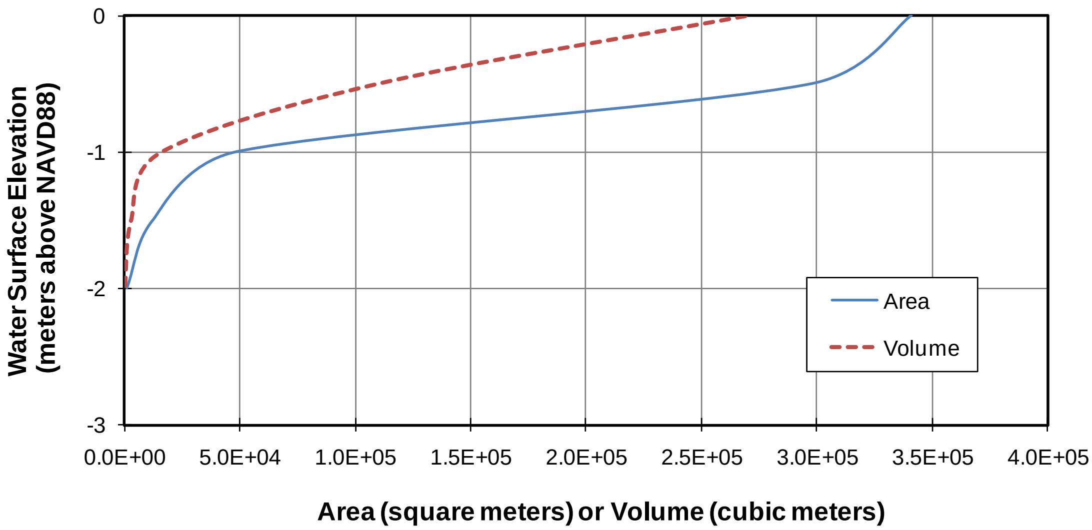


Figure 2-34. Stage-area-volume relationships for the Halls River between river kilometers 0 and 5.6.

2.6 Bottom Substrates

Sloan (1956) provides an early report on the bottom substrates of the Homosassa River from the headwaters area downstream to approximately river kilometer three. Based on sampling that was conducted in the early 1950s, substrates in the Homosassa Main Spring pool were characterized as fine yellow sand. At a site 0.2 miles downstream, Sloan noted an accumulation of organic detritus atop the sand substrate. Further downstream at a site just upstream of the confluence of the Halls and Homosassa Rivers, sediments included sand and fine black silt. Downstream substrates were characterized as mixtures of black silt, organic detritus and “shellbar”.

As part of a District-funded study of several Gulf coastal rivers, Frazer *et al.* (2001a, b) report that mud is the most common bottom type in the Homosassa River, where it was the dominant substrate at 56.7 percent of the 100 sites sampled annually in 1998, 1999 and 2000 at 20 transects located between the community of Homosassa (approximately river kilometer 7.4) and the Main Springs area. Sand was the dominant substrate at 18.3 percent of the sampled sites and a mix of mud and sand was dominant at 15 percent of the sites. Although limestone outcrops are common along the entire river, rock was dominant at only three percent of the sampled sites and a mixture of rock and mud, sand or shell was dominant at about 6.3 percent of the samples sites. Similar results regarding substrate types were reported by Frazer *et al.* (2006) based on sampling of the river from 2003 through 2006 at the same sites surveyed between1998 and 2001.

For more recent District-funded studies of the macroinvertebrates of the Homosassa River system, Grabe and Janicki (2009; included as Appendix D in this report) and Water & Air Research, Inc. (2010; included as Appendix F in this report) qualitatively characterized substrates in the system. Sampling by Grabe and Janicki was conducted on May 12-14, 2008 at

75 sites in the Homosassa River and Southeast Fork of the Homosassa River between river kilometers 0 and 13, and 10 sites in Halls River, between river kilometers 0.4 and 2.2. Shell hash was common in the Homosassa River near Shell Island, and upstream substrates were typically characterized as mixtures of “sand, silt, muck and silt.” Sand-dominated substrate was observed at only a few sites; all were located in upstream reaches of the Homosassa and Halls rivers. Oyster bars are relatively uncommon in the Homosassa River. Although Grabe and Janicki (2009) collected oysters with a dredge between river kilometer 4 and 9, Water & Air Research, Inc. (2010) observed live oyster beds at only three sites in the river, all downstream from river kilometer 1.3, during a field survey completed over two days in the fall of 2008.

2.7 Shoreline

PBS&J (2009; included as Appendix E) recently evaluated shoreline vegetation and the extent of altered shoreline along the Homosassa, Halls and Southeast Fork of the Homosassa Rivers for the District to support development of minimum flows for the Homosassa River system. Shoreline alteration status and natural vegetation within five feet of the edge of water were characterized in October 2008 in the Homosassa River from Shell Island upstream to the bridge in the Homosassa Springs Wildlife Park, approximately 106 m (~350 feet) downstream from the Homosassa Main Springs pool, and in the Southeast Fork upstream to approximately river kilometer 12.95. Shorelines of Halls River were surveyed from the river’s confluence with the Homosassa upstream to approximately river kilometer 3.2. All surveyed shorelines were classified as natural, *i.e.,* naturally vegetated or altered, with altered shorelines including areas of rip-rap, seawall, a combination of rip-rap and seawall and maintained or modified lands. Maintained shorelines include lawns and maintained landscaping. Modified shorelines were those with relatively natural vegetation that has been previously modified.

Natural vegetation occurs along approximately 71 percent of the combined 62,529 m shoreline mapped for the Halls River, Homosassa River and Southeast Fork of the Homosassa Rivers (Figure 2-35, Table 2-6). Most of Halls River upstream from the Halls River Road Bridge is naturally vegetated, including upstream areas that were not mapped or surveyed by PBS&J. Unaltered or natural shoreline is similarly dominant in the Homosassa River downstream from the Homosassa Community near river kilometer 7.2. Although not mapped by PBS&J, the shoreline of Hidden River may be considered unaltered. Additional information on the plant species and communities that occur within the vegetated shorelines of the Homosassa River system is provided in Chapter 3 of this report.

Upstream of approximately river kilometer 7.2, the shoreline of the Homosassa River is mostly altered with the exception of much of the left (south) bank between river kilometers 9.3 and 11.1. Seawalls are the dominant altered shoreline type, especially upstream from river kilometer 8, although rip-rap is the dominant altered shoreline (along the right bank only) between river kilometers 7 and 8. Nearly all altered areas downstream from river kilometer 7 were classified as modified shoreline.

Table 2-6. Summary information for shorelines of the Homosassa River, Halls River and Southeast Fork of the Homosassa River mapped by PBS&J (2010) in October 2008. Maintained shorelines include lawns and maintained landscaping. Modified shorelines were those with relatively natural vegetation that has been modified.

Shoreline Type	Shoreline Length (m)	Percentage of Total Shoreline	Percentage of Altered Shoreline
Natural	44,297	71	NA
Altered - Seawall	7,829	13	43
Altered - Modified	6,803	11	37
Altered - Maintained	410	<1	2
Altered - Rip-Rap	2,614	4	14
Altered - Rip-Rap and Seawall	576	<1	3
All (Total)	62,529	100	100

NA = not applicable

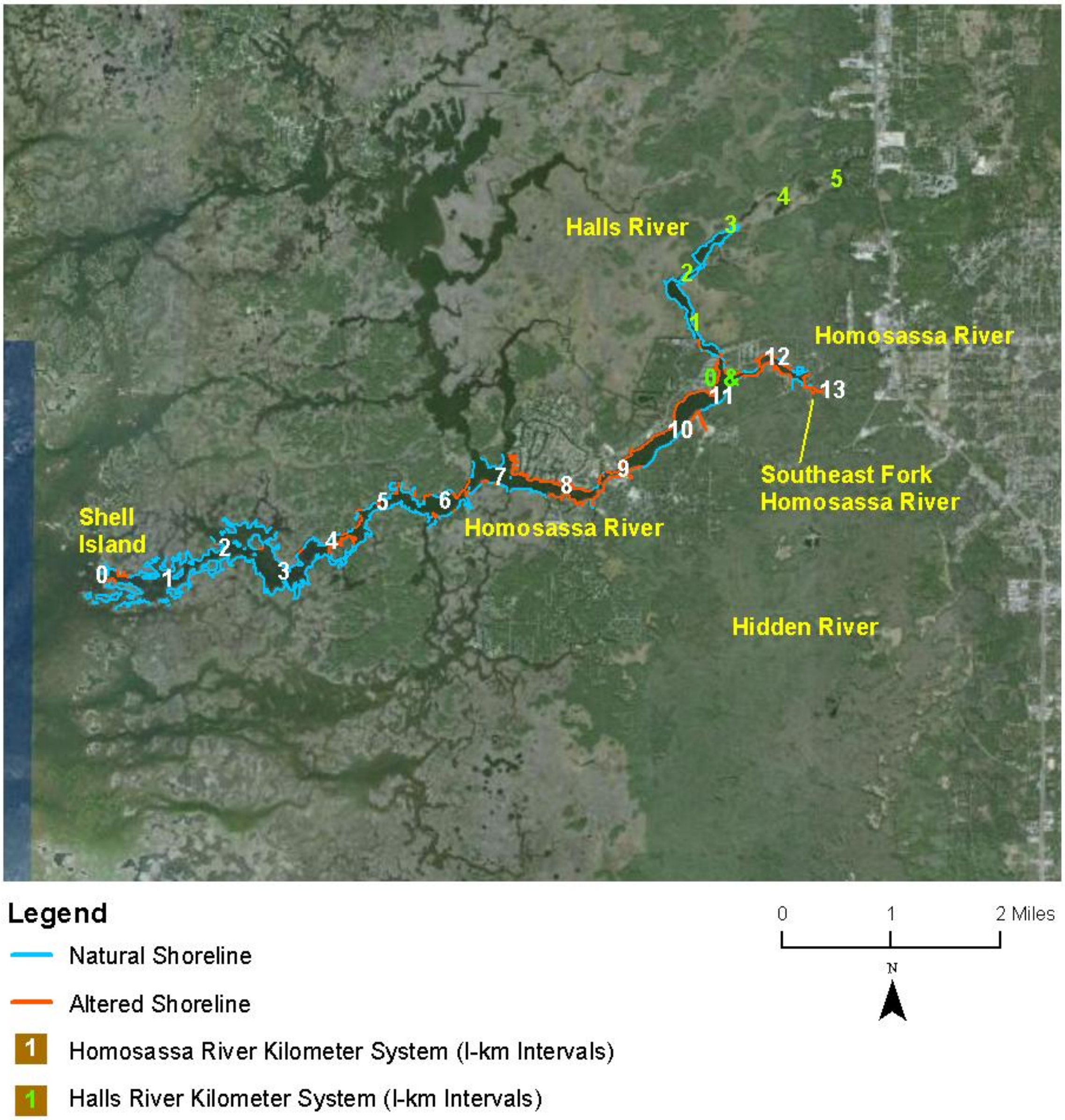


Figure 2-35. Natural and altered shoreline of the Homosassa River/Southeast Fork and the lower 3.2 kilometers of the Halls River in October 2008 as mapped by PBS&J (2010). The shoreline of Hidden River was not mapped, but may be classified as natural shoreline (photographic image sources: Southwest Florida Water Management District 2003c and Woolpert, Inc. 2009).

2.8 <u>Water Quality</u>

2.8.1 Water Classification and Quality

Under Rule 62-302.200, F.A.C., Florida's surface water quality standards consist of four components: 1) the designated use or classification of each water body, 2) the surface water quality criteria (numeric and narrative) for each water body, which are established to protect its designated use, 3) the anti-degradation policy, and 4) moderating provisions, such as mixing zones. Each surface water body in Florida is classified according to its present and future most beneficial use, referred to as its designated use, with class-specific water quality criteria for select physical and chemical parameters, which are established to protect the water body's designated use (Chapter 62-302, F.A.C.). Most coastal waters of Citrus County, including the Homosassa River upstream to about river kilometer 8.4, are classified as Class II waters with a designated use of shellfish propagation or harvesting (Rule 62-302.400(16)(b), F.A.C.). The upper portion of the Homosassa River, Halls River, Hidden River and the springs associated with the Homosassa River system are all designated as Class III waters with designated uses of recreation and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife (Rule 62-302.400, F.A.C.). All water bodies in the Homosassa River system are also classified as Outstanding Florida Waters, a designation associated with Florida's anti-degradation policy (Rule 62-302.700, F.A.C., Florida Department of Environmental Protection 2011).

With regard to compliance with water quality standards, Section 303(d) of the Federal Clean Water Act requires each state to identify and list "impaired" waters where applicable water quality criteria are not being met after implementation of technology-based effluent limitations, and also requires development of Total Maximum Daily Loads (TMDLs) for the water bodies. Total Maximum Daily Loads are the amount of pollutant that a receiving water body can assimilate without causing violation of a pollutant-specific water quality standard. The TMDLs development process identifies allowable loadings of pollutants and supports implementation of management strategies for reducing pollutant loads and ensuring applicable water quality standards are attained.

The most recent 303(d) list of impaired Florida waters was approved by the United States Environmental Protection Agency in 2010 and does not include any water bodies within the Homosassa River system.

Updates to the State's "verified list" of impaired waters in the Springs Coast basin were adopted by the Florida Department of Environmental Protection in February 2012. Bluebird Springs (WBID 1348A), Hidden River Springs (1348E) and Homosassa-Trotter-Pumphouse Springs Group (WBID 1345G) are now listed as impaired based on "other information" that indicates an imbalance in flora or fauna. Nutrients (algal mats) are identified as the parameter assessed in accordance with the Impaired Surface Waters Rule, with nitrate+nitrite levels identified as the likely cause of the impairment. Several other components of the Homosassa River system, including Direct Runoff to Gulf (WBID 1348), Gulf of Mexico (Citrus County (WBID 8041A), Homosassa River (Brackish Portions) (WBID 1345), Game Creek (WBID 1345B), Homosassa River (shellfish portion) (WBID 1345F) and Otter Creek (WBID 1348C) are listed as impaired due to mercury (in fish tissue).

As of the date of this report, no TMDLs have been finalized for impaired waters within the Homosassa River system.

2.8.2 Data Sources for Water Quality Summaries

Temperature, salinity and other water quality information summarized in this report are based on previously published reports, measurements made by the U.S Geological Survey and the District, and data collected for the District by the University of Florida, the University of South Florida and Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute. Although current standard practices in scientific oceanographic work include reporting salinity as a dimensionless number, some results summarized in this report are based on values reported in units of parts per thousand (ppt) or practical salinity units (psu), and original reported units have been retained in some instances. All reported salinity values included in this document should be considered interchangeable or comparable, regardless of the units used for their presentation

In cooperation with the District and Florida Department of Environmental Protection, the U.S Geological Survey regularly monitors near-surface and bottom water temperature and specific conductance at fifteen-minute intervals at the gage sites at Shell Island, Homosassa River, Halls River, Homosassa Springs and the Southeast Fork of the Homosassa River. Data collected at 15-minute intervals and/or mean daily values for these sites for the period from May 17, 2004 through October 19, 2009 were obtained from the U.S Geological Survey and used for the summary analyses described in this report. Sub-sets of these data were used for some analyses, and where appropriate, these periods of record and data types are identified. The U.S Geological Survey also conducts periodic sampling of water quality constituents other than temperature and specific conductance at gage sites in the Homosassa River system. These data were not reviewed for the analyses presented in this report, but summary water quality information based on USGS sampling as reported by Yobbi and Knochenmus (1989), Yobbi (1992) and Knochenmus and Yobbi (2001) were evaluated.

To support the development of minimum flows for the Homosassa River system, the District measured water temperature, salinity, specific conductance and dissolved oxygen concentrations throughout the water column at 14 stations in the Homosassa River system at approximately monthly intervals between February 2008 and February 2009. The stations included ten sites on the Homosassa River between Shell Island (river kilometer 0) and river kilometer 13.2; three sites on Halls River between river kilometers 0.25 and 2.2, and a single site on the Southeast Fork of the Homosassa River (Figure 2-36). Water samples were collected at five of the 14 stations for characterization of ion concentrations and other water quality constituents at the District Chemistry Laboratory. The stations where water samples were collected included three sites on the Homosassa River, and single sites in the Halls River and Southeast Fork of the Homosassa River. Results from these sampling events have not been previously published in report format.

As part of their District-funded studies of several Gulf coastal rivers, researchers from the University of Florida (Frazer *et al.* 2001a, b, 2006) measured near-surface water temperature, dissolved oxygen concentration and salinity at 20 transects located between the main Homosassa Springs complex and a point approximately 0.8 miles west of Shell Island (Figure 2-36). Sampling was conducted at a center-channel site and near each shore at the upper 15 transects and at a single center-channel site at the lower five transects. Water samples were also collected for laboratory analysis of various constituents during the quarterly sampling that was conducted at the Homosassa River from August 1998 through January 2001 and again from February 2003 through December 2005. Summary information presented in Frazer *et al.* (2001a, b, 2006) as well as *in-situ* measurements from center channel sites in the Homosassa River were used for the minimum flows analysis presented in this report.

The District-supported Project COAST, which is administered by the University of Florida, has involved water quality sampling along the west coast of Florida since 1997 (see Jacoby *et al.* 2008). As part of the project, water temperature, dissolved oxygen and salinity measurements and water samples for laboratory analysis of various constituents are collected at a station in the Homosassa River at river kilometer 9 (Figure 2-36). Data for this site were obtained and reviewed for the analyses described in this report.

For their District-funded survey of the fish and invertebrates in the Homosassa River system conducted to support development of minimum flow recommendations, the University of South Florida and Florida Fish and Wildlife Conservation Commission Fish and Wildlife Research Institute (Peebles *et al.* 2009) measured *in situ* water temperature, salinity, pH and dissolved oxygen concentration monthly or bi-monthly between December 2006 and November 2008. Sampling was conducted in the Homosassa River between Shell Island and river kilometer 13.4, downstream from the Homosassa Main Springs complex and also in Halls River (Figure 2-36). Summary information presented in (Peebles *et al.* 2009) as well as the data obtained for their study were used for the minimum flows analysis described in this report.

Field measurements of water temperature, salinity, specific conductance and dissolved oxygen concentration at five sites (Figure 2-36) in the Homosassa River collected between October 2005 and December 2008 in support of the District's Coastal Rivers Monitoring Network project (Project Number B121) were also included in the analyses presented in this report. Results from periodic water sampling conducted to support a variety of other District projects, including Quarterly Springs Water Quality Monitoring (Project Number P889), were also used to characterize water chemistry in the Homosassa River system (locations of these sites are not shown in Figure 2-36, but are included in the surface water data collection geographic information system layer available from the Data Collection Shapefile Library of the Data and Maps – GIS Data page of the District web site at: *http://www.swfwmd.state.fl.us/data/gis/layer_library/category/data_collection.* Summaries of spring water chemistry provided in District reports by Jones *et al.* (2011) and Champion and Starks (2001) were also reviewed.

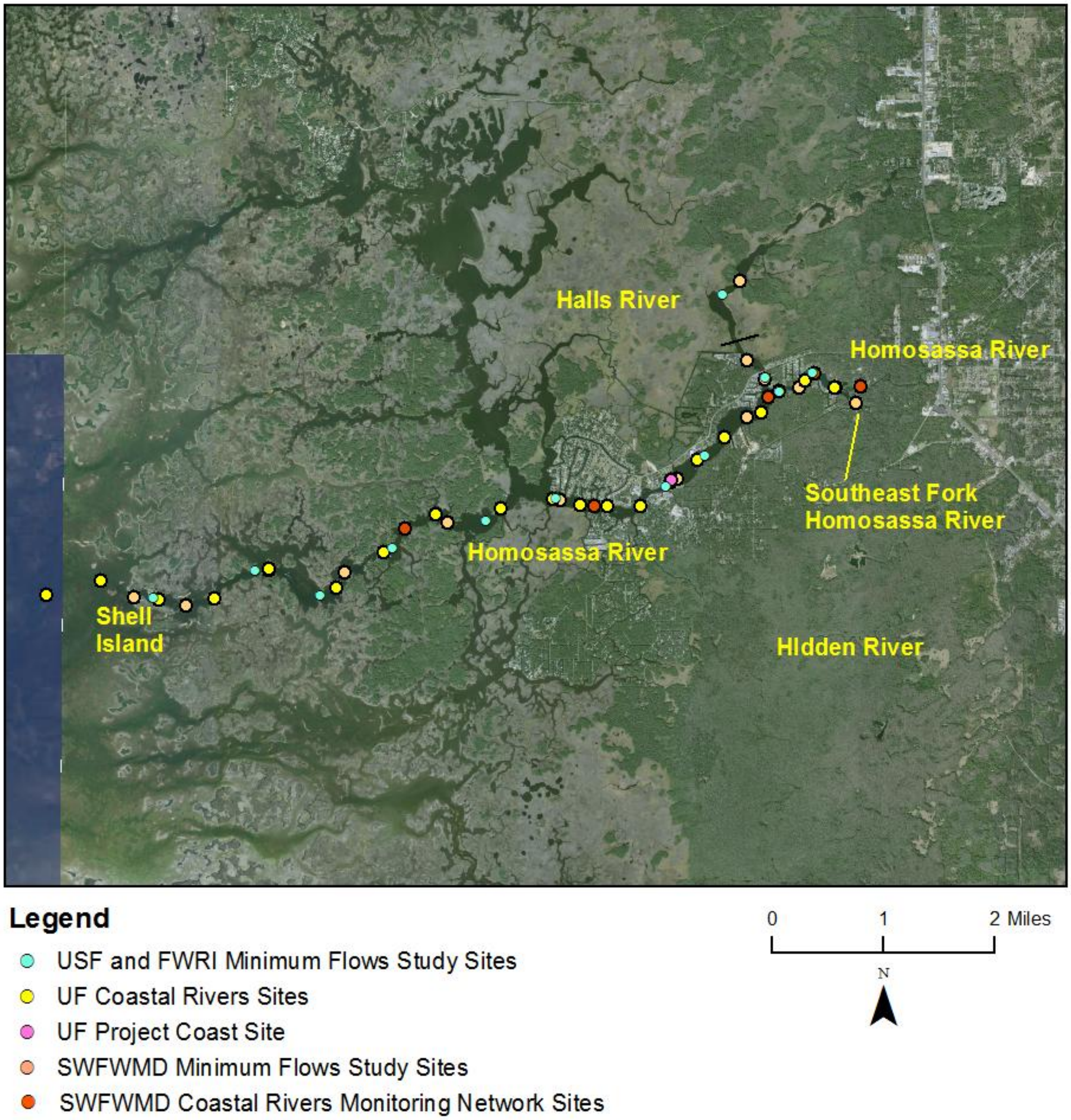


Figure 2-36. Locations of sites where in situ water quality sampling summarized in this report was completed by the University of South Florida (USF) and Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWRI), the University of Florida (UF) and the Southwest Florida Water Management District (SWFWMD) in the Homosassa River system (photographic image source: Southwest Florida Water Management District 2003c and Woolpert, Inc. 2009).

2.8.3 Spring Water Quality

Considerable variation is evident in the chemical composition of water discharging from the springs of the Homosassa River system. Water chemistry varies among springs, and diurnal fluctuations in water quality parameters in individual springs are common, and may be associated with tidal fluctuations (Yobbi 1992). Yobbi and Knochenmus (1989) describe the Homosassa Main Springs and Halls River springs as brackish systems and the springs of the Southeast Fork as freshwater systems. Knochenmus and Yobbi (2001) report that the Homosassa Main Springs, Halls River Head Spring, Hidden River Head Spring and Hidden River Spring Number 6 discharge sodium-chloride type water, based on relatively high concentrations of sodium, chloride and other dissolved ions. They also note that Trotter Spring is a mixed-ion type spring, with waters not dominated by any particular ions; a condition that typically reflects mixing of saltwater and freshwater.

Jones *et al.* (2011) and Champion and Starks (2001) provide recent summaries of water quality and hydrology of springs in the Southwest Florida Water Management District. Variation in the water quality of springs in the Homosassa River system is well described in the paragraphs below, which is excerpted from page 57 of Champion and Starks' report and includes their references to the 1997 version of Jones et al. (2011) through use of a superscripted, parenthetic number 12. Note that parenthetic descriptions presented in the excerpt below for the acronyms TDS and WQMP were not included in Champion and Starks original text.

> *Ground water discharging the Homosassa Springs group may be fresh or brackish, depending on tides and water levels in the Floridan aquifer. At low tide, water quality varies across the spring group with TDS* [Total Dissolved Solids] *concentrations increasing from less than 250 mg/l along the southeastern fork of the Homosassa River to greater than 1,500 mg/l in springs at the head of Hall's River. Chloride concentrations across the group may range from less than 50 mg/l to greater than 500 mg/l, indicating that water quality at the spring group is strongly influenced by the coastal transition zone even at low tide*[(12)]*.*
>
> *Nitrate concentrations at the Homosassa Springs group are typically below 0.7 mg/l. The concentrations vary among the individual springs of the group, possibly in response to mixing in the coastal transition zone and variations in nitrate in Floridan aquifer ground water. Research conducted by the WQMP* [*i.e.*, the District's Water Quality Monitoring Program] *indicates that the nitrate discharging from the springs is most likely derived from an inorganic source of nitrate - inorganic fertilizers applied to residential and golf course turf grass near the springs*[(12)]*.*

Median concentrations of major ions and field-measured parameters based on records currently available from the District Water Management Information System illustrate the variability in most water quality constituents among springs noted by previous investigators (Table 2-7). Salinities estimated from median chloride concentrations based on the general relationship between salinity and chlorinity published by Wooster *et al.* (1969) or estimated from median specific conductance based on the formulae of Cox *et al.* (1967) illustrate the heterogeneity among the systems. Salinity for springs discharging to the Southeast Fork of the Homosassa River was estimated at 0.1 to 0.21, with the exception of the higher estimate for the Southeast Fork Head Spring, which was sampled on a single date. Springs associated with Halls River, Hidden River and the Homosassa Main Spring pool exhibited salinities ranging from 0.7 to 4.8 (Table 2-8). Some parameters, including water temperature and pH were, however, somewhat less variable among the springs. Median water temperature for the 17 Homosassa River system springs examined varied by 2.8 degrees, ranging from 21.5 to 24.3°C. All the springs examined discharge slightly basic water, with median pH values from 7.55 to 8.01.

Median nitrate+nitrite nitrogen concentrations ranged from 0.16 to 0.70 mg/L for the measurements included in the District Water Management Information System for springs of the Homosassa River system (Table 2.7). Elevated nitrate+nitrite nitrogen concentrations have been reported by others for a number of springs within the state, including those of the Homosassa system (Brown *et al.,* 2008, Upchurch *et al.* 2008, Copeland *et al.* 2009, Harrington *et al.* 2010). As noted previously in this chapter, elevated nitrate+nitrite nitrogen concentrations are identified as a likely cause of impairment for several components of the Homosassa River system, including Bluebird Springs, Hidden River Springs and the Homosassa-Trotter-Pumphouse Springs Group.

Temporal trends in nitrate+nitrite nitrogen concentrations and their relationship to flow is an area of active investigation for Florida springs. In a recent study of relationships between spring flows and nitrate concentrations in the Suwannee River Water Management District, Upchurch *et al.* (2008) found that nitrate concentrations increased with increasing spring discharge in 50 percent of the systems examined. They also report that 45 percent of the systems examined showed no relationship between flow and nitrate concentration, while only 5 percent of the systems evaluated (reportedly two springs with relatively poor data sets) exhibit decreased nitrate concentrations with higher flows. Copeland *et al.* (2009) has identified increasing trends in nitrate+nitrite nitrogen concentrations for several springs of the Homosassa River system, including Hidden River Head Spring, Hidden River No. 2 Spring, Pumphouse Spring, Trotter Main Spring, and the three vents of the Homosassa Main Spring. These investigators note a significant decline in flows for the Homosassa Main Spring for the period from 1996 to 2003.

Heyl (2012; included as Appendix AA to this report) evaluated temporal trends and relationships between flows and nitrate+nitrite concentrations for several Florida springs, including selected springs of the Homosassa River Main Spring run and Southeast Fork of the Homosassa River. In addition to exhibiting significant flow trends, each of the spring systems also showed an increasing trend in nitrate+nitrite concentrations. To determine whether the change in nitrogen concentrations were associated with changes in flow or simply related to a temporal trend (potentially associated with changing nutrient loading to the springsheds contributing to spring flows), a LOWESS smoothing approach (Helsel and Hirsch 1992) was used to systematically eliminate the variation in nitrate+nitrite nitrogen concentration attributable to each predictor variable (flow or time). In turn, each predictor variable was regressed against nitrate+nitrite concentrations, and the residuals from the regression, *i.e*., the variation in nitrate+nitrite concentration that could not be accounted for by the predictor variable, were then plotted against the other predictor variable to identify the relationship between the unaccounted-for variability and the other predictor variable. For all the springs evaluated, with the exception of the Weeki Wachee, nitrate+nitrite concentrations were found to be increasing, and the increased concentrations were independent of flow, but strongly dependent on time. Concentrations of nitrate+nitrite nitrogen in the Weeki Wachee system were found to be significantly related to both time and flow.

The Florida criterion for dissolved oxygen in Class III-Fresh water bodies requires that dissolved oxygen concentrations shall not be less than 5.0 mg/L and that "[n]ormal daily and seasonal fluctuations above these levels shall be maintained" (Rule 62-302.530, F.A.C.). The criteria for dissolved oxygen in Class III-Marine and Class II water bodies similarly includes the daily and seasonal requirements, but requires that dissolved oxygen concentrations shall not average less than 5.0 mg/L in a 24-hour period and shall never be less than 4.0 mg/L. Based on data available from the District Water Management Information System, dissolved oxygen concentrations were consistently low at monitored springs within the Homosassa River system. Median concentrations varied from 2.1 to 4.4 mg/L (Table 2-7).

Low dissolved oxygen concentrations are not uncommon in Florida water bodies, particularly in spring pools. Odum (1957) found night-time dissolved oxygen concentrations averaged 2.8 mg/L at eleven (11) Florida springs in July and August 1955 with a value of 4.3 mg/L reported for the Homosassa Springs pool. In an earlier study of the Homosassa River, Sloan (1956) recorded dissolved oxygen concentrations between 4.3 and ~5.5 mg/L at the spring pool between November 1952 and February 1954. McKinsey and Chapman (1998) report dissolved oxygen concentrations averaged 0.20 mg/L at the Singing Springs boil in north-central Florida and cited numerous earlier studies where low oxygen levels were reported for other springs of the state. In a more recent study, Wetlands Solutions, Inc. (2010) report dissolved oxygen concentrations ranged from 0.1 to 3.7 mg/L at ten of the 12 Florida springs they evaluated in 2008 and 2009. At the Homosassa Main Springs pool, they found dissolved oxygen concentration averaged 3.7 mg/L.

Table 2-7. Median water quality constituent/parameter concentrations for selected springs grouped by river components of the Homosassa River system, based on sampling conducted from October 21, 1993 through April 16, 2012 by the Southwest Florida Water Management District. Values are expressed as dissolved mg/L unless otherwise indicated. Dashes indicate that data were not available.

Spring Name	Number of Dates Sampled (N)	Number of Samples (N)	Ca	Cl	F	Mg	K	Na	SO_4	NO_3 + NO_2 - N	Ortho-PO_4 - P	Total Dissolved Solids
Homosassa River												
Homosassa Main Spring No. 1	72	43 - 92	65	1200	0.14	82	24.0	633	173	0.51	0.015	2,206
Homosassa Main Spring No. 2	71	44 - 132	81	1735	0.15	121	35.9	970	252	0.48	0.015	3,266
Homosassa Main Spring No. 3	68	41 - 127	47	414	0.12	33	8.6	231	71	0.52	0.014	889
Southeast Fork												
Abdoney Spring	3	3	38	68	0.11	10	1.3	36	14	0.46	0.032	260
Belcher Spring	3	3	39	57	0.10	10	1.2	35	13	0.44	0.024	242
Homosassa River Spring No. 1	4	3 - 4	67	1,141	0.14	78	22.5	613	166	0.41	0.027	2,045
McClain Spring	3	3	44	80	0.10	12	1.4	45	15	0.37	0.029	292
Pumphouse Spring	35	13 - 42	45	83	0.10	11	1.4	45	15	0.42	0.018	286
Southeast Fork Head Spring	1	1	56	340	0.11	27	6.2	181	51	-	0.020	736
Trotter Spring No. 1.	3	3	39	58	0.11	10	1.2	35	13	0.45	0.024	244
Trotter Main Spring	73	45 - 96	42	85	0.10	12	1.8	47	18	0.54	0.020	285
Halls River												
Halls River Spring No. 1	1	1	107	2,164	0.11	149	43.0	1170	301	0.16	0.020	4,033
Halls River Main Head Spring	31	17 - 53	86	1,555	0.13	103	31.8	803	227	0.30	0.026	2,880
Hidden River												
Hidden River Spring No. 2	73	46 - 81	63	711	0.11	53	13.2	396	105	0.70	0.024	1,419
Hidden River Head Spring	72	45 - 126	59	494	0.11	38	9.4	275	74	0.70	0.022	1,060
Otter Creek Spring[a]	6	4 - 10	133	2,535	0.14	171	46.6	1,350	358	-	0.016	4,775
Bluebird Spring Run												
Bluebird Spring	5	3 - 10	59	280	0.10	21	4.4	146	41	0.64	0.021	628

[a] Spring discharges to Otter Creek

Table 2-7. (continued)

Spring	Temperature (°C)	pH (standard units)	Dissolved Oxygen	Specific Conductance (µS/cm at 25 °C)
Homosassa River				
Homosassa Main Spring No. 1	23.4	7.58	4.1	4,259
Homosassa Main Spring No. 2	23.4	7.55	4.1	6,055
Homosassa Main Spring No. 3	23.4	7.65	4.4	1,920
Southeast Fork				
Abdoney Spring	24.3	7.80	-	496
Belcher Spring	23.1	7.77	-	441
Homosassa River Spring No. 1	23.7	7.62	-	3,890
McClain Spring	23.9	7.67	-	533
Pumphouse Spring	23.1	7.65	3.7	554
Southeast Fork Head Spring	-	8.01	-	1,450
Trotter Spring No. 1.	23.2	7.74	-	451
Trotter Main Spring	23.3	7.70	3.8	617
Halls River				
Halls River Spring No. 1	23.7	7.60	-	6,950
Halls River Main Head Spring	23.1	7.66	2.1	5,190
Hidden River				
Hidden River Spring No. 2	23.2	7.65	3.4	2,846
Hidden River Head Spring	23.2	7.68	3.8	2,490
Otter Creek Spring[a]	21.5	7.68	3.4	8,647
Bluebird Spring Run				
Bluebird Spring	22.9	7.69	2.9	1,199

[a] Spring discharges to Otter Creek

Table 2-8. Estimated salinity for selected springs grouped by river components of the Homosassa River system, based on median chloride concentrations presented in Table 2-7 and the general relationship between salinity and chlorinity[a] presented by Wooster *et al.* (1969) or salinity and specific conductance based on formulae presented by Cox *et al.* (1967).

Spring	Estimated Salinity Based on Chlorinity	Estimated Salinity Based on Specific Conductance
Homosassa River		
Homosassa Main Spring No. 1	2.2	2.2
Homosassa Main Spring No. 2	3.1	3.3
Homosassa Main Spring No. 3	0.7	0.9
Southeast Fork		
Abdoney Spring	0.1	0.2
Belcher Spring	0.1	0.1
Homosassa River Spring No. 1	2.1	2.0
McClain Spring	0.1	0.2
Pumphouse Spring	0.1	0.2
Southeast Fork Head Spring	0.6	0.7
Trotter Spring No. 1.	0.1	0.1
Trotter Main Spring	0.2	0.2
Halls River		
Halls River Spring No. 1	3.9	3.8
Halls River Main Head Spring	2.8	2.8
Hidden River		
Hidden River Spring No. 2	1.3	1.5
Hidden River Head Spring	0.9	1.3
Otter Creek Spring[c]	4.6	4.8
Bluebird Spring Run		
Bluebird Spring	0.5	0.6

[a] Salinity as parts per thousand or ppt = 1.80655 * chlorinity as ppt

[b] Salinity estimated as: -0.08996 + (28.2972 * RC) + (12.80832 * RC^2) – (10.67869 * RC^3) + (5.98624 * RC^4) – 1.32311 * RC^5; with RC calculated as RU + RU * (RU-1) * (Temp – 15) * (96.7 – (72 * RU) + (37.3 * RU^2) – (0.63 + 0.21 * RU^2) * Temp - 15)) * 10^{-5}; RU calculated as specific conductance in units of µS/cm at 25°C / (42,896 * RT); and RT calculated as (0.67654668 + 0.020131661 * Temp) + (0.99886585 * 10^{-4} * $Temp^2$) – (0.19426015 * 10^{-3} * $Temp^3$) – (0.67249142 * 10^{-8} * $Temp^4$)

[c] Spring discharges to Otter Creek

2.8.4 River Temperature

Water temperatures in the Homosassa River system exhibit considerable seasonal variation. Monthly water temperatures for the system are typified by the values shown in Figure 2-37 for the combined Homosassa River and Southeast Fork, where median monthly temperatures based on records collected between 1997 and 2009 ranged from 17.2°C in January to 30.1°C in July. Variation in water temperatures in the upper few kilometers of the Homosassa and Southeast Fork was relatively low during this 12-year period (Figure 2-38, Table 2-9), likely in response to the discharge of nearly constant-temperature water from the headwater springs. Water temperatures were similarly lower in the upstream portion of Halls River (Table 2-9), although they were more variable than in the upper Homosassa (variance information not included in Table 2-9). The relative constancy and magnitude of water temperatures in the upper reaches of the Homosassa River system are important factors associated with use of the system as a thermal refuge by manatees during periods when water temperatures in the Gulf of Mexico fall below critical physiological thresholds for these animals.

Depth-specific measurements of temperature indicate that the water column of the Homosassa River is relatively well mixed. At the U.S. Geological Survey Homosassa River at Shell Island near Homosassa FL gage, maximum top and bottom water temperatures differed by no more than 0.5°C on a daily basis between September 2006 and October 2009 and minimum top and bottom temperatures differed by less than 0.7°C (data not shown). Slightly more variation in water column temperatures is evident at the Homosassa River at Homosassa FL gage, where daily maximum top and bottom water temperatures varied by up to 1.2°C between May 2006 and October 2009 and daily minima varied up to 2.6 in bottom waters (Figure 2-39). On most dates however, differences between top and bottom water temperatures at the Homosassa River at Homosassa gage were less than 1°C.

2.8.5 Modeling River Temperature

A calibrated hydrodynamic model for evaluating the effects of changes in flow on water temperature and salinity in the main channel of the Homosassa River was developed as part of the District effort to develop minimum flow recommendations for the river system. The model, which was developed for the District by HSW Engineering, Inc. (2011), is described in the next sub-section of this chapter. Use of the model for evaluating thermal characteristics of the Homosassa River is discussed in Chapters 4 and 5.

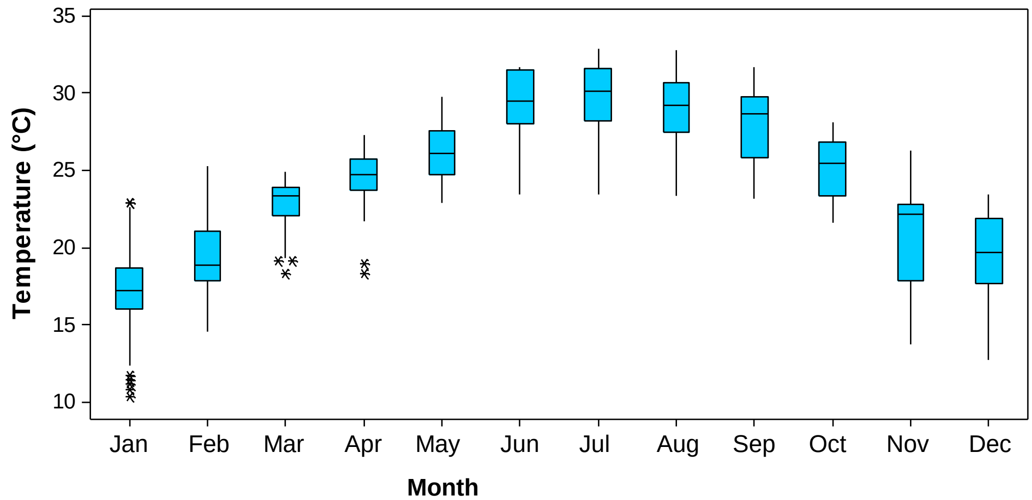


Figure 2-37. Box plot of water temperature in one kilometer segments of the Homosassa River (including the Southeast Fork of the Homosassa River), based on measurements made by the University of South Florida, the University of Florida, Florida Fish and Wildlife Conservation Commission Fish and Wildlife Research Institute and the Southwest Florida Water Management District between January 1997 and February 2009. Box plot formatted as described for Figure 2-14.

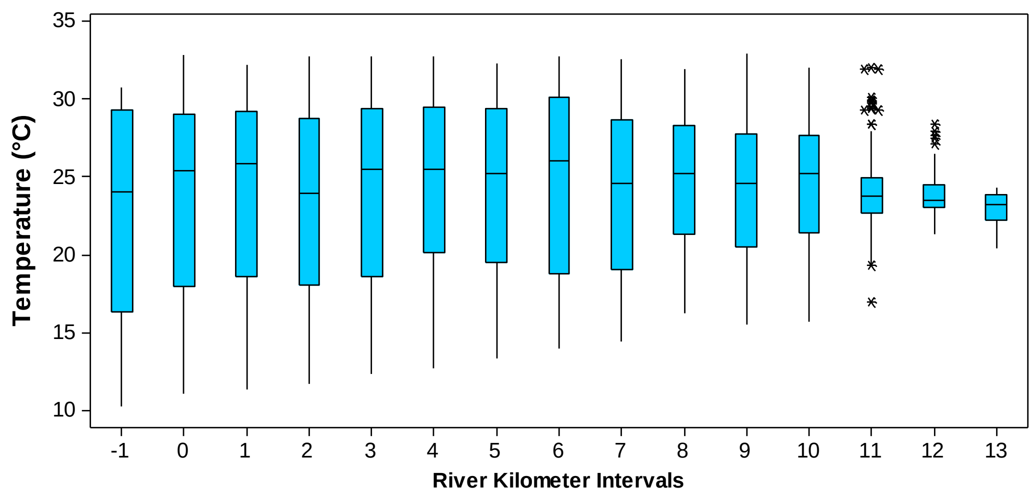


Figure 2-38. Box plot of monthly water temperatures in the Homosassa River and Southeast Fork, based on data sources and period of record identified in Figure 2-37. Box plot formatted as described for Figure 2-14.

Table 2-9. Median water temperature, pH, dissolved oxygen concentration and specific conductance for one-kilometer segments of Halls River and the Homosassa River (including the Southeast Fork), based on data sources and period of record identified in Figure 2-37.

Downstream River-Kilometer Segment Boundary	Number of Samples (N)	Temperature (°C)	pH (standard units	Dissolved Oxygen (mg/L)	Specific Conductance (µS/cm at 25 °C)[a]
Halls River					
0	75-122	24.7	7.8	7.7	4,990
1	58-95	25.6	7.8	7.3	5,150
2	67	27.4	7.6	6.0	5,400
3	44	22.5	7.8	7.7	5,700
4	41	25.0	7.8	6.1	4,700
5	11	21.5	7.7	5.9	5,500
Homosassa River					
-1	40-42	24.0	8.2	7.6	30,880
0	103-187	25.4	7.9	7.0	32,950
1	58-59	25.9	7.9	6.2	26,700
2	87-163	24.0	7.9	7.3	27,600
3	91-178	25.5	7.9	6.6	24,730
4	71-162	25.5	7.8	6.3	21,000
5	108-109	25.2	7.8	6.0	18,490
6	68-141	26.1	7.8	6.6	15,300
7	146-203	24.6	7.8	7.0	13,000
8	85	25.2	7.9	7.5	6,620
9	129-368	24.6	7.9	7.3	5,130
10	127	25.2	7.9	6.9	3,970
11	143-263	23.8	7.8	6.0	3,000
12	171	23.5	7.8	6.0	2,800
13	17	23.2	7.6	6.5	950

[a] Specific conductance values approximated by multiplying reported values, which were expressed in units of mS/cm at 25 °C, by 1,000

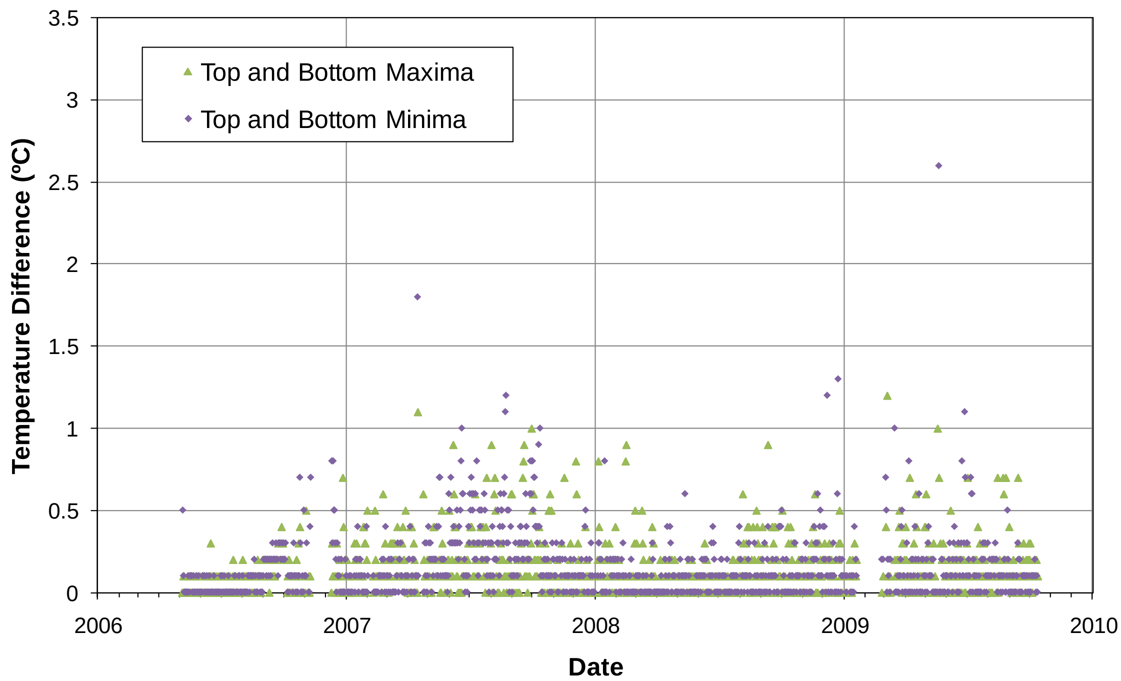
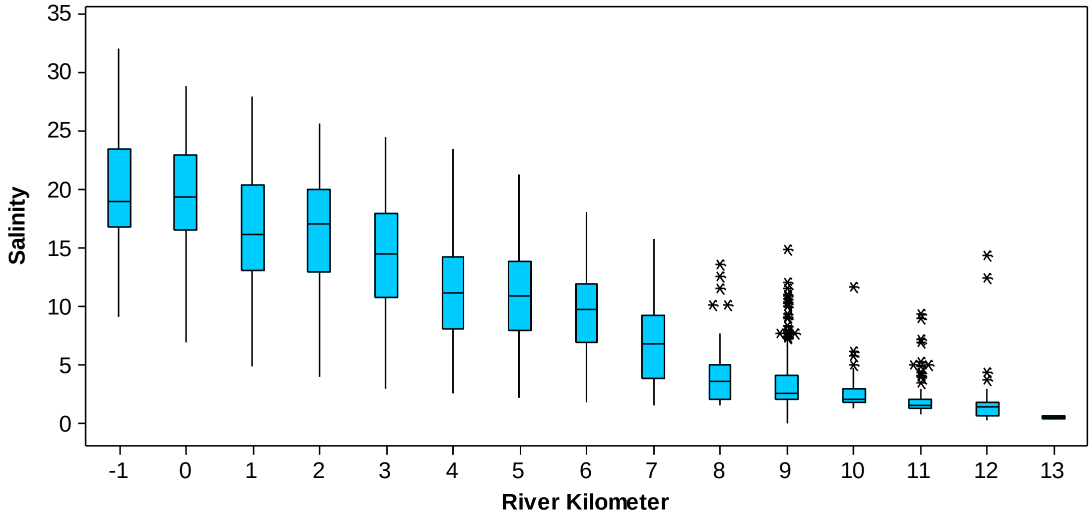


Figure 2-39. Differences between daily water temperature maxima and minima near the top and bottom of the water column at the U.S. Geological Survey Homosassa River at Homosassa FL gage (number 02310700) between May 2006 and October 2009, based on Survey approved data.

2.8.6 River Salinity

Box plots of synoptic salinity measurements made by the District, University of South Florida, University of Florida and the Florida Marine Research Institute between January 24, 1997 and February 17, 2009 illustrate the strong longitudinal salinity gradient that typifies the Homosassa River and Southeast Fork and the relatively low range of salinities in Halls River (Figure 2-40). Based on the Venice System used for classification of marine systems according to salinity (Anonymous 1958), waters in the Homosassa River typically range from oligohaline conditions (approximate salinity range from 0.5 to 5.0) in the headwaters to mesohaline conditions (approximate salinities between 5 and 18) through much of the length of the river and polyhaline conditions (approximate salinity range from 18 to 30) near and downstream from Shell Island at river kilometer zero. Oligohaline conditions are typical throughout the entire Halls River.



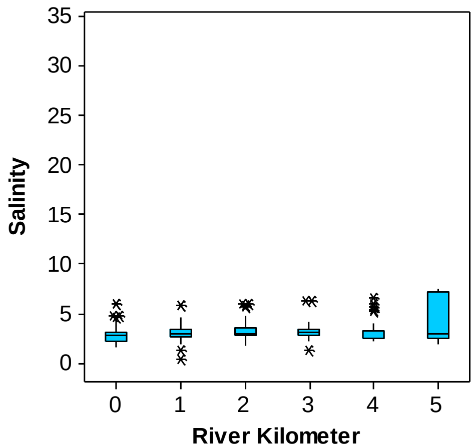


Figure 2-40. Box plots of salinity in one-kilometer segments of the Homosassa River, including the Southeast Fork of the Homosassa River (upper panel), and Halls River (lower panel) based on data sources and period of record identified in Figure 2-37. Box plots formatted as described for Figure 2-14.

Period of record mean daily bottom salinities at United States Geological Survey gage sites on the Homosassa River (Figure 2-41) estimated from reported specific conductance values using the formulae of Cox *et al.* (1967) (see footnote "b" to Table 2-9 for the formulae used for salinity estimation) are consistent with the longitudinal variation of salinities in the river system demonstrated by the recent synoptic sampling. Lowest salinities have typically been recorded at the Southeast Fork of the Homosassa River gage, where the median daily minimum and maximum salinities were 0.4 and 1.4, respectively. Salinities at the Homosassa Springs and Halls River gages have been slightly higher; median daily minimum and maximum salinities at the Homosassa Springs site were 1.5 and 2.4, respectively, and median daily minimum and maximum salinities at the Halls River site were 1.7 and 3. Downstream at the Homosassa River gage, median daily minimum and maximum salinities for the period of record were 2.2 and 6.2, respectively. At the mouth of the river near Shell Island median daily minimum salinity has been 17.5 and median daily maximum salinity has been 24.7.

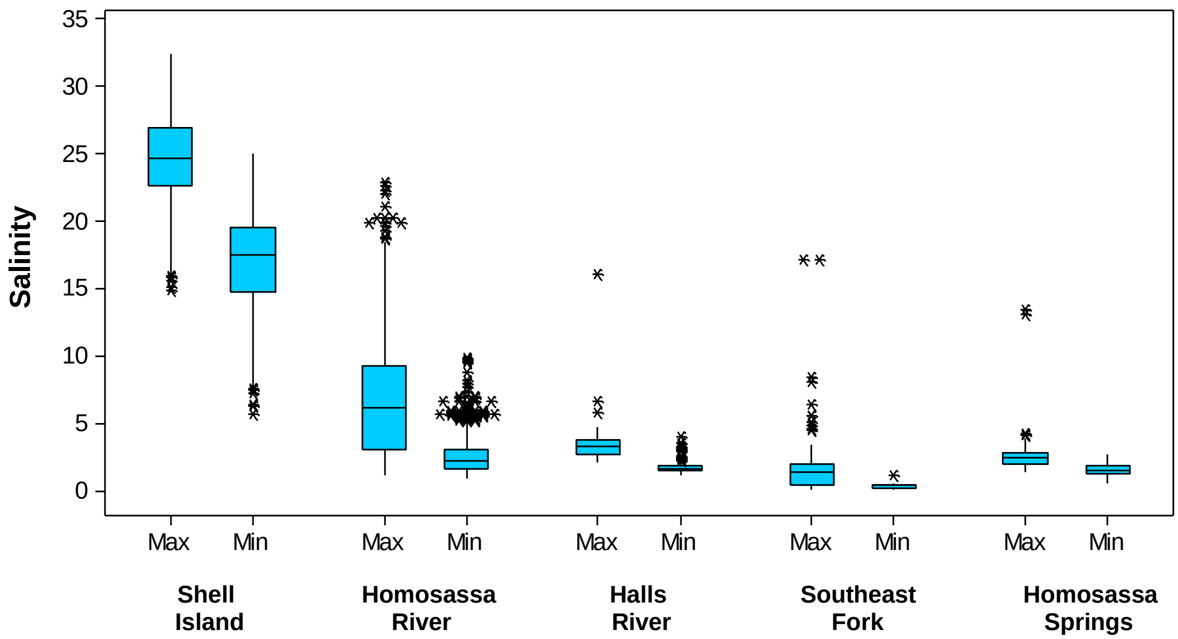


Figure 2-41. Box plot of maximum and minimum daily salinity in the Homosassa River system at U.S. Geological Survey gage sites. Salinities calculated from reported specific conductance; period of record varies by site (see Table 2-2). Box plot formatted as described for Figure 2-14.

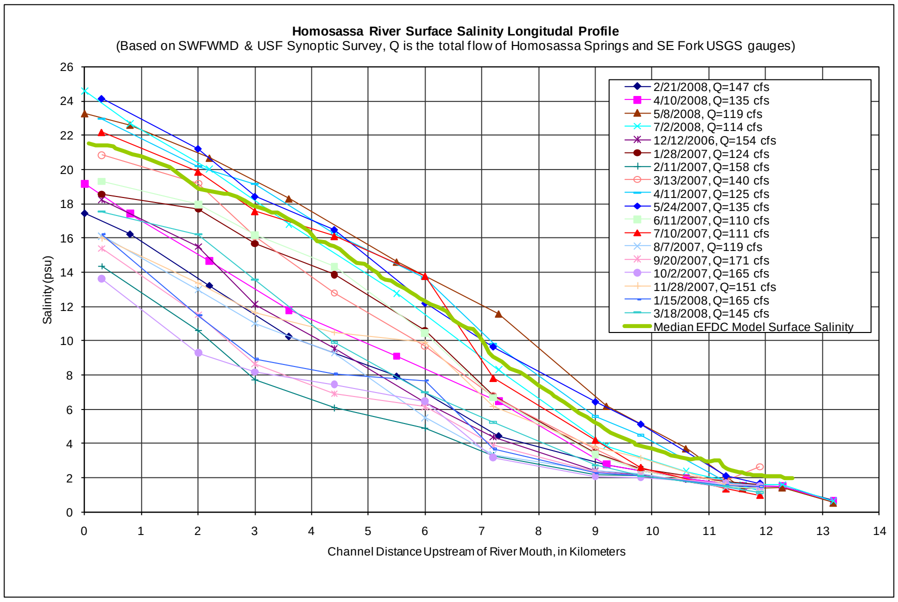
The Florida Department of Environmental Protection uses surface water chloride concentrations to classify surface waters of the State as predominately fresh or marine waters. Surface waters in which the chloride concentration is less than 1,500 milligrams per liter are classified as predominately fresh waters. Surface waters with chloride concentrations greater than or equal to 1,500 milligrams per liter are classified as predominately marine waters (Subsections 62-301.200(22) and (23), F.A.C.). The 1,500 mg/L chloride threshold corresponds roughly to a salinity of 2.7, based on the general relationship between salinity and chlorinity (salinity as parts per thousand or ppt = 1.80655 * chlorinity as ppt) published by Wooster *et al.* (1969). Comparison of salinities shown in Figure 2-42 with this approximate salinity threshold indicates that the Homosassa River upstream of the Homosassa Springs gage and the Southeast Fork of the Homosassa River may be considered predominantly fresh water bodies. Maximum daily bottom salinities at the Halls River gage site often exceed the approximate 2.7 salinity criterion, suggesting that the portion of Halls River near the site may be classified as predominantly marine waters. Bottom salinities at the Homosassa River and Shell Island gage sites also suggest the segments of the Homosassa River near and downstream from the sites may be classified as predominately marine waters.

Yobbi and Knochenmus (1989) evaluated salinity, tide and spring discharge relationships in the Homosassa River during 1984 and 1985 using measurements from fixed gage stations in the Homosassa River and sporadic sampling at several additional sites. Vertical or depth-specific salinity profiles constructed for various isohalines indicated the water column was typically well-mixed during their two-year study period; ratios between top and bottom salinities were on the order of 0.85 to 1.0. Salinities during the two-year study period fluctuated between one to two ppt at river mile 6.5, just downstream of the confluence of the Homosassa and Halls rivers, and ranged between approximately 13 to 26 ppt at the river mouth. Longitudinal salinity profiles developed for the river under a range of flow conditions demonstrated how salinity variation in the upper portion of the river was relatively minor as compared to the variability observed in the lower river. Waters with a salinity of 2 ppt, the threshold used by Yobbi and Knochenmus to identify mixing of seawater and spring water discharged from the system headwaters, were observed during high tide conditions over a 1.7 mile stretch of the river, between miles 4.5 and 6.2 upstream from the river mouth. In contrast, salinities of 25 ppt were observed over a range of 5.4 miles, from a point 5 miles downstream from the river mouth to a point 0.4 miles upstream of the mouth.

More recent characterization of salinities in the Homosassa River has been completed for the District by HSW Engineering, Inc. (2011) in support of the development of minimum flow recommendations. The analyses involved: 1) summarization of synoptic salinity measurements in the Homosassa River completed by and for the District in recent years; 2) evaluation of salinity estimates derived from specific conductance measurements made at fifteen-minute intervals at USGS gage sites in the river system; 3) development of empirical models for predicting salinities in the main channel of the Homosassa River; and 4) hydrodynamic modeling of salinity (and water temperature) in the main channel of the Homosassa River.

Based on synoptic sampling completed by the University of South Florida and the District from December 2006 through July 2008, HSW Engineering, Inc. (2011) found nearly linear longitudinal salinity gradients along the center of the Homosassa River (Figure 2-42). Near surface and bottom salinities of 2.7 or less, the salinity approximating the chloride threshold used by the Florida Department of Environmental Protection for delineating predominately fresh and marine waters, were typically common only above river kilometers 9 or 10, and vertical salinity gradients were minor, indicating the water column was relatively well mixed. In contrast to the 2006 through 2008 period evaluated by HSW Engineering, Inc., near-surface salinities less than the “predominately fresh water” approximated salinity threshold of 2.7 were common downstream as far as river kilometer 7 or 8 from February 2003 through December 2005, when the river was sampled by the University of Florida and combined spring discharge was consistently higher than the 2006-2008 period (Figure 2-43).

Based on salinity estimates derived from specific conductance measurements and reported discharge values for fifteen-minute intervals between 2004 or 2006 and September 2008, HSW Engineering, Inc. (2011) found that salinity in the Homosassa River at the Homosassa River and Shell Island USGS gages was inversely related to combined discharge past the Homosassa Springs and SE Fork gages (Figure 2-44). Salinities at the Halls River gage were not strongly related to discharge from springs in the upper Homosassa River. HSW Engineering, Inc. notes that apparent increased salinity at the Halls River gage during highest observed flows may have been associated with backwater effects of spring discharge at the confluence of the Halls River with the Homosassa River.



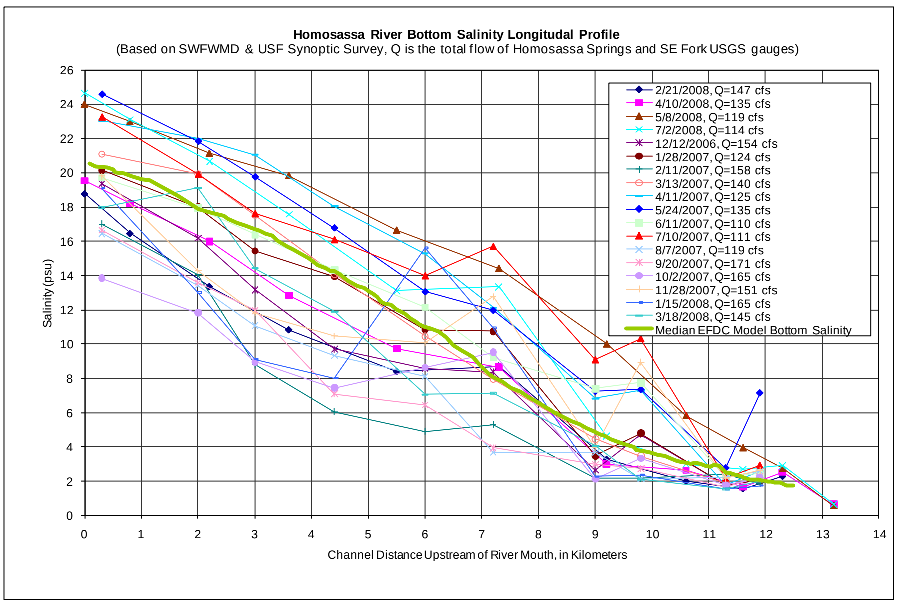


Figure 2-42. Longitudinal surface (upper panel) and bottom (lower panel) salinity profiles for the main channel of the Homosassa River based on synoptic sampling by the University of South Florida and the District during a variety of flow conditions between December 2006 and July 2008. Salinities are expressed as practical salinity units or psu. Flow values (Q) correspond to combined flow at the United States Geological Survey Homosassa Springs at Homosassa Springs, FL and Southeast Fork Homosassa Spring at Homosassa Springs, FL gage sites. Longitudinal surface and bottom salinity profiles for 2007 based on median centerline salinities simulated with the Homosassa River Environmental Fluid Dynamic Code (EFDC) hydrodynamic model are also shown. Panels reproduced from HSW Engineering, Inc. (2011).

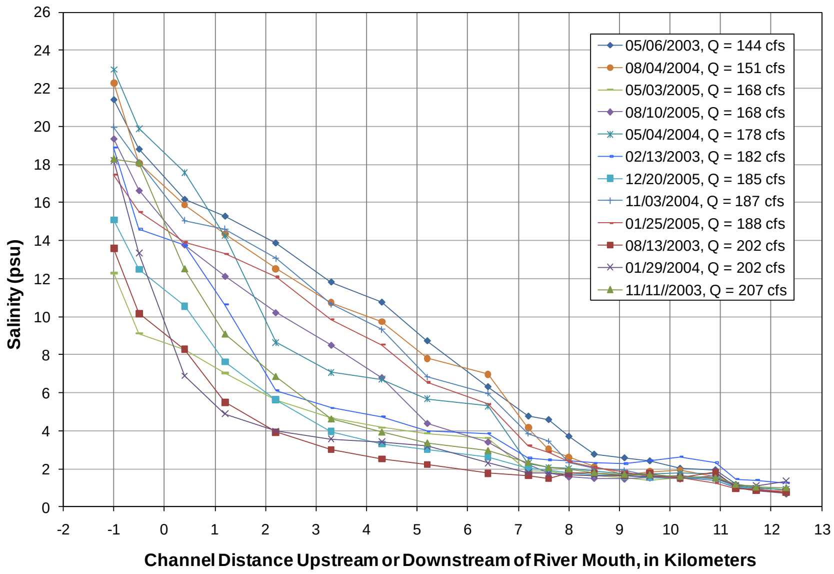


Figure 2-43. Longitudinal profiles of near-surface salinity for the Homosassa River channel center based on synoptic sampling by the University of Florida under a variety of flow conditions between February 2003 and December 2005. Flow (Q) and salinity values as described in Figure 2-42.

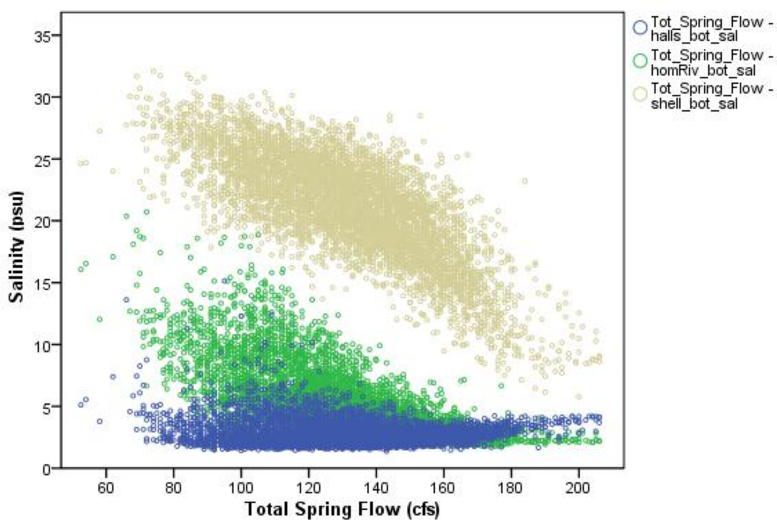


Figure 2-44. Bottom salinity (expressed in practical salinity units or psu) at the U.S. Geological Survey Homosassa River (green), Halls River (blue) and Shell Island (gold) gage sites as a function of total spring flow, i.e., combined discharge past the Homosassa Springs and Southeast Fork gages. Plotted values represent randomly-selected ten-percent subsets of the fifteen-minute-interval discharge values reported by the Survey for the period from 2004 through 2008 or 2006 through 2008 (sample period start date is gage-specific). Figure reproduced from HSW Engineering, Inc. (2011).

2.8.7 Modeling River Salinity – Empirical Regression Models

Empirical regressions for modeling or predicting salinity in the main channel of the Homosassa River were developed by HSW Engineering, Inc. based on salinity, tide stage and discharge records for gage sites in the river and salinity measurements made by the U.S. Geological Survey, he University of South Florida, the University of Florida, the Florida Fish and Wildlife Conservation Commission Fish and Wildlife Research Institute and the Southwest Florida Water Management District. Summary descriptions of the regression equations are presented in this section; details regarding regression model development are provided in HSW Engineering, Inc. (2011), which is included as Appendix A to this report.

The regression models include sets of equations for predicting the location of surface and bottom isohalines for salinities of 3, 5 and 12 in the Homosassa River based on the combined flow at the USGS Homosassa Springs and Southeast Fork Homosassa Spring gage sites and the tide stage at the USGS Homosassa River gage site. Synoptic salinity data collected from 2000 through 2009 were used for development of the regression equations. The equations account for 53-59 percent of the variance in the salinity measurements used to develop the predictive models and may be expressed as

$$RKM = a_0 + a_1 * Q + a_2 * (Q - knot_1) + a_3 * T, \text{ for } Q >= \text{knot}_1 \qquad \text{(Equation 1)}$$

or

$$RKM = a_0 + a_1 * Q + a_3 * T \text{ for } Q < knot_1 \qquad \text{(Equation 2),}$$

where: *RKM* is the isohaline location expressed as the river kilometer or distance upstream from the river mouth near Shell Island;

Q is the combined flow, in cubic feet per second, past the USGS Homosassa Springs at Homosassa Springs and SE Fork Homosassa Spring gages;

$knot_1$ is the inflection *Q* value used in the piecewise regression model (Equation 1); and

T is the tide stage at the USGS Homosassa River gage, in feet above NAVD88, at the time of the salinity measurement.

Summary statistics and regression coefficients for the predictive surface and bottom isohaline models in the form of equations 1 and 2 are provided in Table 2-10. The coefficients a_1 and a_2 in association with the flow (Q) and knot_1 flow in the equations describe the longitudinal change in kilometers associated with a one cfs change in *Q*. For example, if *Q* is less than the knot_1 value of 135 cfs, a ten cfs reduction is predicted to result in a 0.09 km upstream movement of the bottom isohaline with a salinity of 5 based on equation 1. For flows exceeding the knot_1 value of 135 cfs, a ten cfs reduction in flow would be expected to result in an approximate 0.9 km upstream movement of the bottom isohaline with a salinity of 5.

Table 2-10. Summary information for regression equations used to predict surface and bottom isohaline locations for selected salinities in the main channel of the Homosassa River based on data collected from 2000 through 2009 (adapted from HSW Engineering, Inc. 2011).

Salinity Isohaline	Isohaline Type	Regression Coefficients					R^{2} *	SD **	Number of Obser-vations
		a_0	a_1	a_2	a_3	$knot_1$			
3	Surface	11.936	-0.017	-0.029	0.427	128.0	0.54	0.84	59
	Bottom	14.259	-0.026	-0.054	0.443	135.0	0.57	1.24	61
5	Surface	10.991	-0.020	-0.030	0.511	135.0	0.59	0.72	69
	Bottom	10.874	-0.009	-0.081	0.664	135.0	0.53	1.39	65
12	Surface	5.397	0.002	-0.072	1.250	121.6	0.59	1.24	70
	Bottom	9.630	-0.029	-0.060	1.070	131.2	0.54	1.85	49

Equation forms:

$RKM = a_0 + a_1 * Q + a_2 * (Q - knot_1) + a_3 * T$ for $Q >= knot_1$ or

$RKM = a_0 + a_1 * Q + a_3 * T$ for $Q < knot_1$

in which

RKM = the isohaline location expressed as the river kilometer or distance upstream from the river mouth near Shell Island;

Q = the combined flow, in cfs, past the U.S. Geological Survey Homosassa Springs at Homosassa Springs and SE Fork Homosassa Spring at Homosassa Spring gages;

$knot_1$ = the inflection Q value used in the piecewise regression model; and

T = the tide stage at the U.S. Geological Survey Homosassa River gage, in feet above NAVD88, at the time of the salinity measurement.

* R^2 = 1 – (residual sum of squares) / (corrected sum of squares)

** *SD* = standard deviation of the residuals between estimated and observed salinities

2.8.8 Modeling River Salinity – Hydrodynamic Model

In addition to the regression models developed for predicting longitudinal salinity in the Homosassa River, a calibrated hydrodynamic model of the system was developed for the District by HSW Engineering, Inc. (2011) to support minimum flows evaluations.
The model, which was developed using Environmental Fluid Dynamic Code was used to evaluate salinity and thermal characteristics of the Homosassa River main channel for baseline and selected flow-reduction scenarios. The District has also used the Environmental Fluid Dynamics Code to evaluate salinity and thermal characteristics and develop minimum flow recommendations for other estuarine river systems, including the Chassahowitzka River system (Dynamic Solutions, LLC 2009), the Little Manatee River system (Huang and Liu 2007) and the Weeki Wachee River system (Janicki Environmental, Inc. and Applied Technology and Management 2007).

The Homosassa River hydrodynamic model includes a three dimensional orthogonal grid system with up to three vertical layers, depending on water depth in individual grid-cells (Figure 2-45). Boundary conditions for the model were established west of Shell Island and at the headwaters of Halls River and the Homosassa River. Downstream boundary conditions included measured stage, salinity and temperature at the USGS Shell Island gage and modified salinity values developed during the model calibration process. Upstream conditions included discharge, salinity and temperature at the USGS Homosassa Springs and SE Fork gage sites. Boundary conditions for Halls River included statistically modeled values based on the combined discharge past the USGS Homosassa Springs, SE Fork and Homosassa River gages; salinity conditions measured in Halls River and at the Homosassa Springs gage; and a constant temperature of 23.2°C. Meteorological inputs included wind speed and direction and air temperature measured at the FAWN-IFAS Station at Brooksville.

The model was calibrated and validated to achieve optimal agreement with measured water surface elevation and surface, middle water-column and bottom salinity and water temperature. The model was calibrated for the period from September 15, 2006 through December 31, 2006, and model validation and sensitivity analysis were conducted for the period from January 1, 2007 through June 30, 2007. The modeled period used for analysis of flow variation on thermal characteristics of the river extended from October 1, 2007 through March 31, 2008, and the period modeled for evaluation of salinity changes associated with flow reductions extended from January 1, 2007 through December 31, 2007. Flow duration curves generated for the Homosassa Springs and SE Fork Homosassa Spring gages indicate that the timeframes chosen for modeling thermal and salinity characteristics of the river represented relatively low flow conditions (Figure 2-46).

HSW Engineering, Inc. (2011) report that modeling tidal stage at the USGS gage sites with the Environmental Fluid Dynamic Code was somewhat problematic. They indicate that model accuracy for this parameter could be improved by inclusion of additional downstream side channels within the model domain. Mean salinity was modeled adequately at the three gages, but maximum salinities observed at the Halls River and Homosassa River gage sites were underestimated for the calibration and validation periods. Water temperatures were modeled well for the Shell Island sites and reasonably well for the Homosassa River and Halls River sites. Water temperatures were slightly under-predicted for warm months and over-predicted for cold months, suggesting that the thermal effect of spring discharge may be overestimated by the model. Observed and modeled stage, surface water salinity and temperature for the Homosassa River gage site for the model calibration period are shown in Figure 2-47.

Centerline surface and bottom salinities in the Homosassa River were modeled for three-hour increments in calendar year 2007 using the calibrated hydrodynamic model. Median centerline salinities compare favorably with longitudinal salinity profiles for the river channel that were developed based on synoptic sampling completed by the District and others (see Figure 2-42). Use of these baseline modeling results and modeled results associated with various flow reduction scenarios was an important component of the District's minimum flow recommendations for the Homosassa River system and is discussed further in Chapters 4, 5 and 7 of this report.

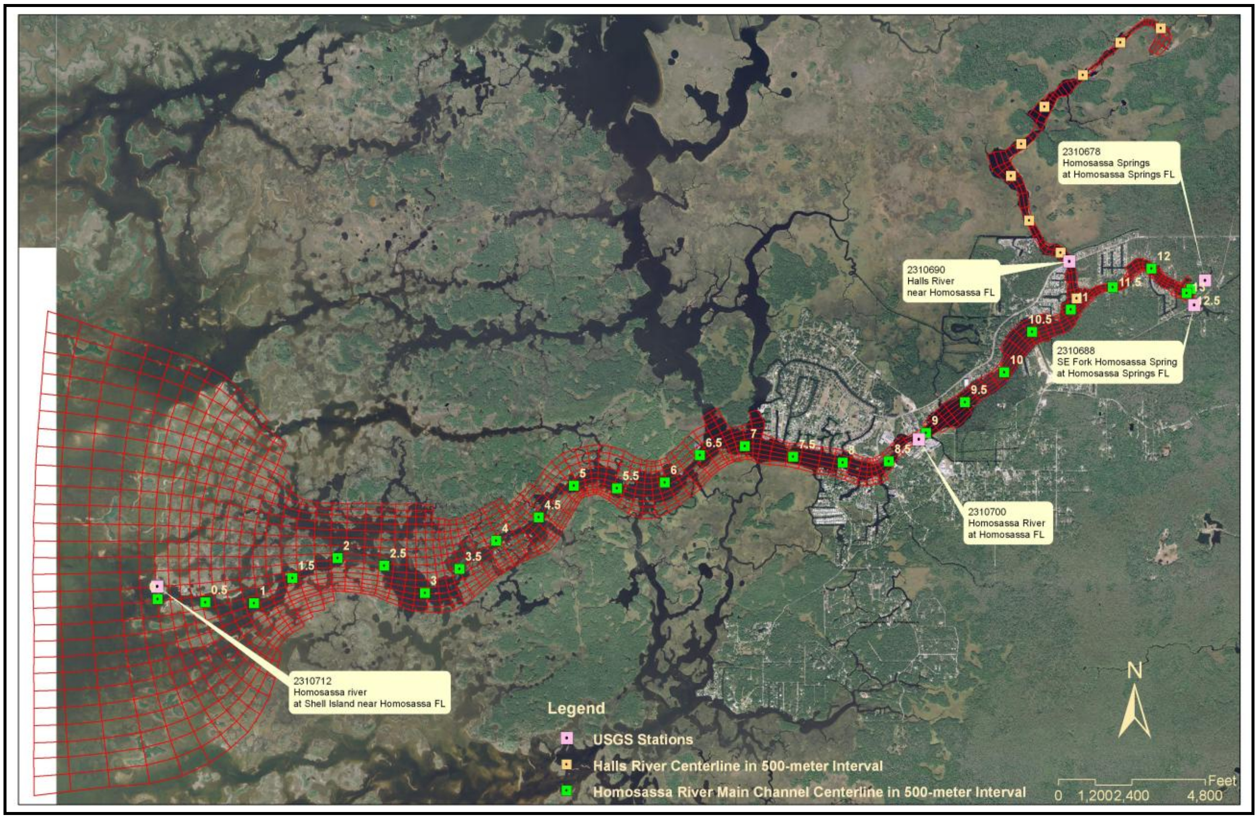
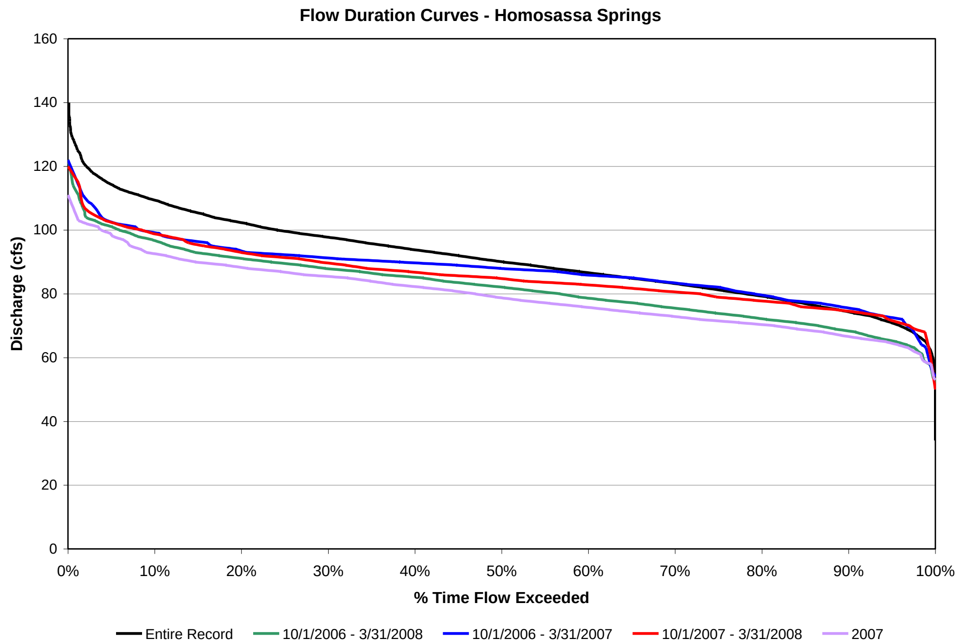


Figure 2-45. Curvilinear-orthogonal grid system for the Homosassa River Environmental Fluid Dynamics Code model (map reproduced from HSW Engineering, Inc. 2011).



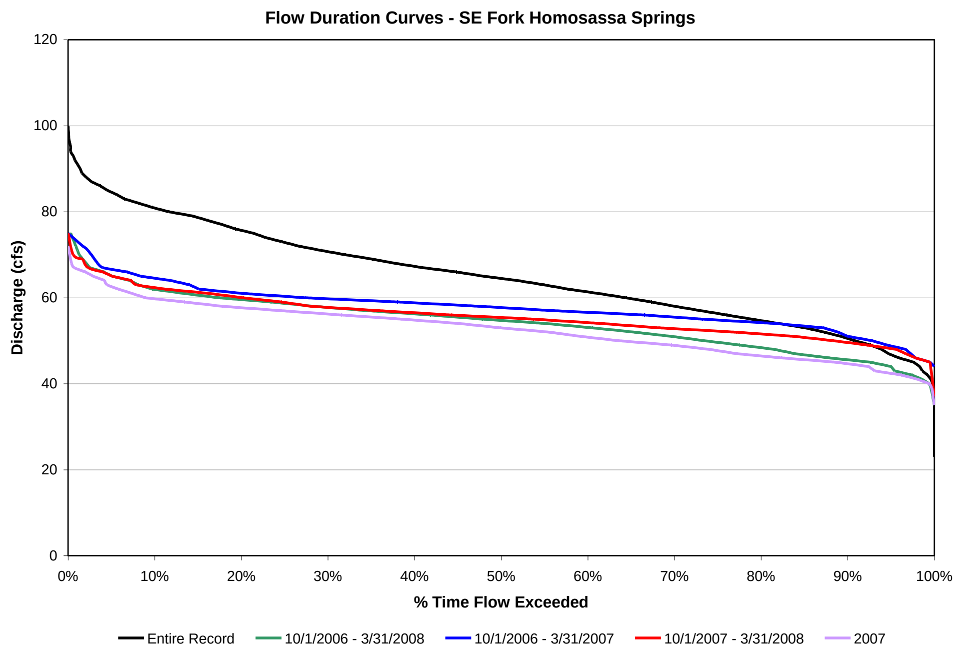


Figure 2-46. Flow duration curves for the U.S. Geological Survey Homosassa Springs at Homosassa, FL (upper panel) and Southeast Fork Homosassa Spring at Homosassa Springs, FL (lower panel) gage sites for selected periods, including the site-specific periods of record and two periods (calendar year 2007 and the period from October 1, 2007 through March 31, 2008) that were used for modeling salinity and thermal characteristics of the Homosassa River. Panels reproduced from HSW Engineering, Inc. (2011).

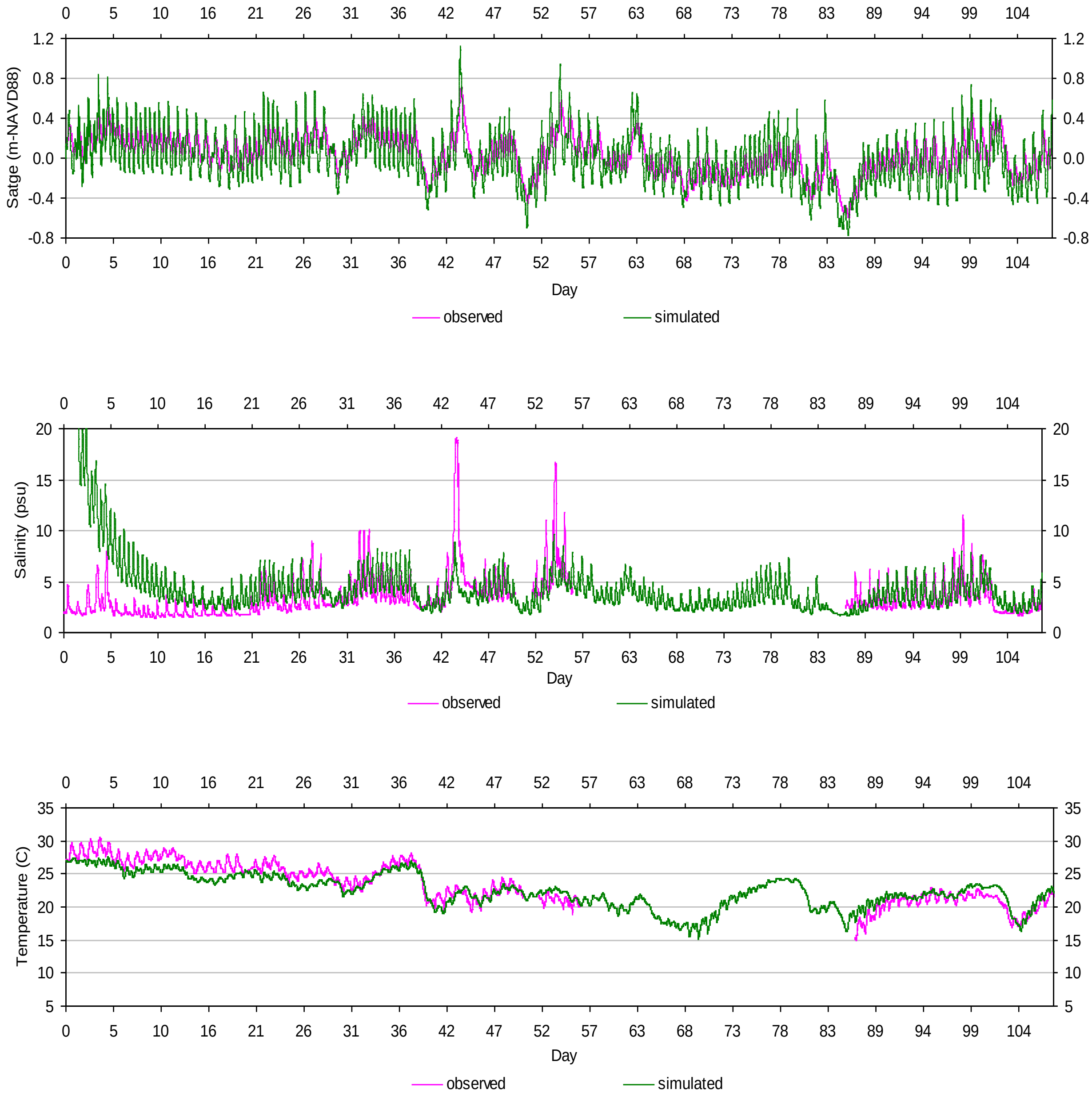


Figure 2-47. Observed and modeled stage (upper panel), surface water salinity (middle panel, expressed as practical salinity units or psu) and water temperature (lower panel) for the U.S. Geological Survey Homosassa River at Homosassa, FL gage site for the September 15. 2006 through December 31, 2006 model calibration period. Modeled values derived using the Environmental Fluid Dynamic Code Homosassa River model. Plots reproduced from HSW Engineering, Inc. (2011).

2.8.9 Modeling River Salinity – Comparison of Hydrodynamic and Empirical Regression Models

Predicted salinities for the Homosassa River in 2007 developed using the Homosassa river hydrodynamic model and the empirical regression modeling approaches were similar. Coefficients of determination for regressions of predicted surface, bottom and depth-average isohalines with salinities of 3,5 and 12 for the two sets of modeled results ranged from 0.63 to 0.73 (see Figures J-5 in Appendix J of HSW Engineering, Inc. 2011, which is included as Appendix A to this report). Modeled isohaline locations associated with the combined discharge past the USGS Homosassa Springs and SE Fork Homosassa Springs gages developed with the hydrodynamic model tended to occur further upstream as compared to the locations predicted using the empirical regression models (Equations 1 and 2 presented in this chapter). Difference in model-predicted isohaline locations were most apparent for surface salinities, as illustrated in Figure 2-48, which includes modeled results for daily surface, bottom and depth-averaged isohalines with a salinity of 3. Similar graphics for the 5 and 12 psu isohalines prepared by HSW Engineering, Inc. (2011) are included in Appendix A of this report.

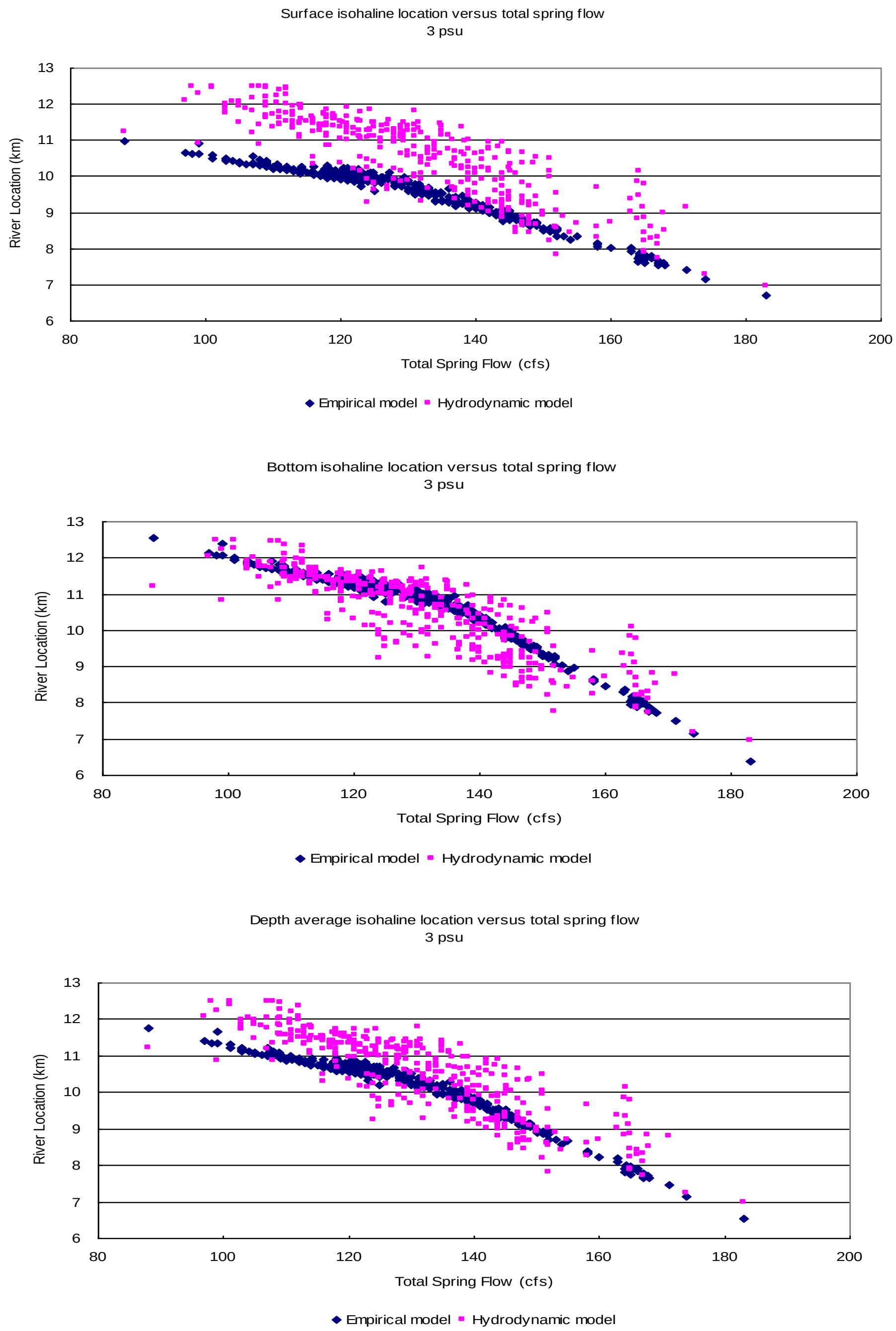


Figure 2-48. Predicted location of the surface, bottom and depth-averaged 3 psu (practical salinity unit) isohaline as a function of total spring flow (combined discharge past the U.S. Geological Survey Homosassa Springs and SE Fork Homosassa Springs gages) for 2007 based on model results derived using empirical regression models and the Homosassa River Environmental Fluid Dynamic Code hydrodynamic model. Depth-average isohaline location for the regression-based results derived through interpolation of bottom and surface isohaline locations. Plots reproduced from HSW Engineering, Inc. (2011).

2.8.10 Other River Water Quality Characteristics

In addition to water temperature and salinity, which were discussed in previous sub-sections of this report, several other water quality parameters were evaluated to support development of recommended minimum flows for the Homosassa River system. For this review, records available from the District Water Management Information system and synoptic sampling completed by and for the District during recent decades were evaluated, along with previously published water quality summaries for the system.

Water in the river channels of the Homosassa River system can be characterized as basic. Median pH values in 1-km segments of the Homosassa River between river kilometers 0 and 13 ranged from 7.6 to 7.9, based on synoptic sampling completed from January 1997 through February 2009 (Figure 2-49, upper panel; see also Table 2-9). Median pH values ranged from 7.7 to 7.8 for 1-km segments of Halls River (Table 2-9). Median pH values for Hidden River Head Spring and Hidden River Spring No. 2 (refer to Table 2-7) indicate that the Hidden River is also a basic system. The range of pH values observed in the Homosassa River system likely reflects the substantial groundwater from springs and diffuse groundwater discharges in the headwater areas and the basic nature of seawater in the lower portions of the system.

The Florida criterion for dissolved oxygen in Class II and Class III-Marine water bodies requires that dissolved oxygen concentrations shall not average less than 5.0 mg/L in a 24-hour period and shall never be less than 4.0 mg/L. The standards also require that "[n]ormal daily and seasonal fluctuations above these levels shall be maintained" (Rule 62-302.530, F.A.C.). Criteria are similar for Class III-Fresh water bodies although dissolved oxygen concentrations are required to equal or exceed 5.0 mg/L at all times. The water quality parameter is an important consideration for the Homosassa River system, as many estuarine organisms cannot tolerate extended periods of concentrations less than about 2 mg/L (United States Environmental Protection Agency 2000, Diaz 2001). Median dissolved oxygen concentrations in 1-km segments of the Homosassa River and Halls River ranged from 5.9 to 7.7 mg/L (see Table 2-9), but concentrations less than 4.0 mg/L were measured in all segments. Longitudinal concentrations of dissolved oxygen are depicted for the Homosassa River in Figure 2-49.

Nitrogen is an essential element for the growth of algae and aquatic plants, and is frequently a limiting nutrient in estuarine systems (Ryther and Dunstan 1971, Nixon 1986, National Research Council 2000). This element occurs in a variety of organic and inorganic forms in natural waters and different forms of nitrogen are often measured for assessments of water quality. Total nitrogen, which is the sum of nitrate, nitrite, ammonia and organic nitrogen, is commonly used for trophic-state evaluations. Median total nitrogen concentrations available for the sites sampled in the Homosassa River system ranged from 0.33 to 0.63 mg/L (Table 2-11). The high end of this range is less than 60 to 70 percent of the total nitrogen levels reported for estuarine sites and less than the levels reported for 80 to 90 percent of the stream sites evaluated by Friedemann and Hand (1989) in their now historical compilation of statewide water quality information. The median observed total nitrogen values are lower than the 1.54 mg/L numeric criterion currently approved by the United States Environmental Protection Agency for free-flowing surface waters in the peninsular region of Florida (Federal Register 2010).

Based on water chemistry sampling at 10 transects within the Homosassa River, Frazer *et al.* (2006) found that total nitrogen concentrations were significantly lower during 2003-2005 as compared to the period from 1998 through 2000, when discharge in the river system was lower. They report similar results for differences in nitrate concentrations between the two periods, noting that this form of nitrogen accounts for the majority of the total nitrogen concentration in the river. Both total nitrogen and nitrate concentrations were greatest in the river's headwaters, particularly at sites upstream from the point where Halls River joins the Homosassa. Total nitrogen and nitrate generally exhibit longitudinal declines along the course of the river toward the Gulf. As part of an ongoing District-funded study of nitrate processing in the spring-dominated rivers, Jacoby *et al.* (2011) found a 70 mg/L decrease in nitrate concentration per meter distance downstream within the Homosassa River based on sampling completed on a single date in January 2011.

Phosphorus is also often identified as a limiting nutrient for the growth of algae and aquatic plants. This element occurs in dissolved and particulate forms in aquatic systems and often cycles rapidly between these two states. Total phosphorus, the sum of dissolved and particulate forms, is often used to characterize the trophic state, or level of biological productivity, of water bodies. Median total phosphorus concentrations for most of the sites sampled in the Homosassa River system were typically between 0.02 and 0.03 mg/L (Table 2-11), a range that is less than 80 to 90 percent of the levels reported for the estuarine sites and less than the levels reported for 80 to 95 percent of the stream sites evaluated by Friedemann and Hand (1989) in their now historical compilation of statewide water quality information. The median total phosphorus values calculated for the Homosassa River system sites were all lower than the 0.12 mg/L numeric criterion currently proposed by the United States Environmental Protection Agency for free-flowing surface waters in the peninsular region of Florida (Federal Register 2010). Frazer *et al.* (2006) found increased total phosphorus concentrations in the river in 2003-2005 as compared to sampling conducted in 1998-2000, and note that concentrations were highest in a middle portion of the river (approximately from river kilometer 3 to river kilometer 10; refer to Figure 2-31 for location information).

Concentrations of orthophosphate-phosphorus, a common form of dissolved phosphorus, ranged from approximately 0.01 to 0.02 mg/L at river sites in the Homosassa River system (Table 2-11). These concentrations correspond to a "good" condition of level for this nutrient, based on a recent assessment of the condition of coastal estuaries of the United States (United States Environmental Protection Agency 2004) and are lower than the 0.107 mg/L numeric criterion currently proposed by the United States Environmental Protection Agency for free-flowing surface waters in the peninsular region of Florida.

Chlorophyll a, a primary pigment involved in plant photosynthesis, is another water quality parameter that is typically assessed when evaluating or describing trophic-state conditions in a water body. Median corrected chlorophyll *a* concentrations at sites in the Homosassa and Halls Rivers ranged from 1 to 9.1 µg/L, with highest medians reported for Halls River and the Homosassa River near the confluence of the two rivers (Table 2-11). Frazer *et al.* (2006) note that chlorophyll maxima in the middle portion of the river may be associated with increased residence time associated with tidal forces in the area of transition between forested wetlands and marsh habitat. For comparative purposes, the median chlorophyll *a* concentrations listed in Table 2-11 may be compared to the reported median values of 8.5 and 5.5 µg/L chlorophyll *a* for Florida estuary and stream sites (Friedemann and Hand 1989).

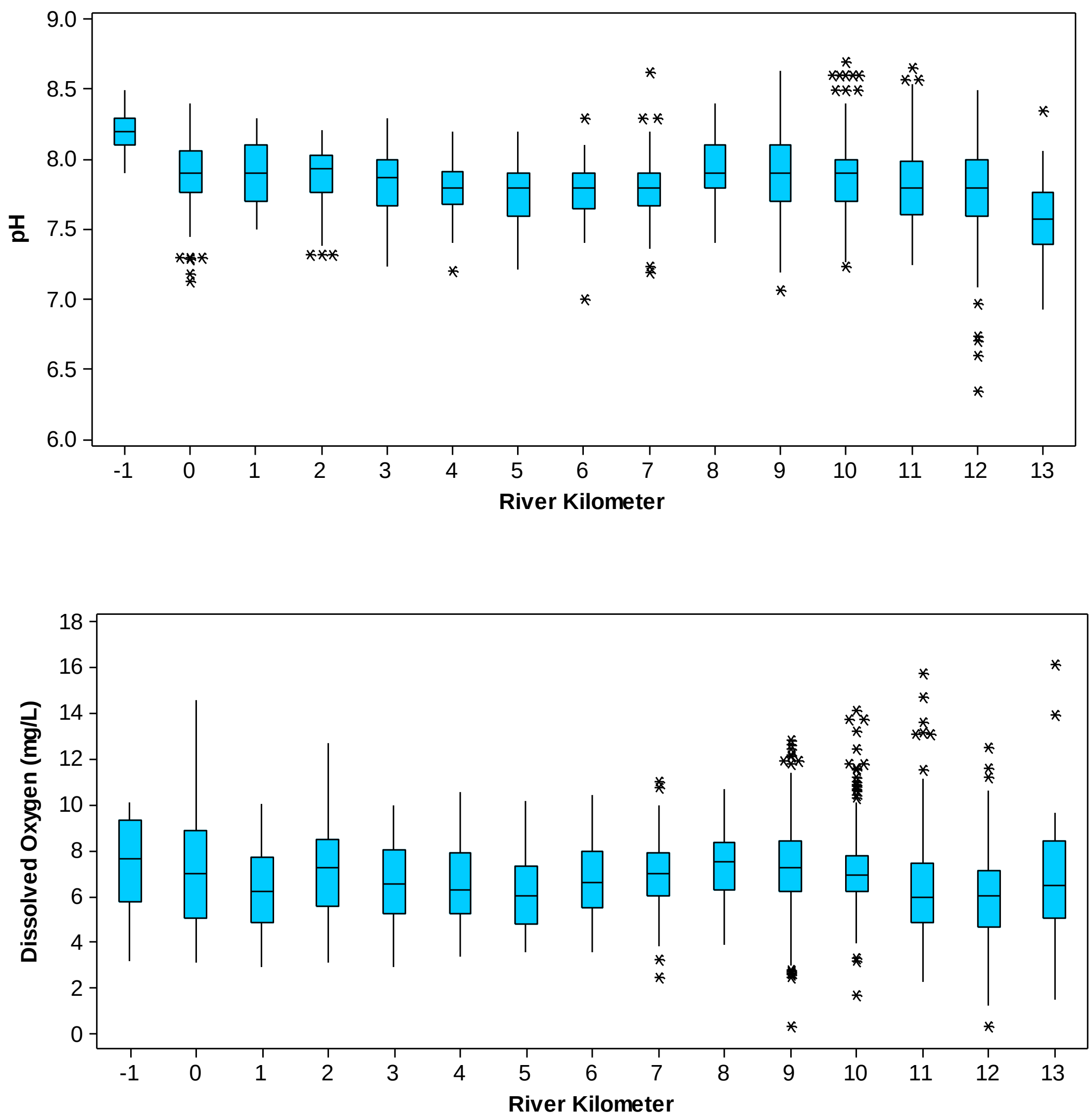


Figure 2-49. Box plots of pH (upper panel) and dissolved oxygen concentrations (lower panel) in one-kilometer segments of the Homosassa River, including the Southeast Fork of the Homosassa River, based on data sources and period of record identified in Figure 2-37.

Table 2-11. Median water quality parameter values for sites in the Homosassa River, Southeast Fork and Halls Rivers, based on data collected between March 24, 1992 and April 24, 2012 by or for the Southwest Florida Water Management District. Values are expressed as dissolved mg/L unless otherwise indicated and dashes indicate measurements were not available.

Site Name	River Kilo-meter	Number of Dates Sampled (N)	Ca	Cl	Mg	K	Na	SO_4	Total N (µg/L)	Total P	Ortho-PO_4 (P)	Total Suspen-ded Solids	Total Chloro-phyll (µg/L)	Color (PCU)
Halls River														
Halls River Bridge	0.4	12	82	1,615	112	31	874	224	0.33	0.020	0.010	3.3	-	18
Halls River AB Homosassa	1.4	26	109	1,877	102	54	1,301	283	-	0.031	0.015	6.0	-	20
Homosassa River WQ HL6	2.2	6	93	937	111	31	895	260	0.59	0.053	0.013	3.3	9.1	25
Homosassa River														
Homosassa River WQ H10	0	7	310	12,200	851	279	7,020	1,795	0.34	0.015	0.005	5.8	1.3	20
Homosassa River WQ H7	3.6	7	248	8,000	572	192	4,740	1,355	0.45	0.022	0.008	4.8	1.9	21
Homosassa River HV5	4.8	37	168	-	421	122	3,400	-	0.40	0.024	0.010	5.6	3.7	23
Homosassa River HV3	7.8	37	100	-	172	50	1,380	-	0.40	0.028	0.010	3.8	8.0	19
Homosassa River AB Gulf	8.4	29	96	2,311	287	55	1,306	337	-	0.028	0.012	3.7	-	20
Homosassa River at Homosassa	8.9	40	71	1,320	68	20	531	183	0.41	0.025	0.010	3.5	-	5
Homosassa River HV1	11.1	37	66	-	66	18	473	-	0.50	0.024	0.010	1.6	3.6	8
Homosassa River AB Halls River	11.4	28	65	670	65	14	314	101	-	0.025	0.016	2.0	-	5
Homosassa River HV0.5	11.9	37	59	-	53	13	382	-	0.58	0.023	0.017	0.7	1.2	5
Homosassa River WQ H1	12.3	7	57	652	48	13	312	97	0.63	0.024	0.019	0.3	1.0	10
Homosassa Wildlife Park	12.6	2	80	601	-	-	-	91	-	0.026	0.017	-	-	-
Homosassa River HV0 (pool)	12.9	37	65	-	78	24	577	-	0.62	0.024	0.018	0.7	1.0	5
Southeast Fork														
Southeast Fork of Homosassa Spring	12.6	7	41	50	11	1	29	12	0.47	0.016	0.017	0.5	-	5
Homosassa River WQ SE1	12.7	7	52	187	18	4	103	36	0.62	0.021	0.016	0.4	1.0	10

[a] Values reported for chlorophyll *a* based on samples collected on or after June 27, 2006.

CHAPTER 3. BIOLOGICAL CHARACTERISTICS OF THE HOMOSASSA RIVER SYSTEM

3.1 Vegetation

3.1.1 Description

The Homosassa River and Southeast Fork of the Homosassa River originate in an extensive wetland system that transitions from hydric hammock and seasonally or temporarily flooded brackish, forested wetlands to irregularly flooded estuarine salt marsh approximately 3.1 miles (5 km) downstream from the river's headwaters near the community of Homosassa (see Figure 2-31). Downstream, the river courses through a complex of irregularly flooded emergent and forested estuarine wetlands and subtidal aquatic beds. Halls River and Hidden River are surrounded by seasonally flooded or tidal brackish, forested and emergent wetlands over their entire lengths.

Descriptions of these and similar coastal wetlands of the region are included in a number of reports published during recent decades. Simons (1990) and Wolfe *et al.* (1990) provide general overviews of wetland and upland vegetation for the Springs Coast, which is the extensive portion of the west coast of Florida ranging from the Pithlachascotee River basin in Pasco County northward to the Waccasassa River basin in Levy County. Simons *et al.* (1989), Vince *et al.* (1989) and Williams *et al.* (2007) focus on hydric hammocks, which are a unique forested wetland type that is most widely distributed in Florida along the Springs Coast and beyond to the St. Marks River area. Comprehensive reviews of seagrass communities in the area include those by Zieman and Zieman (1989), Frazer and Hale (2001), Mattson *et al.* (2007) and Dawes *et al.* (2004). Other studies, including those by Blackburn and Weldon (1967), Gates (1967), the Southwest Florida Water Management District (1989), Kelly (1994), Frazer (1999), Frazer *et al.* (2001a, b), Hoyer *et al.* (2004), Southwest Florida Water Management District (2005), Frazer *et al.* (2006) and PBS&J (2009) provide specific information on the vegetation of the Homosassa River system.

Submersed aquatic vegetation was reportedly quite dense in the Homosassa River in the 1960s (Blackburn and Weldon 1967, Gates 1967), but is currently relatively sparse (Frazer *et al.* 2001a,b. Frazer *et al.* 2006, PBS&J 2009, Frazer *et al.* 2011). Freshwater species of submersed aquatic vegetation extend down the Homosassa River to approximately river kilometer six and are most abundant in Halls River. The most common submersed plants populating the river system in recent years include parrot feather (*Myriophyllum aquaticum),* Eurasian water milfoil *(Myriophyllum spicatum),* southern naiad (*Najas guadalupensis*) and small pondweed (*Potamogeton pusillus*). Although less abundant, hydrilla (*Hydrilla verticillata*), American eelgrass (*Vallisneria americana*), coontail (*Ceratophyllum dermersum*), pondweed (*Potamogeton pectinatus*) and widgeon grass (*Ruppia maritima*) have also been observed. *Sargassum* occurred at a number of sites in the lower Homosassa River, up to about river kilometer 4.4. Marine and freshwater algae, including *Chaetomorpha* and *Lyngbya* are commonly found in the upper and lower portions of the river, respectively. Less common macroalaga include *Chara*, *Gracilaria* and *Enteromorpha*.

The shorelines of the Homosassa River downstream from the Homosassa Community and most of the Halls River are dominated by natural vegetative cover. Black needlerush (*Juncus roemerianus*) is the dominant emergent plant along the shore of the Homosassa River, where it extends upstream to river kilometer 7.4 (PBS&J 2009). The species is also relatively common in Halls River, where cattail (*Typha* sp.) is the dominant emergent plant. Sawgrass (*Cladium jamaicense*) is relatively abundant in Halls River and the Homosassa River. Leather fern (*Achrostichum* spp.) also occurs in both rivers, but is more common in the Homosassa River.

Common trees in the forested wetlands of the Homosassa River system include red maple (*Acer rubrum*), ash (*Fraxinus* spp.), swamp bay (*Persea palustris*), cabbage palm (*Sabal palmetto*), southern red cedar (*Juniperus virginiana* var. *silicicola*) and sweetbay (*Magnolia virginiana*). More salt tolerant trees, including red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*) and buttonwood (*Conocarpus erectus*) are sparsely distributed along the lower segment of the river. Common shrubs include saltbush (*Baccharis* spp.) and wax myrtle (*Myrica cerifera*).

3.1.2 Relationships Between Vegetation, Salinity and Other Physiochemical Variables

Tidal wetlands associated with coastal rivers of the southeastern United States and elsewhere are susceptible to degradation associated with droughts, anthropogenic alteration of natural freshwater inflows or groundwater discharge, land-use changes, hurricanes and other storms, climate change, sea-level trends and sediment or substrate subsidence (*e.g.,* see Boesch *et al.* 1994, Brinson and Malvarez 2002, Kennish 2004, Doyle *et al.* 2007, Stedman and Dahl 2008). Studies addressing effects of salinity increases associated with these factors are particularly relevant to the development of minimum flow requirements for the Homosassa River system and other coastal rivers in the District, where flow reductions may alter salinity patterns within river channels and associated wetlands and effects of sea level rise may also be significant.

Effects of salinity on changes in cypress-dominated and mixed bottomland swamps in tidal segments of southeastern coastal rivers have been considered by numerous investigators. In a review of sea-level rise and coastal forests of the Gulf of Mexico, Williams *et al.* (1999) describe changes associated with sea level variation during the Holocene and summarize recent changes that have been attributed to increased salinity in the Mississippi River delta and south Florida. More recent summaries of saltwater induced changes in southeastern tidal swamps are provided by Conner *et al.* (2007) and Krauss *et al.* (2007). As part of a comprehensive review of tidal floodplain forests of the Suwannee River, Light *et al.* (2002) discuss potential increases in the abundance of salt-tolerant species under various flow-reduction scenarios. In the Northwest Fork of the Loxahatchee River in southeast Florida, recent decline of floodplain swamp vegetation, including bald cypress, has been associated with increased salinity (South Florida Water Management District 2002) resulting from historical water management practices. In response to this environmental degradation and to preserve existing and stressed floodplain swamp communities, a minimum flow for the Loxahatchee River was established to maintain salinities less than 2 at selected sites along the river corridor. Based on review of published salinity tolerance information for common tree species within tidal forested wetlands, including bald cypress and various hardwood species, the Suwannee River Water Management District (Water Resources Associates Inc. *et al.* 2005) also identified a salinity criterion of 2 for consideration in their development of minimum flows for the lower segment of the Suwannee River.

The effects of sea-level rise and increasing salinity have also been evaluated for hydric hammocks, a common forested wetland type extending along the west coast of Florida from the southern Hernando County line north to the vicinity of the St. Marks River. Reduction in the aerial coverage of hydric hammocks, which are typically dominated by cabbage palm, southern red cedar, a mixture of hardwood trees and loblolly pine (*Pinus taeda*), has been extensive during the past century (see review by Williams *et al.* 2007). Recent declines in populations of cabbage palm and southern red cedar at Waccasassa Bay State Preserve have been attributed to sea-level increase and drought by DeSantis *et al.* (2007), who note that recent rates of decline have exceeded predictions derived from previous studies of the area. Castaneda and Putz (2007) documented more than a seventeen percent decline in coastal forest in the Waccasassa Bay State Preserve between 1973 and 2003 as a result of forest replacement with salt marsh species. Modeled wetland changes associated with various sea level increase scenarios for the St. Marks National Wildlife Refuge area also demonstrate potential increases in salt marsh habitat and losses in forested habitat with increased sea levels (Doyle *et al.* 2003). According to analyses conducted by Raabe *et al.* (2004), as cited by Williams *et al.* (2007), decline of hydric hammock vegetation along the Big Bend coastline of Florida since the mid-1800s has been less pronounced in areas with high freshwater discharge, *e.g.,* near the Suwannee and Weeki Wachee Rivers. Field investigations of the survival of transplanted cabbage palm seedlings at Waccasassa Bay and at the Chassahowitzka National Wildlife Refuge (an area of relatively low salinity), provide some support for the mitigation of adverse salinity-effects in areas of higher freshwater discharge (Perry and Williams 1996). However, Williams *et al.* (2007) caution that *"[g]ood quantification of the effect of freshwater discharge on the rates of forest canopy loss and coastal forest retreat requires further study"*.

A number of recent District-funded studies have addressed factors influencing temporal and spatial variation in submersed aquatic, emergent and woody wetland vegetation of the Homosassa River system. Frazer *et al*. (2001a, b), Hoyer *et al.* (2004) and Frazer *et al.* (2006) evaluated factors such as salinity, freshwater flow, substrate, light and nutrient concentrations on submersed aquatic vegetation in the Homosassa River. PBS&J (2009) recently mapped and described submersed and emergent aquatic vegetation and woody vegetation of the Homosassa River, Halls River and Southeast Fork of the Homosassa River to support development of minimum flows for the system.

For their District-funded study of factors controlling plant abundance and distribution in Springs Coast tidal rivers, Hoyer *et al*. (2004) investigated submersed aquatic vegetation in the Homosassa, Chassahowitzka and Crystal rivers between 1998 and 2000. At the Homosassa River, five main-channel sites were sampled during summer months along 20 regularly spaced transects between the Homosassa Main Spring pool and the landward margin of the salt marsh. Plant distributions in all three rivers were associated with flow rate. At sites where flow rates exceeded 0.25 m s^{-1} (0.82 feet s^{-1}), substrates typically consisted of rock and were devoid of vegetation. Similarly, sites where bottom light intensity was less than ten percent of that at the water surface exhibited low plant abundance and biomass. Submersed aquatic vegetation biomass in all three sampled rivers was also nearly zero at sites where annual average salinity exceeded 3.5 ppt. Distributions of individual taxa were associated with average salinity values, with *Hydrilla* and *Gracilaria* found at sites with the lowest (1.5 ppt) and highest (2.6 ppt) mean salinities, respectively. Plant nutrients were found to affect submersed aquatic vegetation biomass much less than the other factors examined, leading Hoyer and his co-authors to assert that flow, substrate type, light intensity and salinity control the distribution and abundance of submersed aquatic vegetation in the Homosassa, Chassahowitzka and Crystal rivers.

Between 1998 and 2000 the University of Florida (Frazer *et al.* 2001a, b) sampled the submersed aquatic vegetation and characterized physical and chemical attributes of five rivers in the Springs Coast, including the Homosassa River. Three of the systems, the Homosassa, Chassahowitzka and Weeki Wachee Rivers, were again sampled by the University between 2003 and 2005 and results from the two study periods, *i.e.,* 1998-2000 and 2003-2005, are described and contrasted by Frazer *et al.* (2006). For both sampled periods, submersed aquatic macrophytes and macroalga were evaluated at a total of 100 sites located along 20 transects in each river between the headwater spring boils and the landward extent of salt marsh (the lowest sampled site on the Homosassa River was located near river kilometer 7.6). Water chemistry and periphtyon associated with macrophytes were sampled at 10 transects in each river.

The number of sites where submersed aquatic vegetation was absent in the Homosassa River and the other systems was substantially higher in the more recent period sampled by Frazer and his colleagues; in the Homosassa River the mean number of sampled sites without vegetation increased 104 percent between the 1998-2000 and 2003-2005 periods. Submersed aquatic vegetation was, however, relatively sparse in the Homosassa River during both sampled periods, as compared to abundances observed on the other rivers. Filamentous algae (primarily *Lyngbya* sp.) and most macrophytes were less abundant in the Homosassa during the more recent period, with mean biomass values for the two periods differing by approximately 66 percent. Exceptions included small pondweed (*Potamogeton pusillus)* and widgeongrass (*Ruppia maritima)*, which both increased in abundance. Biomass of macroalga in the Homosassa River was 62 percent lower in the more recent sampling period. In contrast, biomass of periphyton on submersed aquatic vegetation in the river increased by 85 percent between the two periods.

Interestingly, mean salinity values in the Homosassa River for the more recently sampled period were lower than those for the earlier period, prompting Frazer and his collaborators to note that *"… factors other than an increase in salinity underlie the observed declines in the frequency of occurrence and general downstream decline of submersed aquatic vegetation*." Given that nitrate and soluble reactive phosphorus concentrations were substantially higher during the more recent period, they note that the observed changes in the Homosassa and other studied rivers could be indicative of increasing eutrophication associated with increased nutrient loading.

PBS&J (2009) recently evaluated submersed, emergent and woody shoreline plants along the Homosassa, Halls and Southeast Fork of the Homosassa Rivers. Based on field surveys completed in October 2008 and additional sampling by the District, the University of Florida and others, they delineated salinity zones in each river and characterized plant distributions in the river channels and within five feet of the shorelines. Shorelines of the Homosassa River between Shell Island and the bridge in the Homosassa Springs Wildlife Park near river kilometer 12.6 were evaluated. Southeast Fork shorelines were surveyed upstream to river kilometer 12.95 and Halls River shorelines were characterized from the river's confluence with the Homosassa upstream to approximately river kilometer 3.2. Shorelines were classified as natural or altered, with altered shorelines identified as rip-rap, seawall, maintained or modified. Maintained shorelines include lawns and maintained landscaping. Modified shorelines were those with relatively natural vegetation that have been obviously modified. Natural shoreline vegetation was mapped using a Braun-Blanquet approach and density-weighted cover classes were developed for individual plant species.

Based on salinity data collected by the District and other sources and the Venice Salinity Classification system, PBS&J classified only the most upstream few hundred meters of the Southeast Fork of the Homosassa River as freshwater habitat. Halls River and the Homosassa River segment between river kilometers 10 and 12.6 were classified as an oligohaline zone; the Homosassa River between river kilometers 3 and 10 may be classified as mesohaline zone; and the lower portion of the river between river kilometers 1 and 3 were classified as a polyhaline zone.

PBS&J notes that observed distributions of submersed and emergent aquatic vegetation are consistent with the delineated salinity zones and known salinity tolerances for individual plant taxa (Figures 3-1 through 3-3). Freshwater species of submersed aquatic vegetation were most abundant in Halls River and extended down the Homosassa River to approximately river kilometer 8. Freshwater species of emergent aquatic vegetation were limited to the Homosassa River upstream of its confluence with the Halls River at approximately RK11. Oligohaline emergent species were common throughout Halls River and were typically not distributed below river kilometer 6.6 in the Homosassa River, although leather fen was found as far downstream as river kilometer 2.2. Freshwater tree species were common along the Homosassa River shoreline upstream from river kilometer 9. Oligohaline to mesohaline trees, including cabbage palm and red cedar were the dominant trees in the middle reach of the Homosassa River and were present throughout most of the Homosassa and Halls Rivers. Polyhaline species, including mangroves and buttonwood were dominant in the lowest segment of the Homosassa River.

Although submersed aquatic vegetation has been used to establish minimum flow requirements, PBS&J (2009) note that *"...it is not an adequate indicator of increasing salinities in the Homosassa River due to its limited and declining distribution*." These investigators further suggest that "*EAV [emergent aquatic vegetation] distributions may provide a good indicator for establishing MFLs along the Homosassa River*" noting that "*EAV species distributions generally correspond to mean high salinities along tidally influenced rivers and freshwater species respond relatively quickly to changes in salinities*." In contrast, Clewell *et al.* (2002) report that apparent transitions in shoreline vegetation observed at several other west-Florida coastal rivers sampled for the District "…*may be indicative of general salinity conditions but are not reliable as predictors of specific salinity regimes."* Factors cited by Clewell and his collaborators as contributing to a lack of good correlation between shoreline plant occurrences and salinity included the narrow nature and relatively high frequency of disturbance of riverbank habitat as compared to adjacent marsh or forested habitats.

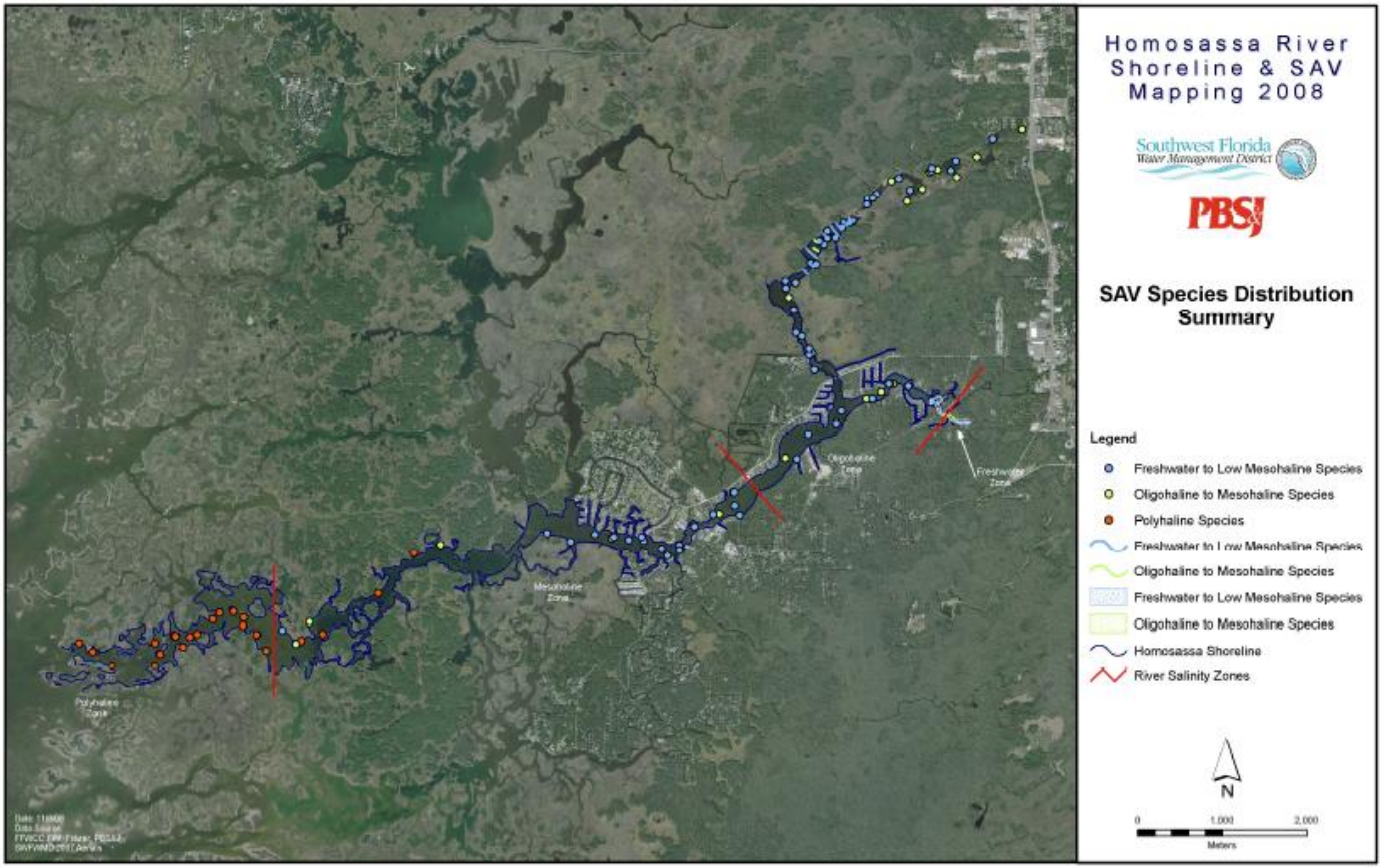


Figure 3-1. River salinity zones and submersed aquatic vegetation distributions in the Homosassa River, Southeast Fork of the Homosassa River and Halls River. Figure reproduced from PBS&J (2009).

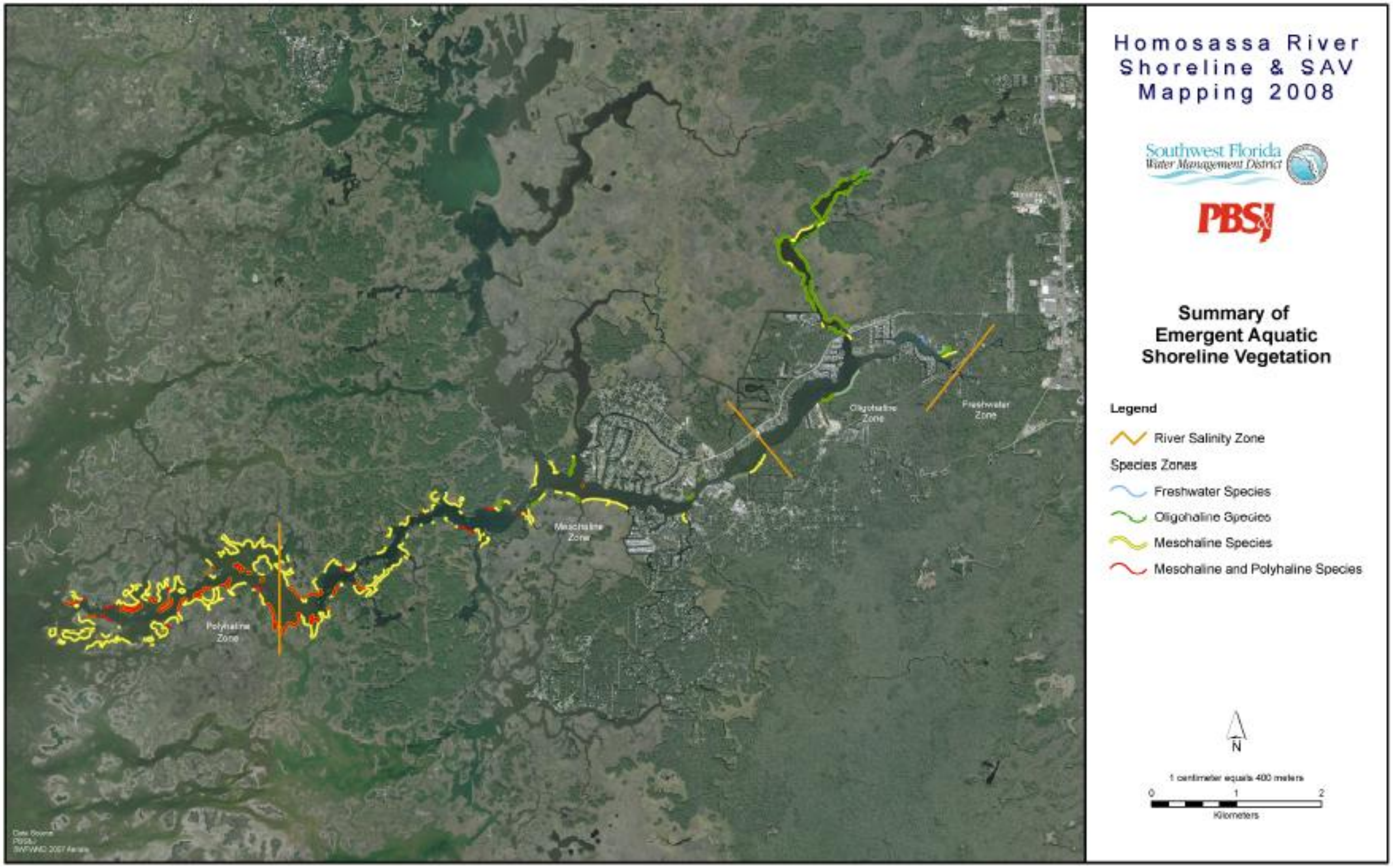


Figure 3-2. River salinity zones and emergent aquatic vegetation distributions in the Homosassa River, Southeast Fork of the Homosassa River and Halls River. Figure reproduced from PBS&J (2009).

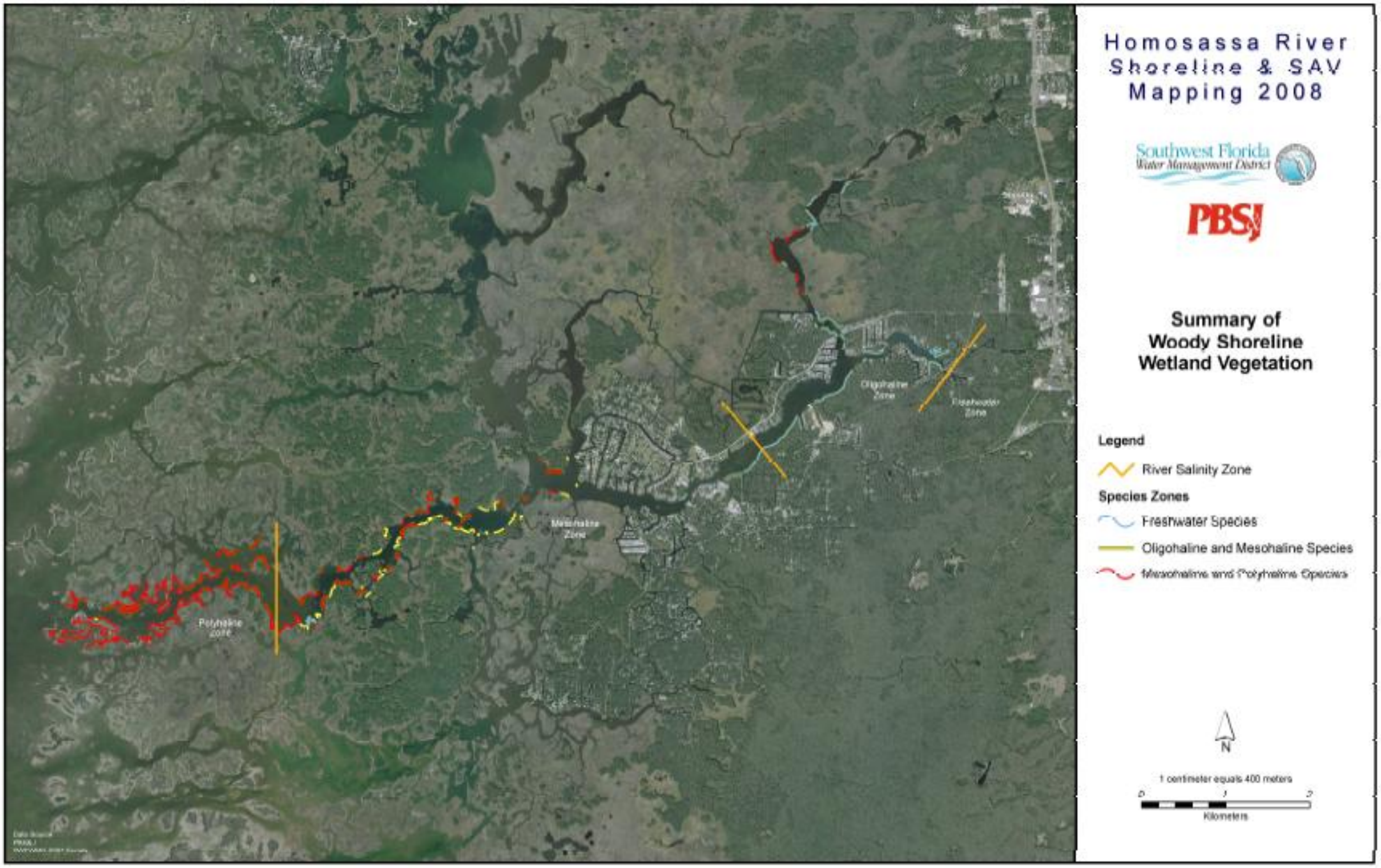


Figure 3-3. River salinity zones and woody plant species distributions in the Homosassa River, Southeast Fork of the Homosassa River and Halls River. Figure reproduced from PBS&J (2009).

3.2 Benthic Macroinvertebrates

3.2.1 Description

Benthic macroinvertebrates, *i.e.,* invertebrates larger than about 0.5 mm that live in, on or near bottom substrates of aquatic systems, are ecologically and recreationally important components of the Homosassa River system fauna. Some species, such as oysters, are sessile, while others, including amphipods or scuds, are highly mobile. The life cycle of many benthic invertebrates include planktonic larvae or eggs that utlimately settle on bottom substrates. Longitudinal gradations in salinity and other physiochemical factors likely contribute to the occurrence, persistence and distribution of benthic invertebrate species in the Homosassa River system.

Sloan (1956) and Wetland Solutions, Inc. (2010) provide descriptions of the aquatic insect component of the Homosassa River benthic macroinvertebrate assemblage. Based on sampling completed in the Homosassa and Weeki Wachee Rivers between November 1952 and February 1954, Sloan found the number of insect species and abundances were lower in the spring pools and downstream estuarine areas as compared to the relatively fresh upstream or middle segments of the rivers. Sloan hypothsizes that the distribution of insect species in the Homosassa River (and the Weeki Wachee River) may be related to low dissolved oxygen concentrations in spring pools and increased chloride concentrations in downstream areas. For a more recent study, that was funded in part by the District, Wetland Solutions, Inc. report that the number of insects emerging from the Homosassa Main Spring run was four times greater than the number emerging from the spring pool, based on a three-day sampling event in November 2008. Although based on limited sampling effort, these findings are consistent with Sloan's characterization of the distribution of insects in the upper Homosassa River and spring pool.

To support development of minimum levels for the Homosassa River system, the District recently funded a study by Janicki Environmental, Inc. designed to characterize the soft-sediment benthic macroinvertebrates in the Homosassa River, Southeast Fork of the Homosassa River and the lower portion of Halls River. The study included evaluation of relationships between macroinvertebrates, salinity and other environmental variables for development of predictive regression equations that describe variation in benthic macroinvertebrate taxa richness, diversity and total abundances. The final report for the project (Grabe and Janicki 2010) is included as Appendix D to this report.

For the study, single three-inch diameter core samples were extracted from 0.43 ft^2 dredge samples collected at 114 sites with a Young-modified Van Veen sampler between May 12 and 14, 2008. Core samples were sieved in the field through a 0.5 mm mesh, preserved and sorted by the Mote Marine Laboratory. Sampled sites included 104 sites in the Homosassa River, five sites in the "spring run" or upper 250 meters of the Homosassa River, ten sites in the Southeast Fork and ten sites in the lower half of Halls River (Figure 3-4). Samples were collected at transects located throughout the river and at haphazardly selected sites in the spring run and Southeast Fork. Four samples were collected at transects in the Homosassa and two were collected at the Halls River transects. Water depth and near-surface and near-bottom water temperature, salinity, conductivity, dissolved oxygen concentration and pH were measured at each sampled site.

Abundance (numbers per square meter) and dominance (the geometric mean of the frequency of occurrence) were determined for the top fifty taxa in the Homosassa River/spring run/Southeast Fork and Halls River (Table 3-1). These taxa accounted for more than 91 percent of the mean total number of individuals collected from the core samples. The number of taxa was highest in the downstream portion of the Homosassa River and lowest between river kilometers 10 and 11 (Figure 3-5).

Abundant/dominant taxa in the Homosassa River and Southeast Fork included the amphipods *Grandidierella bonnieroides* and *Ampelisca* sp., the tanaid crustacean *Halmyrapseudes cf. cubensis*, the polychaete worm, *Mediomastus* sp. and unidentified olgiochaete worms. Amphipods were also abundant and dominant in Halls River, where *G. bonnierodes*, *Cerapus bethophilus* and *Gammarus mucronatus* were common. The isopod *Cassidinidea ovalis*, the Carolina marsh clam, *Polymedosa caroliniana*, and unidentified oligochaetes were also abundant in Halls River. Insect larvae, including midges (a family of flies) and mayflies were encountered primarily in the Southeast Fork and the upper portion of the Homosassa River and Halls River.

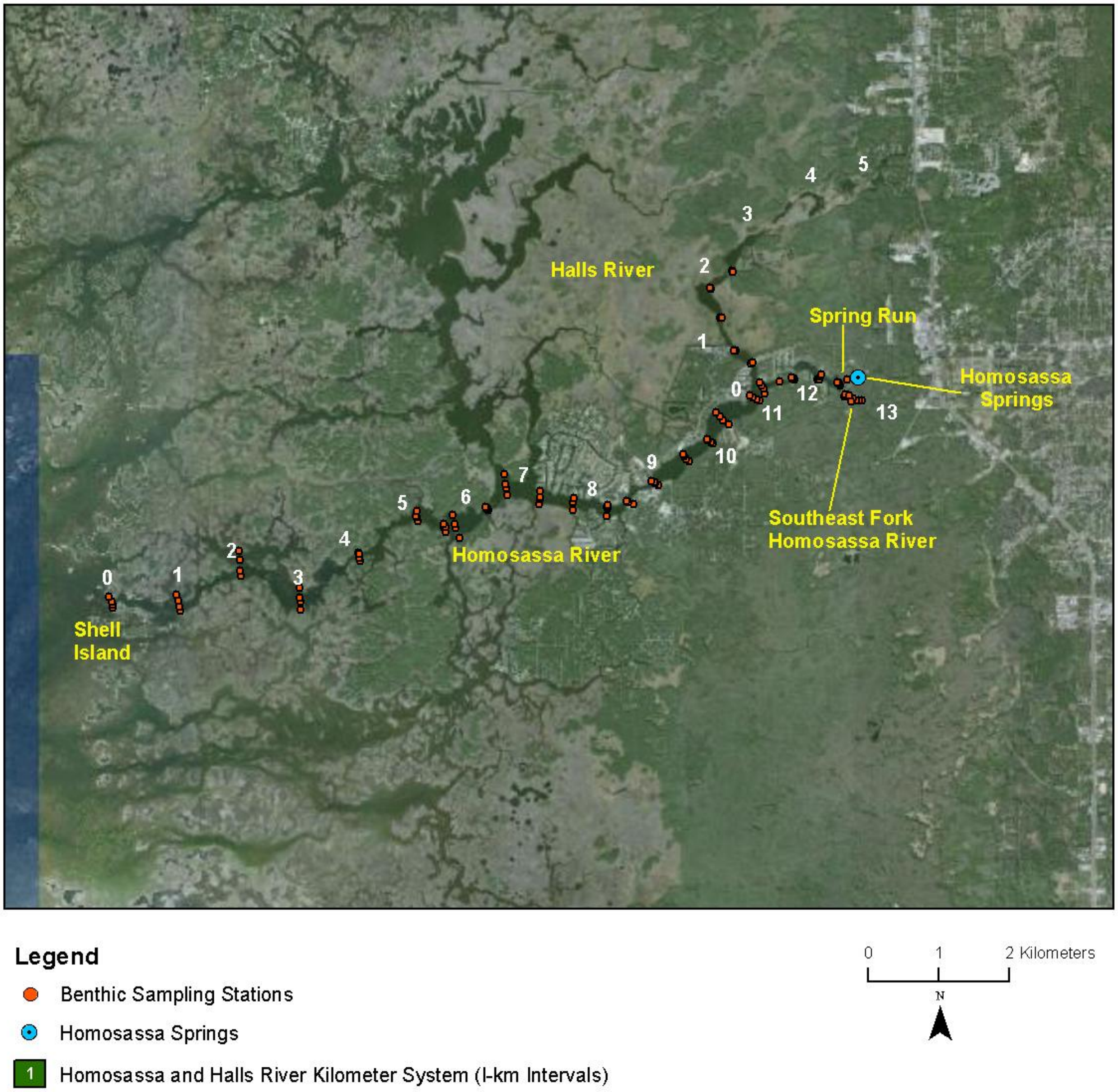


Figure 3-4. Location of stations where benthic macroinvertebrates were sampled by Grabe and Janicki (2010) on May 12-14, 2008 in the Homosassa River (including the spring run), Southeast Fork of the Homosassa River and the lower Halls River (photographic image sources: Southwest Florida Water Management District 2003c and Woolpert, Inc. 2009).

Table 3-1. Mean densities and dominance scores (Dom.) for soft-sediment benthic invertebrate taxa with the top 50 highest dominance scores based on core samples collected from the Homosassa River, Southeast Fork of the Homosassa River and lower Halls River between May 12 and 14, 2008. Center of abundance expressed as river kilometer and mean salinity at capture are also listed for Homosassa River dominants. The symbol "x" indicates absence in core samples. Adapted from Grabe and Janicki (2010).

Taxon	Common Name	Homosassa River				Halls River	
		Mean No./ m^2	Dom.	Center of Abund-ance (RKM)	Mean Salinity at Capture (ppt)	Mean No./ m^2	Dom.
Actiniaria	Sea anemones						
Genera undetermined		274	3.4	3.8	17.9	x	x
Nemertea	Probiscis worms						
Genera undetermined		118	2.3	3.8	17.0	22	0.8
Platyhelminthes	Flatworms						
Genera undetermined		322	2.6	11.9	1.3	x	x
Annelida - Polychaeta	Worms						
Amphicteis gunneri		158	3.0	6.1	13.1	66	2.5
Apomatus sp.		310	1.9	7.1	13.7	x	x
Aricidea philbinae		518	5.4	2.2	19.6	x	x
Brania sp.		126	1.8	2.7	18.2	x	x
Capitella capitata complex		110	2.0	5.3	15.2	x	x
Cirrophorus sp.		320	2.3	0.3	22.6	x	x
Fabriciola sp.		598	4.9	3.3	17.5	x	x
Laeonereis culveri						175	5.2
Leitoscoloplos sp.		173	3.0	4.1	15.9	x	x
Lysilla sp.		101	1.6	1.2	21.0	x	x
Mediomastus sp.		3,573	18.7	6.7	13.1	x	x
Parandalia tricuspis		335	4.9	7.3	11.9	x	x
Polydora socialis		x	x	x	x	22	0.8
Streblospio gynobranchiata		680	6.5	7.5	12.5	22	0.8
Typosyllis alosae		1,004	4.6	0.4	22.1	x	x
Annelida - Oligochaeta	Worms						
Genera undet.		2,156	14.9	10.6	3.4	1,621	18.6
Annelida - Hirudinea	Leeches						
Genera undet.		x	x	x	x	22	0.8

Table 3-1. Continued.

Taxon	Common Name	Homosassa River				Halls River	
		Mean No./ m^2	Dom.	Center of Abund-ance (RKM)	Mean Salinity at Capture (ppt)	Mean No./ m^2	Dom.
Mollusca - Bivalvia	Clams, Mussels						
Angulus versicolor	Many-colored tellin	152	2.9	6.1	13.9	x	x
Branchidontes exustus	Scorched mussel	2,318	6.9	6.4	12.9	22	0.8
Parastarte triquetra	Brown gemclam	331	3.3	4.3	16.2	x	x
Polymesoda caroliniana	Carolina marsh clam	x	x	x	x	1,643	17.4
Mollusca - Gastropoda	Snails						
Acteocina canaliculata	Channeled barrel-bubble	76	1.6	5.6	13.5	x	x
Crepidula sp.	Slipper snail	457	3.3	0.7	21.6	x	x
Hydrobiidea-Genera undetermined	Mud snails	440	4.4	8.4	11.0	482	8.6
Crustacea - Cumacea	Hooded shrimps						
Cyclaspis varians		82	1.8	4.1	15.9	x	x
Crustacea - Isopoda	Isopods						
Cassidinidea ovalis		535	4.8	3.1	17.2		
Cyathura polita		625	6.5	9.3	3.7	1,029	16.8
Valvifera-Genera undet.		213	3.3	10.7	4.9	x	x
Xenanthura brevitelson		467	5.7	5.1	14.4	x	x
Crustacea - Tanaidacea	Tanaids						
Halmyrapseudes cf. Cubensis		1,685	9.6	4.0	16.0	x	x
Hargeria/Letochelia sp. complex		461	5.3	6.3	12.4	44	1.2
Kalliapseudes macsweenyi		1,186	3.3	0.3	22.7	x	x
Crustacea - Amphipoda	Scuds						
Americorophium ellisi		457	4.3	10.2	10.6	x	x
Ampelisca sp.		5,848	23.7	6.0	13.4		
Amphipoda-Genera undetermined		1,504	9.8	7.9	8.3	1,029	13.7
Aoridae-Genera undetermined		937	4.6	11.4	1.7	x	x
Cerapus benthophilus		204	2.8	2.8	5.2	7,118	33.0

Table 3-1. Continued.

Taxon	Common Name	Homosassa River				Halls River	
		Mean No./ m^2	Dom.	Center of Abund-ance (RKM)	Mean Salinity at Capture (ppt)	Mean No./ m^2	Dom.
Corophiidae-Genera undetermined		474	3.7	4.5	10.6	2,256	23.5
Elasmopus sp.		1,154	3.6	0.1	22.6		
Gammarus mucronatus		903	8.2	5.9	3.9	11,388	49.4
Grandidierella bonnieroides		5,208	25.6	10.4	4.3	4,271	32.3
Hourstonius laguna		598	4.4	5.5	14.0	x	x
Hyalella sp. C		2,453	8.0	12.0	0.7	x	x
Melitidae-Genera undetermined		383	7.4	5.6	13.2	x	x
Caprellidae-Genera undetermined		211	2.0	0.6	21.9	x	x
Crustacea - Decapoda	Crabs, Shrimp, Lobsters						
Panopeidae-Genera undetermined	Mud crab	259	3.8	5.3	12.1	460	9.2
Insecta - Diptera	Flies						
Chironomidae sp. - Genera undetermined.		898	6.7	11.4	2.1	285	8.3
Chironomus sp.		230	2.5	10.9	8.4	22	0.8
Cryptochironomus sp.		x	x	x	x	66	2.5
Dicrotendipes sp.		758	5.3	11.8	1.3	66	1.4
Polypedilum halterale Group		x	x	x	x	131	2.8
Procladius sp.		128	2.1	9.2	3.7	416	8.7
Pseudochironomus sp.		246	1.9	11.9	0.5	22	0.8
Insecta - Ephemeroptera	Mayflies						
Stenonema sp. and Genera undetermined		x	x	x	x	22	0.8

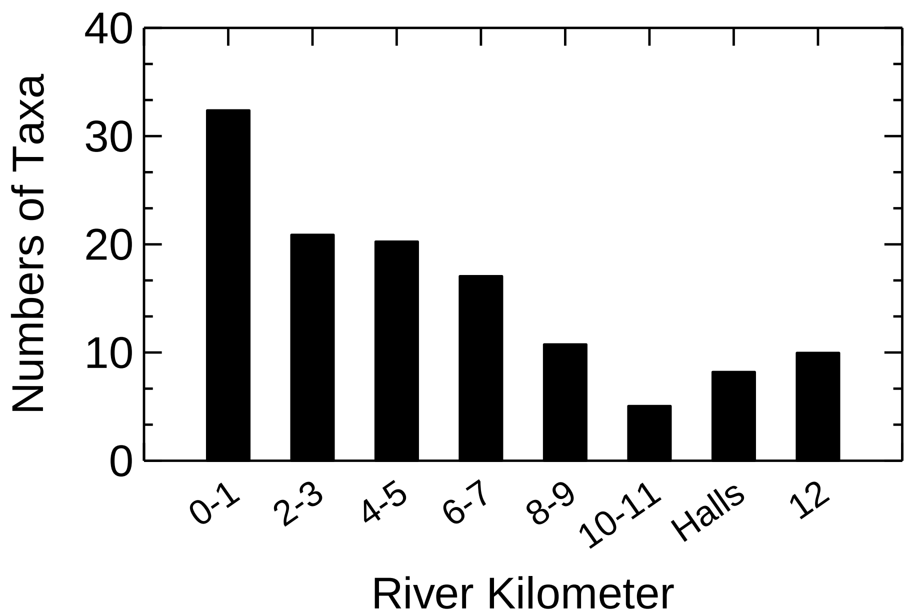


Figure 3-5. Mean number of benthic macroinvertebrate taxa in the Homosassa River (including the spring run and Southeast Fork of the Homosassa River) by river kilometer and in the lower Halls River based on 114 core samples collected between May 12 and 14, 2010. Figure reproduced from Grabe and Janicki (2010).

The University of Florida has also recently completed a survey of invertebrates and fish in the Homosassa and Chassahowitzka River systems (Frazer *et al.* 2011). Within the Homosassa River, aquatic invertebrates associated with aquatic plants and sediments were sampled at five stations along three transects associated with three river reaches (Reach 1 - between river kilometers 11.8 and 12.4; Reach 2 - between river kilometers 10.1 and 11.8; Reach 3 - between river kilometers 8.0 and 8.4) in August 2007 and February of 2008. In years two and three of the study, invertebrates associated with aquatic plants were sampled from Reaches 1 and 2. Results for year one sampling indicate amphipods, ostracods, gastropods, copepods, isopods and roundworms were the most abundant invertebrate taxa associated with submersed aquatic vegetation, which was primarily filamentous algae (Table 3-2). Roundworms, oligochaetes, polychaetes, amphipods, copepods and chironomids were abundant in sediment samples (Table 3-3).

Table 3-2. Counts of invertebrates (per 0.05 m^2) collected from submersed aquatic vegetation in three reaches of the Homosassa River (adapted from Frazer *et al.* 2011).

Taxon	Common Name	Homosassa River					
		August 2007			February 2008		
		Reach 1	Reach 2	Reach 3	Reach 1	Reach 2	Reach 3
Acari	Mites	14	1	0	0	952	433
Hydrozoa	Hydras	0	0	0	0	0	0
Turbellaria	Flatworms	1	0	0	80	0	2
Nemertea	Ribbon worms	7	1	0	0	0	0
Nematoda	Roundworms	148	7	0	2,000	1,776	968
Annelida	Worms						
Oligochaeta	Worms	173	1	0	368	64	48
Polychaeta	Worms	98	0	0	16	0	35
Hirudinia	Leeches	3	1	0	0	8	0
Mollusca	Molluscs						
Gastropoda	Snails	269	26	0	1,974	4,055	405
Pelecypoda	Clams, mussels	47	3	0	119	270	159
Crustactea	Crustaceans						
Amphipoda	Amphipods	2,763	89	0	2,523	2,009	3,324
Cumacea	Hooded shrimps	7	2	0	0	0	72
Palaemonidae	Shrimps	0	0	0	0	0	0
Decapoda	Crabs, Shrimp, Lobsters	1	0	0	32	1	0
Isopoda	Scuds	37	1	0	1,168	90	475
Cambaridae	Crayfish	0	0	0	0	0	0
Mysidacea	Opossum shrimp	1	0	0	0	0	0
Tanaidacea	Tanaids	105	0	0	17	1	403
Cladoceran	Water fleas	0	0	0	0	16	0
Ostracoda	Seed shrimp	1,393	296	0	10,048	2,728	684
Copepoda	Copepods	525	0	0	1,040	1,496	426
Insecta	Insects						
Ephemeroptera	Mayflies	14	0	0	96	16	0
Zygoptera	Dragonflies	0	0	0	0	0	0
Trichoptera	Caddisflies	0	0	0	0	0	0
Lepidoptera	Butterflies	0	0	0	0	0	0
Coleoptera	Beetles	0	0	0	0	0	0
Ceratopogonidae	Biting Midges	15	0	0	17	0	0
Chironomidae	Midges	545	6	0	374	628	27
Diptera	Flies	0	0	0	0	0	0

Table 3-3. Counts of invertebrates (per 0.02 m2) from sediment cores collected from three reaches of the Homosassa River (adapted from Frazer *et al.* 2011).

Taxon	Common Name	Homosassa River					
		August 2007			February 2008		
		Reach 1	Reach 2	Reach 3	Reach 1	Reach 2	Reach 3
Acari	Mites	3	12	19	6	15	52
Hydrozoa	Hydras	0	0	0	0	1	0
Turbellaria	Flatworms	1	0	0	4	0	1
Nemertea	Ribbon worms	23	8	17	0	0	0
Nematoda	Roundworms	750	2,063	1,360	835	1,909	817
Annelida	Worms						
Oligochaeta	Worms	1,002	149	677	672	1,081	63
Polychaeta	Worms	74	36	24	119	150	19
Hirudinia	Leeches	2	1	0	15	3	0
Mollusca	Molluscs						
Gastropoda	Snails	48	96	19	13	14	111
Pelecypoda	Clams, mussels	0	12	33	2	38	256
Crustactea	Crustaceans						
Amphipoda	Amphipods	148	265	126	250	184	389
Cumacea	Hooded shrimps	1	17	6	145	51	6
Palaemonidae	Shrimps	0	2	0	0	0	0
Decapoda	Crabs, Shrimp, Lobsters	0	0	0	0	0	0
Isopoda	Scuds	2	14	13	72	32	34
Cambaridae	Crayfish	0	0	0	0	0	0
Mysidacea	Opossum shrimp	0	1	0	0	3	0
Tanaidacea	Tanaids	7	0	1	32	27	1
Cladoceran	Water fleas	0	0	0	1	14	0
Ostracoda	Seed shrimp	885	1,521	874	517	722	617
Copepoda	Copepods	157	1,008	1,501	34	104	488
Insecta	Insects						
Ephemeroptera	Mayflies	0	0	0	0	0	0
Zygoptera	Dragonflies	0	0	0	0	0	0
Trichoptera	Caddisflies	0	0	0	0	0	0
Lepidoptera	Butterflies	0	0	0	0	0	0
Coleoptera	Beetles	0	0	0	0	2	0
Ceratopogonidae	Biting Midges	6	3	1	3	4	1
Chironomidae	Midges	220	3	2	201	109	43
Diptera	Flies	0	0	0	1	0	0

To improve understanding of mollusc distributions within the Homosassa River, the District contracted with Water & Air Research, Inc. (2010; included as Appendix F to this report) to complete a survey of the assemblage on two dates in the fall of 2008. Quantitative sampling of ~0.25 ft^2 of substrate area was conducted using a Petite Ponar dredge or spade at six transects in the Homosassa River upstream of river kilometer 7.5 and at a single transect in the Southeast Fork of the Homosassa River. Qualitative samples were collected by hand or dip net in the lower portion of the river and the entire river was surveyed to map the locations of live oyster bars (see Figure 3-6 for all sampling locations).

A total of 18 taxa were identified, with live individuals of eight bivalve species and 10 gastropods observed or collected (Table 3-4). Living bivalves included the Eastern oyster (*Crassostrea virginica),* ribbed mussel *(Geukensia demissa*), brackish water mussel (*Mytilopsis leucophaeta*) and Carolina marsh clam (*Polymesoda caroliniana*). Oyster beds with living individuals were found at only three sites in the river, with the most upstream bed located near river kilometer 1.3 (Figure 3-6). This distribution for live oysters differs from that reported by Grabe and Janicki (2010), who found oysters in dredge samples collected between river kilometers 4 and 9 during their May 2008 sampling events. Live snails observed by Water & Air Research, Inc. included the ladder hornsnail (*Cerithidea scalariformis*), marsh periwinkle (*Littorina irrorata*), coffee bean snail (*Melampus coffeus*), Malaysian trumpet snail (*Melanoides tuberculata*), Florida crown conch (*Melongena corona*) and unidentified hydrobiid mud snails.

The District also recently funded a study by Mote Marine Laboratory of barnacle distributions in the Homosassa River and two other Springs Coast river systems (Culter 2010; included as Appendix G in this report). The study included field surveys and deployment of artificial substrates for evaluation of barnacle colonization, abundance and biomass within the Homosassa, Crystal and lower Withlacoochee Rivers. *Balanus subalbidus* was identified as the dominant barnacle in the Homosassa River. Specimens of the exotic species, *Balanus amphitrite,* have also been collected from the river and other species may be present. Based on project sampling, which was completed from mid-March through July 2009, barnacles occur in the Homosassa River upstream to where the Main Spring run interfaces with the river. In this region of the upper river, barnacles are restricted to deeper areas and are not found in the intertidal zone. Results from the study indicate that salinities less than about 2 may be inhibitory to barnacle settlement in the rivers examined, although barnacles were observed on substrates in areas where salinities were less than 2. It may be that during some high tides, incursion of higher salinity water in low-salinity zones supports persistence of barnacles in areas where salinities are typically low.

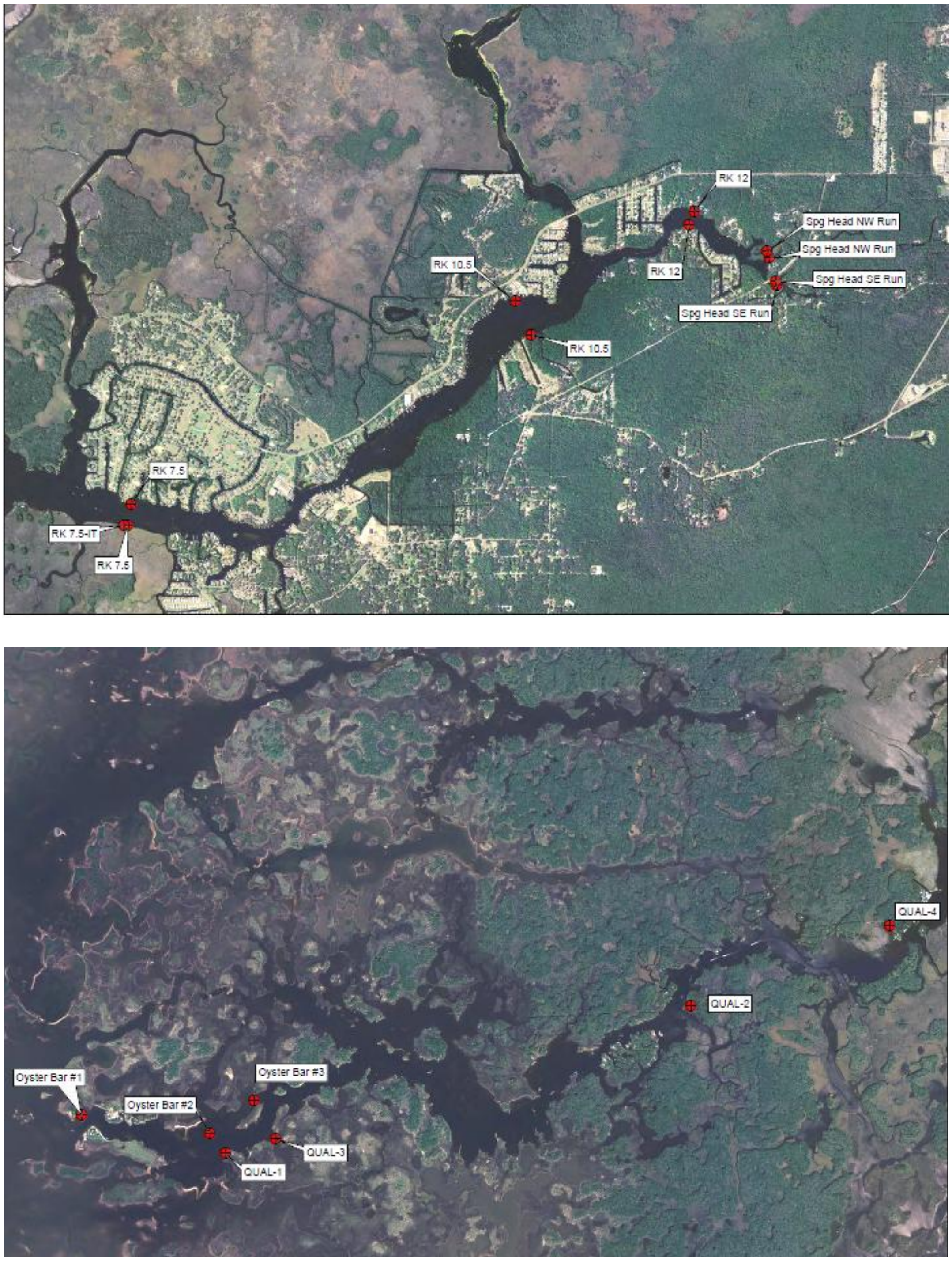


Figure 3-6. Locations where molluscs were quantitatively (upper panel) and qualitatively (lower panel) sampled in the Homosassa River in September and October 2008 and location of oyster bars (lower panel). Panels reproduced from Water & Air Research, Inc. (2010).

Table 3-4. Molluscs (living and dead) observed or collected from the Homosassa River and Southeast Fork of the Homoasassa River in September and/or October 2008 by Water & Air Research, Inc. (2010).

Taxon	Common Name	Live or Dead
Mollusca - Bivalvia	Clams, mussels	
Corbicula fluminea	Asian clam	Dead
Crassostrea virginica	Eastern oyster, American oyster	Live
Geukensia demissa	Ribbed mussel	Live
Ischadium recurvum	Hooked mussel	Dead
Mytilopsis leucophaeta	Brackish water mussel; false dark mussel	Live
cf. *Mytilidae*	Sea mussels	Dead
Polymesoda caroliniana	Carolina marsh clam	Live
Tellinidae	Tellin clams	Dead
Mollusca - Gastropoda	Snails	
Cerithidea scalariformis	Ladder hornsnail	Live
Elimia cf. floridensis	Rasp elimia	Dead
Haitia cubensis	Carib physa	Dead
Hydrobiidae	Mud snails	Live
Littorina irrorata	Marsh periwinkle	Live
Melampus coffeus	Coffee bean snail	Live
Melanoides tuberculata	Malaysian trumpet snail	Dead
Melongena corona	Florida crown conch	Live
Micromenetus floridensis	Penny spring	Dead
Planorbella scalaris	Mesa-rams horn	Dead

3.2.2 Relationships Between Benthic Invertebrates, Salinity and Other Physiochemical Variables

Numerous studies have addressed relationships between benthic invertebrates, salinity and other physiochemical parameters in southwestern Florida tidal rivers. For a recent meta-analysis involving mollusc distribution in six southwest Florida tidal rivers, Montagna *et al.* (2008) report that salinity is the most important variable correlated with mollusc community attributes. In another regional study, Janicki Environmental, Inc. (2007) identified biologically-based salinity classes for benthic invertebrates using data collected at 12 tidal southwest Florida rivers. Four salinity classes (0-7; 7-18; 18-29 and >29) were derived and were referred to as “oligohaline”, “mesohaline”, “polyhaline” and “euhaline” classes, respectively. Analysis of a subset of four of the 12 rivers that discharge along the Spings Coast yielded slightly different salinity class ranges as follows: 0-16; 17-24; 24-30 and >30 (Janicki Environmental, Inc. 2007).

Evaluation of mean salinity-at-capture information reported by Grabe and Janicki (2010) for invertebrates collected from core samples from the Homosassa River, spring run and Southeast Fork of the river (*e.g.,* see Table 3-1) illustrates the potential effect of salinity on the distribution of benthic invertebrates in the system. Some taxa, including unidentified oligochaete worms, larval insects and the dominant amphipod*, G. bonnieroides* were most strongly associated with relatively low salinities (mostly < 7) in the “oligohaline” range for Springs Coast rivers identified by Janicki Environmental, Inc. (2007). Others dominants, including the polychaete worm, *Mediomastus* sp., the tanaid crustacean *Halmyrapseudes* c.f. *cubensis* and the amphipod *Ampelisca* sp. were associated with mean capture-salinities at the higher end of the “oligohaline” range (13.1 to 16). These and other benthic organisms that demonstrate apparent responses to salinity may be expected to exhibit distributional responses to the dynamic salinity-based habitat within the river associated with variation in flows. When examined as a whole, the benthic invertebrate assemblage in the core samples collected by Grabe and Janicki demonstrated significant positive relationships between salinity-at-capture and taxa richness, diversity and total abundance; negative associations were noted for water temperature and the benthic metrics.

Other studies provide supporting information regarding the effect of salinity on benthic macroinvertebrates in the Homosassa River system. As noted in the previous section of this chapter, Sloan (1956) reported associations between the distributions of aquatic insects in the Homosassa River and chloride and dissolved oxygen concentrations, although he considered these associations speculative based on limited knowledge regarding the oxygen and chloride requirements of the insects observed in the river. Also, as noted previously, Culter (2010) suggests that barnacle distribution in the Homosassa River system and other area rivers may be limited by with the distribution of zones or boundaries where salinities of less than 2 are common.

3.3 Fish and Invertebrate Plankton and Nekton

3.3.1 Description

Planktonic (weakly swimming) and nektonic (actively swimming) fish and invertebrates are conspicuous and recreationally and ecologically important components of the Homosassa River system fauna. Some organisms found in the river system exist thoughout their life cyle as either plankton or nekton. Many species shift between planktonic and nektonic forms as they develop and some spend only portions of their lives as plankton and/or nekton after which they settle on bottom substrates to become part of the benthos. Longitudinal gradations in salinity and other physiochemical factors likely contribute to the occurrence and persistence of planktonic and nektonic fish and invertebrates.

Herald and Strickland (1949) provide an early account of the fishes of Homosassa Springs, reporting provisional observation of 34 species. In their historical account, they note with interest the co-occurrence of both marine and freshwater species in the Main Spring pool. In a more recent assessment partially funded by the District, Wetland Solutions, Inc. (2010) found that marine species, including gray snapper (*Lutjanus griseus)* and snook (*Centropomus undecimalis)* accounted for much of the fish biomass in the Homosassa Main Springs pool and upper Homosassa River. During their surveys of the spring and river, which were conducted in November 2008, a total of 22 fish species were observed (Table 3-5). Frazer *et al.* (2011) also report relatively higher densities and biomass of saltwater fish species within the river as compared to freshwater species, especially during winter, when saltwater fish presumably migrate upstream seeking thermally-favorable habitat.

Table 3-5. Fishes in the Homosassa Main Spring pool and upper portion of the Homosassa River in November 2008 as reported by Wetland Solutions, Inc. (2010) and primary habitat information or classification.

Taxon	Common Name	Primary Habitat(s)
Amia calva	Bowfin	Freshwater[a]
Archosargus probatocephalus	Sheepshead	Marine, Brackish[a]
Bagre marinus	Gafftop sail sea catfish	Marine, Brackish[b]
Caranx hippos	Crevalle jack	Marine, Brackish[c]
Centropomus undecimalis	Common snook	Marine, Brackish[a]
Echeneis naucrates	Sharksucker	Marine[d]
Elops saurus	Ladyfish	Marine, Brackish, Freshwater[a]
Eucinostomus harengulus	Tidewater mojarra	Marine, Brackish[a]
Eugerres [Diapterus] plumieri	Striped mojarra	Marine, Brackish[a]
Gambusia holbrooki	Eastern mosquitofish	Freshwater[a]
Lepisosteus platyrhincus	Florida gar	Freshwater[a]
Lepomis auritus	Redbreast sunfish	Freshwater[a]
Lepomis macrochirus	Bluegill	Freshwater[a]
Lucania parva	Rainwater killifish	Brackish[a]
Lutjanus griseus	Gray snapper	Marine, Brackish[a]
Menidia beryllina	Inland silverside	Brackish, Freshwater[a]
Microgobius gulosus	Clown goby	Marine, Brackish[a]
Micropterus salmoides	Largemouth bass	Freshwater[a]
Mugil cephalus	Striped mullet	Marine, Brackish, Freshwater[a]
Pogonias cromis	Black drum	Marine, Brackish[c]
Sciaenops ocellatus	Red drum	Marine, Brackish[a]
Strongylura marina	Atlantic needlefish	Marine, Brackish, Freshwater[a]

[a] Source: A check list of Florida's freshwater fishes, with photos compiled by Gray Bass, Paul Shafland and Bob Wattendord, accessed at *name.htm* on April 23, 2010
[b] Source: Muncy and Wingo (1983)
[c] Source: Florida Fish and Wildlife Conservation Commission Fish Identification – Saltwater web page at *http://www.myfwc.com/WILDLIFEHABITATS/SaltFishID.htm* accessed on April *23*, 2010
[d] Source: Ichthyology at the Florida Museum of Natural History web page *at http://www.flmnh.ufl.edu/fish/Gallery/Descript/LiveSharksucker/LiveSharksucker/html,* accessed on April 23, 2010

To further support development of minimum flows for the Homosassa River system, the District funded a recent, two-year study of freshwater inflow effects on habitat use by planktonic and nektonic fish and invertebrates in the Homosassa River and Halls River. The study, completed by the University of South Florida College of Marine Science and Florida Fish and Wildlife Conservation Commission (Peebles *et al.* 2009; included as Appendix H to this report), included identification of patterns and responses of estuarine fish and invertebrate and abundances and habitat use under variable freshwater inflow conditions, based on sampling completed between December 2006 and November 2008.

Sampling for the plankton-nekton evaluation was conducted on a monthly basis during the first year of the study and every other month during year two, for a total of 18 sampling dates. For sampling purposes, seven zones from which plankton net, seine net and trawl samples were taken, were identified in the Homosassa and Halls Rivers (Figure 3-7). Two plankton net collections were made at fixed stations in zones 1 through 6 on each sampling date; zone 7 in the upper Halls River could not be sampled with the plankton net due to shallow water depths and obstructions. The plankton net had a 500 µm mesh-size and was deployed during nighttime flood tides. Three seine collections were made in each zone at randomly selected stations on each sampling date and three trawl-net deployments were similarly deployed on each date, but only in zones 3, 4 and 6. Rock substrates prevented use of the trawl net in zones 1, 2, 5 and 7. The bag seine had a mesh size of 3.2 mm (0.125 in) and the otter trawl had a 3.2 mm (0.125 in) mesh size; both were deployed during the day under variable tide stages. The seines and trawls were used to sample larger fish and invertebrates that were capable of evading the plankton net. Seines hauls were generally conducted in shallow habitats where water depths were less than five feet and the trawl net was used to sample deeper areas. Salinity, water temperature, dissolved oxygen and pH measurements were measured at the surface and at 1-meter (3.3-feet) intervals to the bottom in association with each net or trawl deployment.

Fish eggs, including those of gobies and anchovies, numerically dominated the fish catch in the plankton net collections. Larval gobies of the genus *Gobiosoma* and the bay anchovy (*Anchoa mitchilli*) were also common. Other abundant larval fishes included rainwater killifish (*Lucania parva*), silversides (*Menidia* spp.), blennies, including the Florida blenny (*Chasmodes saburrae*), skilletfish (*Gobiesox strumosus*) and mojorras (*Eucinostomus* spp.).

Nearly 70 percent of the seine catch was comprised of rainwater killifish, silversides and mojarras. Freshwater taxa, including shiners (*Notropis petersoni, Notropis harperi,* and *Notemigonus crysoleucas)*, bluefin killifish (*Lucania goodei*), largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus)*, redear sunfish (*Lepomis microlophus*) and spotted sunfish (*Lepomis punctatus*) were commonly encountered in both Halls River and the Homosassa River upstream of the confluence of the two rivers, but were much less abundant than marine-oriented species. Fishes caught in the trawl net were dominated by small (< 40 mm in length) and large (>40 mm in length) mojarra, rainwater killifish and bay anchovy, which in combination accounted for 77 percent of the total catch.

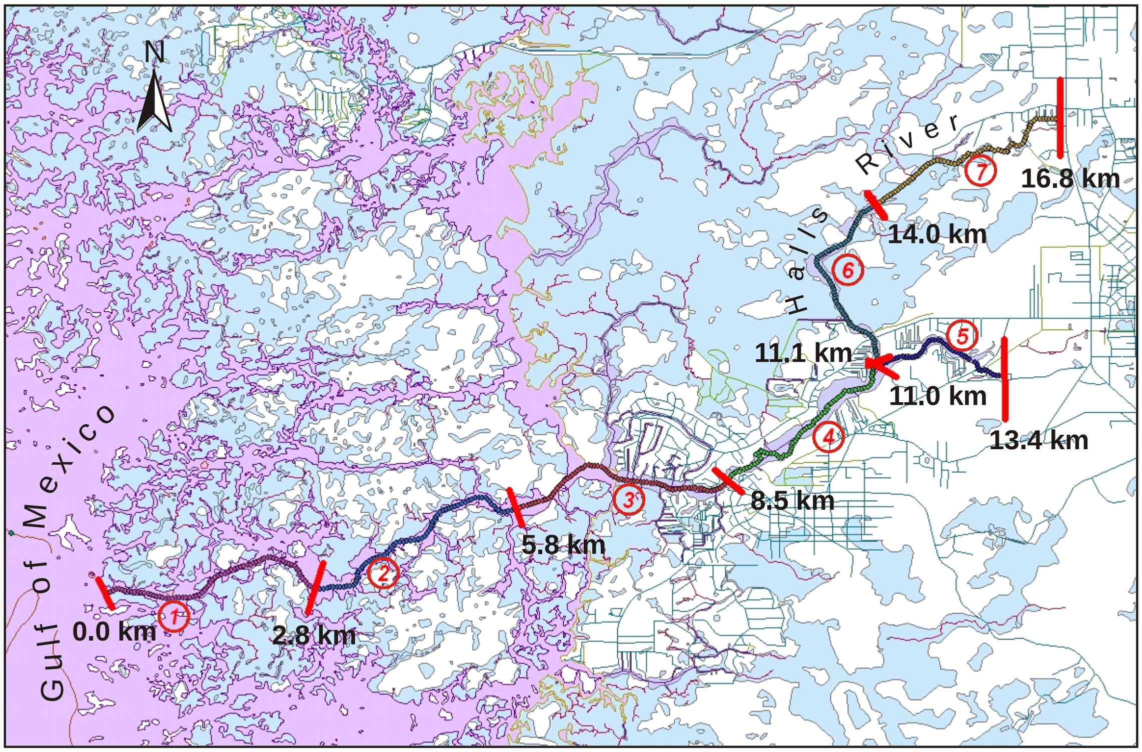


Figure 3-7. Seven zones (delineated by red bars and circled numbers) where plankton, seine and trawl nets were deployed in the Homosassa and Halls Rivers between December 2006 and November 2008. Figure reproduced from Peebles *et al.* (2009).

The invertebrates caught with the plankton net were dominated by larval crabs (decapod zoeae and megalopae), larval shrimps, gammaridean amphipods, the mysid shrimp *Americamysis almyra*, cumacean crustaceans, and the copepod *Acartia tonsa*. Larval crabs and shrimps, amphipods, *A. almyra* and *A. tonsa* were common in all sampled zones. Cumaceans were most abundant the lower portion of the river system. Invertebrates collected with the seine were dominated by brackish grass shrimp (*Palaemonetes intermedius*), daggerblade grass shrimp (*Palaemonetes pugio*), riverine grass shrimp (*Palaemonetes paludosus*) and blue crab (*Callinectes sapidus*). Collectively, these crustaceans accounted for over 96 percent of the total number of invertebrates caught with the seine. Invertebrates in the trawl samples were dominated by blue crab and brackish grass shrimp, which in combination accounted for 90 percent of the total invertebrate trawl catch.

Peebles *et al.* (2009) note that relatively few fish species used the sampled area for spawning. As compared to other area estuaries, the Homosassa River system contained "… relatively few eggs and larvae of broadcast-spawning, estuarine-dependent or coastal species, but instead was dominated by the larvae of small, resident species that have adhesive eggs which hatch into planktonic larvae." Estuary-dependent taxa, which spawn in the Gulf and migrate into the river system, were common and included the recreationally and commercially important blue crab and forage fish such as pinfish and mojarras.

3.3.2 Relationships Between Fish and Invertebrate Nekton and Plankton and Inflow

As part of their recent study of the Homosassa River system, Peebles *et al.* (2009) evaluated responses of planktonic and nektonic taxa to inflow in terms of changes in absolute or relative abundances of organisms within the study area and in terms of organism distribution or location of maximum occurrence. Responses were evaluated for common taxa collected with a plankton net, seine and trawl as described in the previous section of this report and measured or estimated daily flow records for the USGS Homosassa Springs at Homosassa Springs, FL and SE Fork Homosassa Spring at Homosassa Springs, FL gages. Daily mean combined flows on the dates plankton and nekton were sampled ranged from 103 to 163 cfs and averaged 132 cfs. Note that location responses are not discussed further in this report, as they were determined not to be useful for development of minimum flows.

For evaluation of abundance responses to inflow, planktonic and nektonic organisms collected from the Homosassa River system were classified as pseudo-species, based on life-history stage, size class, taxonomic resolution and capture with the differing sampling gear. Absolute abundances of pseudo-species collected with the plankton net were based on samples collected only from the Homosassa River and Southeast Fork. Samples from Halls River were excluded from these analyses because flow estimates for Halls River were not available for evaluation of flow-abundance relationships for the planktonic taxa. Relative abundances were determined for the pseudo-species collected with the seine and trawl for the combined Homosassa River and Southeast Fork, the combined Homosassa River/Southeast Fork/Halls River or Halls River.

For organisms captured with the plankton net, absolute abundance (N) in the combined Homosassa River/Southeast Fork for each one or two month sampling interval was estimated by summing the product of mean organism density and tide-corrected water volume for each study zone according to the equation

$$N = \sum (\overline{U} * V) \qquad \text{(Equation 3),}$$

where: N is the total number of organisms in the Homosassa River and Southeast Fork based on plankton net samples and river volume;

$\overline{U}$ is the zone-specific mean organism density, expressed as number of organisms per cubic meter;

V is the tide-corrected zone specific volume; and

$\sum$ indicates summation of values for all sampled zones.

For the seine and trawl data, relative abundance ($\overline{N}$) was calculated for each one or two month sampling interval or selected intervals based on recruitment periods identified using organism length-frequency distributions (see Peebles et al. 2009 which is included as Appendix H) according to the equation

$$\overline{N} = 100 * N_{total} / A_{total} \qquad \text{(Equation 4),}$$

where: $\overline{N}$ is the relative abundance or mean number of organisms per 100 square meters in the Halls River, Homosassa River/Southeast Fork (seine-collected organisms) or sampled zones for the Halls River/Homosassa River (trawl-collected organisms);

N_{total} is the total number of organisms captured during the sampling interval in the Halls River or Homosassa River/Southeast Fork; and

A_{total} is the total area or the Halls River or Homosassa River sampled during the sampling interval.

Daily mean combined inflows for the USGS Homosassa Springs and Southeast Fork gages were used for model development. For the regressions based on samples collected with the plankton net, inflow (*F*) values for the sampling date and mean inflows for periods up to 120 days including and prior to the sampling date were evaluated. For regressions based on seine and trawl samples, mean flows from the date of sampling were evaluated, as were continuously-lagged weekly mean flows from the day of sampling up to 203 days before sampling (*e.g.*, mean flow for the sampling day and preceding six days; mean flow for sampling day and preceding thirteen days, *etc.)*.

Absolute abundances of 28 of the 64 plankton-net taxa that were evaluated exhibited significant responses to inflow (Table 3-6) (Peebles *et al.* 2009). Negative responses, *i.e*., lower absolute abundances associated with higher flows, were most common and likely reflected organisms being swept from the sampled area during periods of higher inflows. Five taxa, including: the estuarine tanaid crustacean *Hargeria rapax*; postflexion larvae of the rainwater killifish (*Lucania parva)*; ostracods of the order Podocopida, which is an exclusively freshwater order; the estuarine copepod *Acartia tonsa*; and the oligohaline copepod *Eurytemora affinis* exhibited positive responses to flow, *i.e.,* their abundances increased with increased flow. Absolute abundances of these planktonic taxa were associated with lagged flows from periods ranging from 36 to 120 days, with 29 to 62 percent of the variance in their abundances associated with inflow (Table 3-4).

Relative abundances of 40 of the 53 pseudo-species evaluated from the seine and trawl catches were significantly related to inflow (Table 3-7) (Peebles *et al.* 2009). Thirteen pseudo-species exhibited quadratic responses in relative abundance as a function of inflow and 27 exhibited linear responses to inflow. Quadratic responses could be characterized as “intermediate-maximum” or “intermediate-minimum” responses to inflow, with maximum or minimum relative abundances associated at intermediate flows and lower or higher abundances occurring during periods of lower and higher flows.

Linear relationships were split between 12 negative responses and 15 positive responses. Negative linear responses, *i.e*., an inverse relationship between relative abundance and inflow, likely reflected organisms being swept from the sampled area during periods of higher inflows or movement of organisms into higher salinity zones during low flow periods. Positive linear responses were observed for brackish grass shrimp (*Palaemonetes intermedius*), blue crabs (*Callinectes sapidus*) less than and greater than 30 mm in size, Gulf killifish (*Fundulus grandis*), rainwater killifish (*Lucania parva*), mosquitofish (*Gambusia holbrooki*), sailfin mollies (*Poecilia latipinna*), largemouth bass (*Micropterus salmoides*), pinfish (*Lagodon rhomboides*), and spot (*Leiostomus xanthurus*) collected with the seine from shallow areas of the Homosassa River. In addition, abundances of Gulf pipefish (*Syngnathus scovelli*), spotted sunfish (*Lepomis punctatus*) and largemouth bass collected by seine from Halls River and blue crabs and Gulf pipefish collected by trawl net in the Homosassa and Halls Rivers also exhibit significant, positive response to flow. Relative abundances of pseudo-species exhibiting a positive response to flow were associated with lagged flows for periods ranging from 1 to 203 days. Twenty to 78 percent of the variance in abundances of these taxa was explained by the inflow values (Table 3-5). Most regressions were based on occurrence of organisms in samples collected during the entire year, although regressions for Gulf killifish, largemouth bass and spot were based on seasonal occurrences with correspondingly low numbers of dates sampled (see degrees of freedom listed in Table 3-7).

Table 3-6. Regression statistics for plankton-net organism absolute abundance responses (N expressed as number / m3) to mean freshwater inflow (F expressed as cfs) in the Homosassa River system (adapted from Table 3.8.1.1. in Peebles et al. 2009). Statistics listed for the linear equation ln N = Intercept + Slope * ln F include sample size (n), intercept, slope, slope probability (P) and adjusted coefficient of determination (r^2 adj). The number of daily inflow values (D) used to calculate mean freshwater inflow is also shown. Possible serial correlation based on a Durbin-Watson (DW) statistic with p<0.05 indicated by "x".

Taxon	Common Name	Linear Regression Statistics						
		n	*Intercept*	*Slope*	*P*	r^2_{adj}	*DW*	*D*
Crustacea - Maxillipoda	Fish lice							
Branchiurans, *Argulus* spp.	Fish lice	11	35.263	-5.414	0.0014	0.70		42
Crustacea - Copepoda	Copepods							
Acartia tonsa	Copepod	18	-59.762	15.169	0.0183	0.30	x	120
Eurytemora affinis	Copepod	12	-89.289	19.978	0.0482	0.34		36
Crustacea - Decapoda	Amphipods, scuds							
Amphipods, caprellid	Skeleton shrimps	17	43.526	-6.681	0.0007	0.55		20
Crustacea - Decapoda	Crabs, shrimp, lobsters							
Americamysis almyra	Opossum shrimp, mysid	18	50.709	-7.093	0.0000	0.69		1
Decapod megalopae	Post-zoea crab larvae	18	63.694	-10.343	0.0355	0.25		1
Decapod zoeae	Crab larvae	18	134.592	-24.143	0.0004	0.56		16
Decapod mysis	Shrimp larvae	18	122.821	-22.172	0.0000	0.72		16
Bowmaniella dissimilis	Opossum shrimp, mysid	18	76.013	-12.591	0.0039	0.41		113
Palaemonetes pugio juveniles	Daggerblade grass shrimp	12	61.161	-10.466	0.0182	0.44		17
Taphromysis bowmani	Opossum shrimp, mysid	13	55.436	-9.126	0.0084	0.48		1
Unidentified *Americamysis* juveniles	Opossum shrimps, mysids	18	46.748	-6.252	0.0008	0.52		1
Crustacea - Isopoda	Isopods							
Cassidinidea ovalis	Isopod	18	93.659	-16.865	0.0001	0.61		17
Cyathura polita	Isopod	10	48.087	-8.040	0.0092	0.59	x	7
Cymothoid sp. a (*Lironeca*) juveniles	Isopod	18	64.261	-11.212	0.0004	0.56		47
Edotea triloba	Isopod	18	71.411	-12.124	0.0039	0.41		20
Anopsilana jonesi	Isopod	10	58.417	-10.129	0.0018	0.72	x	43
Crustacea - Ostracoda	Isopods							
Ostracods, podocopid	Ostracods, seed shrimps	16	-48.019	11.990	0.0331	0.29		58
Parasterope pollex	Ostracod, seed shrimp	16	47.079	-7.258	0.0238	0.31		16
Crustacea - Tanaidacea	Tanaids							
Hargeria rapax	Tanaid	18	-43.376	11.195	0.0183	0.30		117

Table 3-6. Continued.

Taxon	Common Name	Linear Regression Statistics						
		n	***Intercept***	***Slope***	***p***	r^2_{adj}	***DW***	***D***
Insecta - Diptera	Flies							
Dipterans, pupae	Flies, mosquitoes	18	42.402	-6.331	0.0075	0.37	x	1
Osteicthyes	Bony fishes							
Anchoa mitchilli juveniles	Bay anchovy	17	84.624	-14.977	0.0178	0.32	x	120
Anchoa spp. preflexion larvae	Anchovies	10	38.964	-5.862	0.0467	0.41		1
Gobiid flexion larvae	Gobies	15	111.054	-20.112	0.0001	0.72	x	20
Gobiid preflexion larvae	Gobies	17	111.229	-20.093	0.0011	0.52	x	13
Gobiosoma spp. postflexion larvae	Gobies	16	145.423	-27.173	0.0001	0.66		32
Lucania parva postflexion larvae	Rainwater killifish	12	-49.467	11.652	0.0023	0.62		120
Microgobius spp. postflexion larvae	Gobies	16	81.404	-14.401	0.0070	0.42	x	14

Table 3-7. Summary information for modeled relative abundance ($\overline{N}$) response of seine and trawl-net captured pseudo-species to mean freshwater inflow (F expressed as cfs) in the Homosassa River/Southeast Fore and/or Halls River. The type of response (Resp.) is either linear (L) or quadratic (Q). Linear regressions expressed as ln ($\overline{N}$ + 1) = Intercept + Linear Coefficient * ln (F +1). Quadratic regressions expressed as ln ($\overline{N}$ + 1) = Intercept + Linear Coefficient * ln (F +1) + Quadratic Coefficient * [ln (F + 1)]^2. Listed statistics include degrees of freedom (df), intercept (Int.), slope (Linear Coeff.), slope probability (Linear P), quadratic coefficient (Quad Coeff.), quadratic coefficient probability (Quad P) and adjusted coefficient of determination (r^2 adj). Modeled responses are identified by: River segment (Riv Seg.) for the Homosassa River (HR) or Halls River (HA); pseudo-species Life History type, including Estuarine Spawners (ES), Tidal River Residents (TRR), nearshore spawners (NS) and Offshore Spawners (OS); sampling gear, either seine (S) or trawl (T); taxon size class (range in mm or "All") and identified recruitment Period. An "x" in column labeled DW (Durbin-Watson) indicates that the Durbin-Watson statistic was significant (p<0.05), a possible indication of serial correlation. The number of daily inflow values (D) used to calculate continuously-lagged mean freshwater inflow is also shown. Table is adapted from Table 3.8.2.1 in Peebles *et al.* (2009).

Species	Common name	Life History	Gear	River Seg.	Size	Period	Resp.	*df*	*Int.*	*Linear*		*Quadratic*		r^2_{adj}	DW	D
										Coeff.	*P*	*Coeff.*	*P*			
Palaemonetes intermedius	Brackish grass shrimp	ES	S	HR	All	Jan. to Dec.	L	16	-34.788	7.652	0.013	.	.	0.289		63
Palaemonetes paludosus	Riverine grass shrimp	ES	S	HA	All	Jan. to Dec.	Q	15	5552.469	-2266.036	0.045	231.271	0.048	0.160	x	175
Palaemonetes intermedius	Brackish grass shrimp	ES	T	HR/HA	All	Jan. to Dec.	Q	15	-646.181	264.851	0.047	-27.120	0.047	0.139		84
Callinectes sapidus	Blue crab	NS	S	HR	≤30	Jan. to Dec.	L	16	-66.445	13.809	0.001	.	.	0.560		182
Callinectes sapidus	Blue crab	NS	T	HR/HA	≤30	Jan. to Dec.	L	16	-17.272	3.566	0.002	.	.	0.438		182
Callinectes sapidus	Blue crab	NS	S	HR	>30	Jan. to Dec.	L	16	-16.522	3.479	0.009	.	.	0.320	x	70
Callinectes sapidus	Blue crab	NS	T	HR/HA	>50	Jan. to Dec.	L	16	18.754	-3.687	0.005	.	.	0.363	x	7
Notemigonus crysoleucas	Golden shiner	TRR	S	HA	All	Apr. to Oct.	L	8	28.142	-5.449	0.004	.	.	0.636	x	1
Notropis petersoni	Coastal shiner	TRR	S	HA	All	Jan. to Dec.	L	16	62.221	-12.149	0.001	.	.	0.521		98
Strongylura notata	Redfin needlefish	ES	S	HR	All	Jan. to Dec.	Q	15	-3031.948	1242.757	0.009	-127.302	0.008	0.420	x	203
Strongylura timucu	Timucu	ES	S	HR	All	Jan. to Dec.	Q	15	547.748	-227.051	0.039	23.537	0.037	0.338	x	7
Cyprinodon variegatus	Sheepshead minnow	TRR	S	HA	All	Jan. to Dec.	Q	15	3278.856	-1342.938	0.022	137.526	0.022	0.240		175
Fundulus grandis	Gulf killifish	TRR	S	HR	All	Jan. to May	L	6	-25.551	5.430	0.012	.	.	0.628		1
Fundulus seminolis	Seminole killifish	TRR	S	HA	All	Jan. to Dec.	L	16	26.326	-5.090	0.006	.	.	0.349	x	63
Lucania parva	Rainwater killifish	TRR	S	HR	All	Jan. to Dec.	L	16	-53.560	11.765	0.025	.	.	0.232	x	203

Table 3-7. Continued

Species	Common name	Life History	Gear	River Seg.	Size	Period	Resp.	*df*	*Int.*	*Linear*		*Quadratic*		r^2_{adj}	DW	D
										Coeff.	*P*	*Coeff.*	*P*			
Lucania parva	Rainwater killifish	TRR	S	HA	All	Jan. to Dec.	L	16	38.322	-6.731	0.001	.	.	0.495		7
Lucania parva	Rainwater killifish	TRR	T	HR/HA	All	Jan. to Dec.	Q	15	-2243.555	918.378	0.036	-93.919	0.037	0.187		105
Lucania goodei	Bluefin killifish	TRR	S	HA	All	Jan. to Dec.	L	16	25.199	-4.539	0.028	.	.	0.222		14
Floridichthys carpio	Goldspotted killifish	ES	S	HR	All	Jan. to Dec.	Q	15	2932.867	-1206.984	0.025	124.186	0.025	0.357		140
Gambusia holbrooki	Eastern mosquitofish	TRR	S	HR	All	Jan. to Dec.	L	16	-75.932	15.830	0.004	.	.	0.387		126
Gambusia holbrooki	Eastern mosquitofish	TRR	S	HA	All	Jan. to Dec.	L	16	47.285	-9.388	0.006	.	.	0.348		7
Poecilia latipinna	Sailfin molly	TRR	S	HR	All	Jan. to Dec.	L	16	-14.725	3.092	0.009	.	.	0.313		14
Poecilia latipinna	Sailfin molly	TRR	S	HA	All	Jan. to Dec.	Q	15	-3310.424	1359.001	0.013	-139.371	0.013	0.261	x	98
Heterandria formosa	Least killifish	TRR	S	HA	All	Jan. to Dec.	Q	15	-1480.200	614.829	0.005	-63.724	0.005	0.543		7
Syngnathus scovelli	Gulf pipefish	ES	S	HA	All	Jan. to Dec.	L	16	-28.946	6.149	0.033	.	.	0.207		203
Syngnathus scovelli	Gulf pipefish	ES	T	HR/HA	All	Jan. to Dec.	L	16	-20.789	4.300	0.017	.	.	0.265	x	203
Lepomis macrochirus	Bluegill	TRR	S	HR	≥20	Jan. to Dec.	Q	15	1302.098	-531.893	0.002	54.324	0.002	0.538		42
Lepomis macrochirus	Bluegill	TRR	S	HA	≥20	Jan. to Dec.	L	16	28.295	-5.541	0.020	.	.	0.249	x	7
Lepomis punctatus	Spotted sunfish	TRR	S	HA	≥20	Jan. to Dec.	L	16	-45.400	9.612	0.025	.	.	0.231		203
Micropterus salmoides	Largemouth bass	TRR	S	HR	All	Apr. to Aug.	L	5	-70.8301	14.991	0.005	.	.	0.779		98
Micropterus salmoides	Largemouth bass	TRR	S	HA	All	Apr. to Aug.	L	5	-99.285	20.694	0.021	.	.	0.625	x	203
Eucinostomus harengulus	Tidewater mojarra	OS	T	HR/HA	>40	Jan. to Dec.	L	16	40.798	-8.194	0.0001	.	.	0.619	x	168
Lagodon rhomboides	Pinfish	OS	S	HR	All	Jan. to Oct.	L	13	-56.001	11.957	0.001	.	.	0.541	x	182
Lagodon rhomboides	Pinfish	OS	T	HR/HA	>45	Mar. to Nov.	L	12	6.219	-1.228	0.005	.	.	0.446		1
Leiostomus xanthurus	Spot	OS	S	HR	All	Jan. to May	L	6	-161.044	32.915	0.011	.	.	0.639		147
Gobiosoma bosc	Naked goby	TRR	S	HR	All	Jan. to Dec.	Q	15	-2088.045	851.897	0.043	-86.847	0.044	0.202		182
Microgobius gulosus	Clown goby	TRR	S	HR	All	Jan. to Dec.	L	16	39.109	-7.695	0.002	.	.	0.430		21
Microgobius gulosus	Clown goby	TRR	S	HA	All	Jan. to Dec.	L	16	49.670	-9.640	0.000	.	.	0.747		28
Microgobius gulosus	Clown goby	TRR	T	HR/HA	All	Jan. to Dec.	Q	15	-1778.362	730.117	0.011	-74.895	0.011	0.280	x	84
Trinectes maculatus	Hogchoker	ES	T	HR/HA	All	Apr. to Dec.	Q	10	1095.468	-449.155	0.031	46.047	0.031	0.355	x	126

3.4 Manatees

3.4.1 Description

The Florida manatee (*Trichechus manatus latirostris*), a subspecies of the West Indian manatee, is found primarily in the waters of Florida. This marine mammal is protected by the State of Florida in accordance with the Florida Manatee Sanctuary Act and is a federally listed endangered species. The most recent United States Fish and Wildlife Service (2009) stock estimate for the Florida population indicates around 3,802 animals occur in state waters, based on a synoptic survey completed by the Florida Fish and Wildlife Conservation Commission in January 2009. Of this population, about 400 animals are associated with the Northwest management unit, which extends from the western margin of the panhandle to the border between Hernando and Pasco counties. Recent synoptic aerial survey data for 2010 indicates that the Florida manatee population is larger than reported in 2009. A total of 5,076 animals were counted in state waters in January 2010, with 2,296 observed along the west coast (Florida Fish and Wildlife Conservation Commission 2010a, b).

Since the early 1980s, the U.S. Fish and Wildlife Service has conducted routine aerial surveys of manatees on an approximate biweekly basis in up to 13 river/canal/bay segments along the west coast of Florida, including Kings Bay; Crystal River, the upper Homosassa River, the lower Homosassa River, Salt River, Crystal River Power Plant; Barge Canal, Waccasassa River, Withlacoochee River, Suwannee River, Suwannee River Estuary, Chassahowitzka River, and Weeki Wachee River. Total manatee counts based on surveys of all or some of these sites between January 11, 1985 through May 12, 2010 averaged 154.8 (n = 629 surveys), with a maximum of 650 animals observed on one survey date. Although all sites were not sampled on many of the survey dates, available information indicates that among the sampled sites, manatee abundances are typically highest in King's Bay/Crystal River system. Counts in this system averaged 107.7 animals per survey and ranged up to 565 animals on a single date.

Manatee abundances are also relatively high in the Homosassa River. The United States Fish and Wildlife Service counts manatees in two segments of the Homosassa River; upstream and downstream from Buzzard Point, which is located just downstream from the confluence of the Halls and Homosassa Rivers (see Figure 2-4). Combined counts for both segments ranged from 0 to 156 animals per survey (Figure 3-8), and averaged 31.2 animals per survey. On most sampling dates, counts were higher in the upstream portion of the river (personal communication, Joyce Kleen with the U.S. Fish and Wildlife Service). An early report on manatee distribution in northwest Florida confirms this distributional pattern, with highest numbers of animals in the Homosassa River, observed upstream of, or near Buzzard Point (Rathburn *et al.* 1990). Manatee use of the Homosassa River is typically highest from the late fall through early spring and lower during summer (Figure 3-9). From January 1985 through May 2010 median abundances in the river ranged from 23 to 40 animals per survey for the months of November through March and 4 to 5 animals per survey for the months of July through September.

Shallow water depths and the fence across the Homosassa Main Spring run within Ellie Schiller Homosassa Springs Wildlife State Park have previously been identified as potential accessibility concerns for wild manatees using the river system (Taylor 2006). The recent dredging of the upper segment of the river, funded by the District and the Department of Environmental

Protection, and the Department's decision to open the Main Spring Run to wild manatees during cold periods are expected to enhance habitat accessibility.

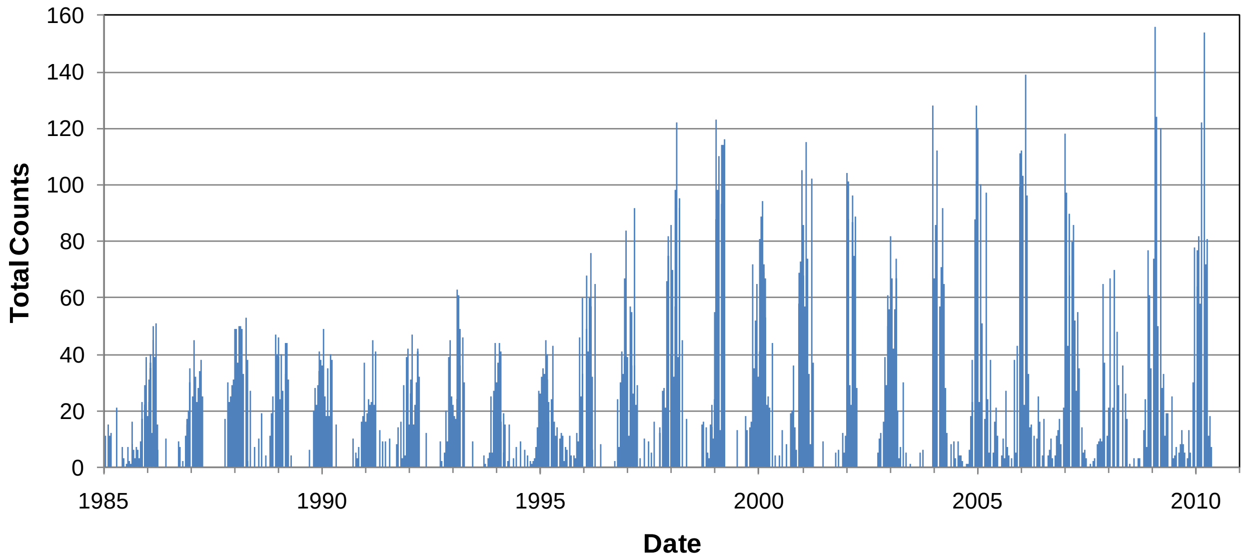


Figure 3-8. Abundance (total counts) of manatees in the Homosassa River from January 11, 1985 through May 12, 2010, based on aerial survey data provided by U.S. Fish and Wildlife Service.

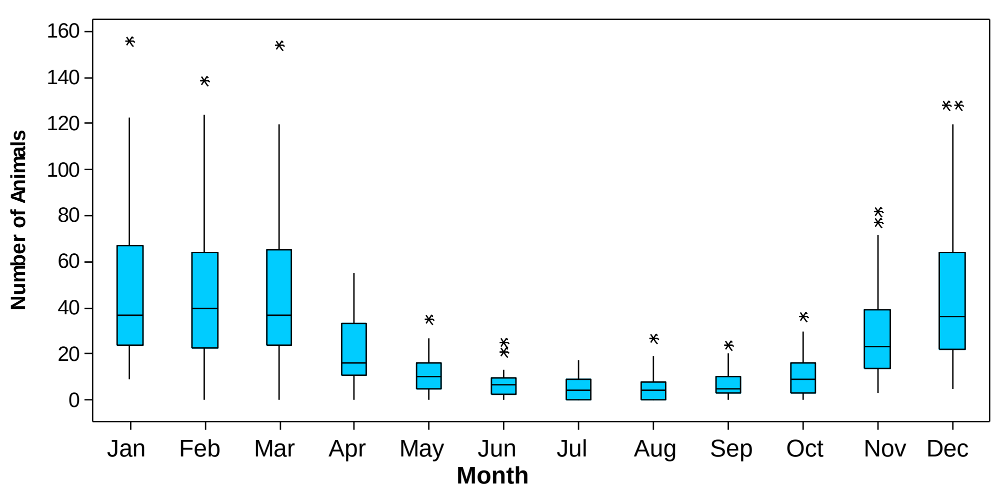


Figure 3-9. Box plot of the number of manatees per survey in the Homosassa River by month from January 11, 1985 through May 12, 2010, based on aerial survey data provided by the U.S. Fish and Wildlife Service.

Throughout the state, many manatees succumb annually to collisions with boats and to a lesser degree from the effects of neurotoxins produced by the dinoflagellate, *Karenia brevis,* during “red tides.” Because manatees are poor thermal regulators, they are also negatively impacted when water temperatures drop below 20^{o}C, although some individuals can survive chronic exposure to temperatures a few degrees lower (see references cited in Laist and Reynolds 2005). To survive through periods of extremely cold weather, manatees often congregate in warm-water natural springs or in the warm cooling-water discharge plumes of power plants located along the coast of Florida. The potential loss of the artificial sources of warm water through plant closing and reduction of natural spring flow due to groundwater withdrawals is identified as a significant concern for management of this endangered species (United States Fish and Wildlife Service 2001, Laist and Reynolds 2005).

3.4.2 Relationships Between Manatees and Inflow

Relatively warm spring water discharged into the Homosassa River system and other spring-fed Florida river systems provides thermal refuge for manatees during extreme cold events. Relationships between spring discharge, river stage and thermal characteristics of river segments or spring runs have been evaluated for numerous minimum flow studies in Florida, beginning with the investigation of Blue Springs in Volusia County by the St. Johns River Water Management District. In support of the development of minimum flows for Blue Springs, Rouhani *et al.* (2007) noted that prolonged exposure to water at 66-68^{o} F (19-20^{o} C) may be extremely detrimental to Florida manatee populations. Based on a 50-year lifespan for the animals, cold-associated “catastrophic conditions” for manatee populations were defined as “extreme hydrologic events lasting three of more days” with a return frequency of 50 years. The return interval for the extreme hydrologic events that could detrimentally affect the manatee population of Blue Springs was estimated as the joint probability product of individual non-exceedance probabilities associated with spring discharge, river water temperature, and river stage.

An approach similar to that used by the St. Johns River Water Management District for Blue Springs has been used by the Southwest Florida Water Management District for establishing minimum flows for the Weeki Wachee River system and proposed minimum flows for the Chassahowitzka River system (see Heyl 2008 and Heyl *et al.*, 2012). Evaluation of flow effects on thermal characteristics has also been used by for development of minimum flows for Sulphur Springs (Southwest Florida Water Management District 2004b) and by the Suwannee River Water Management District (Water Resources Associates, Inc. *et al.* 2005) for establishment of minimum flows for the lower Suwannee River and associated springs.

To support development of minimum flows for the Homosassa River system, volumetric change in thermal-based habitat suitable for preventing or minimizing cold-related adverse impacts to manatees was investigated for the District by HSW Engineering, Inc. (2011) using the hydrodynamic model of the Homosassa River main channel that was also used to characterize salinity in the river. The model was used to evaluate thermal characteristics of the Homosassa River for baseline and various flow-reduction scenarios. Development and application of the model is discussed further in Chapters 4 and 5 of this report.

CHAPTER 4. RESOURCES OF CONCERN AND TECHNICAL APPROACH FOR DEVELOPING RECOMMENDED MINIMUM FLOWS

4.1 Resources of Concern

Based on the summary information described in preceding chapters of this report, several resources of concern were identified for development of criteria that could be used to establish minimum flows for the Homosassa River system. The identified resources included submersed and emergent aquatic and wetland vegetation, benthic macroinvertebrates, fish and invertebrate nekton and plankton, manatees. Based on data limitations and the current understanding of the Homosassa River system, specific criteria were developed only for fish and invertebrate nekton and plankton and manatees. Generalized criteria based on preservation of salinity-based habitats, expressed as riverine areas, volumes or shoreline lengths associated with selected salinity zones were, however, evaluated based on the assumption that these resources of concern are associated with the occurrence and persistence of most, if not all identified resources of concern. Protection of salinity-based habitats was also viewed as a means to afford protection to many physical, chemical and biological processes and system components that were not specifically quantified or described by the data compiled for this minimum flows study.

Significant harm criteria associated with the resources of concern in the Homosassa River system were developed to prevent more than a 15 percent decrease in the resources from baseline conditions. Baseline conditions were identified using information from benchmark periods developed using available data and models developed as part of this minimum flows study. Criteria evaluated for the identified resources of concern are described in subsequent section of this chapter.

4.2 Fish and Invertebrate Plankton and Nekton Criteria and Technical Approach

Development of specific criteria for preventing significant harm to the fish and invertebrate planktonic and nektonic communities of the Homosassa River system was investigated based on identifying flow reductions associated with predicted fifteen percent reductions in abundances of several taxa or pseudo-species that were collected from the system using plankton, seine or trawl nets. Baseline and significant harm threshold values for these metrics were evaluated using regression equations developed by Peebles *et al.* (2009) that relate organism abundances to the combined flow past the USGS Homosassa Springs and Southeast Fork Homosassa River gages. The analysis included identification of flow reductions for pseudo-species that exhibited positive, linear responses to inflow that were developed based on organisms collected from the Homosassa and/or Halls Rivers. Pseudo-species exhibiting positive, linear responses to inflow were evaluated based on the assumption that modeled or actual flow reductions would be associated with reduced organism abundances. Some of the responses evaluated were based on regression equations that exhibited evidence of serial correlation (refer to Tables 3-6 and 3-7), which could potentially limit the usefulness of the flow-related predictions.

Responses of fish and invertebrates captured from the system with a plankton net were evaluated using predicted absolute abundances of the tanaid crustacean *Hargeria rapax*, postflexion larvae of the rainwater killifish (*Luciana parva*), freshwater podocopid ostracods, and the copepods *Acartia tonsa* and *Eurytemora affinis*. Responses of psuedo-species collected with the seine nets from the Homosassa River were evaluated using predicted relative abundances of ten pseudo-species, including: brackish grass shrimp (*Palaemonetes intermedius*); blue crab (*Callinectes sapidus*) greater than and less than 30 mm in size; Gulf killifish (*Fundulus grandis*); rainwater killifish (*Lucania parva*); mosquitofish (*Gambusia holbrooki*); sailfin molly (*Poecilia latipinna*); largemouth bass (*Micropterus salmoides*), pinfish (*Lagodon rhomboides*), and spot (*Leiostomus xanthurus*). Responses based on predicted relative abundances of Gulf pipefish (*Syngnathus scovelli*), spotted sunfish (*Lepomis punctatus*) and largemouth bass collected by seine from Halls River and blue crabs and Gulf pipefish collected by trawl net in the Homosassa and Halls Rivers also evaluated.

For the initial step in these analyses, baseline absolute (plankton-net captured) or relative (seine or trawl-net captured) abundances were estimated for each pseudo-species for two benchmark periods, 2007 and the period from October 18, 1995 through May 13, 2009, using taxon-specific regressions. The single-year benchmark period was used for the analysis to evaluate organism responses to flow variation for one of the same periods used to evaluate salinity-based habitat responses to flow reductions (see the next section of this report). The longer benchmark period was selected based on availability of daily mean flow records for the upper river and corresponded to the other period used for evaluating salinity-habitat responses to flow changes. The record for this longer period included some estimates for dates when flows at either the USGS Homosassa Springs or SE Fork gage were unavailable. Estimates were derived based on simple linear regressions developed using available daily mean flow records for the two gage sites. Flows used for estimation of plankton and nekton abundances for both benchmark periods included the fiftieth and other (tenth, twentieth, thirtieth, fortieth, sixtieth, seventieth, eightieth and ninetieth) percentile flows. Use of these flows, rather than time-lagged inflow values, was considered appropriate for characterizing abundance responses of individual pseudo-species over the majority of the flows that the organisms would be expected to encounter in the Homosassa River system. Predicted baseline absolute or relative abundances associated with the benchmark flows were then reduced by fifteen percent and flows associated with the reduced abundances were calculated using the taxon-specific regression equations. Flows associated with the reduced abundance values were then compared with the benchmark flows associated with the baseline abundances to determine percent-of-flow reductions associated with the fifteen percent changes in abundance.

4.3 Salinity-Based Habitat Criteria and Technical Approach

Generalized criteria for preventing significant harm to submersed aquatic and emergent vegetation, benthic invertebrates, fish and invertebrate plankton and nekton in the Homosassa River system were developed based on modeling of selected salinity-based habitats for baseline conditions in the Homosassa River and determination of percent of flow reductions associated with maintaining at least 85 percent of selected salinity-based habitats expected under baseline conditions. The generalized salinity-habitat criteria were also developed to afford protection to the myriad physical, chemical and biological processes and system components not specifically quantified or described as resources of concern for this minimum flows study. The criteria were based on identifying the volume of water at or below selected salinities and the linear extent of shoreline and area of bottom substrate in contact with water of selected salinities using results from the hydrodynamic model and empirical regression models for the Homosassa River developed for the District by HSW Engineers, Inc. (2011), bathymetric information collected for the District by Wang (2007) and shoreline information collected for the District by PBS&J (2009).

For analyses using the Homosassa River hydrodynamic model, baseline or reference salinity habitats and those associated with percent of flow reductions used to identify significant change criteria were evaluated using model output for calendar year 2007. Use of this single year as a benchmark period for identifying salinity-based habitats and development of significant change criteria was not considered optimal, although data limitations precluded use of a longer period for evaluation of salinity-habitats with the hydrodynamic model. Fortunately, spring discharge and flow in the Homosassa River system were relatively low in 2007 and may, therefore, be considered appropriate for evaluation of minimum flow criteria.

The hydrodynamic modeling involved identification of 2, 3, 5 and 12 salinity isohaline locations based on near surface, near bottom and water-column average salinity estimates for model centerline cells in three-hour increments for 2007. Modeled isohaline locations for the 3-hour increments during the 1-year benchmark period were used to calculate upstream area, volume or shoreline length values using the bathymetric data for the Homosassa River main channel and shoreline information described in Chapter 2 of this report. For these analyses, the shoreline data were truncated to exclude Halls River and Southeast Fork shorelines and the Homosassa River shoreline upstream of river kilometer 12.5. Modifications to the shoreline data set were made using Esri ArcGIS, and were based on domain limits for the hydrodynamic model.

Areas upstream of the selected isohalines were considered representative of salinity-based habitats for benthic organisms in the Homosassa River and were calculated using bottom salinity isohaline and water-column average isohaline locations. Results based on use of bottom salinity isohalines were considered appropriate for deeper bottom habitats since the hydrodynamic model results for bottom salinities were based on salinities for the relatively deep river channel centerline. Use of water-column average isohalines for calculation of bottom area upstream of selected isohalines was considered to be representative of bottom-salinity conditions across the width of the river-channel bottom, including regions of shallower bottom habitats. Volumes for salinity habitats were calculated using water-column average isohaline locations and shoreline-based salinity habitats were characterized using surface isohaline locations. Modeled habitat area, volume and natural shoreline lengths upstream of each respective isohaline for each three-hour increment in the 2007 benchmark period were considered representative of baseline conditions for the system. Median habitat values for the three-hour increment results, as well as other percentiles (the tenth through ninetieth percentiles in ten percent increments) were used to characterize baseline salinity-habitat conditions in the Homosassa River main channel.

Response of modeled salinity-based habitats to hypothetical flow reductions in the Homosassa River were then evaluated for the 2007 benchmark period in a manner analogous to that used for identification of baseline habitats. For these hydrodynamic model runs, flows during the benchmark period were reduced by 5, 10, 15, 20, 25 or 30 percent. Potential significant harm criteria were identified as percent of flow reductions associated with fifteen percent or greater reductions in the water volume, shoreline or bottom area upstream of each isohaline as compared to the respective habitat values for the baseline condition. Similar to the approach used for baseline conditions, the tenth through ninetieth percentiles were calculated for salinity habitats for each flow reduction scenario to characterize effects over the full range of flow conditions during the 2007 benchmark period.

Empirical regression models were also used to evaluate salinity habitats for baseline and flow reduction scenarios. Two benchmark periods – calendar year 2007 and the longer period from October 18, 1995 through May 13, 2009 – were used for these analyses. Salinity habitats during the 2007 benchmark period were evaluated with the regression models for comparison with and to support results obtained from the hydrodynamic modeling effort. The extent of salinity-based habitats for the longer benchmark period (1995 through 2009) were examined to supplement the modeling results for the one-year benchmark period, assuming that the observed responses would better integrate longer-term effects of a relatively wider range of spring discharge and river flow conditions. The period used for the longer benchmark period was limited based on availability of records for the combined discharge past the USGS Homosassa Springs and Southeast Fork gages.

For the regression analyses, equations 1 and 2 described in Chapter 2 of this report were used to predict daily locations of near surface and bottom isohalines corresponding to salinities of 3, 5 and 12 in the Homosassa River. Isohalines associated with a salinity of 2 were not included in the empirical regression analyses, because predictive regression equations for locating surface and bottom salinities of 2 could not be developed for the Homosassa River. The daily mean combined flow records for USGS Homosassa Springs and Southeast Fork used for the regression analyses included estimates derived for days when flow records were missing for either gage site. Daily mean tide values were used for evaluation of salinity habitats for the 2007 benchmark period; monthly mean values were used for evaluation of salinity habitats for the longer 1995-2009 period. Monthly values were used for the longer benchmark period because daily tide values at the Homosassa gage were unavailable for much of the longer time span.

Daily isohaline locations were used to calculate daily upstream areas, volumes and shoreline lengths associated with specific salinities. Median and tenth through ninetieth percentile habitat areas, volumes and shoreline lengths based on the daily values were calculated for the 2007 and 1995-2009 benchmark periods and considered representative of baseline conditions. Salinity-based habitats associated with baseline conditions were then contrasted with habitats modeled using daily spring flow records that were reduced by 5, 10, 15, 20, 25 or 30 percent. Using an approach analogous to that used for the Homosassa River hydrodynamic model output, potential significant harm criteria were identified as percent of flow reductions associated with 15 percent or greater reductions in the bottom area, water volume or natural shoreline length upstream of each isohaline as compared to the respective habitat values for the baseline conditions.

Isohalines used for modeling salinity in the Homosassa River were selected based on salinities of spring water discharged to the system and biologically-relevant salinity preferences or tolerances. Given that estimated median salinities were less than 1 for springs in the Southeast Fork, and ranged from 1 to 3 for the Homosassa Main Spring pool vents (see Table 2-8), it was considered reasonable to evaluate habitats associated with salinities of less than 2 or 3. Analysis of isohalines associated with these two similar salinities was expected to provide useful information on potential flow-related changes in low salinity habitats within the system.

Evaluation of changes in low salinity habitats, *i.e.,* zones where salinities are less than 2 or 3, for development of minimum flow recommendations for the Homosassa River system was also supported by site-specific biological information and by approaches used for environmental flow studies of other estuarine systems. Freshwater insects, oligochaetes, and certain other invertebrate taxa are most abundant in low-salinity areas near the headwater springs of the Homosassa River system (Sloan 1956, Grabe and Janicki 2010, Wetland Solutions, Inc. 2010), suggesting that maintenance of low salinity zones in these areas is important for preservation of these components of the river's biological community. Also, based on recent sampling of the Homosassa and other area rivers, Culter (2010) notes that barnacle distributions in these systems may be limited in areas where salinities less than 2 are common, a finding that lends support to maintenance of low salinity zones for limiting upstream biofouling associated with barnacle attachment. In the Homosassa River and two other coastal rivers of west-central Florida, low biomass of submersed aquatic vegetation was associated with sites where mean salinities exceeded 3.5 (Hoyer *et al.* 2004). Elsewhere in the state, the South Florida Water Management District (2002) and Suwannee River Water Management District (Water Resources Associates, Inc. *et al.* 2005) have established minimum flows based on maintaining zones with salinities less than 2 for preventing significant harm to river floodplain forests. In the Sacramento-San Joaquin estuary system in California, the position of the 2 psu bottom isohaline has been associated with phytoplankton productivity, fish abundances, and survivorship of molluscs, crustaceans and larval fish (Jassby *et al.* 1995) and used for management of inflows to the estuary (Kimmerer *et al.* 2002).

Evaluation of habitats in the Homosassa River with salinities less than 5 and 12 is also supported based on the extent of these zones within the river and the biological communities occurring in these salinity zones. Salinities up to 5 occur routinely upstream from river kilometers 7-8 and zones with salinities up to 12 are common upstream from river kilometer 4, based on median salinity values for the period from January 1997 and February 2009 (refer to Figures 2-31 and 2-40). Salinity tolerances of black needlerush (*Juncus roemerianus*), the dominant emergent plant along the Homosassa River shoreline, exemplify the biological relevance of evaluating changes in zones where salinities are less than 5 or 12. Clewell *et al.* (2002) report twenty-fifth exceedance and median salinities of 3 and 7, respectively, at sites where black needlerush (*Juncus roemerianus*) occurred in seven southwest Florida coastal rivers. The ninetieth percentile exceedance salinity for the sites populated by this important marsh plant was 12. Two common coastal tree species, cabbage palm (*Sabal palmetto*) and southern red cedar (*Juniperus virginiana* var. *silicicola*), are relatively tolerant of salinities of about 10 (references cited in PBS&J 2009), and their abundance in the Homosassa River system provides further support for the evaluation of habitats with salinities up to 12. On a regional scale, the Nature Conservancy has identified oligohaline saltmarsh (with salinities less than 5) as a priority habitat for conservation along the northern Gulf coast (Beck *et al.* 2000). Restoration of oligohaline habitats is also a top priority of the Tampa Bay National Estuary Program (2006), and based on the ecological importance of this low-salinity habitat, the District has established minimum flows for the lower Hillsborough River and Sulphur Springs to maintain salinities less than 5 in portions of the lower river.

4.4 Manatee Thermal Refuge Criteria and Technical Approach

Specific criteria for preventing significant harm to the Florida manatee population that uses the Homosassa River were based on maintaining adequate thermally-based habitat for preventing or minimizing adverse effects associated with exposure to cold water during a six-month "manatee season", between October 1 and March 31. Thermally-favorable habitat was defined as water with a temperature at or above 20^{o}C (68^{o}F) for the duration of a critically cold, three-day chronic period during the manatee season, or water with a temperature above 15^{o}C (59^{o}F) for the duration of a critically cold, four-hour acute period during the manatee season. Because low tides may be associated with water depths that are insufficient for allowing manatees to access warm-water areas of the river, tide stage was also used to define thermally-favorable manatee habitat. A minimum depth of 1.16 m (3.8 ft) was considered necessary for characterization of areas of the river as thermally-favorable habitat. The six-month manatee season was selected for the habitat evaluation, assuming that this period corresponds to the primary period during which manatees would be expected to seek refuge from cold Gulf of Mexico waters in warm water areas such as the upper reach of the Homosassa River (see Figure 3-9 for actual manatee use data for the river). The significant harm criteria were developed to limit volumetric changes in thermally favorable habitat to no more than a 15 percent reduction in the extent of habitat available during baseline chronic and acute cold conditions.

The extent of thermally-favorable habitat for manatees in the Homosassa River during critical cold periods under existing baseline flow conditions and hypothetical flow-reduction scenarios was evaluated for the District by HSW Engineering, Inc. (2011), using the Homosassa River hydrodynamic model and bathymetric information developed for the District by the University of South Florida (Wang 2007). For the analysis, a critically cold three-day period for evaluating thermally-favorable habitat was identified using a method similar to the approach used previously by the District for investigation of manatee habitat in the Chassahowitzka and Weeki Wachee River systems (see Janicki Environmental, Inc. and Applied Technology & Management 2007, Dynamic Solutions, Inc. 2008, Heyl 2008, Heyl *et al.* 2012). First, Cunnanae probabilities of non-exceedance for air temperature as measured at the Brooksville FAWN-IFAS station, discharge past the USGS Homosassa Springs gage, and tide stage at the USGS Homosassa River gage was calculated for each day during the 2007-2008 manatee season. The daily joint probability of non-exceedance was calculated as the product of the three probabilities, and three-day moving averages of the joint probabilities were developed to identify three-day periods with low air temperature, discharge and tide stage. Three-day joint probabilities were also calculated using daily non-exceedance probabilities for air temperature and discharge only, because missing tide stage values precluded calculation of three-day joint probabilities for all three factors for some dates during the 2007-2008 manatee season. Review of calculated three-day joint probabilities indicated that two time periods, December 16 through 18, 2007 and January 2 through 4, 2008, could potentially be used to evaluate thermally-favorable manatee habitat in the river (Figure 4-1). Review of three-day moving average air temperature and daily mean high tide values indicated that the January 2-4, 2008 time period was a more appropriate critically cold period for evaluating thermally-favored manatee habitat. Use of this period was also supported through review of two-factor (air temperature and discharge) and three-factor (air temperature, discharge, tide stage) joint probabilities estimated for the 1997-1998 through 2007-2008 manatee seasons (see technical memorandum included as Appendix J in HSW Engineering Inc. 2010). The three-factor joint probability for the January 2-4, 2008 critically cold period was the second lowest among all three-day periods evaluated, and the two-factor probability was ranked in the top 5 percent of the 1,708 three-day periods occurring during the combined 1997 through 2008 manatee seasons.

The Homosassa River hydrodynamic model was then used to estimate depth-average water temperatures for model domain cells for baseline conditions and for various flow-reduction scenarios during the three-day (January 2-4, 2008) critically cold period based on combined discharge measurements for the USGS Homosassa Springs and Southeast Fork gages. The extent (volume) of thermally favorable manatee habitat during the baseline critically cold three-day chronic and four-hour acute conditions during the three-day period were quantified using the modeled depth-averaged water temperatures and bathymetric data to identify portions of the river that met the thermal and water depth requirements of the animals. Changes in the volume of thermally-favored manatee habitat available associated with 5, 10, 15, 20, 25 and 30 percent reductions in flow from baseline conditions were also modeled and evaluated to identify flow reductions associated with more than a 15 percent decrease in the volume of thermally-favorable habitat available under baseline conditions.

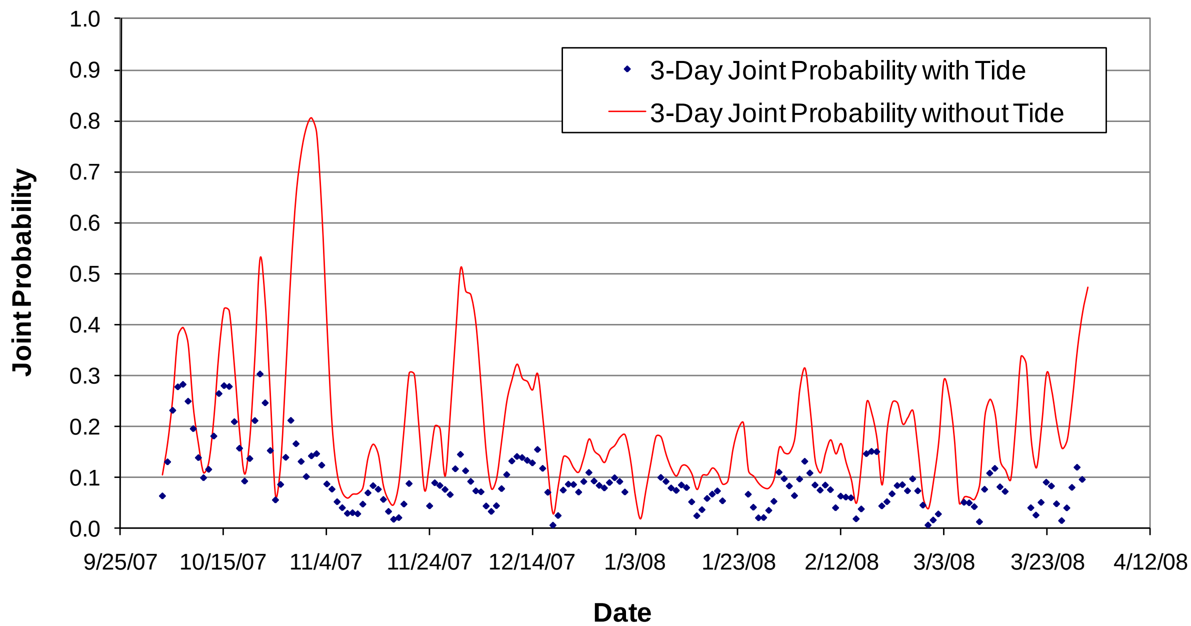


Figure 4-1. Three-day average joint non-exceedance probabilities for air temperature, spring discharge and tide stage (3-Day Joint Prob. with Tide) and air temperature and spring discharge (3-Day Joint Probability without Tide) during the 2007-2008 manatee season.

CHAPTER 5. RESULTS AND INITIAL RECOMMENDED MINIMUM FLOWS

5.1 Introduction

Results from application of the technical approaches described in Chapter 4 are summarized in this chapter and were used to develop initial minimum flows recommendations for the Homosassa River system. The results are grouped based on methods used to investigate flow-reduction responses of planktonic and nektonic fish and invertebrates, salinity-based habitats and extent of thermal refuge for the Florida manatee.

5.2 Results for Fish and Invertebrate Plankton and Nekton Analyses

All taxa or pseudo-species that were evaluated exhibited sensitive modeled responses to flow reductions for both the 2007 and the longer 1995 through 2010 benchmark periods. The five fish and invertebrate taxa that were evaluated with regressions based on organisms collected from the Homosassa River using a plankton net exhibited fifteen percent decreases from median baseline abundances with flow reductions ranging from less than one up to 1.4 percent (Table 5-1). Among the planktonic taxa evaluated, the response of the copepod, *Acartia tonsa*, was based on a regression equation that exhibited evidence of problems associated with serial correlation. Use of natural logarithmic transformed lagged flow and abundance values for development of the regression equations for the planktonic taxa (see Table 3-6) resulted in a constant response in predicted relative abundances as a function of flow across the range of evaluated benchmark inflow values; *i.e.*, flow reductions associated with 15 percent decreases from all benchmark percentile flows were the same as those associated with the median benchmark flows. Summary information regarding baseline and flow reduction scenario abundances associated with tenth to ninetieth baseline flows for the 2007 and 1995 through 2009 benchmark periods are included in Tables I1 through I5 in Appendix I.

Responses of pseudo-species evaluated using regressions based on organisms captured from shallow and deeper areas of the Homosassa and/or Halls Rivers with seine and trawl nets were similar to those for taxa collected with the plankton net. Flow reductions ranging from less than one to 2.7 percent were associated with fifteen percent reductions in relative abundances associated with median flows for the 2007 and 1995 through 2010 benchmark periods (Table 5-1). Among the pseudo-species evaluated, the responses of blue crab >30mm in size, rainwater killifish, and pinfish collected with seines from the Homosassa River were based on regression equations that exhibited evidence of problems associated with serial correlation. This was also the case for responses of largemouth bass collected from Halls River with a seine, and for Gulf pipefish collected by trawl from the Homosassa and Halls Rivers. Responses of all pseudo-species were more sensitive for the 2007 benchmark period flows as compared to the 1995 through 2010 flows and likely reflected the relatively low flow conditions that occurred during 2007.

Responses to flow reductions associated with median benchmark flows were generally similar to the responses predicted across the range of benchmark flows examined (see Tables I6 through I20 in Appendix I), although variable responses were noted for some taxa. Some pseudo-species, *e.g.,* blue crabs (*Callinectes sapidus)* greater than 30 mm in length, exhibited increasingly sensitive responses to flow reductions from progressively lower baseline flow percentiles (Table I-8 in Appendix I). The regression equation used to predict baseline abundance for one pseudo-species, spot (*Leiostomus xanthurus*), indicated that for at least half the time, the sampled size-class for this fish would not be expected to occur in the shallow portions of the Homosassa River that were sampled with the seine net – predicted baseline abundance at the median flow for the 2007 benchmark periods was less than zero (Table 5-1). Lack of occurrence of the fish from shallow regions of the river was similarly predicted for the longer 1995 through 2010 benchmark period, based on the twentieth percentile flow for the period (Table I-20, Appendix I). Baseline relative abundances less than zero were predicted for nine additional pseudo-species based on lower (tenth to thirtieth percentile) baseline flows for the 2007 benchmark period and a single pseudo-species for the tenth percentile baseline flow for the 1995 through 2009 benchmark period.

Table 5-1. Summary information pertaining to identification of percentage of flow reductions associated with 15 percent decreases in absolute (plankton net captured) or relative (seine or trawl-net captured) abundances of planktonic and nektonic fish and invertebrates in the Homosassa River and/or Halls River as compared to abundances for median baseline flows in the Homosassa River for the benchmark periods of 2007 and October 18, 1995 through May 13, 2009 (1995-2009).

Taxon or Pseudo-Species	Benchmark Period	Baseline Flow[a] (cfs)	Baseline Abundance (number/ channel or number/ $100m^2$)	85% of Baseline Abundance (number/ channel or number/ $100m^2$)	Flow Associated with 85% of Baseline Abundance (cfs)	Percent of Flow Reduction Associated with 85% of Baseline Abundance (%)
Plankton-Net Captured			**(number/ channel)**	**(number/ channel)**		
Hargeria rapax[b]	2007	130	67,242	57,155	128.1	1.4
	1995-2009	150	333,722	283,663	147.8	1.4
Lucania parva postflexion larvae[b]	2007	130	1,407	1,196	128.2	1.4
	1995-2009	150	7,457	6,339	147.9	1.4
Ostracods, podocopid[b]	2007	130	31,031	26,376	128.2	1.3
	1995-2009	150	172,563	146,678	148.0	1.3
Acartia tonsa[b]	2007	130	1,294,494	1,100,319	128.6	1.1
	1995-2009	150	11,345,444	9,643,627	148.40	1.1
Eurytemora affinis[b]	2007	130	2,849	2,421	128.9	0.8
	1995-2009	150	49,686	42,233	148.8	0.8
Seine-Net Captured			**(number/ $100m^2$)**	**(number/ $100m^2$)**		
Palaemonetes intermedius[c]	2007	130	11.4	9.7	127.5	1.9
	1995-2009	150	35.8	30.4	146.9	2.1
Callinectes sapidus; <30 mm in length[c]	2007	130	1.4	1.2	129.1	0.7
	1995-2009	150	16.1	13.7	148.3	1.1
Callinectes sapidus; >30mm in length[c]	2007	130	0.5	0.5	128.0	1.6
	1995-2009	150	1.5	1.3	145.9	2.7
Fundulus grandis[c]	2007	130	1.5	1.3	127.7	1.7
	1995-2009	150	4.4	3.8	146.4	2.4
Lucania parva[c]	2007	130	43.6	37.0	128.3	1.3
	1995-2009	150	236.1	200.6	147.9	1.4
Gambusia holbrooki[c]	2007	130	4.9	4.2	128.9	0.8
	1995-2009	150	55.3	47.0	148.5	1.0
Poecilia latipinna[c]	2007	130	0.4	0.4	128.1	1.5
	1995-2009	150	1.2	1.0	145.9	2.7
Syngnathus scovelli[d]	2007	130	1.8	1.5	127.9	1.6
	1995-2009	150	5.7	4.9	146.7	2.2

Table 5-1. Continued.

Taxon or Pseudo-Species	Benchmark Period	Baseline Flow[a] (cfs)	Baseline Abundance	15% Decrease from Baseline Abundance	Flow Associated with 85% of Baseline Abundance (cfs)	Percent of Flow Reduction Associated with 85% of Baseline Abundance (%)
Lepomis punctatus[d]	2007	130	3.3	2.8	128.3	1.3
	1995-2009	150	15.9	13.5	147.6	1.6
Micropterus salmoides[c]	2007	130	8.5	7.2	128.8	1.0
	1995-2009	150	79.2	67.3	148.4	1.1
Micropterus salmoides[d]	2007	130	4.0	3.4	129.2	0.6
	1995-2009	150	92.9	79.0	148.8	0.8
Lagadon rhomboides[c]	2007	130	8.9	7.6	128.4	1.2
	1995-2009	150	53.1	45.1	148.0	1.3
Leiostomus xanthurus[c]	2007	130	<0	NA	NA	NA
	1995-2009	150	59.3	50.4	149.3	0.5
Trawl-Net Captured			**(number/ $100m^2$)**	**(number/ $100m^2$)**		
Callinectes sapidus[e]	2007	130	0.1	0.1	129.4	0.5
	1995-2009	150	0.9	0.7	147.0	2.0
Syngnathus scovelli[e]	2007	130	0.2	0.2	129.3	0.6
	1995-2009	150	1.2	1.0	147.0	2.0

[a] Daily flow records used to calculate median baseline flows include a small number of estimated flow values derived for days when flows were unavailable for either the Homosassa Springs or Southeast Fork Homosassa River gage sites maintained by the U.S. Geological Survey
[b] Abundances reported for Homosassa River between river kilometers 0 and 11
[c] Relative abundances reported for Homosassa River between river kilometers 0 and 13
[d] Relative abundances reported for Halls River between river kilometers 0 and ~5.8
[e] Relative abundances reported for Homosassa River between river kilometer 5.8 and 11 and Halls River between river kilometers 0 and ~3

5.3 <u>Results for Salinity-Based Habitat Analyses</u>

5.3.1 Overview

Salinity-based habitats characterized using the Homosassa River hydrodynamic model and predictive regression models exhibited expected declines in response to modeled flow reductions. Results are summarized in this section for modeled responses for the benchmark period of 2007 based on hydrodynamic and regression modeling approaches and for the longer benchmark period, from October 18, 1995 through May 13, 2009 based on the regression models. For both the hydrodynamic and regression-model analyses, the tenth to ninetieth percentiles for isohaline location and salinity-based habitat values were derived for baseline (*i.e.,* no flow reduction) and 5, 10, 15, 20, 25 and 30 percent flow-reduction scenarios. Flow-reduction effects on habitat were characterized primarily with median isohaline and salinity-based habitat values, although effects of flow reductions on other isohaline locations and habitat percentiles were also reviewed.

5.3.2 Isohaline Locations – 5 to 30 Percent Flow Reduction Results

Isohaline locations for median baseline conditions for the modeled 2007 and 1995-2009 benchmark periods are listed in Tables 5-2 through 5-7 and isohaline location percentiles for the five to thirty percent modeled flow reduction scenarios are provided in Appendices J through L.

In 2007, which was a relatively dry or low-flow year, model results indicated low salinity waters, *i.e.*, with salinities less than 2 or 3, were typically limited to the portion of the Homosassa River upstream from or near the confluence of the Homosassa and Halls Rivers (Tables 5-2 through 5-7). Median baseline bottom, surface and water-column isohalines with a salinity of 2 were located at or upstream of river kilometer 12.0, based on hydrodynamic modeling results. Review of modeled three-hour increment results indicated waters with salinities less than 2 were restricted to the uppermost portion of the river, upstream from the model domain boundary at river kilometer 12.5 for 47, 33 and 39 percent of the time, based on the respective locations of the bottom, surface or depth-average isohalines (see Tables J-1, J-5 and J-9 in Appendix J). Median locations of modeled isohalines with a salinity of 3 occurred between river kilometers 9.7 and 10.9 in 2007, based on both the hydrodynamic and regression model results. The median downstream extent of the oligohaline zone, demarcated by the isohaline with a salinity of 5, was located between river kilometers 8.5 and 9.8 in 2007. Modeled median locations of the isohalines associates with a salinity of 12 occurred between river kilometers 5.2 and 6.0.

Flow reduction scenarios for 2007 evaluated with the hydrodynamic and regression models indicated median locations of the isohalines evaluated would be located between 0.1 and 1.2 km upstream of the locations associated with baseline, *i.e.*, no flow reduction, conditions (Tables 5-2 through 5-7). As expected, the greatest predicted upstream displacement of isohalines was associated with the thirty percent, or highest modeled flow reduction scenario. Flow reductions of 5 percent were associated with relatively minor upstream movement of isohaline locations. Upstream movement of 0.2 kilometers or less was predicted for all median isohaline locations in 2007, with the exception of the isohaline with a salinity of 12. Based on regression modeling results the median location for this isohaline was predicted to move upstream 0.4 kilometers in association with a five percent flow reduction. Modeled flow reductions of 10 percent were associated with the displacement of median isohaline locations upstream from 0.1 to 0.5 kilometers.

Median locations of baseline isohalines for the 1995-2009 benchmark period developed using the regression approach occurred between 0.7 and 2.7 kilometers downstream from the isohaline locations modeled for the 2007 benchmark period (Tables 5-8 through 5-10). Relative upstream displacement of median isohaline locations from baseline conditions for the 1995-2009 benchmark period ranged from 0.3 and 0.7 kilometers for the 5 percent flow reduction scenario from 1.3 to 2.4 km for the 30 percent flow reduction scenario.

5.3.3 Note Concerning Use of Hydrodynamic Modeling Results for Habitats Associated with Salinities of 2 or Less

Use of the hydrodynamic model for evaluating the location of bottom, surface and water-column average isohalines associated with a salinity of 2 was considered problematic because salinities of model inputs associated with water discharged from the Homosassa Springs main pool and springs of the Southeast Fork often exceeded 2 during the modeled 2007 benchmark period and isohalines associated with a salinity of 2 were often near or upstream of the model domain. Medians of estimated daily bottom salinity maxima and minima were 2.8 and 1.8, respectively at the U.S. Geological Survey Homosassa Springs gage site in 2007, where salinities in excess of 2 were common (Figure 5-1, upper panel). Salinities at the Southeast Fork gage site were typically lower than at the Homosassa Springs site in 2007, but salinities in excess of 2 were not uncommon (Figure 5-1, lower panel); median daily maximum and minimum salinities at the Southeast Fork gage site were 1.5 and 0.4, respectively.

Further complicating use of the hydrodynamic modeling results for evaluation of isohalines with salinity of 2 was the predicted occurrence of these isohalines near or at the upper boundary of the model domain. As noted above, isohaline boundaries associated with salinities of 2 or less frequently occurred upstream of the model domain, even for baseline flow conditions modeled for 2007, and therefore precluded evaluation of isohaline locations for much of the modeled benchmark period. This inability to model the distribution of waters with salinities of 2 or less under baseline conditions and the flow-reduction scenarios examined for the minimum flows analysis indicates that results based on use of the hydrodynamic model for evaluating isohalines and habitats associated with salinities of 2 or less may not be adequate for the purpose of developing specific, quantitative minimum flow recommendations. Consequently staff determined that these modeling results would not be directly used for development of minimum flow recommendations for the Homosassa River system, but would instead be used as qualitative indicators of potential system responses to flow reductions. Results derived from use of the hydrodynamic model to evaluate areas of the river system where salinities are 2 or less are, however, presented in a quantitative manner in this report, as this information was considered useful in combination with the consideration of other quantitative modeling results.

Table 5-2. Median river kilometer (Rkm) location and relative change of bottom isohalines with salinities of 2, 3, 5 and 12 for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period of 2007 based on modeling conducted with the Homosassa River hydrodynamic model. Isohaline locations upstream of river kilometer 12.5 were outside the model domain and could not be determined. Table adapted from HSW Engineering, Inc. (2011).

Salinity Isohaline	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Rkm	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)
2	12.3	>12.5	>0.2	>12.5	>0.2	>12.5	>12.5	>12.5	>0.2	>12.5	>0.2	>12.5	>0.2
3	10.9	11.0	0.1	11.1	0.2	11.2	0.3	11.3	0.4	11.5	0.6	11.6	0.7
5	9.1	9.2	0.1	9.4	0.3	9.6	0.5	9.7	0.6	10.0	0.9	10.3	1.2
12	6.2	6.4	0.2	6.4	0.2	6.5	0.3	6.7	0.5	6.9	0.7	7.0	0.8

Note: Any differences between Relative Change values and results obtained by comparison of Rkm values are associated with rounding of presented values

Table 5-3. Median river kilometer (Rkm) location of surface isohalines with salinities of 2, 3, 5 and 12 for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period of 2007 based on modeling conducted with the Homosassa River hydrodynamic model. Isohaline locations upstream of river kilometer 12.5 were outside the model domain and could not be determined.

Salinity Isohaline	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Rkm	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)
2	12.0	12.1	0.1	12.3	0.3	12.3	0.3	>12.5	>0.5	>12.5	>0.5	>12.5	>0.5
3	10.9	11.0	0.1	11.0	0.2	11.2	0.3	11.3	0.4	11.4	0.5	11.6	0.7
5	8.9	9.1	0.2	9.2	0.3	9.4	0.5	9.6	0.7	9.7	0.8	10.0	1.1
12	5.5	5.7	0.1	5.8	0.2	5.9	0.4	6.2	0.7	6.3	0.8	6.5	1.0

Note: Any differences between Relative Change values and results obtained by comparison of Rkm values are associated with rounding of presented values

Table 5-4. Median river kilometer (Rkm) location of water-column average isohalines with salinities of 2, 3, 5 and 12 for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period of 2007 based on modeling conducted with the Homosassa River hydrodynamic model. Isohaline locations upstream of river kilometer 12.5 were outside the model domain and could not be determined. Table adapted from HSW Engineering, Inc. (2011).

Salinity Isohaline	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Rkm	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)
2	12.2	12.3	0.1	12.4	0.2	>12.5	>0.3	>12.5	>0.3	>12.5	>0.3	>12.5	>0.3
3	10.9	11.0	0.1	11.1	0.2	11.2	0.3	11.3	0.4	11.4	0.5	11.6	0
5	9.0	9.2	0.1	9.3	0.3	9.5	0.5	9.7	0.7	9.9	0.9	10.2	1.2
12	5.8	5.9	0.1	6.2	0.3	6.3	0.5	6.4	0.6	6.5	0.7	6.7	0.9

Note: Any differences between Relative Change values and results obtained by comparison of Rkm values are associated with rounding of presented values

Table 5-5. Median river kilometer (Rkm) location of bottom isohalines with salinities of 3, 5 and 12 for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period of 2007, based on modeling of daily values conducted with empirical regression models.

Salinity Isohaline	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Rkm	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)
3	10.9	11.1	0.2	11.3	0.3	11.5	0.5	11.6	0.7	11.8	0.9	12.0	1.0
5	9.8	9.9	0.1	9.9	0.1	10.0	0.2	10.0	0.2	10.1	0.3	10.2	0.4
12	6.0	6.2	0.2	6.4	0.4	6.6	0.6	6.8	0.8	7.0	1.0	7.2	1.1

Note: Any differences between Relative Change values and results obtained by comparison of Rkm values are associated with rounding of presented values

Table 5-6. Median river kilometer (Rkm) location of surface isohalines with salinities of 3, 5 and 12 for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period of 2007, based on modeling of daily values conducted with empirical regression models.

Salinity Isohaline	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Rkm	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)
3	9.7	9.9	0.2	10.0	0.3	10.1	0.4	10.2	0.5	10.4	0.6	10.5	0.8
5	8.5	8.6	0.1	8.7	0.3	8.9	0.4	9.0	0.5	9.1	0.6	9.3	0.8
12	5.2	5.6	0.4	5.8	0.5	5.8	0.6	5.8	0.6	5.8	0.6	5.8	0.5

Note: Any differences between Relative Change values and results obtained by comparison of Rkm values are associated with rounding of presented values

Table 5-7. Median river kilometer (Rkm) location of water-column average isohalines with salinities of 3, 5 and 12 for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period of 2007, based on modeling of daily values conducted with empirical regression models.

Salinity Isohaline	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Rkm	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)
3	10.3	10.5	0.2	10.7	0.3	10.8	0.5	10.9	0.6	11.1	0.8	11.2	0.9
5	9.1	9.2	0.1	9.3	0.2	9.4	0.3	9.5	0.4	9.6	0.5	9.7	0.6
12	5.6	5.9	0.3	6.1	0.5	6.2	0.6	6.3	0.7	6.4	0.7	6.5	0.8

Note: Any differences between Relative Change values and results obtained by comparison of Rkm values are associated with rounding of presented values

Table 5-8. Median river kilometer (Rkm) location of bottom isohalines with salinities of 3, 5 and 12 for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period from October 18, 1995 through May 13, 2009, based on modeling of daily values conducted with empirical regression models.

Salinity Isohaline	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Rkm	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)
3	9.6	10.2	0.6	10.8	1.1	11.0	1.4	11.2	1.6	11.4	1.8	11.6	2.0
5	8.4	9.1	0.7	9.6	1.2	9.8	1.3	9.9	1.5	10.0	1.5	10.0	1.6
12	4.3	5.0	0.7	5.6	1.3	6.0	1.7	6.3	2.0	6.5	2.2	6.7	2.4

Note: Any differences between Relative Change values and results obtained by comparison of Rkm values are associated with rounding of presented values

Table 5-9. Median river kilometer (Rkm) location of surface isohalines with salinities of 3, 5 and 12 for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period from October 18, 1995 through May 13, 2009, based on modeling of daily values conducted with empirical regression models.

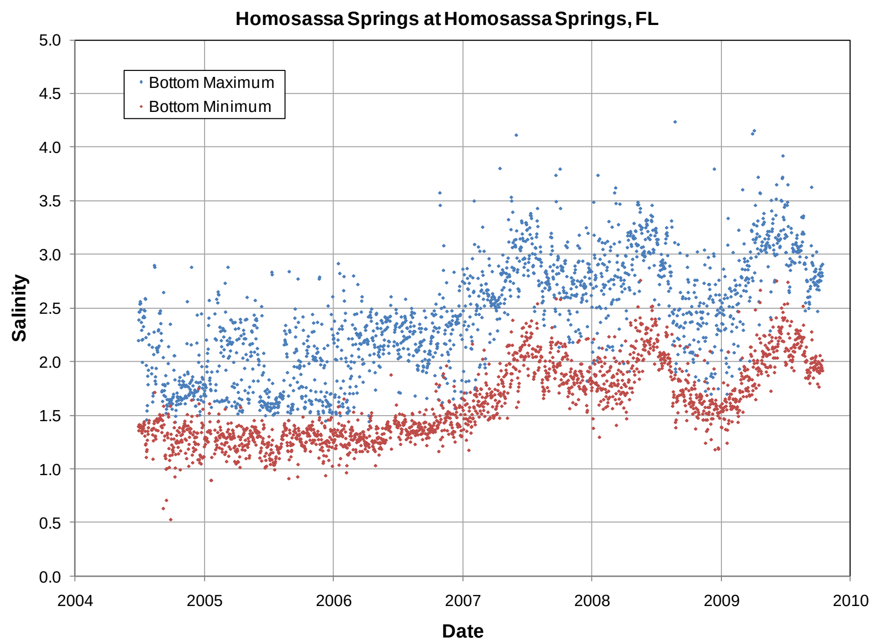
Salinity Isohaline	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Rkm	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)
3	8.8	9.2	0.3	9.5	0.7	9.8	1.0	10.0	1.1	10.1	1.3	10.2	1.4
5	7.6	8.0	0.4	8.3	0.7	8.5	0.9	8.7	1.0	8.8	1.2	9.0	1.3
12	3.8	4.4	0.5	4.9	1.1	5.4	1.6	5.6	1.7	5.7	1.9	5.7	1.9

Note: Any differences between Relative Change values and results obtained by comparison of Rkm values are associated with rounding of presented values

Table 5-10. Median river kilometer (Rkm) location of water-column average isohalines with salinities of 3, 5 and 12 for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period from October 18, 1995 through May 13, 2009, based on modeling of daily values conducted with empirical regression models.

Salinity Isohaline	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Rkm	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)	Rkm	Relative Change (km)
3	9.2	9.7	0.5	10.1	0.9	10.4	1.2	10.6	1.4	10.7	1.5	10.9	1.7
5	8.0	8.5	0.5	9.0	0.9	9.2	1.1	9.3	1.2	9.4	1.4	9.5	1.5
12	4.1	4.7	0.6	5.3	1.2	5.7	1.6	5.9	1.9	6.1	2.0	6.3	2.2

Note: Any differences between Relative Change values and results obtained by comparison of Rkm values are associated with rounding of presented values



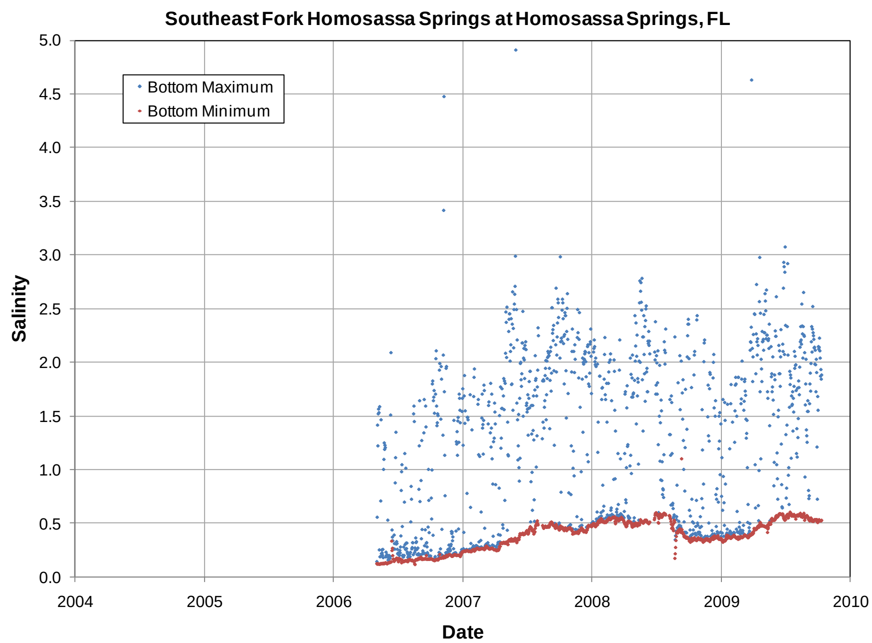


Figure 5-1. Daily maximum and minimum salinity at the U.S. Geological Survey Homosassa Springs and Southeast Fork Homosassa Springs gage sites estimated from Survey-approved specific conductance records for the period from June 28, 2004 through October 14, 2008. Two Bottom Maximum records for the Homosassa Springs site and nine Bottom Maximum records for the Southeast Fork site exceeded a salinity of five and are not shown in the plots.

5.3.4 Salinity-Based Bottom Habitats – 5 to 30 Percent Flow Reduction Results

Modeled baseline and flow-reduction scenario bottom areas associated with specific salinity zones were evaluated using both bottom and water-column average isohaline locations. In some cases, modeled bottom areas associated with specific salinity zones differed considerably, depending upon whether bottom or water-column average isohalines were used for calculating areas for the salinity habitats. Flow reductions associated with fifteen percent decreases in bottom area from baseline conditions were not, however, in most cases substantially influenced by the choice of isohaline for calculation of bottom area.

Model results for median baseline and flow-reduction scenarios are summarized in Tables 5-11 through 5-15. The scenarios evaluated suggest that the areal extent of river bottom in the Homosassa River exposed to salinities up to 2 or 3 was relatively sensitive to flow reductions. Hydrodynamic modeling output indicated that flow reductions of less than 5 percent, the lowest modeled flow scenario, were predicted to result in more than a 15 percent decrease in median baseline bottom area exposed to salinities of 2 or less during the 2007 benchmark period. Hydrodynamic model results for 2007 also indicate that flow reductions between 5 and 10 percent would result in more than a 15 percent reduction in median baseline habitat where salinities were less than or equal to 3. Predictions for bottom area with salinities of 3 or less based on the regression modeling approach were more sensitive than the responses predicted for the same salinity zone with the hydrodynamic model. Regression models predicted that flow reductions of less than 5 percent would cause more than 15 percent reductions in habitat area with salinities less than 3 for both the 2007 and 1995-2009 benchmark periods.

Fifteen percent reductions in median bottom area exposed to salinities up to 5 were associated with 10 to greater than 30 percent flow reductions, based on hydrodynamic and regression model output for the 2007 benchmark period. As was the case for results based on changes in median bottom area associated with a salinity of 3 or less, the regression modeling for the 1995-2009 benchmark period yielded the most sensitive responses to flow reductions for bottom area with salinities of 5 or less. Flow reductions between 5 and 10 percent for the 1995-2009 benchmark period resulted in a 15 percent decrease in the median bottom habitat area associated with salinities of 5 or less.

Among the bottom-habitat salinity zones examined, bottom areas associated with salinities less than or equal to 12 were the least sensitive to flow alterations. Modeled flow reductions between 10 and 30 percent were associated with 15 percent reductions in habitat area from median baseline conditions. The most sensitive responses for this salinity-habitat were predicted for the 1995-2009 benchmark period using the regression modeling approach.

The sensitivity of changes in salinity-based bottom habitats to flow reductions was not limited to changes associated with median baseline conditions. For example, hydrodynamic modeling for the 2007 benchmark period indicated that bottom area associated with the fortieth percentile baseline conditions, *i.e.,* approximately associated with forty percent exceedance flows, was reduced by more than 15 percent when flows were reduced by five percent (see Table M-4 in Appendix M). Changes in bottom area associated with all modeled salinity zones across the range of baseline conditions, from tenth to ninetieth percentiles, are presented in Appendices M, N and O.

Table 5-11. . Median daily bottom area upstream of bottom isohalines with salinities of 2, 3, 5 and 12 and relative change in bottom area percentiles for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period of 2007 based on modeling conducted with the Homosassa River hydrodynamic model. Yellow shaded cells correspond with or bracket flow reductions associated with a 15 percent relative change (reduction) in baseline bottom area. Orange shaded cell indicates lowest modeled flow reduction scenario resulted in more than a 15 percent reduction in baseline bottom area. Table adapted from HSW Engineering, Inc. (2011).

Salinity Zone	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Area (m^2)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)
≤ 2	14,470	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
≤ 3	162,199	149,769	8	134,345	17	107,030	34	94,817	42	82,209	49	79,029	51
≤ 5	508,851	488,602	4	450,710	11	415,959	18	393,589	23	347,073	32	304,949	40
≤ 12	1,047,360	1,017,990	3	1,004,54	4	989,253	6	935,873	11	890,436	15	866,732	17

NA = isohaline for salinity zone boundary located upstream of model domain

Table 5-12. Median daily bottom area upstream of water-column average isohalines with salinities of 2, 3, 5 and 12 and relative change in bottom area percentiles for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period of 2007 based on modeling conducted with the Homosassa River hydrodynamic model. Yellow shaded cells correspond with or bracket flow reductions associated with a 15 percent relative change (reduction) in baseline bottom area. Orange shaded cell indicates lowest modeled flow reduction scenarios resulted in more than a 15 percent reduction in baseline bottom area. Table adapted from HSW Engineering, Inc. (2011).

Salinity Zone	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Area (m^2)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)
≤ 2	30,504	18,201	40	10,175	67	NA	NA	NA	NA	NA	NA	NA	NA
≤ 3	164,680	152,891	7	137,149	17	108,939	34	100,287	39	82,344	50	81,341	51
≤ 5	518,409	498,393	4	465,521	10	429,087	17	395,735	24	358,883	31	324,816	37
≤ 12	1,127,570	1,098,010	3	1,053,619	7	1,024,120	9	1,004,918	11	984,638	13	929,789	18

NA = isohaline for salinity zone boundary located upstream of model domain

Table 5-13. Median daily bottom area upstream of bottom isohalines with salinities of 3, 5 and 12 and relative change in bottom area percentiles for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period of 2007, based on modeling conducted with empirical regression models. Yellow shaded cells bracket flow reductions associated with a 15 percent relative change (reduction) in baseline bottom area. Orange shaded cell indicates the lowest modeled flow reduction scenario resulted in more than a 15 percent reduction in baseline bottom area.

Salinity Zone	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Area (m^2)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)
≤ 3	159,128	129,245	19	99,989	37	82,291	48	80,345	50	71,191	55	51,248	68
≤ 5	378,197	369,390	2	360,703	5	352,111	7	343,432	9	334,609	12	325,786	14
≤ 12	1,076,754	1,041,844	3	1,008,080	6	964,576	10	915,935	15	868,381	19	820,908	24

Table 5-14. Median daily bottom area upstream of water-column average isohalines with salinities of 3, 5 and 12 and relative change in bottom area percentiles for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period of 2007, based on modeling conducted with empirical regression models. Yellow shaded cells bracket flow reductions associated with a 15 percent relative change (reduction) in baseline bottom area. Orange shaded cell indicates the lowest modeled flow reduction scenario resulted in more than a 15 percent reduction in baseline bottom area.

Salinity Zone	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Area (m^2)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)
≤ 3	286,890	240,324	16	207,447	28	180,052	37	159,403	44	135,286	53	109,057	62
≤ 5	503,809	486,083	4	463,881	8	443,819	12	426,316	15	409,129	19	394,403	22
≤ 12	1,170,686	1,100,269	6	1,061,060	9	1,045,838	11	1,030,616	12	1,015,393	13	1,000,171	15

Table 5-15. Median daily bottom area upstream of bottom isohalines with salinities of 3, 5 and 12 and relative change in bottom area percentiles for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period from October 18, 1995 through May 13, 2009, based on modeling conducted with empirical regression models. Yellow shaded cells correspond with or bracket flow reductions associated with a 15 percent relative change (reduction) in baseline natural shoreline length. Orange shaded cell indicates the lowest modeled flow reduction scenario resulted in more than a 15 percent reduction in baseline bottom area.

Salinity Zone	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Area (m^2)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)
≤ 3	405,494	311,957	23	186,320	54	148,878	63	111,884	72	82,922	80	81,714	80
≤ 5	566,623	507,782	10	408,937	28	383,252	32	365,293	36	353,908	38	343,711	39
≤ 12	1,369,157	1,290,431	6	1,165,769	15	1,077,869	21	1,027,324	25	986,503	28	929,843	32

Table 5-16. Median daily bottom area upstream of water-column average isohalines with salinities of 3, 5 and 12 and relative change in bottom area percentiles for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period from October 18, 1995 through May 13, 2009, based on modeling conducted with empirical regression models. Yellow shaded cells bracket flow reductions associated with a 15 percent relative change (reduction) in baseline natural shoreline length. Orange shaded cell indicates the lowest modeled flow reduction scenario resulted in more than a 15 percent reduction in baseline bottom area.

Salinity Zone	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Area (m^2)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)	Area (m^2)	Relative Change (%)
≤ 3	489,079	394,129	19	328,534	33	269,681	45	223,104	54	191,044	61	164,737	66
≤ 5	637,346	552,737	13	525,058	18	502,149	21	476,917	25	451,617	29	429,912	33
≤ 12	1,406,014	1,322,300	6	1,244,244	12	1,154,915	18	1,092,838	22	1,056,988	25	1,031,303	27

5.3.5 Salinity-Based Volumetric Habitats – 5 to 30 Percent Flow Reduction Results

Baseline and flow reduction scenario water volumes associated with specific salinity zones in the Homosassa River were evaluated using water-column average isohaline locations derived using both the hydrodynamic and regression modeling approaches. Summary output on salinity-zone volumes from the modeled scenarios for median baseline conditions is presented in Tables 5-17 through 5-19. Changes in water volumes associated with modeled salinity zones across the range of baseline conditions, from tenth to ninetieth percentiles, are presented in Appendix M for the hydrodynamic modeling of the 2007 benchmark period and in Appendices N and O for the modeling of the 2007 and 1995-2010 benchmark periods using the regression approach.

Responses of salinity-based water volumes to modeled flow reductions were similar to the changes observed for modeled salinity-based bottom area. Flow reductions of 5 percent were associated with more than 15 percent reductions in baseline median water volumes with salinities of up to 2 or 3, based respectively on results from the hydrodynamic modeling of the 2007 benchmark period and use of the regression approach for the 1995 through 2010 benchmark period. Relatively sensitive responses to flow reductions, *i.e.,* habitat volume changes between 5 and 10 percent, were also predicted for baseline median water volumes with salinities less than or equal to 3 for the 2007 benchmark period and for the zone of salinity less than or equal to 5 for the 1995-2010 benchmark period, based on regression modeling results. The median baseline volume of water with salinities up to 12 was less affected by flow reductions, with the most sensitive result indicating that a 10 to 15 percent flow reduction for the 1995 through 2010 benchmark period would lead to a 15 percent reduction in the salinity-based habitat.

Table 5-17. Median daily water volume upstream of selected water-column average isohalines with salinities of 2, 3, 5 and 12 and relative change in bottom area percentiles for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period of 2007 based on modeling conducted with the Homosassa River hydrodynamic model. Yellow shaded cells correspond with or bracket flow reductions associated with a 15 percent relative change (reduction) in baseline volume. Orange shaded cell indicates lowest modeled flow reduction scenario resulted in more than a 15 percent reduction in baseline water volume. Table adapted from HSW Engineering, Inc. (2011).

Salinity Zone	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Volume (m^3)	Volume (m^3)	Relative Change (%)	Volume (m^3)	Relative Change (%)	Volume (m^3)	Relative Change (%)	Volume (m^3)	Relative Change (%)	Volume (m^3)	Relative Change (%)	Volume (m^3)	Relative Change (%)
≤ 2	49,013	27,034	45	13,298	73	NA	NA	NA	NA	NA	NA	NA	NA
≤ 3	236,409	220,729	7	202,052	15	170,745	28	164,479	30	149,022	37	138,453	41
≤ 5	687,505	661,379	4	625,837	9	585,520	15	540,490	21	485,803	29	436,621	36
≤ 12	1,565,149	1,515,635	3	1,446,498	8	1,402,774	10	1,374,312	12	1,344,007	14	1,261,02	19

NA = isohaline for salinity zone boundary located upstream of model domain

Table 5-18. Median daily water volume upstream of water-column average isohalines with salinities of 3, 5 and 12 and relative change in volume percentiles for baseline and 5 to 30 percent flow reduction for the benchmark period of 2007, based on modeling conducted with empirical regression models. Yellow shaded cells bracket flow reductions associated with a 15 percent relative change (reduction) in baseline volume.

Salinity Zone	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Volume (m^3)	Volume (m^3)	Relative Change (%)	Volume (m^3)	Relative Change (%)	Volume (m^3)	Relative Change (%)	Volume (m^3)	Relative Change (%)	Volume (m^3)	Relative Change (%)	Volume (m^3)	Relative Change (%)
≤ 3	389,912	334,216	14	293,379	25	256,857	34	229,391	41	199,894	49	170,830	56
≤ 5	668,449	647,625	3	624,100	7	602,388	10	582,347	13	561,905	16	538,362	19
≤ 12	1,637,370	1,519,419	7	1,457,527	11	1,434,964	12	1,412,402	14	1,389,839	15	1,367,277	16

Table 5-19. Median daily water volume upstream of water-column average isohalines with salinities of 3, 5 and 12 and relative change in volume percentiles for baseline and 5 to 30 percent flow reduction for the benchmark period from October 18, 1995 through May 13, 2009, based on modeling conducted with empirical regression models. Yellow shaded cells bracket flow reductions associated with a 15 percent relative change (reduction) in baseline natural shoreline length. Orange shaded cell indicates the lowest modeled flow reduction scenario resulted in more than a 15 percent reduction in baseline volume.

Salinity Zone	Flow Scenario												
	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Volume (m^3)	Volume (m^3)	Relative Change (%)	Volume (m^3)	Relative Change (%)	Volume (m^3)	Relative Change (%)	Volume (m^3)	Relative Change (%)	Volume (m^3)	Relative Change (%)	Volume (m^3)	Relative Change (%)
≤ 3	650,799	537,923	17	442,073	32	369,460	43	313,535	52	271,511	58	236,485	64
≤ 5	867,470	760,824	12	698,454	19	666,282	23	637,912	26	611,105	30	586,465	32
≤ 12	2,063,155	1,919,863	7	1,765,365	14	1,610,953	22	1,506,972	27	1,451,491	30	1,413,421	31

5.3.6 Salinity-Based Shoreline Habitats – 5 to 30 Percent Flow Reduction Results

Baseline and flow reduction scenario shoreline lengths associated with specific salinity zones were evaluated using surface isohaline locations for both the hydrodynamic and regression modeling approaches. Regions of the Homosassa River classified as “natural” shoreline, *i.e*., non-hardened shoreline with natural vegetation, were examined to evaluate potential changes in flow that may affect these relatively natural components of the Homosassa River system. Summary output from the modeled scenarios for median baseline conditions is presented in Tables 5-20 through 5-22. Changes in natural shoreline lengths associated with modeled salinity zones across the range of baseline conditions, from tenth to ninetieth percentiles, are presented in Appendix M for the hydrodynamic modeling of the 2007 benchmark period and in Appendices N and O for the modeling of the 2007 and 1995-2010 benchmark periods using the regression approach.

Modeling of the benchmark period of 2007 with the hydrodynamic model indicated that a 5 percent reduction in median flows would result in a 16 percent reduction in natural shoreline length in the zone where salinities were 2 or less (Table 5-20). Similar sensitivity to flow reductions was evident for shoreline lengths exposed to salinities up to 12, based on regression model output for the 2007 and 1995-2009 benchmark periods. Regression model results indicated that the median length of natural shoreline habitat associated with salinities of 12 or less would be decreased by 15 percent when flows were reduced by 5 percent (Tables 5-21 and 5-22). Natural shoreline lengths exposed to waters with salinities of up to 3 and 5 were less sensitive to changes in flows. Fifteen percent decreases in median shoreline habitat length exposed to these salinity zones were associated with flow reductions ranging from between 5 and 10 percent to more than 30 percent.

Table 5-20. Median daily natural shoreline length upstream of selected surface isohalines with salinities of 2, 3 and 5, and relative change in bottom area percentiles for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period of 2007 based on modeling conducted with the Homosassa River hydrodynamic model. Yellow shaded cells correspond with or bracket flow reductions associated with a 15 percent relative change (reduction) in baseline natural shoreline length. Orange shaded cell indicates the highest modeled flow reduction scenario resulted in less than a 15 percent reduction in baseline natural shoreline length.

Salinity Zone	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Length (m)	Length (m)	Relative Change (%)	Length (m)	Relative Change (%)	Length (m)	Relative Change (%)	Length (m)	Relative Change (%)	Length (m)	Relative Change (%)	Length (m)	Relative Change (%)
≤ 2	881	737	16	737	16	730	17	NA	NA	NA	NA	NA	NA
≤ 3	1,538	1,372	11	1,276	17	1,197	22	1,197	22	1,197	22	1,038	33
≤ 5	2,834	2,834	0	2,834	0	2,660	6	2,556	10	2,356	17	2,046	28
≤ 12	7,975	7,660	4	7,451	7	6,720	16	6,227	22	5,732	28	5,552	30

NA = isohaline for salinity zone located upstream of model domain

Table 5-21. Median daily natural shoreline length upstream of selected surface isohalines with salinities of 3, 5 and 12 and relative change in bottom area percentiles for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period of 2007, based on modeling conducted with empirical regression models. Yellow shaded cells correspond with or bracket flow reductions associated with a 15 percent relative change (reduction) in baseline natural shoreline length. Orange shaded cell indicates the highest modeled flow reduction scenario resulted in less than a 15 percent reduction in baseline natural shoreline length.

Salinity Zone	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Length (m)	Length (m)	Relative Change (%)	Length (m)	Relative Change (%)	Length (m)	Relative Change (%)	Length (m)	Relative Change (%)	Length (m)	Relative Change (%)	Length (m)	Relative Change (%)
≤ 3	2,356	2,157	8	2,046	13	1,925	18	1,846	22	1,846	22	1,846	22
≤ 5	2,997	2,874	4	2,874	4	2,834	5	2,834	5	2,834	5	2,834	5
≤ 12	8,985	7,660	15	7,451	17	7,451	17	7,451	17	7,451	17	7,451	17

Table 5-22. Median daily natural shoreline length upstream of selected surface isohalines with salinities of 3, 5 and 12 and relative change in bottom area percentiles for baseline and 5 to 30 percent flow reduction scenarios for the benchmark period from October 18, 1995 through May 13, 2009, based on modeling conducted with empirical regression models. Yellow shaded cells correspond with or bracket flow reductions associated with a 15 percent relative change (reduction) in baseline natural shoreline length. Orange shaded cell indicates the highest modeled flow reduction scenario resulted in less than a 15 percent reduction in baseline natural shoreline length.

Salinity Zone	Baseline	5% Reduction		10% Reduction		15% Reduction		20% Reduction		25% Reduction		30% Reduction	
	Length (m)	Length (m)	Relative Change (%)	Length (m)	Relative Change (%)	Length (m)	Relative Change (%)	Length (m)	Relative Change (%)	Length (m)	Relative Change (%)	Length (m)	Relative Change (%)
≤3	2,834	2,834	0	2,556	10	2,356	17	2,157	24	2,046	28	1,846	35
≤5	3,295	3,141	5	3,141	5	2,960	10	2,874	13	2,834	14	2.834	14
≤12	13,795	11,675	15	10,299	25	8,707	37	7,975	42	7,451	46	7,451	46

5.3.7 Salinity-Based Habitats Summary – 5 to 30 Percent Flow Reduction Results

Percentage-of-flow reductions associated with modeled fifteen percent reductions in median baseline salinity habitats in the Homosassa River are compiled in Table 5-23. Results are shown for model runs for the 2007 and 1995 through 2009 benchmark periods based on output from the hydrodynamic and regression modeling approaches. For both benchmark periods, flow reductions of five percent were predicted to result in greater than 15 percent reductions in bottom area and water volume associated with salinities of up to 2 or 3. The most sensitive model responses for bottom and volumetric habitats associated with salinities up to 5 indicated that flow reductions of five to ten percent would result in 15 percent reductions in habitat from baseline conditions. Linear interpolation based on modeled habitat reductions associated with five and ten percent flow reductions for these habitats indicated that the 15 percent habitat reductions would result from flow reductions ranging from 6.3 to 7 percent. Among the habitats associated with salinities up to 12, natural shoreline length exhibited the most sensitive response to flow reductions. Flow reductions of five percent were predicted to result in more than a fifteen percent loss of natural shoreline in contact with salinities of 12 or less for both the 2007 and the 1995-2009 benchmark periods.

Table 5-23. Modeled percent-of-flow reductions associated with 15 percent decreases in median baseline salinity-based habits for the benchmark period of 2007 evaluated with the Homosassa River hydrodynamic model and empirical regression models and for the benchmark period from October 18, 1995 through May 13, 2009, based on modeling conducted with the empirical regression models. Linearly-interpolated values for percent-of-flow reductions between 5 and 10 percent are indicated in parentheses.

Salinity-Based Habitat	Percent-of-Flow Reduction Associated with 15% Reductions in Habitat from Median Baseline Conditions		
	Hydrodynamic Model 2007 Benchmark Period	*Regression Model 2007 Benchmark Period*	*Regression Model 1995-2009 Benchmark Period*
Bottom Area			
Salinity ≤ 2 Based on Bottom Isohaline Location	< 5	NM	NM
Salinity ≤ 2 Based on Water-Column Average Isohaline Location	< 5	NM	NM
Salinity ≤ 3 Based on Bottom Isohaline Location	5 – 10 (8.9)	< 5	< 5
Salinity ≤ 3 Based on Water-Column Average Isohaline Location	5 – 10 (9.1)	< 5	< 5
Salinity ≤ 5 Based on Bottom Isohaline Location	10 – 15	> 30	5 – 10 (6.3)
Salinity ≤ 5 Based on Water-Column Average Isohaline Location	10 – 15	20	5 – 10 (7.0)
Salinity ≤ 12 Based on Bottom Isohaline Location	25	20	10
Salinity ≤ 12 Based on Water-Column Average Isohaline Location	25 – 30	30	10 – 15
Water Volume			
Salinity ≤ 2	< 5	NM	NM
Salinity ≤ 3	10	5 – 10 (5.3)	< 5
Salinity ≤ 5	15	20 – 25	5 – 10 (6.9)
Salinity ≤ 12	25 – 30	25	10 – 15
Natural Shoreline Length			
Salinity ≤ 2	<5	NM	NM
Salinity ≤ 3	5 – 10	10 – 15	10 – 15
Salinity ≤ 5	20 – 25	> 30	> 30
Salinity ≤ 12	10 – 15	5	5

NM = not modeled

5.4 <u>Results for Manatee Thermal Refuge Analyses</u>

Modeled thermally-favorable manatee habitat, *i.e*., regions meeting minimum temperature and water-depth requirements, in the Homosassa River for the critically cold three-day period in 2008 are shown in Figures 5-2 and 5-3. Areas of the river meeting the manatee thermal requirements, but not the minimum water-depth requirement are also shown, and identify additional regions of the Homosassa River where manatees could potentially seek refuge from cold waters.

Modeled baseline volume of thermally-favorable manatee habitat during the three-day, chronic cold period in January 2008 was 64,566 m^3 (Table 5-24). Baseline volume of thermally-favorable habitat during acute cold conditions within the three-day period was nearly twice as large, at 112,288 m^3. Modeled scenarios indicate that flows could be reduced between 25 and 30 percent before thermally-favorable habitat of sufficient depth was reduced by 15 percent during the three-day, chronic period. Thermally-favorable habitat for acute cold conditions was more sensitive to modeled flow reductions. A modeled flow reduction between 5 and 10 percent would be associated with more than a 15 percent reduction in water volume meeting the defined manatee needs during acute cold conditions. Linear interpolation of percent change values for the 5 and 10 percent flow reduction scenarios indicated that a flow reduction of 7.5 percent would be associated with a 15 percent reduction in thermally-favorable habitat for the acute cold period.

Available abundance estimates for Florida manatees, information on their usage of another state spring system as a thermal refuge, and modeled volumes of thermally-favorable habitat in the Homosassa River suggest, however, that the volume of available thermal refuge in the Homosassa River may not be a limiting factor for the local manatee population. The Florida Fish and Wildlife Conservation Commission (2010a, b) recently estimated the Florida and west coast of Florida manatee population sizes at 5,976 and 2,296 animals, respectively. At the Homosassa River, a maximum of 156 manatees has recently been observed during aerial surveys conducted over the past 25 years (unpublished data provided by the United States Fish and Wildlife Service. Based on information on adult manatee size and observed manatee use of Blue Springs in Volusia County, Rouhani *et al.* (2007) identified a volumetric constraint of 3.1 m^3 for individual manatees as part of their development of minimum flows for the spring system. Assuming that an individual manatee occupies 3.1 m^3 of refuge volume in the Homosassa River during critical cold periods, volumes associated with thermally-favorable habitat for the modeled scenarios with 30 percent flow reductions could be expected to accommodate 9,968 and 23,833 animals, respectively, during the critically cold chronic and acute conditions modeled for 2008. These estimates greatly exceed reported manatee population sizes for the Homosassa River, west coast and the entire state. Given that the estimated numbers of manatees that could be accommodated in the Homosassa River may be high, based on social behaviors or other factors that could limit manatee distributions within the system, the magnitude of the estimates still suggests that the flow reductions evaluated are not likely to be limiting for manatee use of the river system as a thermal refuge. The recent decision by the Florida Department of Environmental Protection to open the Homosassa Main Spring run to wild manatees also suggests that relatively low flow reductions would not be expected to limit manatee populations, based on the substantially increased thermal refuge habitat now available during critically cold periods.

Table 5-24. Summary of thermally-favorable manatee habitat in the Homosassa River for baseline and 5 to 30 percent flow reduction scenarios for chronic and acute cold conditions based on modeling conducted with the Homosassa River hydrodynamic model. Yellow shaded cells bracket flow reductions associated with a 15 percent decrease in thermally-favorable baseline volume (adapted from HSW Engineering, Inc. 2011).

Cold Condition	Flow Scenario	River Kilometer	Volume (m^3)	Volumetric Change (m^3)	Relative Change (%)
Chronic	Baseline	11.46	64,566	NA	NA
	5% Reduction	11.53	64,153	412	1
	10% Reduction	11.58	63,859	707	1
	15% Reduction	11.67	63,144	1,422	2
	20% Reduction	11.73	62,632	1,934	3
	25% Reduction	11.84	58,191	6,375	10
	30% Reduction	12.10	30,901	33,665	52
Acute	Baseline	9.56	112,288	NA	NA
	5% Reduction	9.69	103,212	9,075	8
	10% Reduction	10.00	87,749	24,539	22
	15% Reduction	10.34	73,881	38,407	34

NA = not applicable

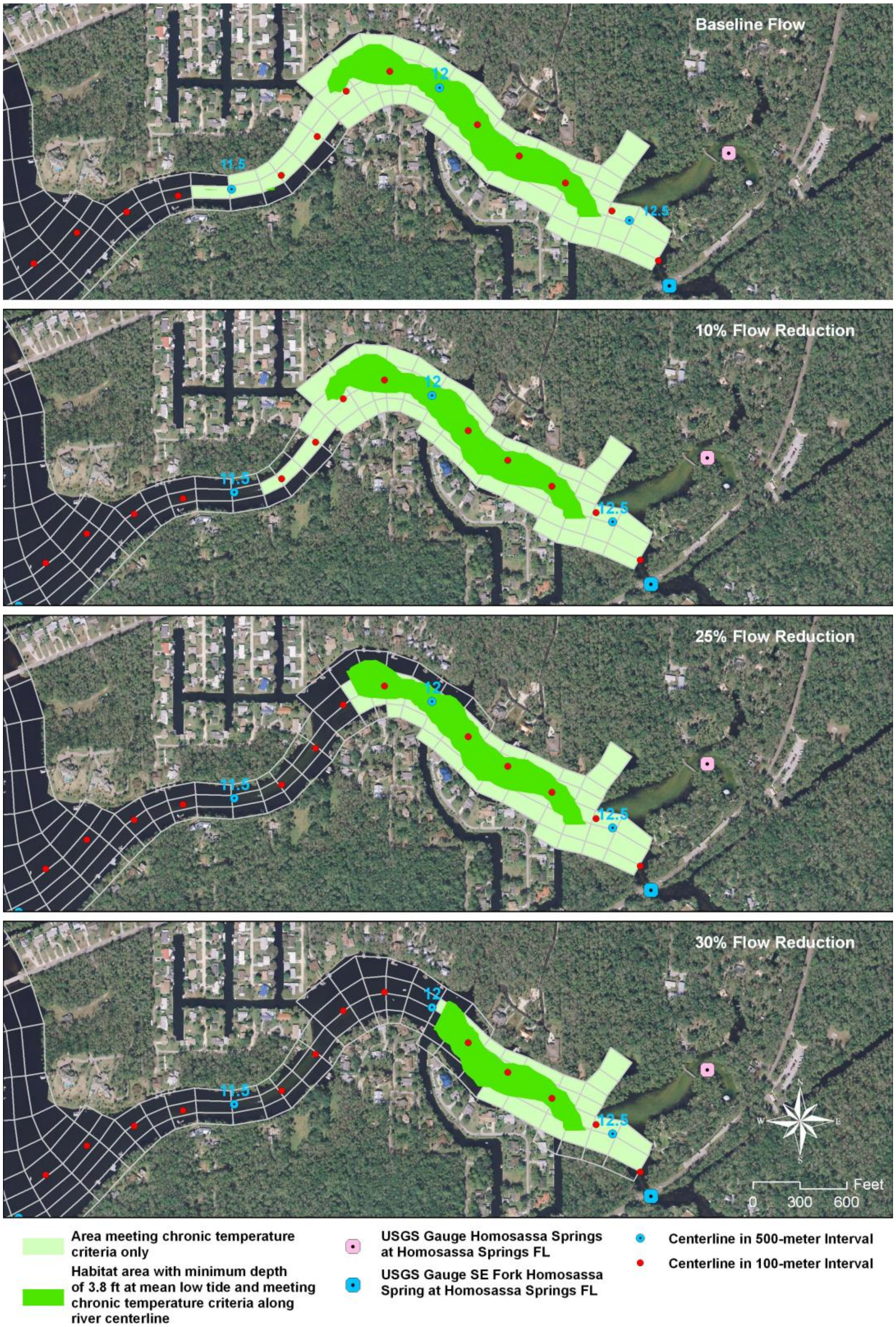


Figure 5-2. Thermally-favorable manatee habitat modeled for chronic cold conditions in 2007. Figure reproduced from HSW Engineering, Inc. (2011)

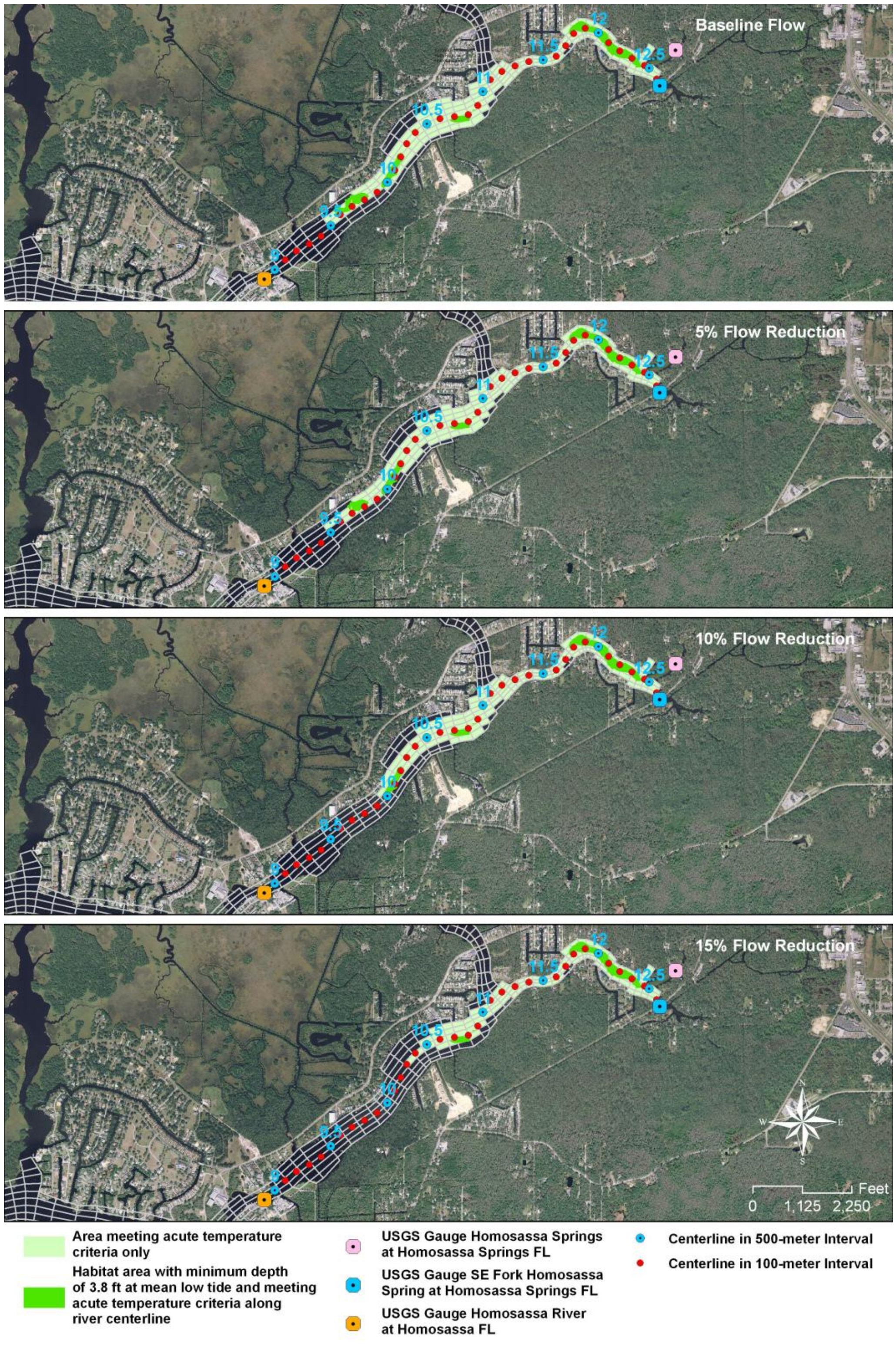


Figure 5-3. Thermally-favorable manatee habitat modeled for acute cold conditions in 2007. Figure reproduced from HSW Engineering, Inc. (2011).

5.5 <u>Initial Minimum Flows Recommendation</u>

Results from modeling approaches used to identify percent-of-flow reductions associated with fifteen percent changes in planktonic and nektonic fish and invertebrates, salinity-based habitats and thermally-favorable habitat for manatees during critical cold periods were presented for the Homosassa River or larger extent of the Homosassa River system in the preceding sub-sections of this chapter.

The most sensitive resource responses to modeled flow reductions were exhibited by fish and invertebrate plankton and nekton. Flow reductions of 0.6 to 2.7 percent from median baseline conditions were associated with 15 percent reductions in predicted abundances of individual pseudo-species or taxa. Similar or increased sensitivity to flow reductions was predicted for many taxa across the range of baseline flows, in particular for baseline flows less than the median flows. For some flow ranges, some nektonic taxa were predicted to not occur in the portions of the system for which the models were applicable, *e.g.,* in shallow areas for which empirical regression were constructed based on animals collected with a seine net.

It is possible that the apparent acute sensitivity of the evaluated plankton and nekton taxa to flow reductions in the Homosassa River system is an artifact of spurious relationships between the inflow values and organism count data used for development of the predictive regression models. Although all significant, positive linear models developed by Peebles *et al.* (2009) for planktonic and nektonic fish and invertebrates collected from the river system were retained for the minimum flows analysis outlined in previous sections of this report, the amount of variation accounted for by individual models and sample sizes used for model construction varied considerably, and were typically quite low. Despite this variation in the quality of the regression models, predicted responses of all evaluated planktonic and nektonic pseudo-species or taxa exhibited similar sensitivity to flow reductions. It is possible that the very sensitive modeled responses of these organisms to flow reductions are a function of the relatively stable flow conditions of the spring-dominated system. It should, however, be noted that several of the responses evaluated were based on regression equations exhibiting some evidence of potential problems associated with serial correlation, potentially limiting the usefulness of the predicted flow-related responses.

The utility of the predicted changes in plankton and nekton abundances as a function of change in flow may also be questioned based on issues associated with the adequacy of the length of the sampling period (December 2006 through November 2008) used for development of the flow-abundance regression equations. In a recent evaluation addressing use of regressions for predicting plankton and nekton abundances as a function of flow, Wessel (2012) found that for ten taxa with long-term data sets available for the Alafia River, there was limited consistency among predictions based on regressions developed for differing time periods. In some cases use of data from differing time periods yielded regression equations with reversed slope estimate signs, *i.e*., both positive and negative slopes were identified for flow-abundance relationships developed for an individual taxon. Wessel notes that '[o]nly with at least 4 years of data collection did the slope estimates tend to stabilize toward a particular direction, and in several instances, 4 years of data was not enough to achieve statistical significance" adding that "*[t]ogether, these issues regarding the existing analytical methods to establish the fish-flow relationship revealed that more work was needed to describe the effects of freshwater inflows on fish abundance in tidal rivers*."

Given the findings of Wessel (2012) and other concerns identified for the predicted plankton and nekton responses to flows, percentage-of-flow reductions from baseline conditions identified for taxa from the Homosassa River system were not considered appropriate for development of minimum flow recommendations.

Modeled responses of some salinity-based habitats in the Homosassa River main channel were also relatively sensitive to flow reductions. Flow reductions of less than five percent were associated with more than 15 percent reductions in selected salinity-based habitats associated with isohalines with salinities of 3 (refer to Table 5-23). Similar responses were also predicted for salinity-based habitats where salinities were 2 or less, but were not considered reliable, as discussed in a previous section of this chapter. Other relatively sensitive salinity-habitats associated with isohalines with salinities of 3, 5 and 12 were predicted to be reduced by fifteen percent when baseline flows were reduced by 5 to 10 percent (refer to Table 5-23).

The volume of thermally favorable habitat available to manatees during acute cold conditions was also sensitive to modeled flow reductions, although the sensitivity was not as great as that predicted for the most sensitive salinity-based habitats. Flow reductions between 5 and 10 percent were predicted to reduce favorable manatee habitat by fifteen percent during a recent critically cold period. The absolute volume of thermally-favorable habitat available for critically-cold baseline and all flow-reduction scenarios examined suggests, however, that flow reductions up to 30 percent are not likely to be limiting for manatee use of the Homosassa River system as a thermal refuge.

Based on the sensitive resource responses demonstrated by the various modeling approaches used to evaluate the Homosassa River system, a 5 percent-of-flow reduction was initially recommended as an appropriate minimum flow criterion for the Homosassa River system in July 2010. This initial minimum flow recommendation was included in the District's draft report titled *Recommended Minimum Flows for the Homosassa River System, July 12, 2010 Peer-Review draft* (Leeper *et al.* 2010; included as Appendix P to this report). The 2010 report was presented to the District Governing Board (see Appendices Q and R), subjected to scientific peer-review and reviewed by numerous interested stakeholders. This review process led to the completion of additional analyses by District staff and consultants to the District, and ultimately to the development of revised minimum flow recommendations, as outlined in the following two chapters of this updated minimum flows report.

CHAPTER 6. PEER REVIEW AND STAKEHOLDER INPUT

6.1 Introduction

The District solicits scientific peer review and public comment on proposed minimum flows and levels and the methods used for their development. These efforts are undertaken to inform stakeholders about proposed minimum flows and levels and to solicit feedback. These processes ensure that the best possible minimum flows and levels are adopted and used for District permitting and planning programs.

In addition to the independent scientific peer review of minimum flows and levels that is required by state law, the District conducts extensive internal reviews of new methods and proposed minimum flows or levels using staff experts and external consultants. Also, as outlined in Rule 40D-8.011(5), F.A.C., the District coordinates with local governments and other affected and interested stakeholders to promote independent scientific and technical review of ongoing work related to minimum flows and levels. Other forms of peer review have occurred through presentation of methodological approaches in professional journals and other scientific publications.

All interested stakeholders are afforded opportunities to learn about and provide input on proposed minimum flows and levels and the methods used for their development. Distribution of reports and other materials, presentations made to stakeholder groups and individuals, public workshops concerning identification of priority water bodies for minimum flows and levels development, and public workshops addressing development of rules associated with minimum flows and levels are undertaken to engage stakeholders in the minimum flows and levels development process.

6.2 Independent Scientific Peer Review

Section 373.042(4)(a), F.S., requires that "[u]pon written request to the department [Department of Environmental Protection] or governing board by a substantially affected person, or by decision of the department or governing board, prior to the establishment of a minimum flow or level and prior to the filing of any petition for administrative hearing related to the minimum flow or level, all scientific or technical data, methods, and models, including all scientific and technical assumptions employed in each model, used to establish a minimum flow or level shall be subject to independent scientific peer review. Independent scientific peer review means review by a panel of independent, recognized experts in the fields of hydrology, hydrogeology, limnology, biology, and other scientific disciplines, to the extent relevant to the establishment of the minimum flow or level." Findings of peer review panels are summarized in reports which are to be given "significant weight" when establishing MFLs (Section 373.042(4)(b), F.S.).

The District's initial recommended minimum flows for the Homosassa River system were outlined in a draft report titled *Recommended Minimum Flows for the Homosassa River System,* *July 12, 2010 Peer-Review draft* (Leeper *et al.* 2010; included as Appendix P to this report). This report was presented by staff to the District Governing Board on July 27, 2010 (Appendices Q and R) and subsequently submitted to independent, scientific peer-review.

The peer-review panel (Panel) convened to review the document concerning the initial proposed minimum flows included scientists with extensive experience in ecology, hydrology and freshwater inflow relationships. The Panel's findings were summarized in a report that was submitted to the District in October 2010 (Hackney *et al.* 2010; included as Appendix S to this report). The Panel's report and staff response to the peer-review was provided to the District Governing Board for consideration at the November 16, 2010 Board meeting (see Appendices T and U).

The Panel's report was supportive of the District's initial recommended minimum flows, but suggested additional monitoring to enhance understanding of the impacts of groundwater withdrawals on flows and salinity of the system. In reference to the District's report on the recommended minimum flows, identified as Leeper *et al.* (2010), the Panel concluded that *"[e]vidence presented by Leeper et al (2010) is adequate to conclude that the proposed maximum 5% reduction in Minimum Flow satisfies the language and intent of the Statute and will result in "no significant harm" to the flora and fauna of the Homosassa River System.*" The Panel identified eight central questions that served as the primary basis for their evaluation of the District's minimum flows report. The questions, reproduced below from the Panel's peer review report, are:

1. *Is the District's threshold of a maximum 15 % change of resource within the system a reasonable approach?*
2. *Was there an adequate data base for development of the regression model?*
3. *Was there an adequate data base for development of the hydrodynamic model?*
4. *Were the models used by the SWFWMD the best models for determining the MFL for the Homosassa River system?*
5. *Was the data collection approach adequate to determine the past and present natural resources on the river system?*
6. *Were appropriate assumptions and analyses made in the use and extrapolation of these data?*
7. *Was the weight of evidence enough to convince the panel that the recommended MFL satisfied the Florida Statute establishing the MFL requirement?*
8. *Are there additional data that should be collected in the future that would add confidence to the MFL SWFWMD recommendations?*

In their report, the Panel notes that the answer to each of these questions is "yes", although an answer of "yes" and "no" was developed for question five. With regard to their response to question five, the Panel indicates that data are adequate for evaluating past and present flow conditions, but data addressing historical changes in salinity conditions and some biological components of the system are sparse. Specifically, the Panel notes that *"…it can only be inferred that present-day salinities discharging from the springs into the river system are still at* *natural levels*, but acknowledge that the District's approach "…*is the best that can be done at this time."* With regard to characterization of changes in biological components of the river system, the Panel notes that this type of information is often not available for environmental studies, and suggests that the biological information collected in support of the District's minimum flow study may serve as a baseline for future minimum flow evaluations. In answering "yes" to question eight, the Panel suggests that the District should collect additional data on the salinity, temperature and flow in the river system, and continue to evaluate physical and chemical properties of the contributing groundwater systems. Goals for these efforts include improved understanding of and ability to model impacts of regional groundwater withdrawals on salinity, other water quality characteristics, and flows. In addressing their eight central questions, the Panel also provided a number of specific comments and recommendations concerning various sections of the report, and identified a number of editorial comments.

Staff supports the Panel's major recommendation that the District continue to collect data to improve understanding of water quality and flow in the Homosassa River system and contributing groundwater basin. Continued data collection is considered essential for future re-evaluation of the minimum flows that are to be established for the river system and other nearby spring-dominated systems. Detailed staff responses to peer-review findings are included in Appendix V. Most, but not all, of the peer-review Panel's suggestions and comments were addressed in the preceding or subsequent sections of this updated minimum flows report. Issues raised by the Panel that were not incorporated into this report are addressed in subsequent paragraphs of this report section.

The Panel suggests that some additional analyses of some of the biological data presented in the original report could be useful. For example, they suggest that both positive and negative plankton and nekton abundance responses to flow could be considered to evaluate community-level changes, rather than individual responses of specific taxa or pseudo-species. However, the Panel did not identify how a shift in community structure could be translated into a quantitative minimum flows threshold. Staff does not concur with the suggested use of negative or inverse relationships between flows and predicted abundances of plankton and nekton for development of minimum flow recommendations for the Homosassa River system. When attempting to identify allowable percentage of flow reductions that could be used to establish minimum flows, it seems reasonable to consider competent, direct relationships for predicting declines in freshwater and estuarine taxa that may be associated with flow reductions. In contrast, it is not clear how competent, inverse relationships, which if available would predict increased abundances with decreased flows, could be used for minimum flows development. In many instances, increases in individual estuarine-dependent taxa that are associated with lower flows could be viewed as beneficial. With regard to addressing changes in community structure through use of direct and indirect relationships between flows and organism abundances, staff has not identified a practical approach that could be used for minimum flows purposes.

Then Panel suggests that staff consider using a multivariate approach when considering positive and negative abundance responses to changes in flows. Staff appreciates the appeal of a multivariate approach, but is unsure how results from such an analyses could be used for development of minimum flow recommendations. Staff also notes that development and use of an appropriate multivariate approach would be predicated on development of multiple, competent univariate relationships, and is not confident that such relationships are currently available for the Homosassa River system.

Staff agrees with the Panel's recommendation that it could be useful to develop land-use information based on springshed boundaries to supplement the land-use information presented in Chapter 2 of the original (and this current) minimum flows report for the Homosassa River system. This information was not, however, considered critical to the development of minimum flow recommendations for the system, and as such, has not yet been developed. Staff anticipates development of ground-water basin land-use data for a future reevaluation of minimum flows that are adopted for the river system.

At several points within their report, the Panel suggests that the District revise some of the supporting documents that are included as appendices to the minimum flows report. In some cases, changes were made to documents included as appendices to the original minimum flows report. These changes were made specifically to documents that were in the process of being finalized as the original minimum flows report was being developed. Other suggested changes were not made, with the acknowledgment that supporting documents prepared by consultant's to the District are in many cases, considered final documents and may include recommendations or data interpretations that are not endorsed by staff.

The Panel also questions whether it would be possible to develop figures that depict changes in the extent of river shoreline exposed to particular salinities for the modeled flow reduction scenarios used to develop minimum flow recommendations. Staff acknowledges that graphics depicting changes in shoreline length exposed various salinities could be developed, but notes that changes in isohaline location for the flow reduction scenarios are relative minor, as presented in Table 5-3 of the original and this updated report.

6.3 Stakeholder Review and Public Outreach

In addition to subjecting the report on initial, proposed minimum flows for the Homosassa River to independent scientific peer-review, the District has engaged a number of stakeholders to obtain input on the proposed minimum flows. Early in the process of developing minimum flows for the river system, the District took advantage of numerous opportunities to make stakeholders aware of the process. Development of minimum flows for the system was first identified for completion in 2011 on the 1996 Priority List and Schedule for the Establishment of Minimum Flows and Levels. The priority list and schedule identifies water bodies for minimum flow or levels development based on the importance of the waters to the state or region and the existence of or potential for significant harm to the water resources or ecology of the area (Section 373.042(2), F.S.). The priority list is required to include waters that are currently or may reasonably be expected to experience adverse impacts associated with water use. The list must also include all first magnitude springs and all second magnitude springs within state or federally owned lands purchased for conservation purposes. Annual public workshops addressing updates to the District's priority list and schedule, along with other presentations concerning minimum flows and levels provided numerous opportunities for stakeholder involvement in the minimum flows development process for the Homosassa River system. A current version of the list and schedule is available on the District Minimum Flows and Levels (Environmental Flows) Documents and Reports web page (Southwest Florida Water Management District 2011a) and in the District's Consolidated Annual Report (Southwest Florida Water Management District 2012).

Public outreach for the Homosassa minimum flows effort continued through staff presentations to various groups and organizations, including the Save the Homosassa River Alliance (January 2008, March 2010) and the Citrus County Task Force of the Citrus/Hernando Waterways Restoration Council (May 2008, August 2010). In July 2010, the draft report on initial, recommended minimum flows was provided to the Florida Department of Environmental Protection, the Florida Fish and Wildlife Conservation Commission, the United States Fish and Wildlife Service and other interested stakeholders via the District's Minimum Flows and Levels (Environmental Flows) web page. Following release of the draft report, staff met and discussed important study findings with representatives from the U.S. Fish and Wildlife Service (August 2010, January 2011), the Florida Department of Environmental Protection and other State Water Management District staff (September 2010), Citrus County Utility Infrastructure Advisory Group (December 2010), and Citrus County Board of County Commissioners (April 2011).

Rule development workshops associated with the proposed minimum flows were held within Citrus County in October 2010 and January 2011. Based on stakeholder interest in the development of minimum flows for the Homosassa River system and other nearby water bodies, the District hosted a series of three public workshops and facilitated a fourth stakeholder-initiated workshop in the spring and summer of 2011 for discussion of the data and methodologies that have been or could be used to develop minimum flows for spring-dominated tidal river systems of the Springs Coast and to support decisions regarding timelines for adoption or re-evaluation of minimum flows for the systems.

The spring-summer workshops were well attended and information associated with the workshop series was posted on the District's Springs Coast MFL Working Group web page created specifically for exchange of relevant information (Southwest Florida Water Management District 2011b).

In addition to sponsoring numerous public meetings, the District has engaged in a vigorous outreach effort involving exchange of written communications and other information to facilitate public understanding of the minimum flows process and to provide opportunities for stakeholder input. Correspondence has involved communication with individuals, and letters to the editor of the Citrus County Chronicle, the Save the Homosassa River Alliance's Voice of the River and Too Far News, a newsletter developed for members of the organization TOOFAR, Inc. Written communications and other relevant documents associated with stakeholder input and public outreach activities concerning development of minimum flows for the Homosassa system are compiled in Appendix W.

Stakeholder input received through all outreach efforts and submitted directly to the District varied in substance, but may be generally associated with a small number of issues, including the following.

Issue 1. Use of fifteen percent change criteria for developing minimum flow recommendations;

Issue 2. Not allowing additional water use based on existing, observed environmental change (*e.g.*, tree death and expanded upstream distribution of barnacles) and further environmental change;

Issue 3. Application of the Outstanding Florida Waters policy and components of the Federal Clean Water Act;

Issue 4. Development and use of improved methods, tools or models for evaluating ground water flow and water withdrawal impacts;

Issue 5. The measurement of discharge and use of discharge data for analyses supporting minimum flow recommendations;

Issue 6. Evaluation of withdrawal related changes to thermally favorable habitat for manatees during recent, extremely cold seasons; and

Issue 7. Development and use of additional predictive models for evaluating effects of flow reductions on plants, animals and ecosystem-level characteristics (*e.g.*, blue crabs, primary productivity).

Staff has carefully considered each of these issues in association with minimum flow development for the Homosassa River system. Summary comments on each issue are provided below. Additional staff comments are provided in correspondence and other documents included in Appendix W.

Staff understand the perspective advanced by stakeholders that the fifteen percent change criteria currently used by the District for developing minimum flows should be modified for systems such as the Homosassa River system (Issue 1). Staff notes, however, that this criterion has been reviewed and accepted by numerous independent, scientific peer-review panels, including the Panel convened to evaluate the initial minimum flow recommendations for the Homosassa River system. Use of this criterion has also been accepted by policy decision of the District Governing Board for adoption of minimum flows for many priority water bodies. Additional information pertaining to District staff's position on this issue is outlined in the "Significant Harm" section of Chapter 1 of this report.

Staff acknowledges environmental changes that have occurred in the Homosassa Rivers system, but attributes these changes primarily to changes in sea level and variation in rainfall and the effect of this variation on discharge and salinity patterns within the Homosassa River system (Issue 2). The District, has, however, attempted to incorporate potential change in sea level and associated environmental effects into analyses supporting revised minimum flow recommendations for the river system. This approach is outlined in Chapter 7 of this revised minimum flows report.

Regarding Issue 3 above, an Outstanding Florida Waters designation is part of Florida's anti-degradation policy, which is designed to prevent worsening of water quality from specified activities unless it is found to be in the public interest. Florida's anti-degradation policy does not apply to water quantity decisions such as minimum flows and levels; instead it applies to activities that incorporate a discharge of pollutants or dredge and fill activities.

With regard to the development and use of improved methods, tools or models for evaluating ground water flow and water withdrawal impacts (Issue 4), staff agrees that competent hydrologic data and appropriate groundwater flow models are essential for establishing and monitoring compliance with adopted minimum flows and other water management activities. Staff notes that the District relies on a rich database for construction and calibration of regional groundwater flow models for analysis of historic and projected water use impacts. The District is committed to continued development of these data and refinement of groundwater flow models, such as the Northern District Model (see Chapter 2, Basso 2010, HydroGeoLogic 2008, 2010), and other tools that can be used to evaluate withdrawal impacts on the Homosassa River system and other priority water bodies.

Staff, stakeholders and staff from the United States Geological Survey have expended considerable effort in reviewing and identifying ways to enhance the measurement and reporting of discharge for sites within the Homosassa River system (Issue 5; see also Jenter *et al.* 2012). With District funding, the Survey has recently deployed advanced discharge monitoring equipment at the existing gage site in the Southeast Fork of the Homosassa River and at a new site within Halls River. It is anticipated that data collected at these sites will enhance our understanding of the complex flows within these river segments and support the future reevaluation of minimum flows that are adopted for the greater Homosassa River system.

With regard to the reporting of historic discharge records for the Homosassa River system (Issue 5), staff notes that discrete or instantaneously measured historical discharge measurements are available for the Homosassa River and Southeast Fork of the Homosassa River and has included these data in Chapter 2 of this revised minimum flows report. Staff asserts, however, that the "historical" record should be excluded from the analyses used for developing the minimum flows recommendation, based on: the discontinuous nature of the record; differences between the instantaneously recorded "historic" record and the daily means record derived for the more recent period, *i.e.*, from the mid-1990s to the present; the presumed increased usefulness of relatively continuous daily records as compared to relatively discontinuous instantaneous measurements; and the determination that variability in the "historical" and more recent discharge records is consistent with available rainfall information and not indicative of a flow decline that may be substantially attributed to anthropogenic activities.

With regard to the suggestion that withdrawal related changes to thermally favorable habitat for manatees during recent, extremely cold seasons should be evaluated (Issue 6), staff notes that the initially recommended minimum flows were developed based on the best information that was available at the time the thermal-modeling of the Homosassa River system was completed. Because change in thermally favorable manatee habitat was not the most limiting criterion identified for development of the initial minimum flow recommendations for the system, and because the Department of Environmental Protection has recently made the decision to open the main spring run to wild manatees during cold periods, thereby substantially increasing the availability of thermally-favorable habitat, modeling of changes in habitat available to manatees during recent cold winters was not completed for development of revised minimum flow recommendations. Staff acknowledges that it may be beneficial to continue to evaluate potential effects of reduced flows on the availability of thermally-favorable manatee habitat in the Homosassa River system, based on future environmental conditions, and expects that efforts directed towards this goal will be implemented when the District completes a reevaluation of minimum flows for the river system.

With regard to the development and use of predictive models for evaluating effects of flow reductions on plants, animals, and ecosystem-level characteristics (Issue 7), staff notes that as indicated in Chapter 5 of this report, relationships developed for predicting effects of flow reductions on abundances of plankton and nekton in the Homosassa River system were not considered to be particularly useful for developing quantitative minimum flow recommendations. Staff has examined the potential application of a statistical relationship between average discharges and measured of gross primary productivity and found that the relationships do not appear to be as sensitive as other criteria that have been used for development of minimum flow recommendations for the Homosassa River system (these analyses are discussed in Chapter 7 of this report).

Of additional relevance to Issue 7, staff notes that blue crabs have been identified as an important species to consider when evaluating responses to flow reductions in the Homosassa River system. Commercial landings of hard shelled blue crabs ranged from 0.3 to 1.1 million pounds annually in Citrus County from 2001 through 2010, according to the Florida Fish and Wildlife Conservation Commission (2012). In addition to their commercial value, blue crabs may be an important food source for the endangered whooping cranes that overwinter in the Chassahowitzka National Wildlife Refuge (which includes portions of the Homosassa River system), as has been reported for a site in Texas.

In recognition of the commercial and ecological significance of the blue crab, the District contracted with the Florida Fish and Wildlife Conservation Commission to review relationships that have been developed between blue crab abundances and freshwater inflow along the Gulf Coast, including flows from several District rivers. Gandy *et al.* (2011) summarizes results from the review and discussed limitations with the various studies. Interestingly, in 15 of the 25 cases evaluated, reducing inflow was predicted to be associated with increased number of blue crabs, while in the remaining 40 percent of the cases flow reductions would be predicted to result in fewer crabs. As discussed in Chapter 5 of this report, flow-abundance regressions for blue crab and other evaluated taxa sampled by the University of South Florida and the Florida Fish and Wildlife Conservation Commission in the Homosassa River were not considered appropriate for developing minimum flow recommendations. Staff also notes that based on review of available commercial landings information for the region, these data were similarly not considered appropriate for minimum flow development.

CHAPTER 7. RESULTS OF ADDITIONAL ANALYSES AND REVISED MINIMUM FLOWS RECOMMENDATIONS

7.1 Introduction

Results from an analysis of flow-related changes in system productivity and application of the technical approaches described in Chapter 4 are summarized in this chapter for additional analyses that were completed following development of the initial minimum flow recommendations outlined in Chapter 5. The new analyses were based, in part, on comment received from the peer-review and other stakeholder input processes described in Chapter 6. Results from the new analyses were used to develop revised minimum flows recommendations for the Homosassa River system. The additional analyses were focused on potential flow-related changes in system productivity and salinity-based habitats and included:

1) evaluation of the response of measures of system productivity to potential changes in flow;

2) evaluation of responses of sensitive salinity-based habitats to modeled flow reduction of 1 to 4 percent;

3) evaluation of changes in salinity-based habitats for future conditions, based on scenarios associated with predicted sea level rise; and

4) evaluation of responses of sensitive salinity-based habitats for current and future conditions based on an adjusted flow record that accounts for existing withdrawal impacts.

7.2 Productivity-Based Analyses

Staff evaluated the potential application of statistical relationships between average discharge and gross primary productivity and photosynthetic efficiency to determine whether the relationships could be useful for developing minimum flow recommendations for the Homosassa River system. The analyses were undertaken based on the positive relationship between average discharge and gross primary productivity and photosynthetic efficiency reported for a number of Florida springs by Wetland Solutions, Inc. (2010, 2011).

As part of an ecosystem-level study of several Florida springs, Wetland Solutions, Inc. (2010) report that gross primary productivity in several Florida spring runs is related to average spring discharge according to the following equation (presented in Figure 70 of the 2010 report):

$y = 2.0830632 + 0.00002 * x$; $r^2 = 0.48$ (Equation 5),

where: y is gross primary productivity expressed as grams of oxygen produced per square meter per day;

x is average spring discharge, in cubic meters per day; and

r^2 is the coefficient of determination for the regression.

Gross primary production efficiency, or photosynthetic efficiency, which is the ratio or percentage of gross primary productivity to photosynthetically active radiation, is also related to spring discharge. Exhibit 3-15 from in Wetland Solutions, Inc. (2011) indicates that gross photosynthetic efficiency expressed as a percentage can be related to average discharge according to the following equation:

$y = 0.0904 * x^{0.6861}$; $r^2 = 0.6246$ (Equation 6),

where: y is the average gross primary productivity efficiency expressed as a percentage;

x is average spring discharge, in cubic feet per second; and

r^2 is the coefficient of determination for the regression.

Although it is not necessarily clear what magnitude of flow-related change in productivity may be appropriate for the Homosassa River or other spring-dominated systems, for illustrative purposes one may assume that it would not be appropriate to allow more than a 15 percent reduction in gross primary production or gross primary production efficiency that is flow related (or at least associated with flow). Given this assumption and based on the relationship between average discharge and average gross primary production identified above (Equation 5), flow reductions ranging from 18 to 26 percent would be associated with a15 percent reduction in gross primary production for the range of flows that occurred during the 1995 through 2009 benchmark flow period, with a response based on the average spring discharge for the benchmark period falling between these extremes. Based on the equation relating average discharge to gross primary production efficiency (Equation 6), a flow reduction of 21 percent would be associated with a 15 percent reduction in the efficiency variable.

The two productivity measures evaluated appear to be less sensitive to changes in flow than the sensitive salinity habitat responses (see Table 5-23) that were used to develop initial minimum flow recommendations for the Homosassa River system. Based on this relative insensitivity to flow changes, it was determined that a primary productivity criterion based on information presented by Wetland Solutions, Inc. (2010, 2011) would not yield percent-of-flow reduction information that was likely to contribute to revised minimum flow recommendations for the Homosassa River system.

7.3 Additional Salinity-Based Habitat Analyses

7.3.1 Sensitive Salinity-Based Habitats – 1 to 4 Percent Flow Reduction Results

Salinity-based habitats that exhibited more than a 15 percent reduction in response to a modeled five percent flow reduction (refer to Table 5-23) were selected for further evaluation, to identify potential flow reductions that may be used to establish revised minimum flow recommendations for the Homosassa River system. The Homosassa River hydrodynamic model and predictive regression models were used along with modified bathymetric information (discussed below) to characterize changes to these habitats that would be associated with one to four percent flow reductions. Results are summarized in this section for modeled responses for the benchmark period of 2007 based on hydrodynamic and regression modeling approaches and for the longer benchmark period, from October 18, 1995 through May 13, 2009 based on the regression models. For both the hydrodynamic and regression-model analyses, salinity-based habitat values were derived for median baseline (*i.e.,* no flow reduction) conditions and compared to median conditions associated with the flow-reduction scenarios to identify percentage-of-flow reductions associated with more than a 15 percent reduction in habitat.

For these additional salinity-habitat analyses, area and volume estimates were developed for upper areas of the Homosassa River and Southeast Fork Homosassa River and used to amend the bathymetric data sets developed and evaluated by Wang (2007) and HSW Engineering, Inc. (2011). The estimates and amended values were developed to more accurately represent areas and volumes associated with the evaluated salinity-based habitats. Polygons for upstream areas were delineated and aerial estimates were calculated using Esri ArcGIS software. The total upstream area for the delineated polygons was 29,034 m^2 (Figure 7-1) and this value was used to amend the original bathymetric data sets. The area estimated for the Homosassa Main Spring run, 11,337 m^2, was similar to the 11,319 m^2 value reported for the run by Wetland Solutions, Inc. (2010), who, with funding from the District and others, used a recording depth finder and global positioning system in November 2008 to develop bathymetric information for the Homosassa Main Springs pool and upper portion of the Homosassa River as part of their ecosystem-level study of several Florida springs. Based on the similarity of the District-derived spring run area and that reported by Wetland Solutions, Inc., the estimated volume of 12,353 m^3 for the Homosassa Main Spring bowl and run reported in Wetland Solutions, Inc. (2010) was used to characterize the volume of this portion of the upper system. A depth of 1-m was assumed for all other areas of the upper system shown in Figure 7-1, yielding a total upstream volume of 30,050 m^3 used for amending the original bathymetric data sets.

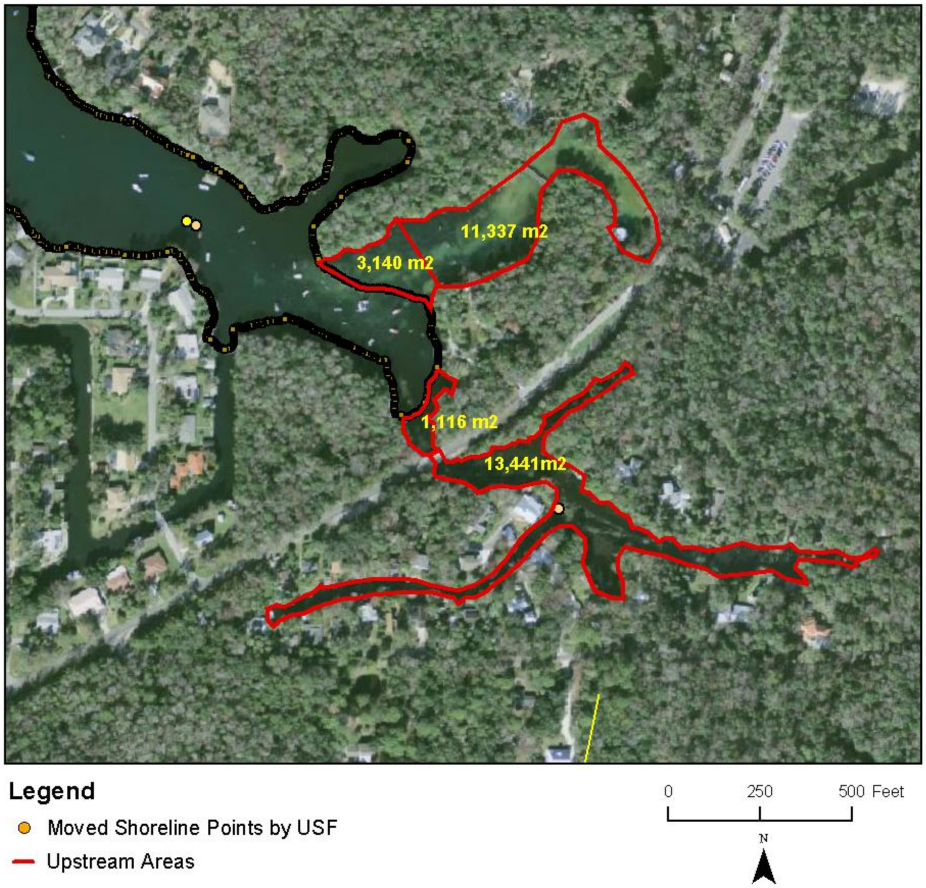


Figure 7-1. Upper areas of the Homosassa River and Southeast Fork Homosassa River that were not included in bathymetric data presented in Figures 2-30, 2-32 and 2-33.

Percentage-of-flow reductions associated with modeled fifteen percent reductions in median baseline salinity habitats for the identified sensitive habitats in the Homosassa River are compiled in Table 7-1. Results shown for habitats associated with salinities of 2 or less were developed based on Homosassa River hydrodynamic model output presented in Watson *et al.* (2011; included as Appendix X to this report) that was adjusted to account for river area and volume upstream from the model domain. Results included in Table 7-1 for other salinity-based habitats were developed with the predictive regression models used for previous Homosassa River system salinity analyses, and were also adjusted to account for upstream river area and volume.

Habitats associated with salinities of 2 or less were most sensitive to flow reductions. Bottom area based on water-column average isohaline location and water volume where salinities were 2 or less were predicted to change 15 percent or more with modeled flow reduction of one percent or less. As discussed in Chapter 5 of this report, in HSW Engineering, Inc. (2011) and in Watson *et al.* (2011,), use of the hydrodynamic model for evaluating the location of bottom, surface and water-column average isohalines (and corresponding salinity-based habitats) with a salinity of 2 was considered problematic because salinities of model inputs associated with water discharged from the Homosassa Springs main pool and springs of the Southeast Fork often exceeded 2 during the modeled 2007 benchmark period and isohalines associated with a salinity of 2 were often near or upstream of the model domain. Further complicating use of the hydrodynamic modeling results for evaluation of isohalines with a salinity of 2 was the predicted occurrence of these isohalines near or at the upper boundary of the model domain. Isohaline boundaries associated with salinities of 2 or less frequently occurred upstream of the model domain, even for baseline flow conditions modeled for 2007, and therefore precluded evaluation of isohaline locations for much of the modeled benchmark period. This inability to model the distribution of waters with salinities of 2 or less under baseline conditions and the flow-reduction scenarios examined for the minimum flows analysis indicated that results based on use of the hydrodynamic model for evaluating isohalines and habitats associated with salinities of 2 or less may not be adequate for the purpose of developing specific, quantitative minimum flow recommendations. Consequently staff determined that these modeling results would not be directly used for development of minimum flow recommendations for the Homosassa River system, but would instead be used as qualitative indicators of potential system responses to flow reductions. Results derived from use of the hydrodynamic model to evaluate areas of the river system where salinities are 2 or less are, however, presented in a quantitative manner in this report, as this information was considered useful for comparison with other quantitative modeling results.

Responses of salinity-based habitats associated with a salinity of 3 were considered more reliable than those predicted for habitats where salinities were 2 or less. For the 2007 benchmark period, median bottom area exposed to salinities of 3 or less was predicted to be reduced more than 15 percent with flow reductions of 4 to 5 percent. For the longer 1995-2009 benchmark period, bottom area for this salinity zone was predicted to change by more than 15 percent with flow reduction of 3 to 4 percent.

Table 7-1. Results from 1 to 4 percent flow reduction modeling for salinity-based habitats exhibiting more than a 15 percent change from baseline with a five modeled five percent flow reduction. Percent-of-flow reductions associated with fifteen percent decreases in median baseline salinity-based habits for the benchmark period of 2007 were evaluated with the Homosassa River hydrodynamic model and empirical regression models and were evaluated for the benchmark period from October 18, 1995 through May 13, 2009 using empirical regression models.

Salinity-Based Habitat	**Percent-of-Flow Reduction Associated with 15% Reductions in Habitat from Median Baseline Conditions**		
	Hydrodynamic Model 2007 Benchmark Period	***Regression Model 2007 Benchmark Period***	***Regression Model 1995-2009 Benchmark Period***
Bottom Area			
Salinity ≤ 2 Based on Bottom Isohaline Location	2-3	NM	NM
Salinity ≤ 2 Based on Water-Column Average Isohaline Location	1	NM	NM
Salinity ≤ 3 Based on Bottom Isohaline Location	NE	4 – 5	3 – 4
Salinity ≤ 3 Based on Water-Column Average Isohaline Location	NE	5	4
Salinity ≤ 5 Based on Bottom Isohaline Location	NE	NE	NE
Salinity ≤ 5 Based on Water-Column Average Isohaline Location	NE	NE	NE
Salinity ≤ 12 Based on Bottom Isohaline Location	NE	NE	NE
Salinity ≤ 12 Based on Water-Column Average Isohaline Location	NE	NE	NE
Water Volume			
Salinity ≤ 2	<1	NM	NM
Salinity ≤ 3	NE	NE	4 – 5
Salinity ≤ 5	NE	NE	NE
Salinity ≤ 12	NE	NE	NE
Natural Shoreline Length			
Salinity ≤ 2	4 – 5	NM	NM
Salinity ≤ 3	NE	NE	NE
Salinity ≤ 5	NE	NE	NE
Salinity ≤ 12	NE	NE	NE

NM = not modeled
NE = not evaluated because fifteen percent changes in salinity-based habitats from baseline conditions were greater than five percent

7.3.2 Sea Level Rise Scenarios – 1 to 4 Percent Flow Reduction Results

Global sea level has been rising since the last glacial maximum of the current ice age. Figure 7-2, adapted from Balsillie and Donoghoue (2011), illustrates that approximately 22,000 years before the present time, sea level was 120 meters (~ 400 feet) lower than it is today. Approximately 100,000 years prior to that time, during the last interglacial stage, sea level was likely six or more meters (~20 feet) higher than today (Kopp *et al.* 2009). Recent rates of sea level change are subject to ongoing debate, although at two long-term monitoring sites near the Homosassa River system, mean sea level has risen 0.09 and 0.07 inches per year during the past 50 to 100 years (Figure 7-3). Averaging these rates for these two sites yields a recent mean sea level rise of 0.08 inches per year (2.1 mm/yr) for the area.

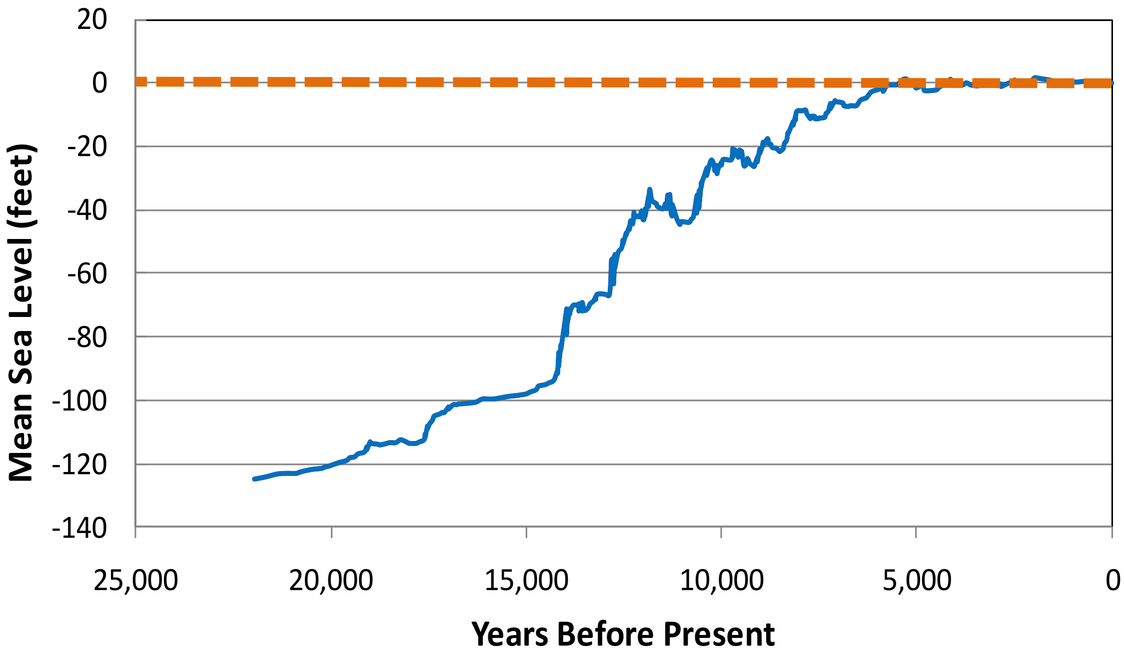


Figure 7-2. Mean sea level for the Gulf of Mexico relative to current mean sea level (0 feet). Figure adapted from Balsillie and Donoghue (2011).

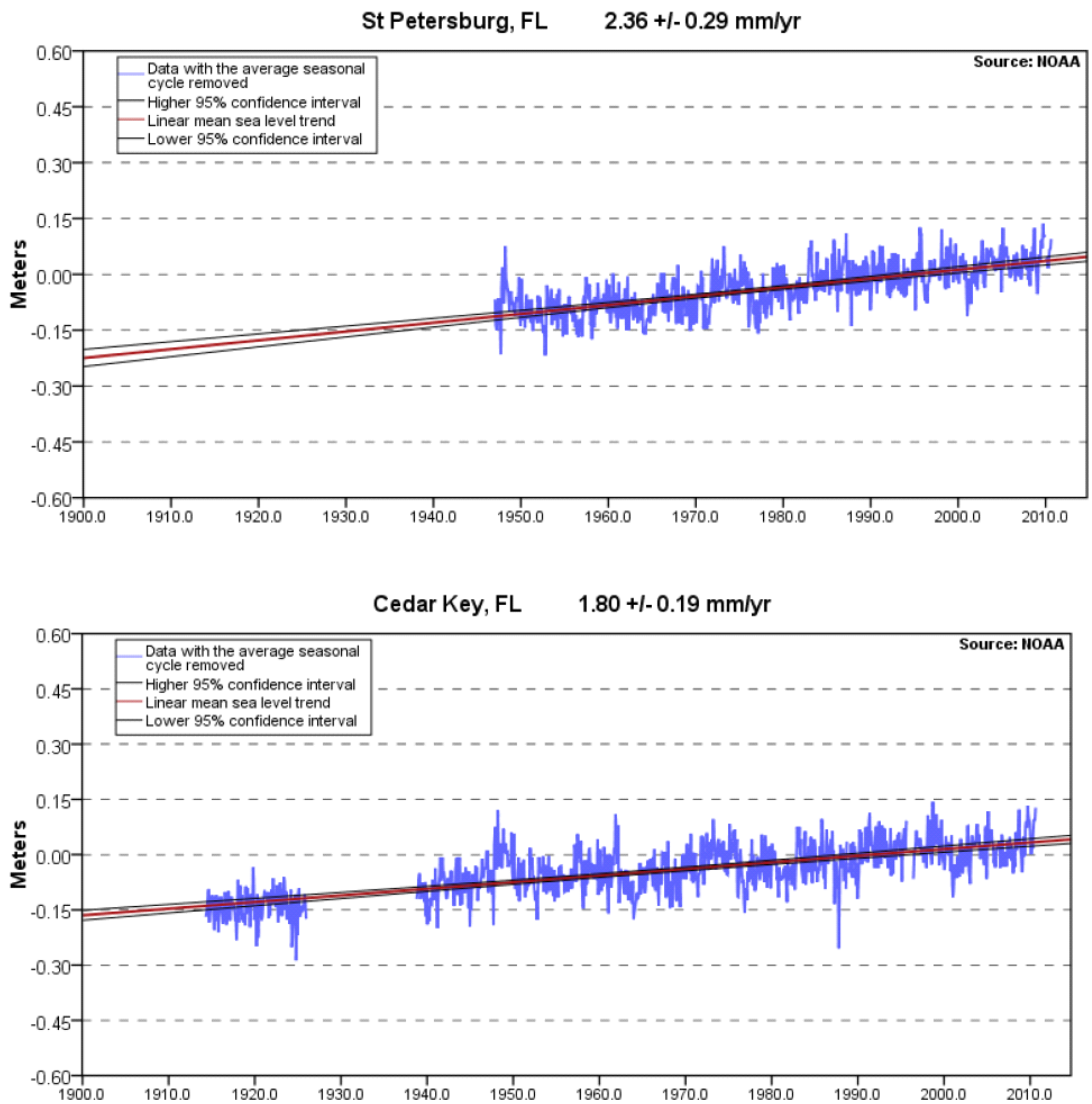


Figure 7-3. Regional mean sea level trend at sites south (St. Petersburg) and north (Cedar Key) of the Homosassa River system for the past approximate one hundred years. Figures reproduced from the Mean Sea Level Trends for Stations in Florida page of the National Oceanic and Atmospheric Administration (2011) Tides and Currents web site.

Effects of observed sea level rise can be seen along many coastlines, including the Springs Coast (refer to Chapter 3 of this report) and may be expected to persist or accelerate based on future increases in sea level. The Intergovernmental Panel on Climate Change (2007) reports that recent modeling suggests sea-level rise on the order of 0.18 to 0.59 meters (0.59 to 1.94 feet) for the period from 1980-1999 to the end of the current century. Although the recent sea level trend has been linear, several investigators have predicted exponential increases in the future (see review by Woodworth *et al.* 2009). In contrast, Houston and Dean (2011) studied 57 tide sites with 60-156 years of data and concluded that there has not been an acceleration in sea level change during the 20th century. Thirty of the sites they examined showed a slight deceleration in rate, while 27 showed slight accelerations. The United States Army Corps of Engineers has issued guidance (2009, 2010, 2011) for the design of coastal projects that incorporates use of “low”, “intermediate” and “high” rates of sea level rise. Projected sea level rise from 2007 for the Homosassa River system area is shown in Figure 7-4, based on Corps guidance for future sea level conditions.

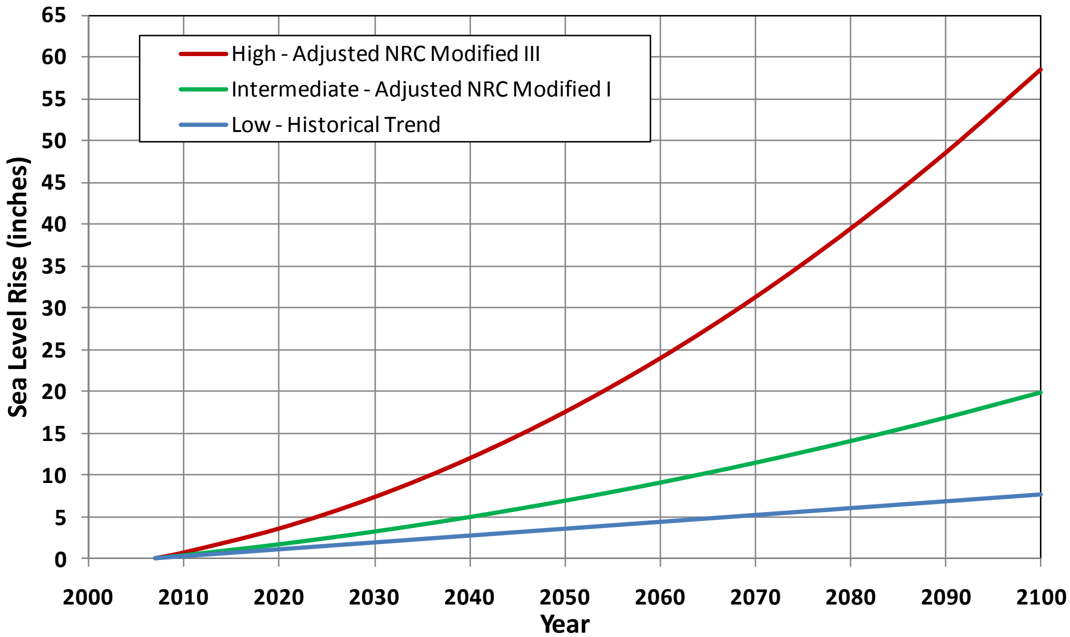


Figure 7-4. Predicted sea level rise from year 2007 in the vicinity of the Homosassa River system, based on guidance provided in Circular No. 1165-2-212 by the United States Army Corps of Engineers (2011).

For an initial analysis of the impact of sea level change on the Homosassa River system, the Homosassa River Hydrodynamic model was used to evaluate changes in salinity-based habitats as a function of decreased and increased sea levels, as well as increased and decreased flows that could occur as a result of sea level change (Watson and Yang 2011a, included as Appendix Y to this report). The impact of a potential four percent flow reduction was also simulated to address potential withdrawal effects on habitats associated with salinities of 3, 5 and 12. The analyses involved five sea level change scenarios (-6, -2, +2, +6, and +12 inches) and potential changes in flows based on the equations used by the United States Geological Survey to derive discharge at the Homosassa Springs and Southeast Fork Homosassa Springs gage sites. The potential changes in flows were developed assuming that the groundwater level at the Weeki Wachee well, which is used to derive flows at the Homosassa gage sites, is not affected by sea level change.

Results from these initial sea-level rise impact analyses suggested that the sea level declines evaluated would increase spring discharge by about 3 to 12 percent, and the sea level increases evaluated would result in about 3 to 25 percent decreases in flows. It is worth emphasizing, however, that these potential changes in discharge were based on the assumption that the groundwater level at the Weeki Wachee well, which is used to estimate discharge at the Homosassa Springs and Southeast Fork gage sites is not affected by the sea level change. This assumption may have led to overestimation of the magnitude of changes in discharge as a function of sea level change, as sea level change may be associated with increased storage of fresh water in the aquifer system underlying peninsular Florida and therefore an increased potentiometric surface in the Floridan aquifer system. This change in the aquifer system could be associated with a change in groundwater level at the Weeki Wachee well and could counteract the dampening effect of higher sea levels on spring flows past the Homosassa and Southeast Fork gage sites.

The initial analyses indicated that sea level rise would typically result in habitat loss while sea level decline would increase the habitat associated with particular salinity-habitats. Greater relative changes from baseline were predicted for habitats associated with a salinity of 3 or less (as compared to habitats associated with salinities of 5 or less and 12 or less) because the baseline habitat quantities estimated upstream of the low-salinity isohaline*, i.e.*, the isohaline corresponding to a salinity of 3, were smaller than those for the other two isohalines.

In an attempt to incorporate environmental effects of future sea level rise into the development of minimum flow recommendations for the Homosassa River system, flow-related changes in salinity-based habitats were evaluated for several sea-level rise scenarios predicted for year 2030 (Watson and Yang 2011b, included as Appendix Z to this report). Analyses were conducted using the Homosassa River hydrodynamic model and empirical regression models to evaluate effects of 1, 2, 3, 4 and 5 percent flow reductions on salinity-based habitats associated with baseline conditions that would be expected using 2007 benchmark flows and three sea-level conditions predicted for year 2030. Sea level conditions for the year 2007 analyses were developed using United States Army Corps of Engineer (2011) guidelines and include “low” (1.9 inch), “intermediate (3.2 inch) and “high” (7.3 inch) increases in sea level, relative to 2007 conditions. The empirical regression models were also used to evaluate effects of 1, 2, 3, 4 and 5 percent flow reductions on salinity-based habitats associated with baseline conditions that would be expected based on 1995 through 2009 benchmark flow conditions and “low”, “intermediate” and “high” sea level conditions predicted for each year of the longer benchmark flow record. Future sea level conditions for each year of the longer record were developed using Corps guidelines to adjust 2009 sea level conditions to 2030 conditions, 2008 conditions to 2029 conditions, and so on. Based on this approach, a 1.7 inch increase in sea level conditions was used for the longer benchmark scenario involving a “low” rate of sea level rise, increases of 2.3 to 3.0 inches were used for the “intermediate” scenario, and increases of 4.2 to 6.9 inches were used for the “high” sea-level rise scenario. The sea-level rise values used for the Homosassa River system analyses appear to be reasonable, based on sea level rise increases of 2.8-3.5 inches and 10 to 13.6 inches predicted by Harrington and Walton (2008) for six Florida counties for the periods from 2006-2030 and 2006-2080, respectively.

For the year 2030 sea-level scenario analyses, baseline conditions were derived for each sea-level condition assuming there would be no change in flows associated with change in sea level. Baseline conditions were also derived assuming that flows would change with sea level change. For the latter approach, baseline flow changes were predicted based on the U.S. Geological Survey equations used to derive discharge at the Homosassa Springs and Southeast Fork Homosassa Springs gage sites. For the reasons outlined above for the initial analyses of the impact of sea level change on the Homosassa River system, model results based on spring flow changes predicted with the USGS equations were considered less representative of expected future conditions and were ultimately not used for identification of percent-of-flow reductions that could be used to develop minimum flow recommendations for the Homosassa River system.

Salinity-based habitats associated with a salinity of 3 exhibited the most sensitive response to modeled flow reductions for the sea level rise scenarios evaluated that did not include a predicted change in spring discharge. Specifically, bottom habitats exposed to a salinity of 3 or less were decreased by 15 percent or more with flow reductions of 3 to 4 percent from baseline conditions for the “low”, “intermediate” and “high” sea-level rise scenarios based on either the 2007 or the longer (1995 through 2009) benchmark flow conditions (Tables 7-2 through 7-4).

Table 7-2. Modeled percent-of-flow reductions associated with a 15 percent decrease in median baseline salinity-based habitats for a "low" sea level rise scenario. Percent-of-flow reductions were evaluated for the 2007 benchmark period using the Homosassa River hydrodynamic model and empirical regression models and for the October 18, 1995 through May 13, 2009 benchmark period using empirical regression models

Salinity-Based Habitat	Percent-of-Flow Reduction Associated with 15% Reductions in Habitat from Median Baseline Conditions		
	Low Sea Level Rise Scenario Based on Hydrodynamic Model 2007 Benchmark Period [a]	*Low Sea Level Rise Scenario Based on Regression Model 2007 Benchmark Period* [a]	*Low Sea Level Rise Scenario Based on Regression Model 1995-2009 Benchmark Period* [b]
Bottom Area			
Salinity ≤ 2 Based on Bottom Isohaline Location	NE	NM	NM
Salinity ≤ 2 Based on Water-Column Average Isohaline Location	NE	NM	NM
Salinity ≤ 3 Based on Bottom Isohaline Location	>5	4	3 – 4
Salinity ≤ 3 Based on Water-Column Average Isohaline Location	>5	4 – 5	4
Salinity ≤ 5 Based on Bottom Isohaline Location	>5	>5	>5
Salinity ≤ 5 Based on Water-Column Average Isohaline Location	>5	>5	>5
Salinity ≤ 12 Based on Bottom Isohaline Location	>5	>5	>5
Salinity ≤ 12 Based on Water-Column Average Isohaline Location	>5	>5	>5
Water Volume			
Salinity ≤ 2	NE	NM	NM
Salinity ≤ 3	>5	>5	4 – 5
Salinity ≤ 5	>5	>5	>5
Salinity ≤ 12	>5	>5	>5
Natural Shoreline Length			
Salinity ≤ 2	NE	NM	NM
Salinity ≤ 3	>5	>5	>5
Salinity ≤ 5	>5	>5	>5
Salinity ≤ 12	>5	4 – 5	>5

[a] *Scenario corresponds to a 1.9 inch sea level rise from 2007 conditions*
[b] *Scenario corresponds to a 1.7 inch sea level rise from 1995 through 2009 conditions*
NM = not modeled
NE = not evaluated because responses for habitats based on salinities of 2 or less were considered unreliable

Table 7-3. Modeled percent-of-flow reductions associated with a 15 percent decrease in median baseline salinity-based habitats for an "intermediate" sea level rise scenario. Percent-of-flow reductions were evaluated for the 2007 benchmark period using the Homosassa River hydrodynamic model and empirical regression models and for the October 18, 1995 through May 13, 2009 benchmark period using empirical regression models.

Salinity-Based Habitat	Percent-of-Flow Reduction Associated with 15% Reductions in Habitat from Median Baseline Conditions		
	Intermediate Sea Level Rise Scenario Based on Hydrodynamic Model 2007 Benchmark Period [a]	*Intermediate Sea Level Rise Scenario Based on Regression Model 2007 Benchmark Period* [a]	*Intermediate Sea Level Rise Scenario Based on Regression Model 1995-2009 Benchmark Period* [b]
Bottom Area			
Salinity ≤ 2 Based on Bottom Isohaline Location	NE	NM	NM
Salinity ≤ 2 Based on Water-Column Average Isohaline Location	NE	NM	NM
Salinity ≤ 3 Based on Bottom Isohaline Location	3 – 4	3 – 4	3 – 4
Salinity ≤ 3 Based on Water-Column Average Isohaline Location	4	4 – 5	4
Salinity ≤ 5 Based on Bottom Isohaline Location	>5	>5	>5
Salinity ≤ 5 Based on Water-Column Average Isohaline Location	>5	>5	>5
Salinity ≤ 12 Based on Bottom Isohaline Location	>5	>5	>5
Salinity ≤ 12 Based on Water-Column Average Isohaline Location	>5	>5	>5
Water Volume			
Salinity ≤ 2	NE	NM	NM
Salinity ≤ 3	5	>5	4 – 5
Salinity ≤ 5	>5	>5	>5
Salinity ≤ 12	>5	>5	>5
Natural Shoreline Length			
Salinity ≤ 2	NE	NM	NM
Salinity ≤ 3	>5	>5	>5
Salinity ≤ 5	>5	>5	>5
Salinity ≤ 12	>5	4 – 5	>5

[a] *Scenario corresponds to a 3.2 inch sea level rise from 2007 conditions*
[b] *Scenario corresponds to a 2.3 to 3.0 inch sea level rise from 1995 through 2009 conditions*
NM = not modeled
NE = not evaluated because responses for habitats based on salinities of 2 or less were considered unreliable

Table 7-4. Modeled percent-of-flow reductions associated with a 15 percent decrease in median baseline salinity-based habitats for a "high" sea level rise scenario. Percent-of-flow reductions were evaluated for the 2007 benchmark period using the Homosassa River hydrodynamic model and empirical regression models and for the October 18, 1995 through May 13, 2009 benchmark period using empirical regression models.

Salinity-Based Habitat	Percent-of-Flow Reduction Associated with 15% Reductions in Habitat from Median Baseline Conditions		
	High Sea Level Rise Scenario Based on Hydrodynamic Model 2007 Benchmark Period [a]	*High Sea Level Rise Scenario Based on Regression Model 2007 Benchmark Period* [a]	*High Sea Level Rise Scenario Based on Regression Model 1995-2009 Benchmark Period* [b]
Bottom Area			
Salinity ≤ 2 Based on Bottom Isohaline Location	NE	NM	NM
Salinity ≤ 2 Based on Water-Column Average Isohaline Location	NE	NM	NM
Salinity ≤ 3 Based on Bottom Isohaline Location	>5	>5	3 – 4
Salinity ≤ 3 Based on Water-Column Average Isohaline Location	>5	>5	4 – 5
Salinity ≤ 5 Based on Bottom Isohaline Location	>5	>5	4 – 5
Salinity ≤ 5 Based on Water-Column Average Isohaline Location	>5	>5	>5
Salinity ≤ 12 Based on Bottom Isohaline Location	>5	>5	>5
Salinity ≤ 12 Based on Water-Column Average Isohaline Location	>5	>5	>5
Water Volume			
Salinity ≤ 2	NE	NM	NM
Salinity ≤ 3	>5	>5	4 – 5
Salinity ≤ 5	>5	>5	>5
Salinity ≤ 12	>5	>5	>5
Natural Shoreline Length			
Salinity ≤ 2	NE	NM	NM
Salinity ≤ 3	>5	>5	>5
Salinity ≤ 5	>5	>5	>5
Salinity ≤ 12	>5	>5	>5

[a] *Scenario corresponds to a 7.3 inch sea level rise from 2007 conditions*
[b] *Scenario corresponds to a 4.2 to 6.9 inch sea level rise from 1995 through 2009 conditions*
NM = not modeled
NE = not evaluated because responses for habitats based on salinities of 2 or less were considered unreliable

7.3.3 Sensitive Salinity-Based Habitats – Adjusted Flow Record Results

As noted in Chapter 2 of this report, existing water withdrawals have decreased combined discharge from springs of the Homosassa River system by approximately 1.1 percent. Based on this relatively low estimated impact, measured and modeled flows used for the analyses supporting development of initial minimum flow recommendations for the river system were not adjusted and were considered baseline flows. However, given the sensitivity of salinity-based habitats in the river system to modeled flow reductions (see Chapter 5 and the preceding sections of this chapter), staff determined that it would be appropriate to use adjusted flow records for identifying percent-of-flow reductions that could be used to develop revised minimum flow recommendations for the river system.

For analyses supporting identification of these percent-of-flow reductions, adjusted discharge records for the 2007 and 1995 through 2009 benchmark periods were developed by increasing individual flow records by 1 percent. The 1-percent flow adjustment was determined by evaluating: 1) the effect of existing withdrawals on combined discharge from Abdoney, Belcher, Homosassa Main, McClain, Pumphouse and Trotter 1 springs, which are included as drain cells in the Northern District model and contribute to flows past the United States Geological Survey Homosassa Springs and Southeast Fork Homosassa Springs gage sites; and 2) the effect of existing withdrawals on these springs and on Halls River 1 and Halls River Head Main springs which are also included as drain cells in the Northern District model and contribute to Homosassa River flows downstream from the Homosassa Springs and Southeast Fork gage sites. The effect of withdrawals on first group of springs was made based on the use of flows from these springs for regression-based salinity-habitat modeling. Withdrawal impacts on the second group of springs were evaluated based on use of discharge from these springs for hydrodynamic-based habitat modeling. Review of predicted withdrawal related flow changes for both spring groupings indicated that a 1 percent increase would be appropriate for adjusting the two benchmark flow records.

Salinity-based habitats other than those based on salinities of 2 or less that exhibited the most sensitive responses to modeled flow reductions (see Tables 7-1 through 7.4) were included in the analyses involving use of adjusted benchmark flow records. Habitats with salinities of 2 or less were excluded based on reasons discussed previously in this report. For both the 2007 and longer 1995-2009 benchmark periods based on current and future sea level conditions, the most sensitive habitat identified was bottom area where salinities were 3 or less. Flow-related changes in this habitat were, therefore, evaluated using the Homosassa River hydrodynamic model (Watson and Yang 2012; included as Appendix AB) and predictive regression models along with modified bathymetric information and the adjusted benchmark flow records. For both the hydrodynamic and regression-model analyses, salinity-based habitat values were derived for median baseline (*i.e.,* no flow reduction) conditions and compared to median conditions associated with the flow-reduction scenarios to identify percentage-of-flow reductions associated with more than a 15 percent reduction in the low-salinity bottom habitat.

Percent-of-flow reductions associated with modeled 15 percent reductions in median baseline salinity habitats for the sensitive low-salinity bottom habitat of the Homosassa River are compiled in Table 7-5. For the current and future sea level condition scenarios evaluated, bottom area based on bottom isohaline location where salinities were 3 or less was predicted to change 15 percent or more with modeled flow reductions between 3 and 4 percent. One exception to this response was for bottom habitat evaluated using adjusted 2007 benchmark flows under an intermediate sea level rise scenario; in that case a 4 to 5 percent flow reduction was associated with a 15 percent change in habitat.

Table 7-5. Results based on use of adjusted flow records to identify percent-of-flow reductions associated with a 15 percent decrease in median baseline bottom area associated with salinities of 3 or less, a habitat exhibiting strong sensitivity to flow reductions. Percent-of-flow reductions were evaluated for the 2007 benchmark period using the Homosassa River hydrodynamic model and empirical regression models and for the October 18, 1995 through May 13, 2009 benchmark period using empirical regression models. Results are shown for current sea level conditions (Current SL), and low, intermediate and high sea level rise (Low SLR, Intermediate SLR, High SLR) conditions.

Salinity-Based Habitat	**Percent-of-Flow Reduction Associated with 15% Reductions in Habitat from Median Baseline Conditions**		
	Hydrodynamic Model 2007 Benchmark Period	***Regression Model 2007 Benchmark Period***	***Regression Model 1995-2009 Benchmark Period***
Bottom Area			
Salinity ≤ 3 Based on Bottom Isohaline Location	NE	NE	3 – 4 Current SL
Salinity ≤ 3 Based on Bottom Isohaline Location	NE	NE	3 – 4 Low SLR
Salinity ≤ 3 Based on Bottom Isohaline Location	4 – 5 Medium SLR	4 Medium SLR	3 – 4 Medium SLR
Salinity ≤ 3 Based on Bottom Isohaline Location	NE	NE	3 – 4 High SLR

NE = not evaluated because the habitat response for the particular scenario was not as sensitive as that predicted for other evaluated scenarios

7.4 Revised Minimum Flows Recommendation

Based on the percent-of-flow reductions identified for a 15 percent reduction in the sensitive bottom habitats associated with salinities of 3 or less, a revised recommended minimum flow for the Homosassa River system is suggested for regulatory purposes as an allowable 3 percent reduction in natural flow in the Homosassa River system. An alternative, perhaps more appropriate expression of regulatory minimum flows for the river system would be that the minimum flows are 97 percent of the natural flow. For either expression, natural flow is defined as the flow that would exist in the absence of water-withdrawal impacts. This natural flow may be calculated based on withdrawal-impact corrected combined flows measured at the U.S. Geological Survey's Homosassa Springs at Homosassa Springs, FL Gage No. 02310678 and

SE Fork Homosassa Spring at Homosassa Springs, FL Gage No. 02310688, or based on modeled flows developed through application of numerical or statistical models. As additional flow data become available, the calculation of natural flow may also include measured flow from other named and unnamed springs and tributaries that discharge to the Homosassa River System. The recommended minimum flows identified in this paragraph are considered a revised recommendation, as the allowable percent-of-flow reduction differs from the initial 5 percent reduction in flows associated with the minimum flow recommendation presented in Chapter 5 of this report and in Leeper *et al.* (2010).

Long-term hydrologic statistics based on reductions from baseline conditions associated with the percent-of-flow reduction defined by the recommended minimum flows are typically calculated for District minimum flows determinations. The statistics can be used to aid in the evaluation of compliance with adopted minimum flows. Because long-term records are limited for the Homosassa River system, a synthetic record of natural flows for the period from June15, 1966 through February 6, 2012 was used to calculate appropriate long-term hydrologic statistics. The synthetic flow record was based on approved daily discharge at the U.S. Geological Survey Homosassa and Southeast Fork gages for dates when these data were available and discharge estimates developed using regression equations based on discharge at each gage and approved daily maximum water level records for the U.S. Geological Survey Weeki Wachee well. No attempt was made to infill discharge values for dates when water level records were not available for the Weeki Wachee well.

The synthetic flow record was adjusted to represent natural flows by accounting for existing withdrawal impacts. Withdrawal-related adjustments were based on results derived from application of the Northern District Model as described in the previous sub-section of this chapter. Daily flow values in the synthetic record for prior to 1975 were not adjusted, based on the assumption that prior to the issuance of the first water use permit in the area in 1975 flows in the Homosassa River system were not affected by water use. For the period from 1975 through 2004, a linearly increasing impact of up to one percent was assumed and applied to daily flows in the synthetic record. For synthetic flow records from 2005 through the present time, a constant 1 percent impact on flows was assumed and the daily flow values were accordingly adjusted.

Once adjusted, the synthetic natural record of daily flows was modified (multiplied by 0.97) to reflect a three percent reduction that could be allowed based on adoption and implementation of the revised minimum flow recommendations outlined in this report. Long-term hydrologic statistics, including five and ten-year running average and median flows, were then calculated for the modified synthetic flow record. The statistics were calculated as moving values by advancing 5 or 10-year periods by a single day through the modified synthetic flow record time-series. Minimum long-term hydrologic statistics, *i.e*., the five and ten-year statistics associated with the lowest flow values, were identified from the populations of moving average and median flows (Table 7-6). The minimum statistics correspond with long-term flows that may be expected given the minimum flows requirement that 97 percent of natural flows be maintained.

The minimum long-term hydrologic statistics are intended to serve as a hydrologic reference provided that climatic conditions remain similar to those that occurred during period used for their development. The statistics may be used for minimum flows compliance evaluations for the Homosassa River system in conjunction with gaged flow measurements, application of numerical or statistical models and consideration of other appropriate information, including well water levels, reported and estimated water use, landscape alterations and rainfall.

Table 7-6. Minimum long-term hydrologic statistics for the Homosassa River system based on a modified synthetic record of combined daily discharge at the U.S. Geological Survey Homosassa Springs and Southeast Fork Homosassa Springs gage sites that maintains 97 percent of natural flows in accordance with the revised minimum flow recommendations outlined in this report.

Long-Term Hydrologic Statistic	Discharge (cfs)
Minimum five-year moving average	133
Minimum five-year moving median	131
Minimum ten-year moving average	145
Minimum ten-year moving median	144

Given that portions of the Homosassa River are currently listed as impaired based on water-column concentrations of nitrate+nitrite and mercury concentrations in fish tissues collected from the region, it was considered appropriate to consider whether implementation of the revised minimum flow recommendations included in this report would be expected to exacerbate impairment related to these water quality concerns. As noted in Chapter 2 of this report, staff examined the observed increasing trend in nitrate+nitrite concentrations at springs associated with the river system, and found a relationship between the concentration of this water quality constituent and time but did not detect a relationship with flow (Heyl 2012). The nature of impairment for components of the Homosassa River system associated with mercury concentrations in fish tissue was determined not to be amenable to this type of analysis.

Staff also examined the potential for the implementation of minimum flows to exacerbate impairment associated with nitrate+nitrite concentrations by substantially altering river/estuary flushing rates. Flushing time is the time needed to flush a conservative pollutant from a defined point within an estuary. Based on the fraction of freshwater method outlined by the United States Environmental Protection Agency (Mills *et al.* 1985), flushing time was evaluated for 2007 and 1995-2009 Homosassa River system benchmark flows and compared with flushing times that would be expected if the flows were reduced by the three percent associated with the revised minimum flows recommendation. For the 2007 benchmark flows, median flushing times ranged from 6.5 to 7.4 days for the median and lowest daily flows, respectively. A three percent flow reduction increased flushing times for these flows 1.3 and 2 hours, respectively, or 0.9 and 1.1 percent. For the 1995-2009 benchmark period, median flushing times ranged from 6.2 to 8.9 days for the median and lowest daily flows, respectively. A three percent flow reduction increased flushing times for these flows 1.4 and 3.1 hours, respectively, or 1.0 and 1.5 percent. These minor changes in flushing time suggest that the revised minimum flow recommendations for the Homosassa River system would not be expected to exacerbate existing impairment associated with nitrate+nitrite concentrations.

Based on the estimated withdrawal impacts on spring discharge to the Homosassa River system (see Chapter 2), the development of a recovery strategy in association with adoption of the revised, recommended minimum flows is not necessary. As discussed in the 2010 Regional Water Supply Plan for the District's Northern Planning Region (Southwest Florida Water Management District 2011c), a three-component minimum flows and levels prevention strategy will be implemented to ensure that minimum flows established for the Homosassa River system will not be violated as a result of water withdrawals. The strategy includes ongoing monitoring of flows and water levels; assessment of potential impacts associated with water supply development through the regional water supply planning process and other planning and assessment activities, and implementation of a protective water-use permitting program that includes recent enhancements associated with conservative per capita water use requirements that were previously only applicable in District Water Use Caution Areas where withdrawal-related impacts have been documented.

Because climate change, structural alterations and other changes in the watershed and groundwater basin of the Homosassa River system could potentially affect surface water or groundwater flow characteristics, and because additional information relevant to minimum flows development may become available, the District is committed to periodic reevaluation and if necessary, revision of minimum flows for this priority water body. Also, given the relatively small magnitude of the allowable percent-of-flow reduction associated with the revised minimum flows recommendation and the relatively short period of available flow records for gage sites within the system, staff recommends that minimum flows established for the river system be reevaluated 10 years after they are adopted into rule. Finally, based on insight that may be gained from additional stakeholder and Governing Board review, staff notes that the revised, recommended minimum flows presented in this report may be modified prior to adoption of associated rule amendments into Rule 40D-8.041, F.A.C.

CHAPTER 8. CITED DOCUMENTS AND OTHER RELEVANT LITERATURE

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