Proposed Minimum Flows and Levels for the Upper Segment of the Myakka River, from Myakka City to SR 72

Southwest Florida Water Management District

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Executive Summary

The Southwest Florida Water Management District, by virtue of its responsibility to permit the consumptive use of water and a legislative mandate to protect water resources from “significant harm," has been directed to establish minimum flows and levels (MFLs) for streams and rivers within its boundaries (Section 373.042, Florida Statutes). As currently defined by statute, "the minimum flow for a given watercourse shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." In this report, minimum flows are proposed for the fresh water segment of the Myakka River, defined as the stretch of the river from the United States Geological Survey Myakka River at Myakka City gage downstream to the Myakka River near Sarasota gage.

Fundamental to the approach used for development of minimum flows and levels is the realization that a flow regime is necessary to protect the ecology of the river system. The initial step in this process requires an understanding of historic and current flow conditions to assess to what extent withdrawals or other anthropogenic factors have affected flows. To accomplish this task the District has evaluated the effects of climatic oscillations on regional river flows and has identified two benchmark periods for evaluation flows in the Myakka River.

For development of MFLs for the Myakka River, the District identified seasonal blocks corresponding to periods of low, medium and high flows. Short-term minimum flow compliance standards for the Sarasota gage site were developed for each of these seasonal periods using a "building block" approach. The compliance standard includes prescribed flow reductions based on limiting potential changes in aquatic and wetland habitat availability that may be associated with seasonal changes in flow. Low flow thresholds, based on fish passage depth and wetted perimeter inflection points are normally incorporated into the short-term compliance standards. However, in the case of the Myakka River, historic flows demonstrate that a low flow threshold should be set at zero cubic feet per second (cfs) due to the naturally ephemeral nature of the system.

The low flow threshold is defined to be a flow that serves to limit withdrawals, with no withdrawals permitted unless the threshold is exceeded. For the Myakka River gage site, the low flow threshold was determined to be zero cubic feet per second. A Prescribed Flow Reduction for the low flow period (Block 1, which runs from April 20 through June 24) was based on review of limiting factors developed using the Physical Habitat Simulation Model (PHABSIM) to model potential changes in habitat availability for several fish species and macroinvertebrate diversity. It was determined using PHABSIM that the most restrictive limiting factors were adult and juvenile largemouth bass and adult spotted sunfish. Based on the 1940 through 1969 benchmark period, adult spotted sunfish exhibit a 15% loss of habitat when flows are reduced by 18%. In both benchmark periods, simulated reductions in historic flows greater than 15%

resulted in more than 15% loss of available habitat for adult largemouth bass and a 14% reduction in flow resulted in a 15% loss of habitat for juvenile largemouth bass. Using these limiting factors, the prescribed flow reduction during the low flow period was defined as a 15% reduction in natural flow at the Myakka River near Sarasota gage.

For the high flow season of the year (Block 3, which runs from June 25 to October 27), a prescribed flow reduction was based on review of limiting factors developed using the HEC-RAS floodplain model and Regional and Long Term Positional Hydrographic (RALPH) analyses to evaluate percent of flow reductions associated with changes in the number of days of inundation of floodplain features. It was determined that a stepped flow reduction of 16% and 7% of historic flows, with the step occurring at the 15% exceedance flow (577 cfs) resulted in a decrease of 15% or more in the number of days that flows would inundate floodplain features as measured at the Sarasota gage.

For the medium flow period (Block 2, which runs from October 28 of one year to April 19 of the next), PHABSIM analyses were used to model flows associated with potential changes in habitat availability for several fish species and macroinvertebrate diversity. In addition, flows associated with inundation of instream woody habitats were evaluated using the HEC-RAS model and RALPH analyses. Using the more conservative of the two resulting flows, it was determined that PHABSIM would define the percent flow reduction. It was determined that more than 15% of historically available habitat would be lost for specific species life-stages if flows were reduced by more than 5% as measured at the Sarasota gage during the medium flow period.

Because minimum flows are intended to protect the water resources or ecology of an area, and because climatic variation can influence river flow regimes, we developed long-term compliance standards for the Myakka River gage site near Sarasota. The standards are hydrologic statistics that represent flows that may be expected to occur during long-term periods when short term-compliance standards are being met. The long-term compliance standards were generated using gage-specific historic flow records and the short-term compliance standards. Because, considerable augmentation occurs in the Myakka River relative to flows during Blocks 1 and 2, an altered flow record was created for the period 1970-1999 which subtracts out the median values of the estimated excess flow. For the analyses, the entire flow record, including the corrected 1970-1999 data was altered by the maximum allowable flow reductions in accordance with the prescribed flow reductions and the low flow threshold. Hydrologic statistics for the resulting altered flow data sets, including five and ten-year mean and median flows were determined and identified as long-term compliance standards. Because these long-term compliance standards were developed using the short-term compliance standards and the historic flow records, it may be expected that the long-term standards will be met if compliance with short-term standards is achieved. It should be noted that because the flow record was corrected to estimate natural flows that the compliance standards are constructed in accordance with the natural flow regime and not reflective of the augmented conditions found in the river during approximately the last 27 years.

Collectively, the short and long-term compliance standards proposed for the USGS gage site near Sarasota comprise the District's proposed minimum flows and levels for the Myakka River. The standards are intended to prevent significant harm to the water resources or ecology of the river that may result from water use. Since future structural alterations could potentially affect surface water or groundwater flow characteristics within the watershed and additional information pertaining to minimum flows development may become available, the District is committed to revision of the proposed levels as necessary.

Acknowledgement

The authors would like to thank Richard Gant, Jason Hood, Michelle Dachsteiner, Mike Lee, Ryan Horstman, Tiffany Dawson, and Jason Fulton of the Southwest Florida Water Management District for their assistance in data collection. We also thank Lisa Henningsen and Frank Sargent for assistance with land-use maps and data and Michelle Dachsteiner for data entry and analysis work in compiling the appendix. Dr. James Gore of the University of South Florida performed all PHABSIM modeling and consulted frequently on the application of PHABSIM analysis. We also thank the property owners and land managers who facilitated our access to the river, including, Thomas Keith of Hidden River Estates, Fleta and Tony Carlton, Hoyt Brawn, Chuck Downs, and from Myakka River State Park Diana Donaghy and Paula Benshoff.

Chapter 1 Minimum Flows and Levels

1.1 Overview and Legislative Direction

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

According to state law, minimum flows and levels are to be established based upon the best available information (Section 373.042, F.S.), and shall be developed with consideration of “...changes and structural alterations to watersheds, surface waters and aquifers and the effects such changes or alterations have had, and the constraints such changes or alterations have placed, on the hydrology of the affected watershed, surface water, or aquifer...” (Section 373.0421, F.S.). Changes, alterations and constraints associated with water withdrawals are not to be considered when developing minimum flows and levels. However, according to the State Water Resources Implementation Rule (Chapter 62-40.473, Florida Administrative Code), “consideration shall be given to the protection of water resources, natural seasonal fluctuations in water flows or levels, and environmental values associated with coastal, estuarine, aquatic and wetlands ecology, including:

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

Because minimum flows are used for long-range planning and since the setting of minimum flows can potentially impact (restrict) the use and allocation of water, establishment of minimum flows will not go unnoticed or unchallenged. The science upon which a minimum flow is based, the assumptions made, and the policy used must, therefore be clearly defined as each minimum flow is developed.

1.2 Historical Perspective

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

1.3 The Flow Regime

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

1) flood flows that determine the boundaries of and shape floodplain and valley features;
2) overbank flows that maintain riparian habitats;

3) in-channel flows that keep immediate streambanks and channels functioning; and
4) in-stream flows that meet critical fish requirements.

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

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

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

Common to this list and the flow requirements identified by Hill et al. (1991) is the recognition that in-stream flows and out of bank flows are important and that seasonal variability of flows should be maintained. Based on these concepts, the preconception that minimum flows (and levels) are a single value or the absolute minimum required to maintain ecologic health in most systems has been abandoned in recognition of the important ecologic and hydrologic functions of streams and rivers that are maintained by different ranges of flow. And while the term "minimum flows" is still used, the concept has evolved to one that recognizes the need to maintain a "minimum flow regime". In Florida, for example, the St. Johns River Water Management District (typically develops multiple flows requirements when establishing minimum flows and levels (Chapter 40-C8, F.A.C) and for the Wekiva River noted that, "[s]etting multiple minimum levels and flows, rather than a single minimum level and flow, recognizes that lotic [running water] systems are inherently dynamic" (Hupalo et al. 1994).

1.4 Ecosystem Integrity and Significant Harm

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

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

1.5 Summary of the SWFWMD Approach for Developing Minimum Flows

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

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

3) a unit of measure (e.g., flow in cubic feet per second, habitat in usable area, inundation to a specific elevation for a specified duration);
4) a benchmark period, and
5) a protection standard statistic.

The District's approach for minimum flows development incorporates the five elements listed by Beecher (1990). The goal of an MFL determination is to protect the resource from significant harm due to withdrawals and was broadly defined in the enacting legislation as "the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." What constitutes "significant harm" was not defined. Impacts on the water resources or ecology are evaluated based on an identified subset of potential resources of interest. Ten potential resources were listed in Section 1.1. They are: recreation in and on the water; fish and wildlife habitats and the passage of fish; estuarine resources; transfer of detrital material; maintenance of freshwater storage and supply; aesthetic and scenic attributes; filtration and absorption of nutrients and other pollutants; water quality and navigation. The approach outlined in this report identifies specific resources of interest and identifies when it is important seasonally to consider these resources.

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

Fundamental to the approach used for development of minimum flows and levels is the realization that a flow regime is necessary to protect the ecology of the river system. The initial step in this process requires an understanding of historic and current flow conditions to determine if current flows reflect past conditions. If this is the case, the development of minimum flows and levels becomes a question of what can be allowed in terms of withdrawals before significant harm occurs. If there have been changes to the flow regime of a river, these must be assessed to determine if significant harm has already occurred. If significant harm has occurred, recovery becomes an issue. For development of minimum flows for the upper Peace River (i.e., the river corridor upstream of the United State Geological Survey Peace River at Zolfo Springs, FL. streamflow gage site), the District used a "reference" period, from 1940 through 1956, to evaluate flow regime changes (SWFWMD 2002). More recently, the District has adopted an approach for establishing benchmark flow periods that involves consideration of the effects of multidecadal climatic oscillations on river flow patterns. The approach, which led to identification of separate benchmark periods for flow records collected prior to and after 1970, was used for development of MFLs for the freshwater segment of the Alafia River and middle Peace River (Kelly et al. 2005a, Kelly et al. 2005b) and has been utilized for analyses of flows in the Myakka River.

Following assessment of historic and current flow regimes and the factors that have affected their development, the District develops protection standard statistics or criteria for preventing significant harm to the water resource. For the upper segment of the Peace River, criteria associated with the fish passage in the river channel and maximization of the wetted perimeter were used to recommend a minimum low flow (SWFWMD 2002). Criteria associated with medium and higher flows that result in the inundation of woody habitats associated with the river channel and vegetative communities on the floodplain were described. These criteria were not, however, used to develop recommended levels, due to an inability to separate water withdrawal impacts on river flow from those associated with structural alterations within the watershed. For the middle segment of the Peace River, the District has used criteria to protect low flows and applied approaches associated with development of medium to high flow criteria per recommendations contained in the peer review of the proposed upper Peace River minimum flows (Gore et al. 2002). These efforts have included collection and analyses of in-stream fish and macroinvertebrate habitat data using the Physical Habitat Simulation (PHABSIM) model, and evaluation of inundation characteristics of floodplain habitats.

1.5.1 A Building Block Approach

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

Conceptually, the approach used by the District for development of MFLs for the upper Peace River (SWFWMD 2002) was consistent with the building block approach. Available flow records were summarized and used to describe flow regimes for specific historical periods. Resource values associated with low, medium and high flows were identified and evaluated for use in the development of MFLs for each flow range. Low minimum flows, corresponding to maintaining instream flow requirements for fish passage and wetted perimeter were proposed. Medium and high minimum flows were not, however, proposed for the river segment, due primarily to an inability to separate the effects of natural and anthropogenic factors on flow declines. Nonetheless, methods were used to evaluate potential ecological changes associated with variation in medium to high flows. The methods focused on the inundation of desirable in-stream habitats and on floodplain wetlands. Implicit in this approach was the concept that the three ranges of flow (low, medium and high) were associated with specific natural system values or functions.

For development of minimum flows and levels for the Myakka River, the District has explicitly identified three building blocks in its approach. The blocks correspond to seasonal periods of low, medium and high flows. The three distinct flow periods are evident in hydrographs of median daily flows for the river (e.g., Figure 1-1). Lowest flows occur during Block 1, a 66-day period that extends from April 20 to June 25 (Julian day 110 to 176). Highest flows occur during Block 3, the 123-day period that immediately follows the dry season (June 26 to October 26). This is the period when the floodplain is most likely to be inundated on an annual basis; although high flows can occur in early to mid-March. The remaining 176 days constitute an intermediate or medium flow period, which is referred to as Block 2.

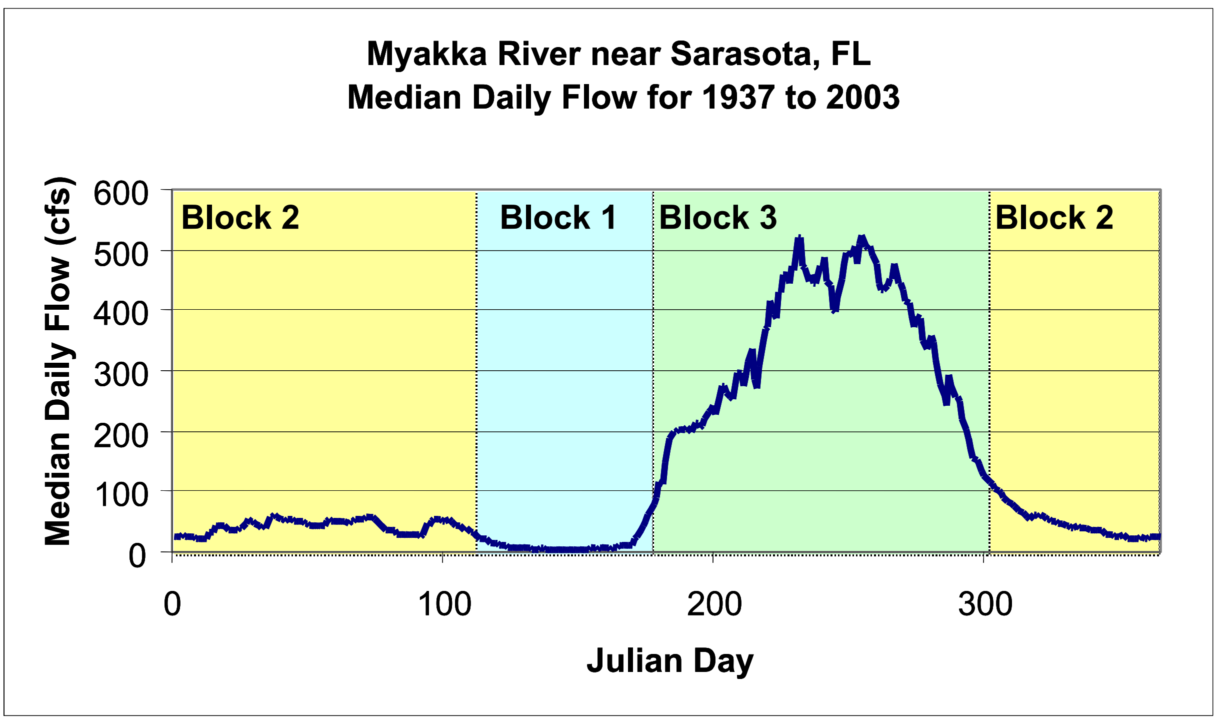


Figure 1-1. Median daily flows for 1937 through 2003 at the USGS Myakka River near Sarasota, FL gage site and seasonal flow blocks (Blocks 1, 2 and 3) for the upper Myakka River.

1.6 Flows and Levels

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

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

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

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

1.7 Content of Remaining Chapters

In this chapter, we have summarized the requirements and rationale for developing minimum flows and levels in general and introduced the need for protection of the flow regime rather than protection of a single minimum flow. The remainder of this document considers the development of minimum flows and levels specific to the Myakka River, which is defined as the river corridor occurring between streamflow gaging stations at Myakka City and near Sarasota. In Chapter 2, we provide a short description of the entire river basin and its hydrogeologic setting, and consider historic and current river flows and the factors that have influenced the flow regimes. Identification of at least two benchmark periods of flow, resulting from natural climatic oscillations is noted and seasonal blocks corresponding to low, medium and high flows are identified. Water quality changes related to flow are also summarized in Chapter 2 to enhance understanding of historical flow changes in the watershed. Chapter 3 includes a discussion of the resources of concern and key habitat indicators used for developing minimum flows. Specific methodologies and tools used to develop the minimum flows are outlined in Chapter 4. In Chapter 5, we present results of our analyses and provide flow prescriptions that are used for developing proposed minimum flows for the Myakka River. The report concludes with recommendations for evaluating compliance with the proposed minimum flows, based on the short and long-term compliance standards for the Myakka River.

Chapter 2 BASIN DESCRIPTION WITH EMPHASIS ON LAND USE, HYDROLOGY AND WATER QUALITY

2.1 Overview

This chapter includes a brief description of the Myakka River watershed and is followed by a presentation and discussion of land use, hydrology, and water quality data relevant to the development of MFLs on the upper (freshwater) segment of the Myakka River. Land use changes within the basin are evaluated to support the hydrology discussion that follows and to address questions that have been raised regarding the potential impact of land use changes on river flow volumes. Flow trends and their potential causes are discussed for the Myakka River and other regional rivers to provide a basis for identifying benchmark periods and seasonal flow blocks that are used for a building block approach in the establishment of minimum flows. Water chemistry changes are discussed to illustrate how land use changes may have affected observed trends in certain water quality parameters, and to demonstrate how these trends are useful in interpreting flow changes over time.

2.2 Watershed Description (material in this section was taken largely from *Myakka River Comprehensive Watershed Management Plan*, SWFWMD 2004)

2.2.1 Geographic Location

The Myakka River basin has a drainage area of approximately 598 square miles (Figure 2-1) that includes portions of Manatee, Sarasota, Hardee, Desoto, and Charlotte counties. The principal drainage system within the basin is the Myakka River which flows southwest nearly 66 miles from Myakka Head to Charlotte Harbor. Just downstream of Myakka Head, seven tributary creeks come together near Myakka City to form Flatford Swamp. Other important surface features within the upper watershed include portions of Tatum Sawgrass, and Upper and Lower Myakka Lakes. The stretch of the Myakka River (34 miles) in Sarasota County has been designated a Wild and Scenic River by the State of Florida. The Myakka River, including its estuarine portion, has been designated an Outstanding Florida Water by the Florida Department of Environmental Protection (FDEP).

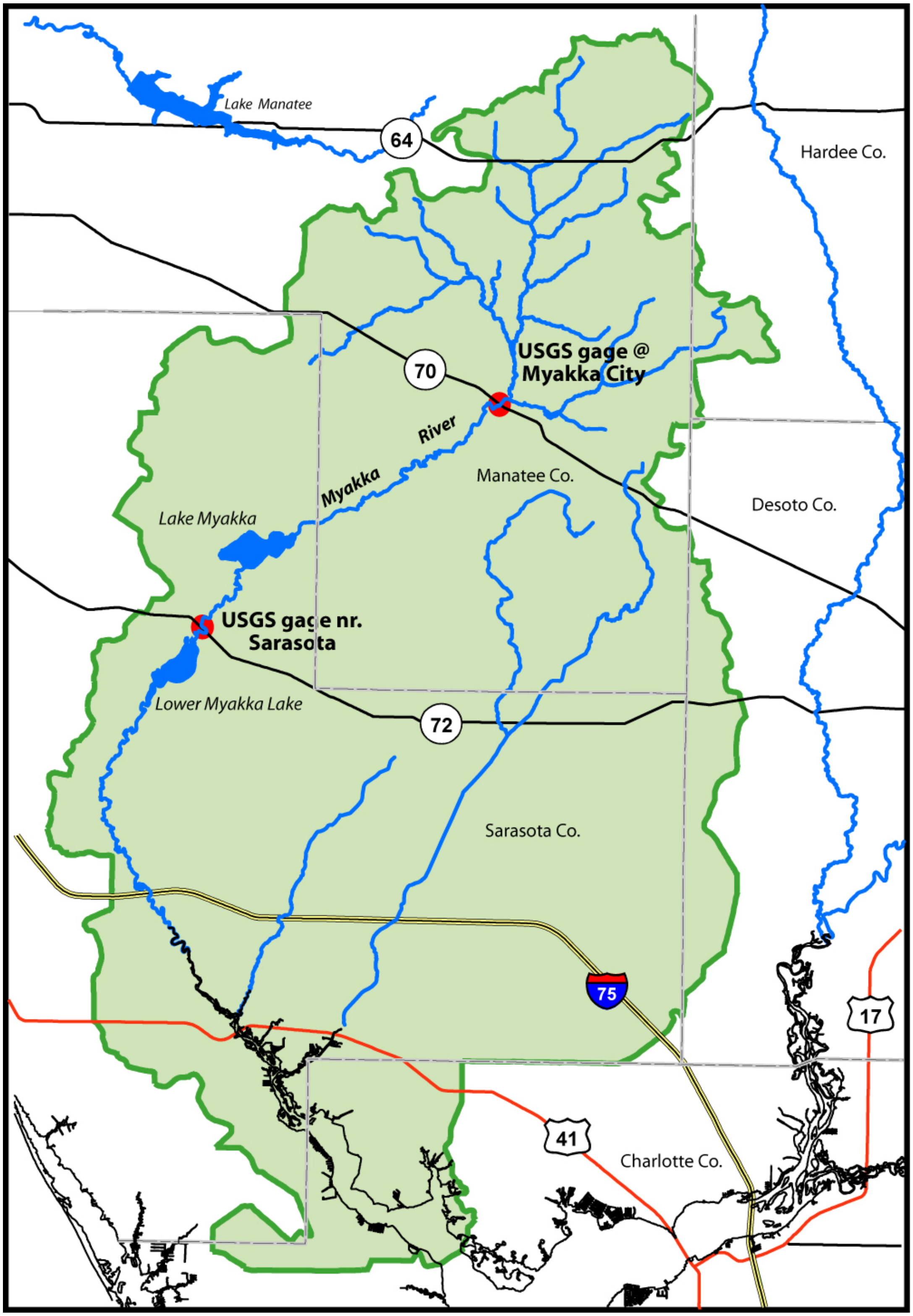


Figure 2-1. Map of the Myakka River watershed showing the Myakka River main-stem and tributaries, sub-basins and long-term USGS gage site locations.

2.2.2 Climate

The climate of west-central Florida is described as humid subtropical. Mean annual air temperature within Sarasota County is 73 degrees Fahrenheit, with a mean daily temperature range of 84^{o} F in summer to 61^{o} F in winter. Along the coast, temperatures are slightly higher in winter and lower in summer due to the moderating effect of the Gulf of Mexico. The average annual rainfall, based on a number of rainfall stations in the area, is approximately 52 inches. National Oceanic and Atmospheric Administration's (NOAA) Florida Division 4 Rainfall Zone includes the watershed of the Myakka River (see Figure 2-2). Approximately 60% of annual precipitation falls during the months of June, July, August and September and is caused by convective storms that move across the area. Periods of very heavy rainfall associated with the passage of tropical low pressure systems may occur during the summer and early fall. Lowest rainfall occurs during the month of November with another seasonal low typically occurring in April.

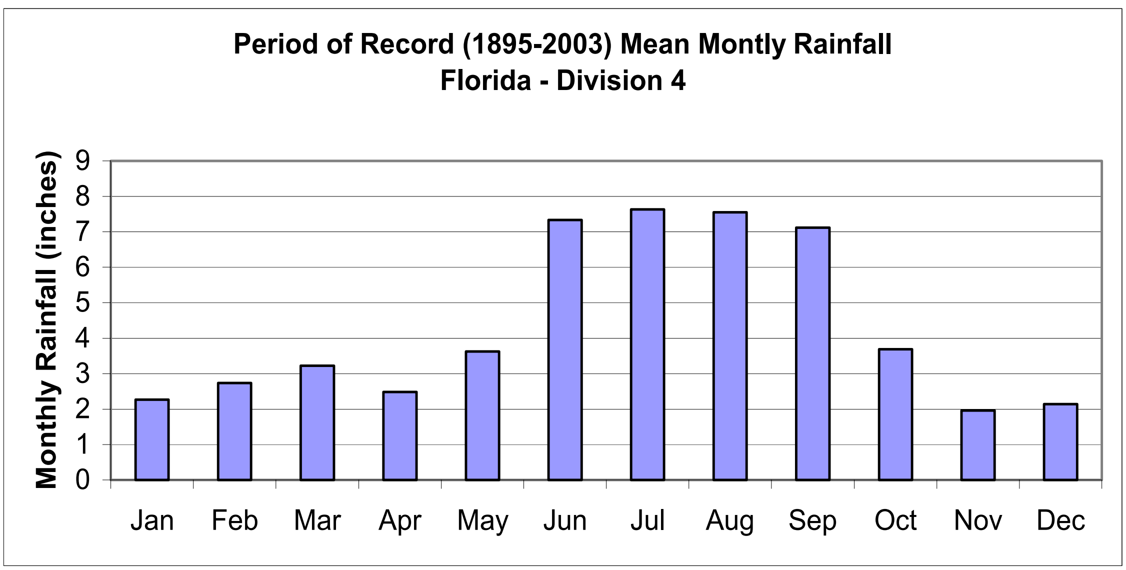


Figure 2-2. Average total monthly rainfall in Florida Division 4 for period of record 1895 to 2003.

2.2.3 Physiography

The Myakka River watershed lies within three subdivisions of the central or mid-peninsular physiographic zone of Florida, predominantly Gulf Coastal Lowlands with the upper portion of the river within the DeSoto Plain and a small part of the headwaters in the Polk Upland unit. The Gulf Coastal Lowlands are characterized by flat topography with elevations generally below 40 feet and sandy, shelly, and silty sand soils with little organic matter. The DeSoto Plain consists of generally white sandy soils at elevations from 40 to 100 feet. The maximum watershed elevation is 116 feet above the National Geodetic Vertical Datum of 1929 (NGVD) in the northeastern part of the basin where terraces have eroded into rolling hills. The southwestern part of the basin is less than 20 feet above NGVD and has little local relief.

2.2.4 Hydrogeology

The Myakka River watershed is located within the Southern West-Central Florida Ground-Water Basin (Basin), one of three distinct ground water basins within west-central Florida. No significant ground water flow crosses the basin boundaries; hence, all ground water is derived from recharge by rainfall within the basin. Upper Floridan aquifer flow in the Basin is derived primarily from rainfall recharge that occurs outside the Myakka River watershed in the Lake Wales Ridge area to the east and on a limited basis from the Green Swamp. Down gradient of these areas, ground water flows west and southwest toward and into the Gulf of Mexico.

Within the Basin, the ground water system is divided into three main aquifers: the surficial, the intermediate and the Floridan. Each aquifer is separated by a confining layer of variable thickness and areal extent. The uppermost aquifer, the surficial, is largely undeveloped due to its small thickness and low permeability, except near the coast and in Charlotte County where ground water from deeper aquifers is too mineralized for potable use. The surficial aquifer occurs in the undifferentiated sands that overlie the watershed and generally varies from less than 25 feet in the southern areas to more than 50 feet in thickness in the northeastern areas of Manatee County. These sands yield limited quantities of water, primarily used for lawn irrigation, and are economically mined for their silica and shell hash content.

Underlying the surficial aquifer is the intermediate or secondary artesian aquifer system, which occurs in the Hawthorn Group. The intermediate aquifer system is a moderately prolific but highly developed source of water, and is widely used for domestic and public supplies south of Polk County. Within the Basin, the intermediate aquifer averages 700 feet in thickness in southern Charlotte County, but thins toward the north. Within the Myakka River watershed, the intermediate aquifer varies in thickness from less than 200 feet, to more than 350 feet. The upper Hawthorn consists of a green sand and clay containing black phosphate grains. This upper unit is sometimes included with the Bone Valley member and targeted for open pit phosphate mining. The lower Hawthorn is yellow to white sand, clay, and limestone residual from carbonate rock. The fine sand is quartz with black or brown phosphate. Lenses of pure limestone, clay and sand exist throughout the formation and domestic water well production occurs from the porous limestone layers.

The lowermost and most productive aquifer is the Floridan aquifer system. The Floridan aquifer is the primary artesian aquifer throughout Florida and much of the southeastern United States. It consists of two transmissive zones, the Upper Floridan and lower Floridan aquifer, which are separated by the middle confining unit. This aquifer consists of a thick sequence of sedimentary rocks of Eocene to Miocene age. These chemically precipitated deposits of limestone and dolomite contain shells and shell fragments of marine origin, which accumulated throughout the Tertiary period. These limestone units comprise the Tampa, Suwannee, Ocala, and Avon Park formations. The Avon Park formation is the deepest containing potable water. The Floridan aquifer system thickens from approximately 1,200 feet in the northern areas of the watershed to more than 1,800 feet to the south. Generally, water quality in the Upper Floridan aquifer is good but tends to deteriorate due to increasing mineralization as one moves south and toward the coast. The Upper Floridan is the major source of water for agriculture, industry and public supply, except in southern DeSoto and Charlotte counties and the coastal areas of Manatee and Sarasota counties where water quality is relatively poor.

2.3 Land Use Changes in the Myakka River Watershed

2.3.1 Myakka River Watershed

A series of maps, tables and figures were generated for the entire Myakka River watershed for three specific years (1972, 1990 and 1999) for purposes of reviewing land use changes that have occurred during the last several decades. The 1972 maps, tables, and figures represent land use and land cover generated using the USGS classification system (Anderson et al. 1976). The USGS classification system incorporates a minimum mapping unit of 10 acres for man-made features with a minimum width of 660 feet. The minimum mapping unit for non-urban and natural features is 40 acres with a minimum width of 1320 feet. The 1990 and 1999 maps and data represent land use and land cover information developed using the Florida Department of Transportation's (1999) Florida Land Use, Cover and Forms Classification System (FLUCCS). The FLUCCS system is more detailed than the USGS system, with minimum mapping units of 5 acres for uplands and 0.5 acres for wetlands. Some differences in land-use estimates for the three periods may therefore be attributed to analytic precision differences. However, for presentation and discussion purposes, we combined numerous land use types into fairly broad categories, and thereby eliminated some of the error associated with use of the two classification systems.

For our analyses, land use/cover types identified included: urban; uplands (rangeland and upland forests); wetlands (wetland forests and nonforested wetlands); mines; water; citrus; and other agriculture. We examined changes in these use/cover types for the entire watershed and also for 11 sub-basins. Since this MFL report addresses the upper segment of the Myakka River, most of the discussion that follows deals with sub-basins above the Myakka River gage near Sarasota and includes the following named sub-basins: Flatford Swamp, Owen Creek, Tatum Sawgrass, Upper Myakka Lake, Upper Myakka River, and Myakka River between the Lakes.

Before discussing individual sub-basin land use changes, it is informative to discuss the entire watershed of the Myakka River to get an appreciation of the major land uses/covers and the changes that have occurred during the nearly 30 years for which land use maps are available. Land use/cover maps for 1972 and 1999 for the entire Myakka River watershed are shown in Figures 2-3 and 2-4. Based on these maps, the Myakka River watershed is 598 square miles or 382,764 acres in size. The uppermost section of the Myakka River, i.e., the area above the Myakka City gage, is 125 square miles as reported by the USGS. The area above the Sarasota gage is 238 square miles using the land-use maps prepared for this study compared with the 229 square miles reported by the USGS. This is about a 4% difference and is considered minimal for the analyses done in this report; however, for all computations (other than landuse) where watershed area was used, we used the USGS reported value of 229 square miles for consistency.

Because we combine several agricultural land use types for our analysis, temporal changes in land use from 1972 to 1999 may not reflect the shift which has occurred from less intensive types of land use to those requiring greater amount of water. For example, the net change in agricultural land in the Myakka River basin from 1972 to 1999 reflects only a small percent change in total acreage (equating to less than a 1% increase in agricultural lands). However, it can be demonstrated that considerably more water is now discharged from agricultural lands due to conversion from uses requiring less water to those requiring more. It should be noted, however, that of the major land use categories, the amount of land converted to urban uses has shown the single greatest increase. This land use has increased most notably in the southern part of the watershed, that part which drains most directly to the lower Myakka River and Charlotte Harbor.

In many instances, within sub-basins, what appears to be a substantial decrease in uplands and increase in wetlands is actually an artifact of the disparity in resolution of features denoted in 1972 and 1999 mapping. While it appears that the amount of wetlands has increased in most sub-basins, this is probably not the case. Because many wetlands are small in size and interspersed within upland areas, they were not delineated under the relatively coarser resolution employed in the 1972 mapping. Apparent increases in wetlands (resulting in a concomitant decrease in uplands) were the consequence of increased resolution rather than the conversion of, for example, uplands to wetlands. In many cases what appear to be substantial declines in uplands should more appropriately be interpreted as an improvement in map resolution. However, relatively large decreases in uplands have occurred in some sub-basins. It is helpful when interpreting these data to view the sum of the wetlands and uplands as natural area, and the decline in this total as a measure of conversion to some other more intensive land use (e.g, agriculture, mining, urban).

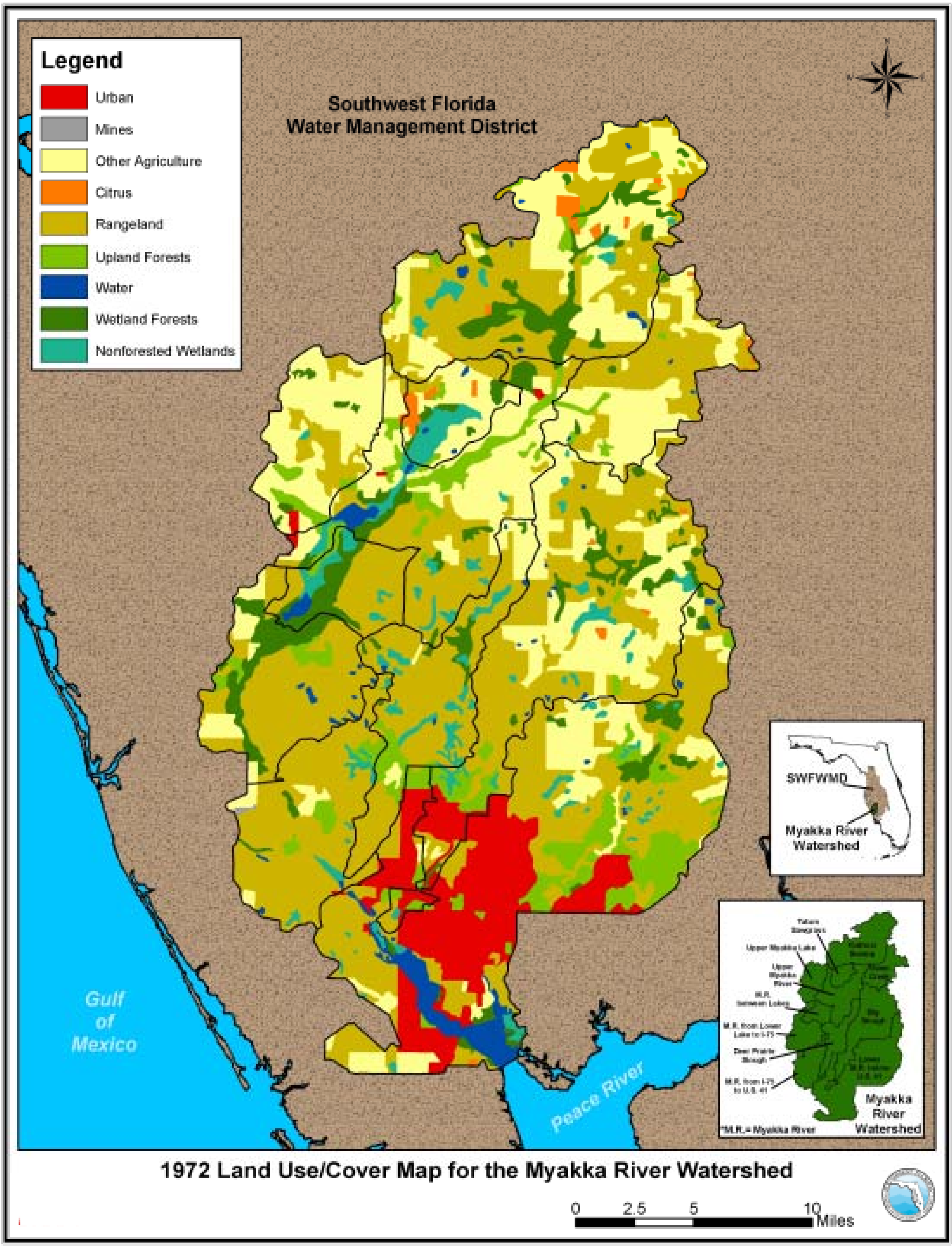


Figure 2-3. 1972 land use/cover map of the Myakka River watershed.

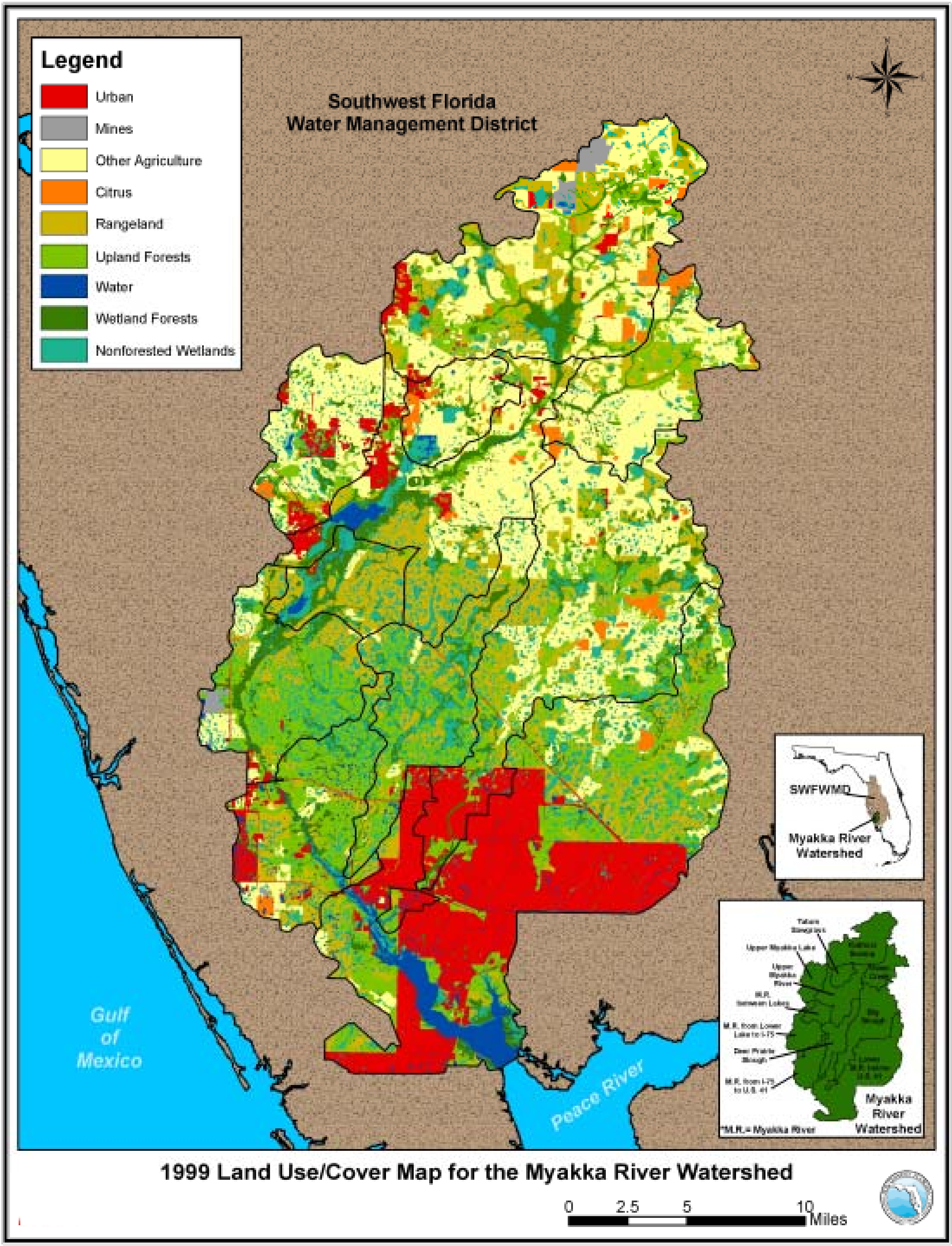


Figure 2-4. 1999 land use/cover map of the Myakka River watershed.

Based on the 1999 map, a significant amount of the watershed remains in fairly natural cover; uplands and wetlands comprise approximately 55% of the watershed (Table 2-1, Figure 2-5). On a percentage basis considerably more of this watershed remains in a relatively undisturbed state as contrasted with either the Peace or Alafia watersheds, where the combined acreage in uplands and wetlands, is 32% and 20%, respectively (Kelly et al. 2005a, 2005b). Unlike the neighboring Peace and Alafia watersheds, only a small portion of the Myakka watershed has been mined (0.6%). Agriculture represents a major land use in the Myakka River watershed (27%); however, the amount of acreage in citrus is small (1.7%). As of 1999, 14% of the watershed was in urban land use. The amount of urbanization is comparable, on a percentage basis, to that in the Peace (10.5%) and Alafia River (17.6%) watersheds. There is, however, little urbanization in the upper watershed. Most of the 85 square miles of urban land is in the lower portion of the watershed (Figure 2-4).

Total acreage of agricultural lands has remained relatively stable from 1972 to 1999 (Table 2-1, Figure 2-5). However, it should be remembered that agriculture, as used in this report, is a broad category that defines a range of agricultural activities such as cropland and pastureland, row crops, feeding operations, nurseries, and fish farming. Some of these uses require considerably more water than others. For example, the conversion of pastureland to row crops would not be shown as a change in total agricultural lands, but such a conversion could result in greater quantities of augmentation into the river from irrigation water and agricultural water management practices. As discussed with respect to river flows, it is believed that off-site movement of irrigation water (discharged to streams) has increased river flow. It has been documented elsewhere that tree die-off in the Flatford Swamp area is most probably related to increasing low flows due directly or indirectly to agricultural water management practices (PBS&J 1999). The hydroperiod of the swamp has been increased, and although plant species in the swamp are adapted to long periods of inundation, the swamp now experiences continuous inundation to the detriment of the plant communities that were adapted to shorter periods of inundation. Land use changes in a portion of the upper Myakka River watershed between two agricultural land use types (pasture land and row crops) are shown in Table 2-2.

Unfortunately agricultural land use information available for the 1972 mapping exercise was not in sufficient enough detail to distinguish between acreages in row crops and pasture land. However, the 1990 and 1999 land use data was refined enough to examine land use changes in these two agricultural land use types. For purposes of this report, each sub-basin contributing to the watershed of Flatford Swamp was examined for changes in acreage in pasture and row crops for the decade 1990 to 1999. Overall the total acreage in agricultural land use changed very little, but there were noticeable reductions in pastureland and increases in row crop acreage. In sum, the total acreage in pasture and row crops in the Flatford Swamp watershed decreased from 1990 to 1999 by less than 5% (21,465 acres to 20,450 acres); however, acreage in row crops increased from 4,721 acres to 8,222 acres (almost 75%).

Table 2-1. Land use and land cover percentages in the 382,764-acre Myakka River watershed for three time periods: 1972, 1990 and 1999.

Myakka River Watershed	1972	1990	1999
Urban	7.8	13.4	14.2
Citrus	0.8	1.0	1.7
Other Agriculture	25.8	25.5	25.6
Uplands	53.0	36.2	34.0
Wetlands	10.5	21.5	21.0
Mines	0.0	0.2	0.6
Water	2.0	2.3	2.8

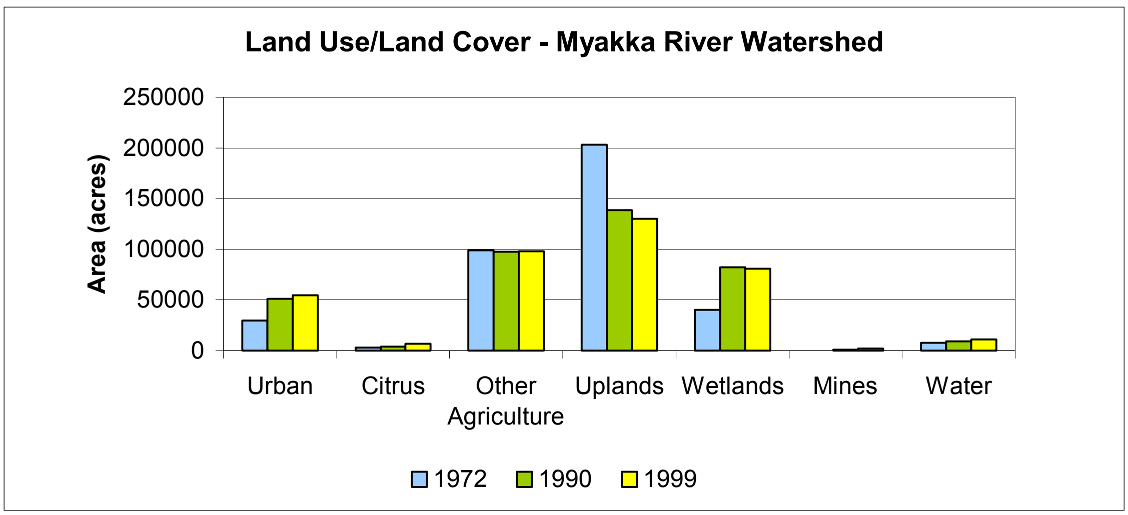


Figure 2-5. Land use/cover acreage in the Myakka River watershed in 1972, 1990 and 1999.

Table 2-2. Change in two agricultural land use types (pasture and row crops) in the sub-basins composing the watershed at and above Flatfrod Swamp between 1990 and 1999.

	1990 Pasture (acres)	1990 Row Crops (Acres)	1999 Pasture (acres)	1999 Row Crops (acres)	Change in Pasture (acres)	Change in Row Crops (acres)
Boggy Creek	282	599	35	793	-247	194
Coker Creek	1097	981	367	1308	-730	327
Johnson Creek	236	306	507	388	271	82
Long Creek	2249	290	884	1273	-1365	983
Maple Creek	736	864	206	1165	-530	301
Myakka Flatford	2959	245	2650	385	-309	140
Ogleby Creek	2129	567	1891	1218	-238	651
Sand Slough	70	127	13	276	-57	149
Taylor Creek	365	139	149	404	-216	265
Unnamed Creek	1908	0	1982	0	74	0
Unnamed Ditch	1469	562	583	693	-886	131
Wingate Creek	1662	30	1436	0	-226	-30
Young Creek	1582	11	1525	319	-57	308
Totals	16744	4721	12228	8222	-4516	3501
1990 and 1999 Totals		21465		20450		

2.3.2 Flatford Swamp Sub-Basin

The predominant land use in the Flatford Swamp sub-basin is agriculture, which collectively in 1999 accounted for 43.7% of the sub-basin land use. Unfortunately, as indicated above, agricultural land use information available for the 1972 (Figure 2-7) mapping exercise was not in sufficient enough detail to distinguish between acreages in row crops and pasture land. However, as mentioned above between 1990 and 1999, pasture acreage declined by 4516 acres in the Flatford Swamp sub-basin while row crop acreage increased by 3501 acres.

Table 2-3. Land use/cover and land cover percentages in the 54,322-acre Flatford Swamp watershed for three time periods, 1972, 1990 and 1999.

Flatford Swamp	1972	1990	1999
Urban	0.0	1.3	3.6
Citrus	2.8	1.9	4.0
Other Agriculture	33.5	40.8	39.7
Uplands	48.7	36.5	31.7
Wetlands	14.3	18.0	17.7
Mines	0.0	0.9	2.7
Water	0.7	0.5	0.5

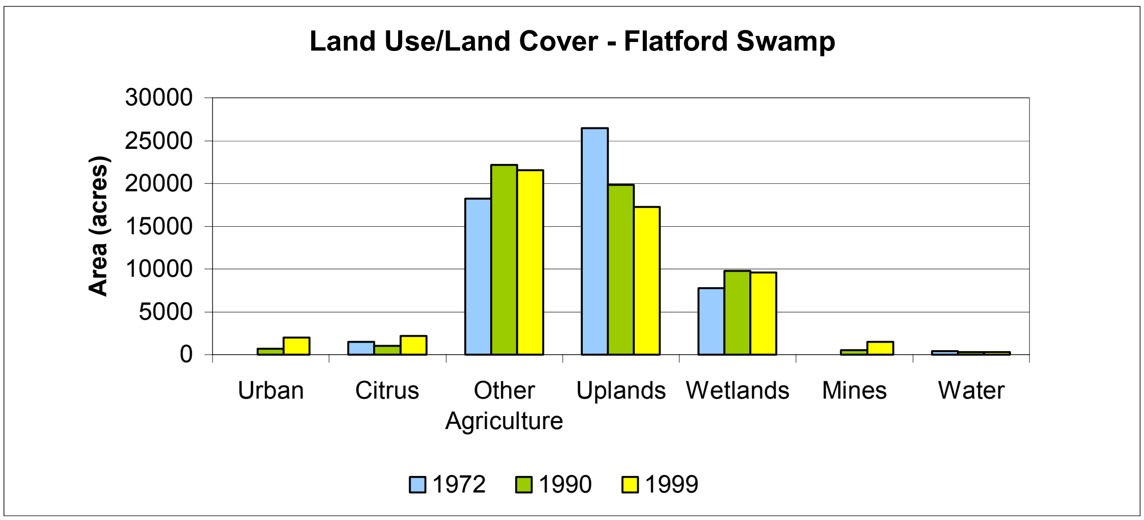


Figure 2-6. Land use/cover acreage in the Flatford Swamp sub-basin in 1972, 1990 and 1999.

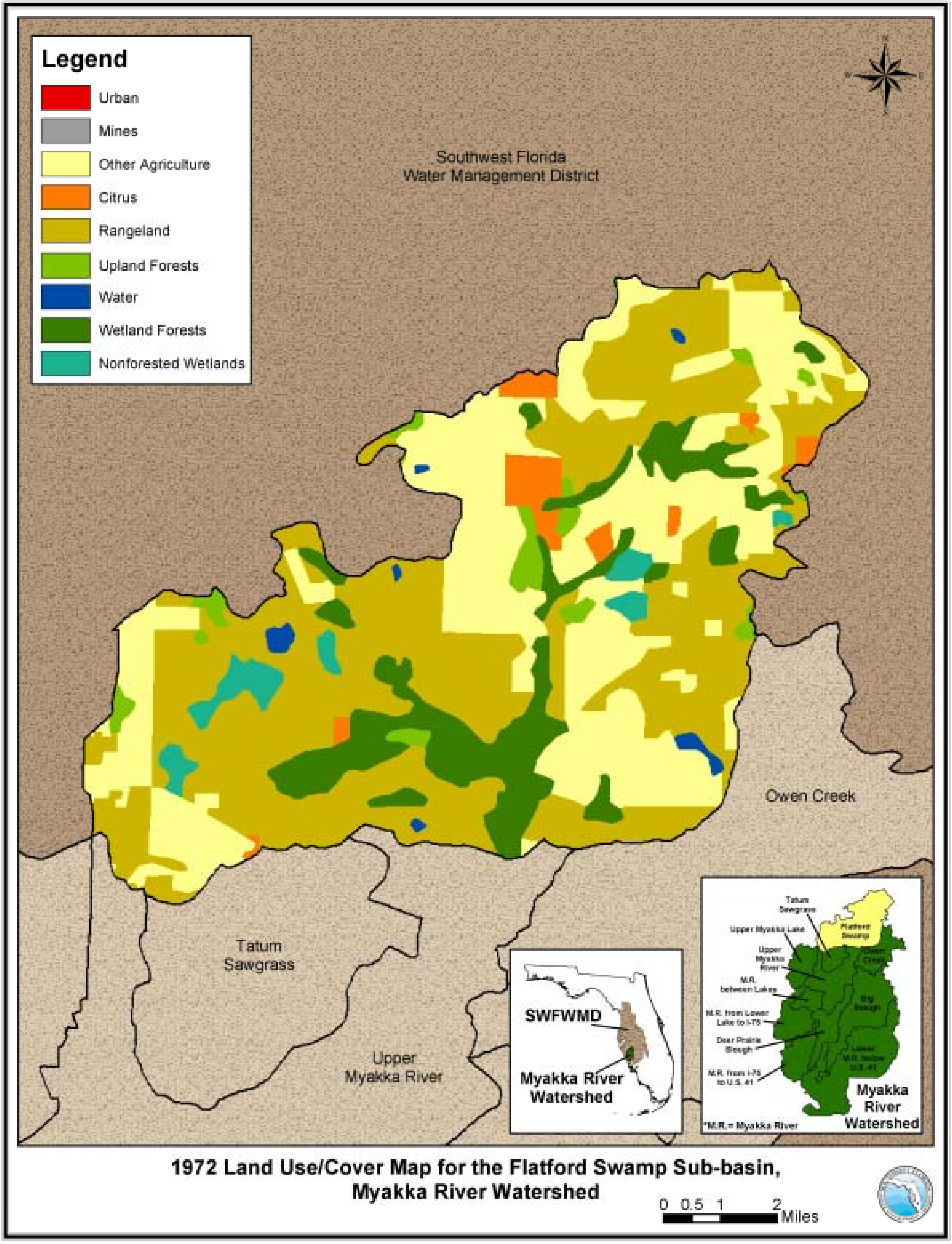


Figure 2-7. 1972 Land use/cover map of the Flatford Swamp sub-basin.

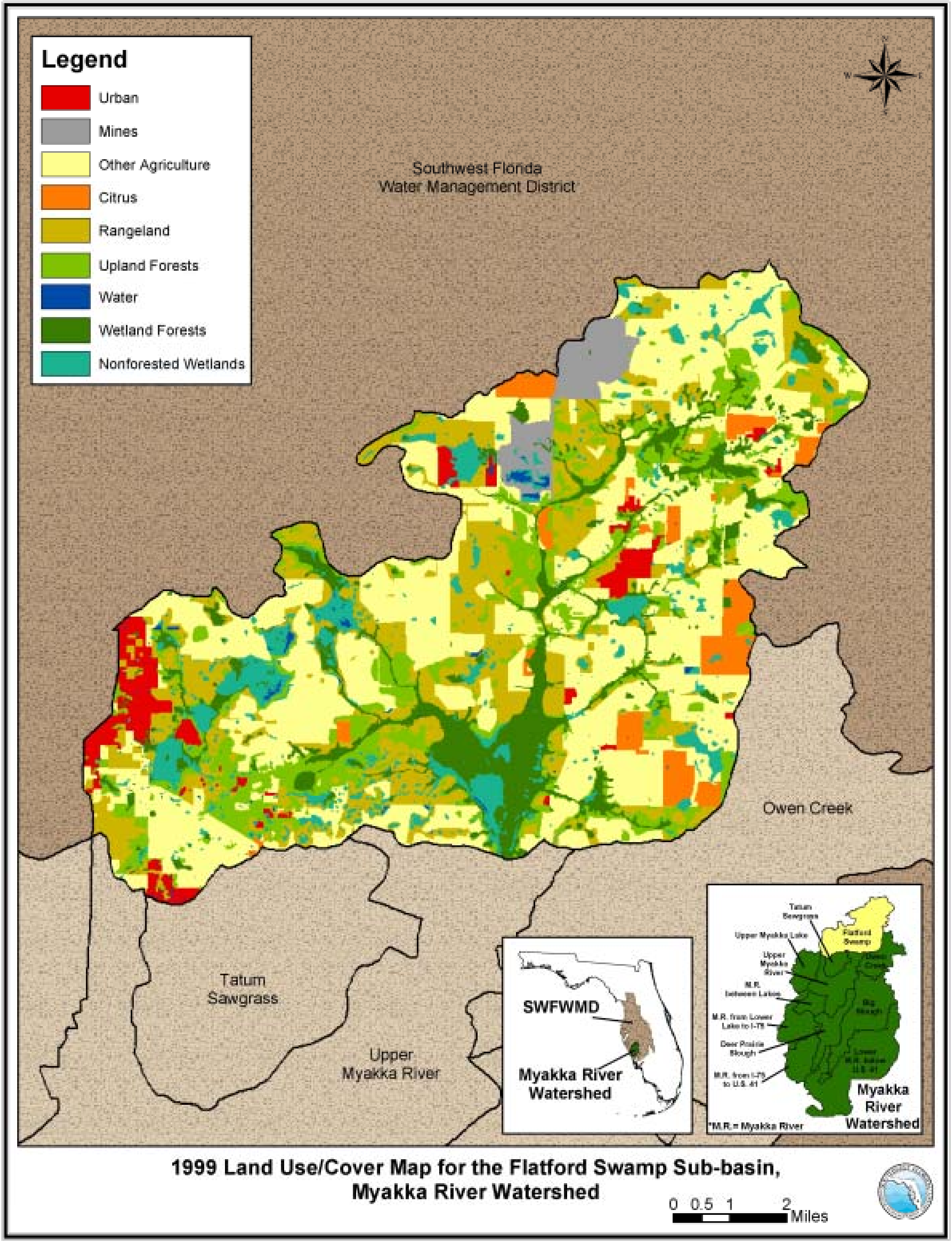


Figure 2-8. 1999 Land use/cover map of the Flatford Swamp sub-basin.

2.3.3 Owen Creek Sub-Basin

Land use in the Owen Creek sub-basin is also dominated by agricultural uses (Table 2-4, Figure 2-9). Approximately 60% of this sub-basin's land use is agriculture. Between 1972 and 1990, this land use expanded to cover an additional 10% of the watershed, but there was little change in net agricultural acreage in the last decade (1990 to 1999). There is little urbanization in this watershed, less than 0.1%, and natural lands (uplands and wetlands) now comprise approximately 40% of the sub-basin's watershed.

Table 2-4. Land use/cover percentages in the 22,179-acre Owen Creek sub-basin for three time periods, 1972, 1990 and 1999.

Owen Creek	1972	1990	1999
Urban	0.0	0.0	0.1
Citrus	0.9	3.1	5.1
Other Agriculture	49.1	57.6	55.7
Uplands	48.7	28.3	26.8
Wetlands	1.0	10.8	12.0
Mines	0.0	0.0	0.0
Water	0.3	0.1	0.3

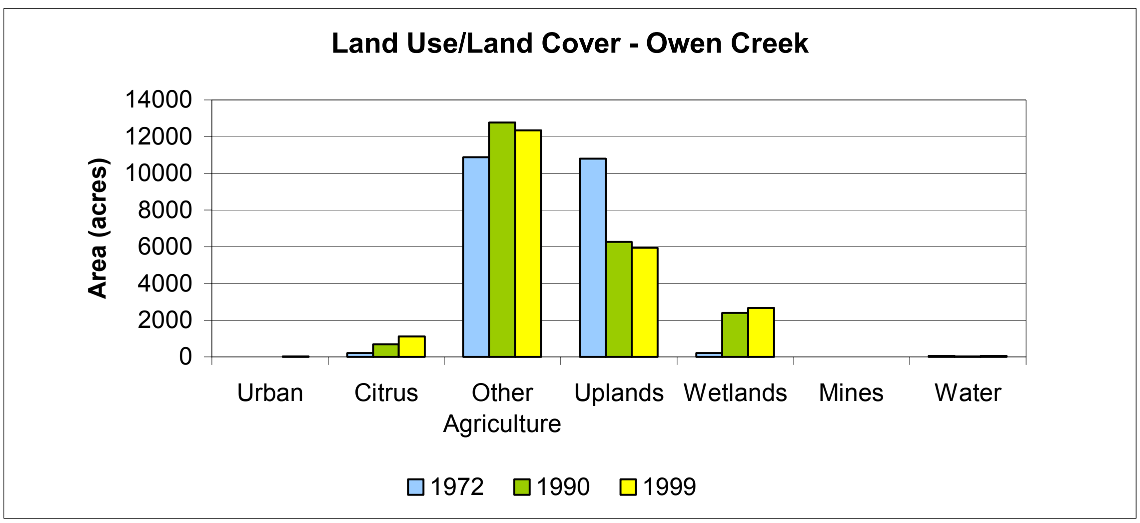


Figure 2-9. Land use/ cover in the Owen Creek sub-basin in 1972, 1990 and 1999.

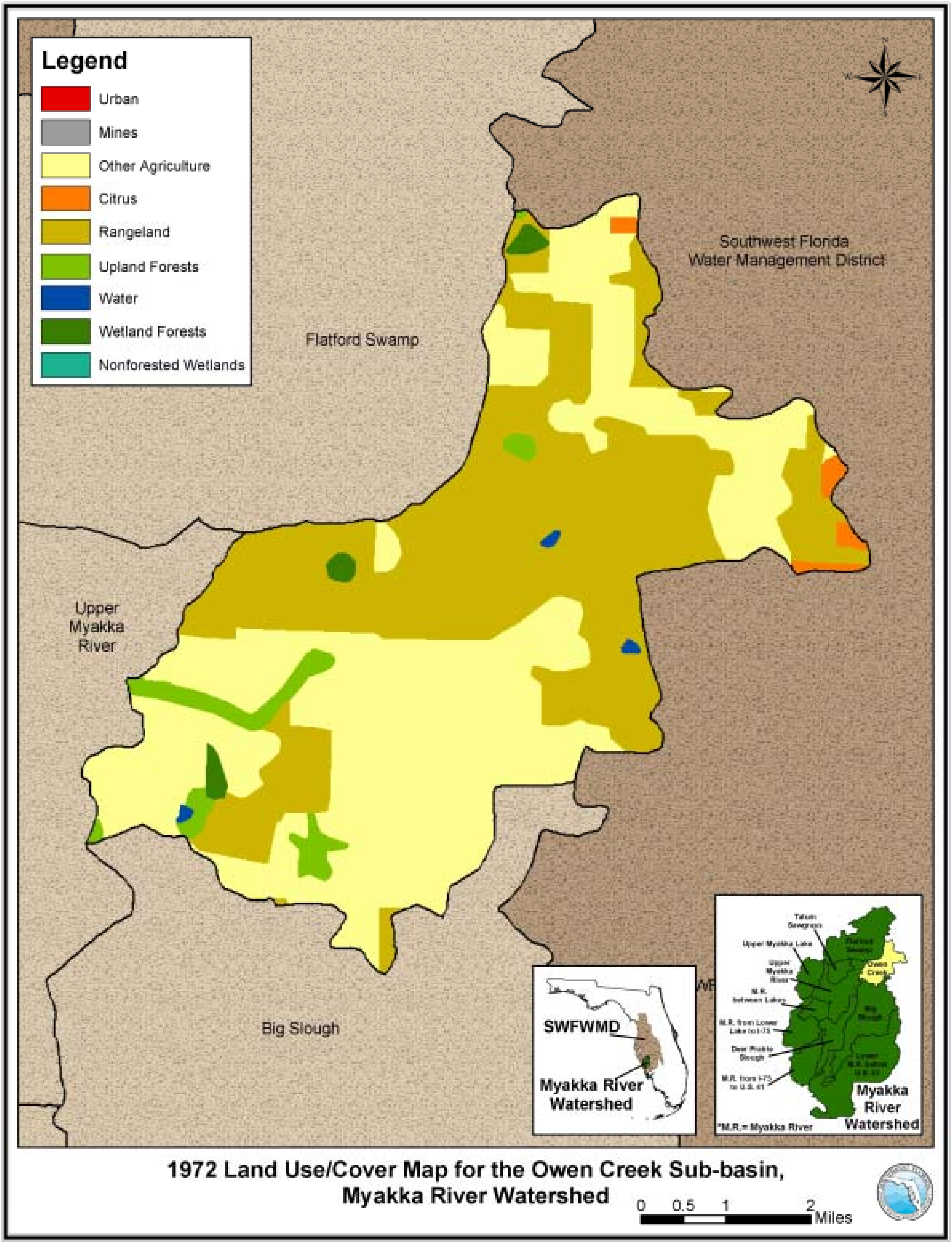


Figure 2-10. 1972 Land use/cover map of the Owen Creek sub-basin.

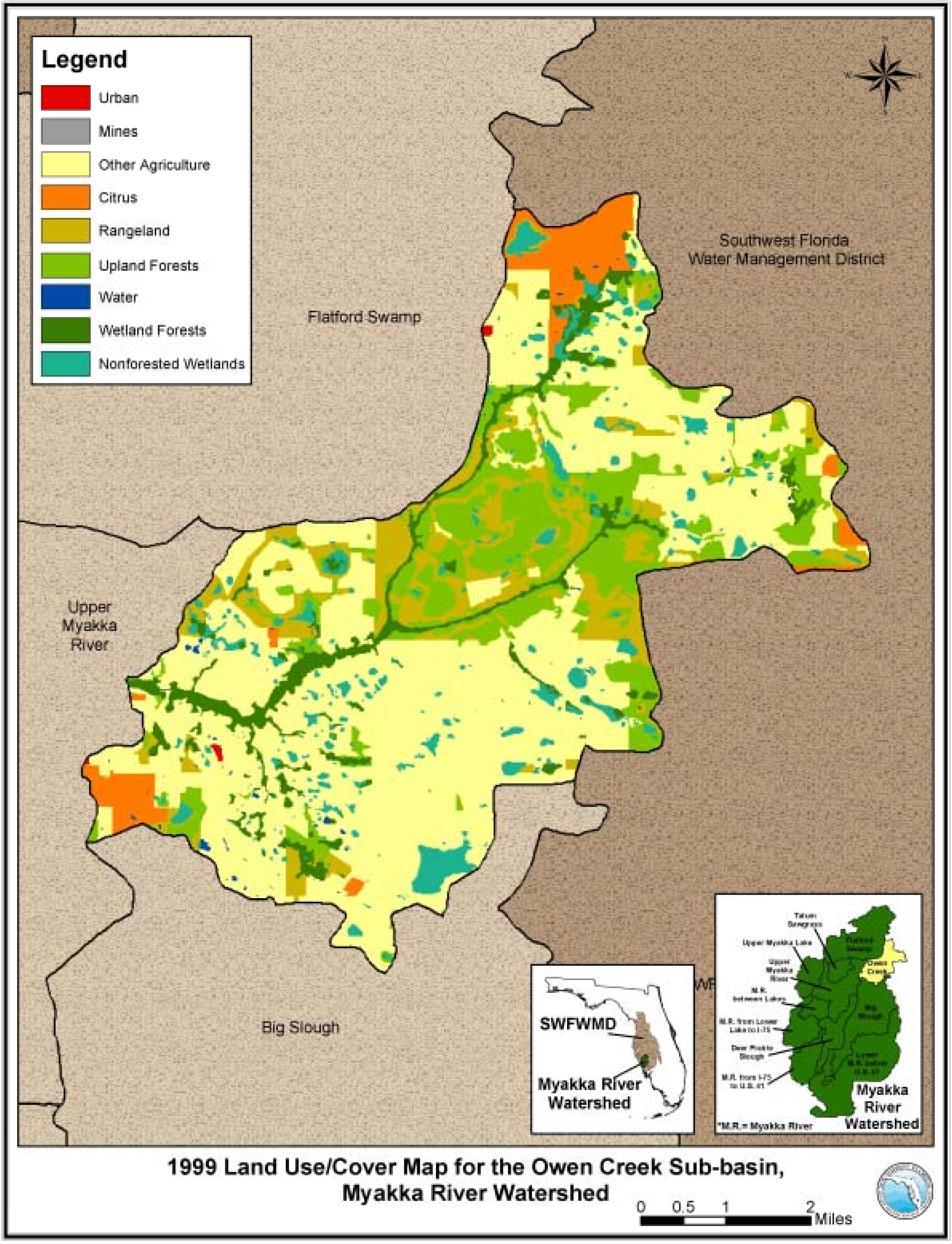


Figure 2-11. 1999 Land use/cover map of the Owen Creek sub-basin.

2.3.4 Tatum Sawgrass Sub-Basin

The single predominant land use in this sub-basin is agriculture (Table 2-5, Figure 2-12). In 1972, agricultural lands comprised approximately 53% while the total natural land use (wetlands and uplands). By 1999, agriculture had increased to almost 65%, while total acreage in uplands and wetlands decreased to less than 30%. The amount of urbanized land has increased from near 0% in 1972 to 4% in 1999, and citrus acreage has remained relatively stable, 7 to 8%.

Table 2-5. Land use/cover percentages in the 9,697-acre Tatum Sawgrass sub-basin for three time periods: 1972, 1990 and 1999.

Tatum Sawgrass	1972	1990	1999
Urban	0.0	1.1	4.0
Citrus	8.0	7.1	7.3
Other Agriculture	45.5	56.6	57.2
Uplands	15.5	10.9	8.6
Wetlands	29.7	23.3	20.2
Mines	0.0	0.0	0.0
Water	1.2	1.0	2.6

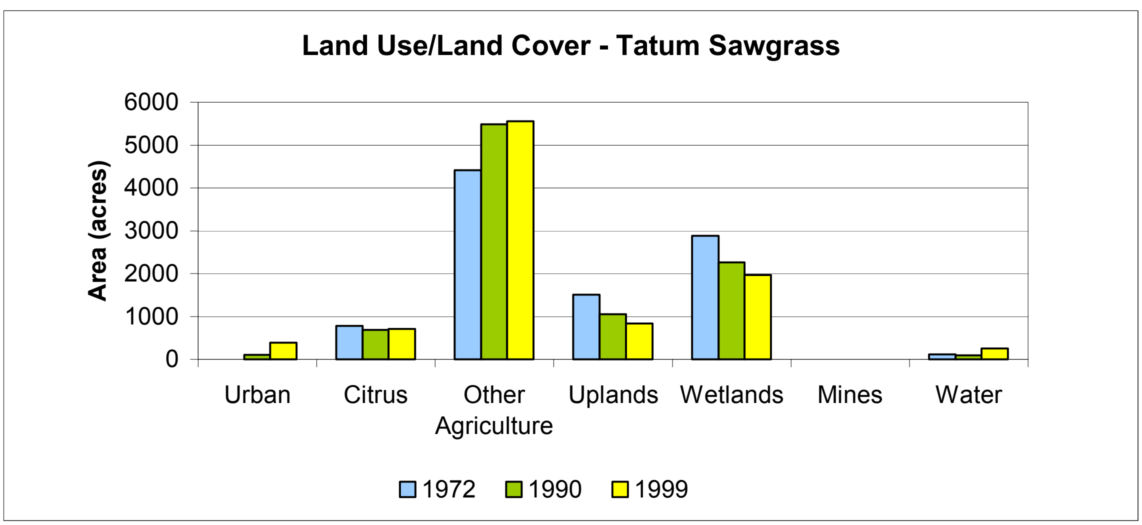


Figure 2-12. Land use/ cover in the Tatum Sawgrass sub-basin in 1972, 1990 and 1999.

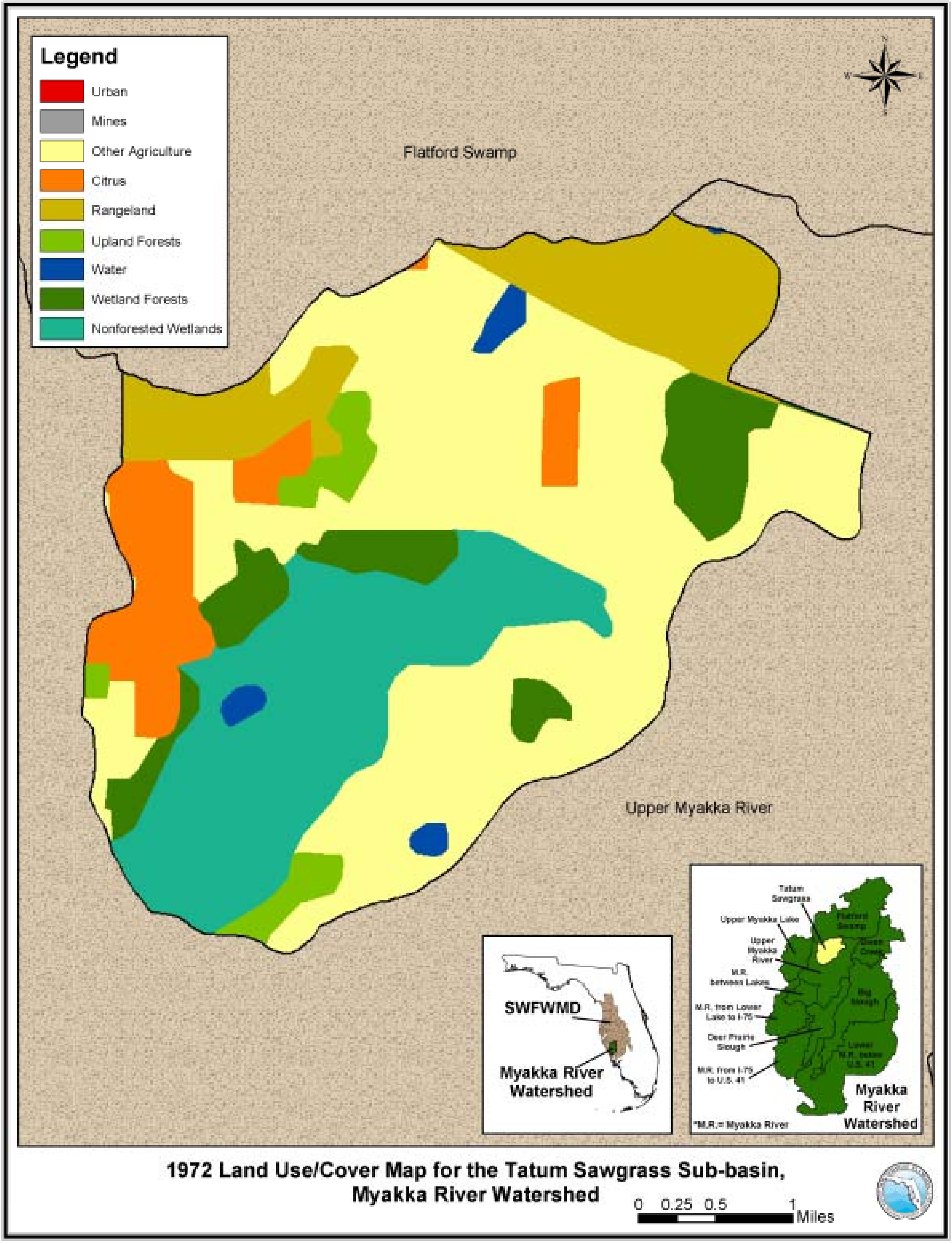


Figure 2-13. 1972 Land use/cover map of the Tatum Sawgrass sub-basin.

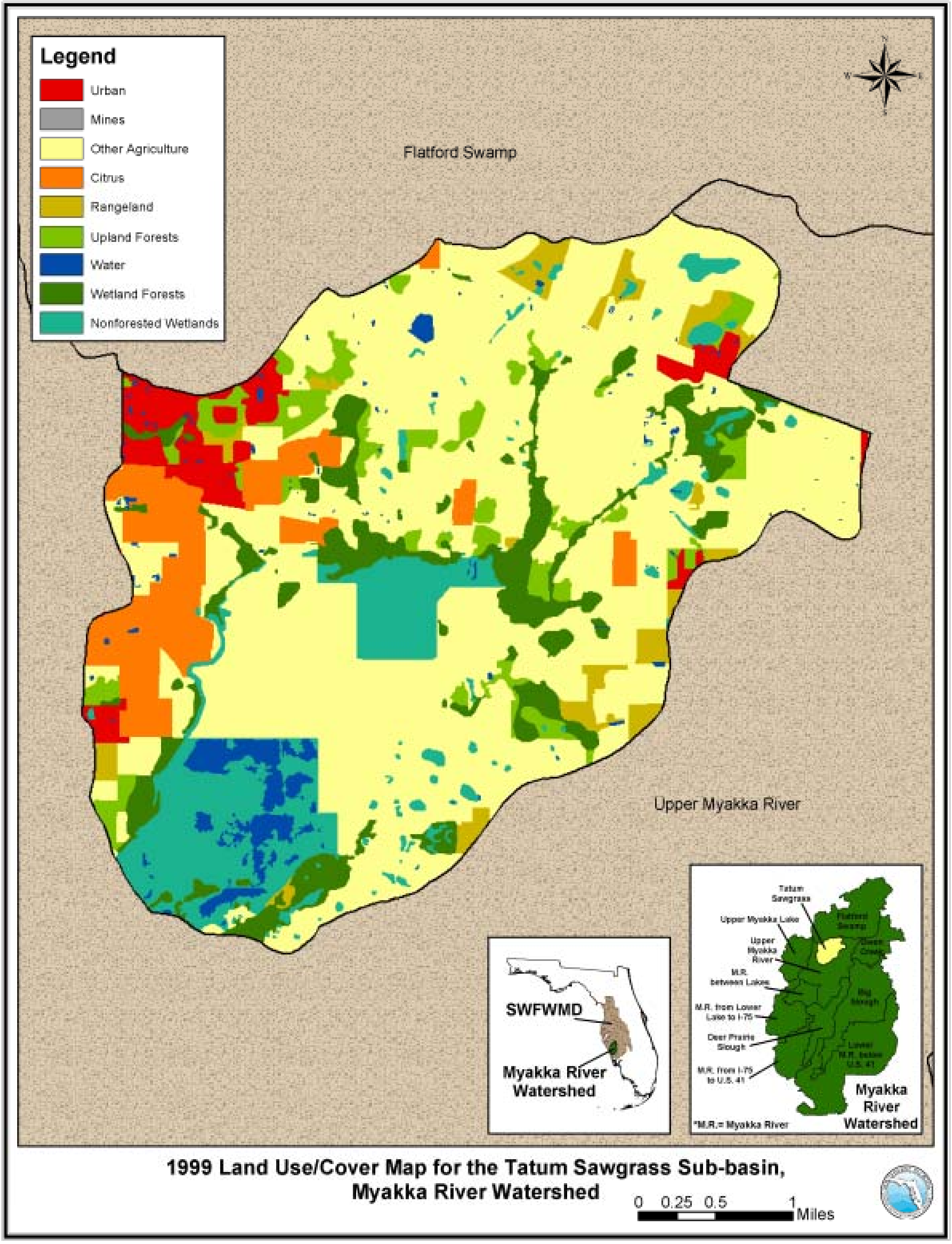


Figure 2-14. 1999 Land use/cover map of the Tatum Sawgrass sub-basin.

2.3.5 Upper Myakka Lake Sub-Basin

The dominant land use in the Upper Myakka Lake sub-basin is agriculture (Table 2-6, Figure 2-15). However, agricultural acreage has declined measurably, from almost 70% in 1972 to just over 55% in 1999. Most of this decline in agricultural use can be attributed to increased urbanization of the watershed as urban land use increased to cover an additional 10% of the watershed from 1972 to 1999.

Table 2-6. Land use/cover percentages in the 18,634-acre Upper Myakka Lake sub-basin for three time periods: 1972, 1990 and 1999.

Upper Myakka Lake	1972	1990	1999
Urban	1.3	9.1	11.7
Citrus	0.0	0.2	1.5
Other Agriculture	69.5	57.2	55.2
Uplands	25.8	13.5	12.9
Wetlands	3.4	18.8	17.6
Mines	0.0	0.0	0.0
Water	0.0	1.2	1.1

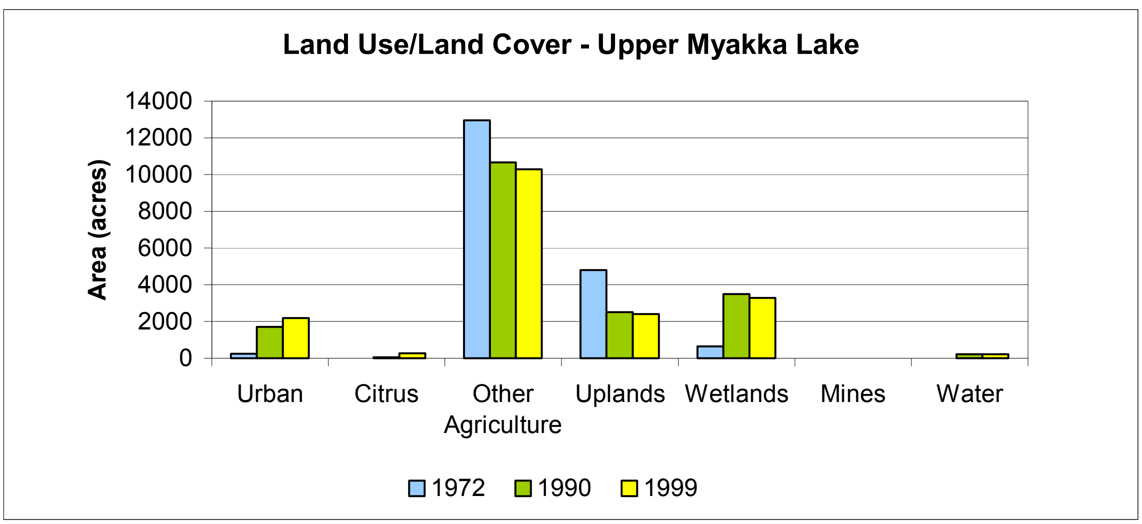


Figure 2-15. Land use/ cover in the Upper Myakka Lake sub-basin in 1972, 1990 and 1999.

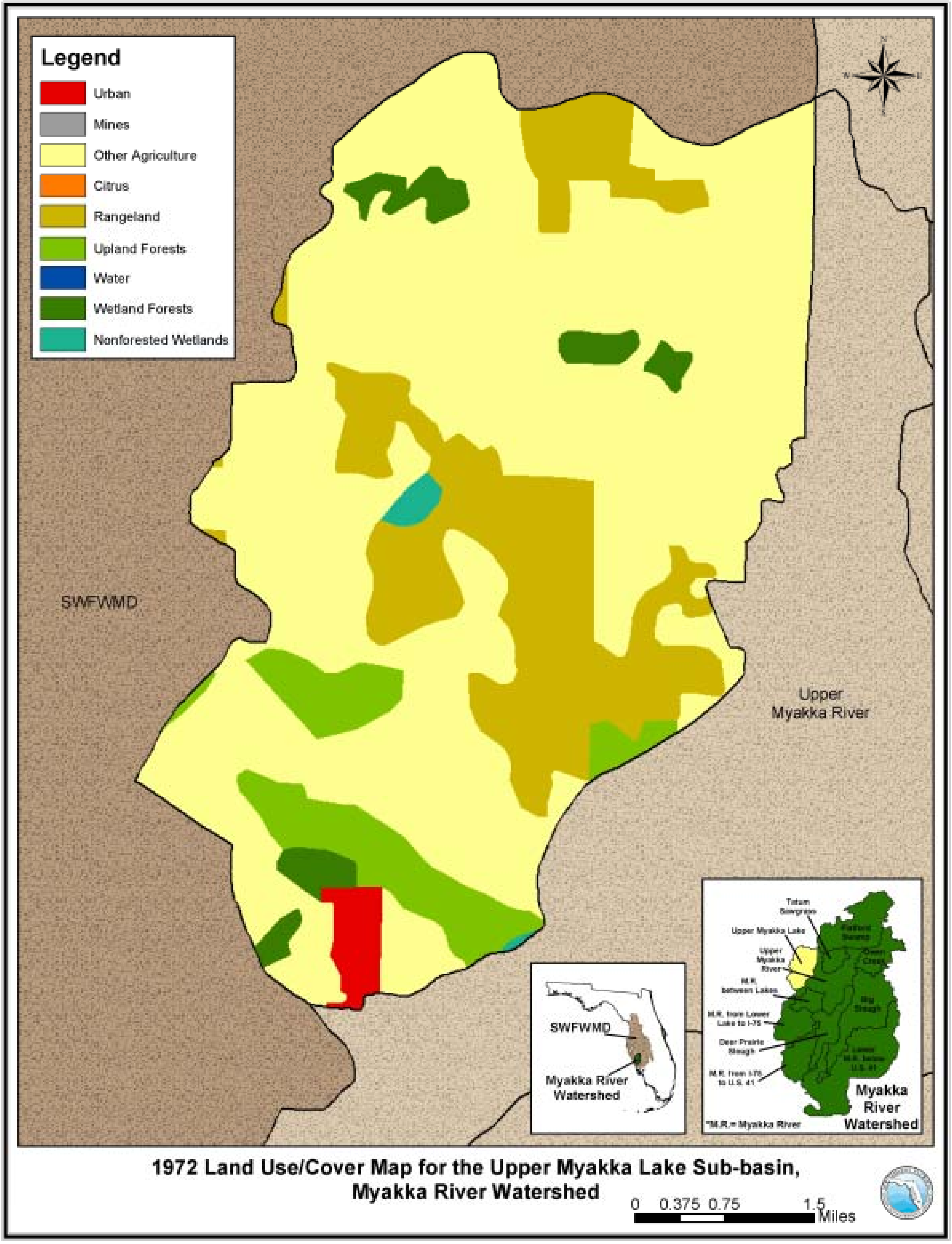


Figure 2-16. 1972 Land use/cover map of the Upper Myakka Lake sub-basin.

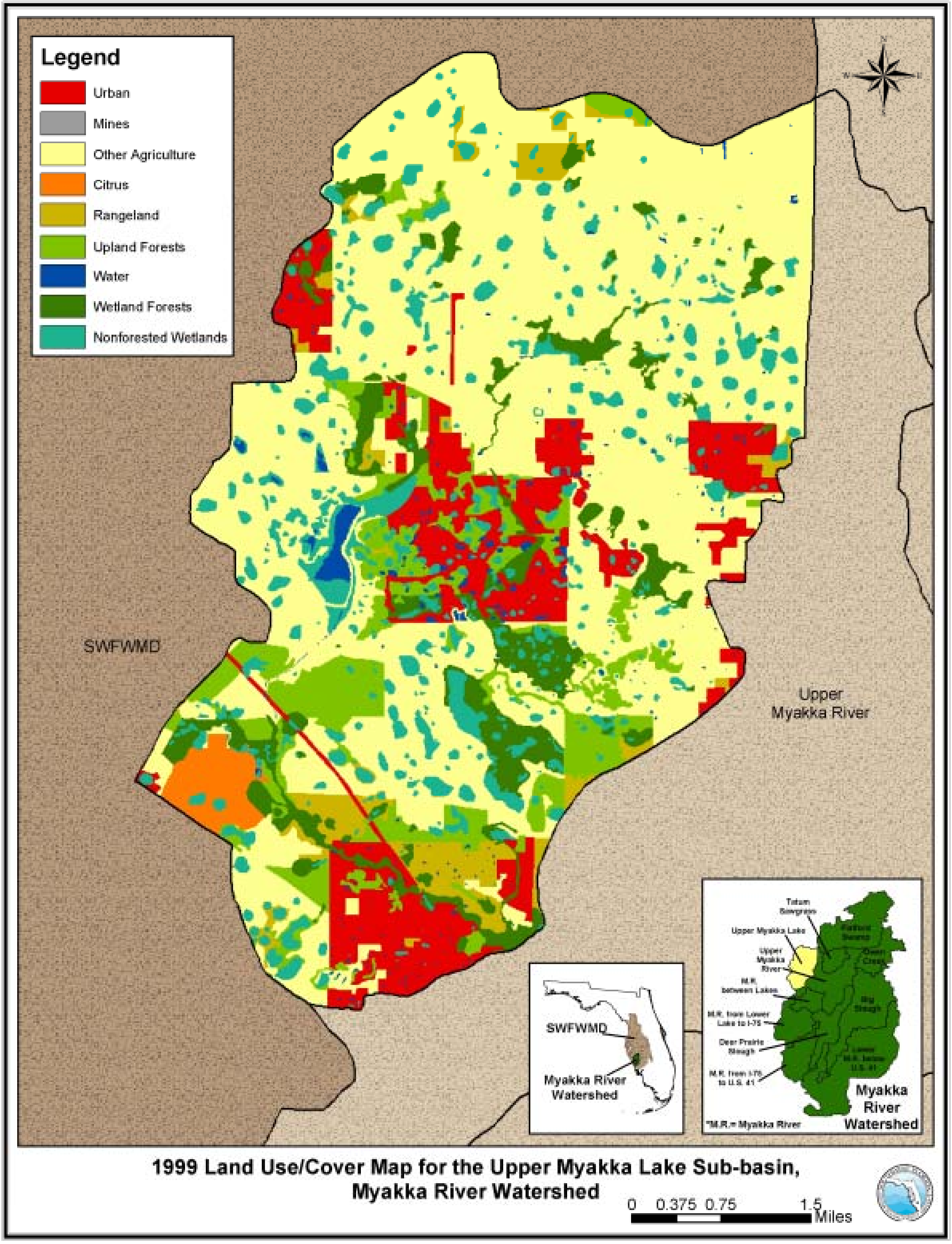


Figure 2-17. 1999 Land use/cover map of the Upper Myakka Lake sub-basin.

2.3.6 Upper Myakka River Sub-Basin

This sub-basin remains relatively undeveloped (Table 2-7, Figure 2-18). Net agricultural acreage has declined slightly over the period examined (1972 – 1999). The single greatest land use change has been in the amount of urbanized land (from less than 1% of the watershed in 1972 to slightly greater than 7% in 1999). During this time, combined acreage in uplands and wetlands declined slightly from approximately 58% in 1972 to about 54% in 1999.

Table 2-7. Land use/cover percentages in the 36,945-acre Upper Myakka River sub-basin for three time periods: 1972, 1990 and 1999.

Upper Myakka River	1972	1990	1999
Urban	0.8	4.1	7.3
Citrus	0.2	0.4	1.3
Other Agriculture	38.3	36.0	34.8
Uplands	45.9	31.3	28.3
Wetlands	12.5	26.0	25.4
Mines	0.0	0.0	0.0
Water	2.3	2.2	2.9

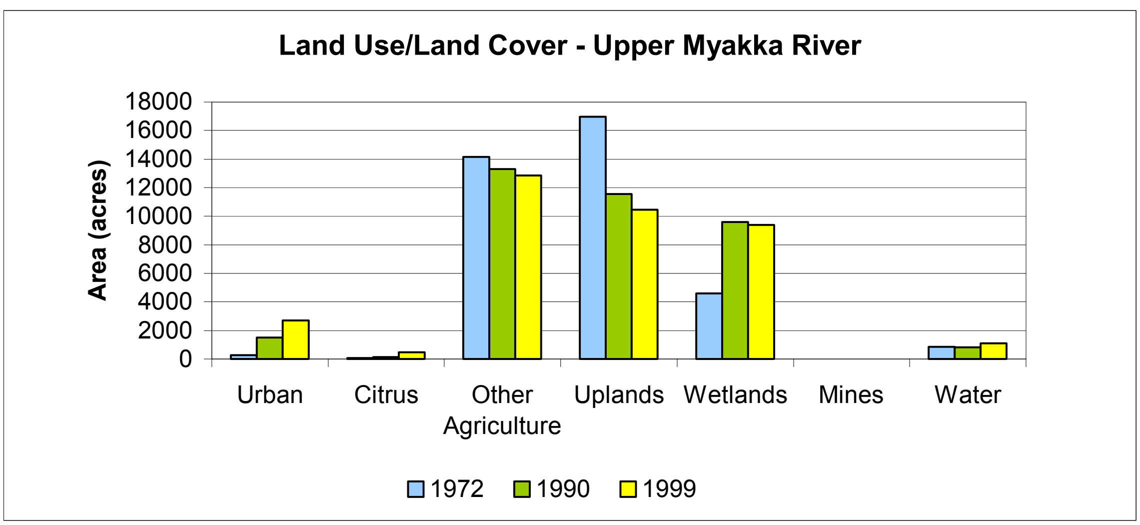


Figure 2-18. Land use/ cover in the Upper Myakka River sub-basin in 1972, 1990 and 1999.

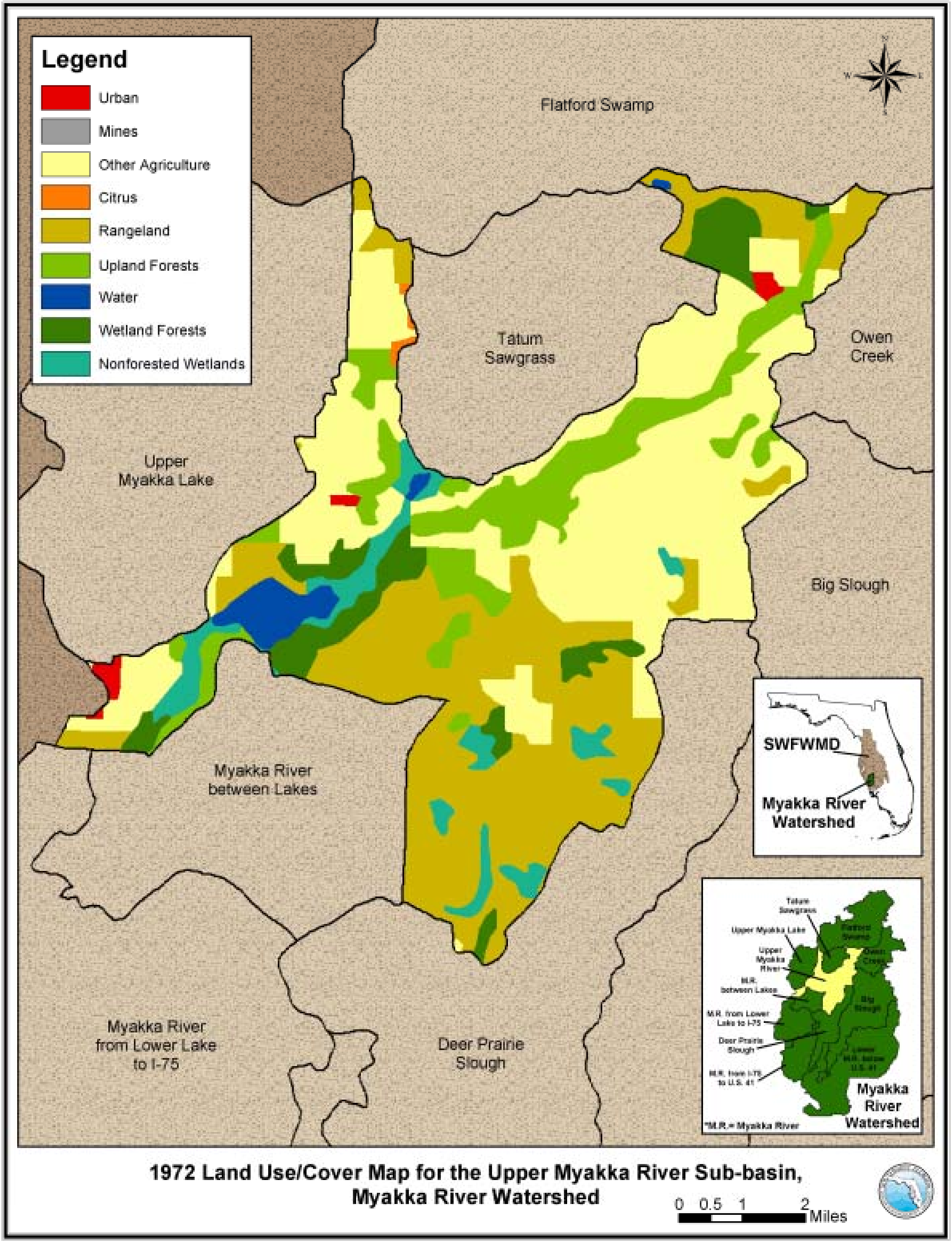


Figure 2-19. 1972 Land use/cover map of the Upper Myakka River sub-basin.

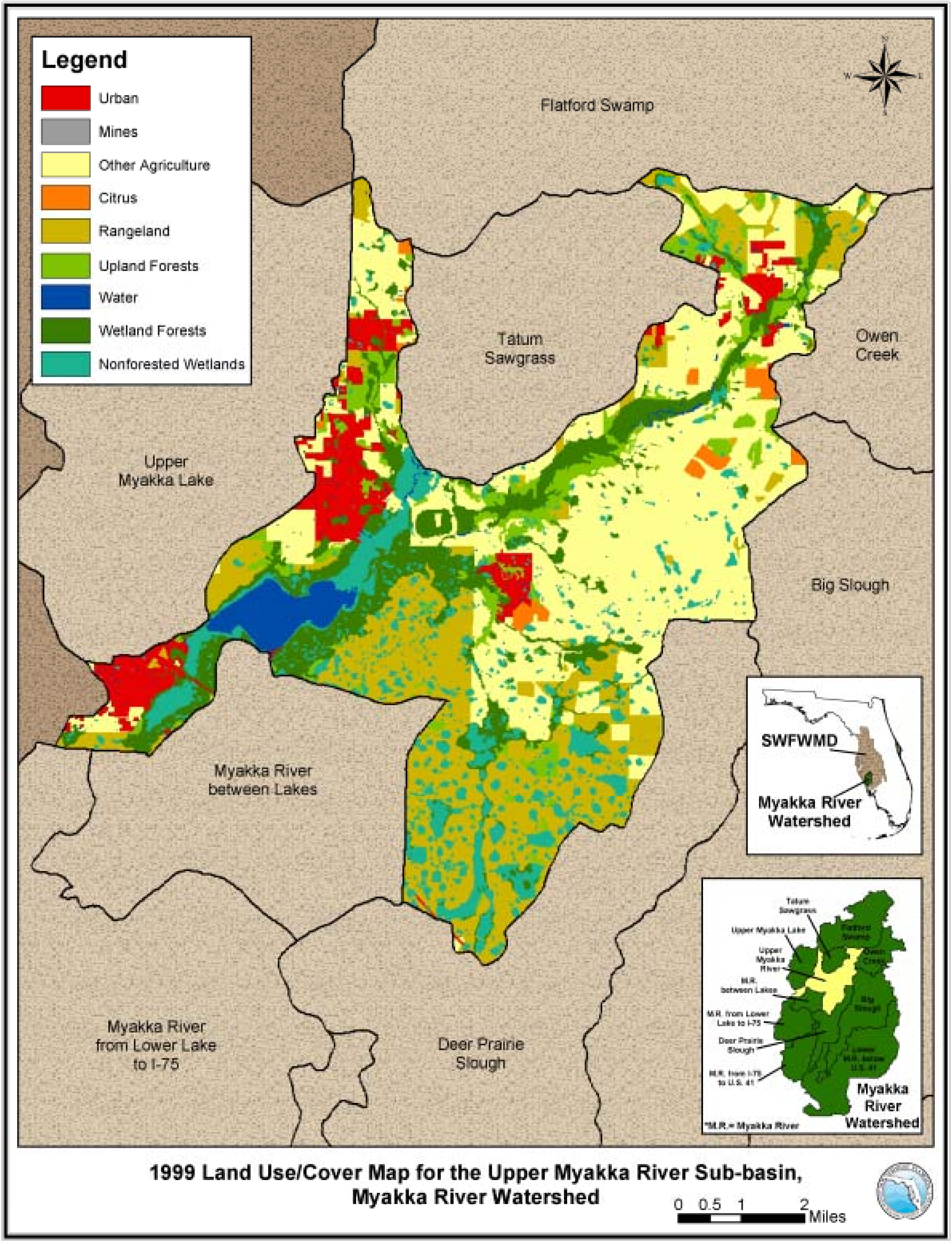


Figure 2-20. 1999 Land use/cover map of the Upper Myakka River sub-basin.

2.3.7 Myakka River between the Lakes Sub-Basin

The Myakka River between the Lakes sub-basin is largely undeveloped due to the presence of a state park and other conservation land holdings (Table 2-8, Figure 2-21). Greater than 92% of this sub-basin's watershed remains in either wetlands or uplands. Agriculture accounts for less than 4% of the sub-basin's area, and there is essentially no mining, no citrus and very little urbanization (less than 1%) in this sub-basin.

Table 2-8. Land use/cover percentages in the 10,843-acre Myakka River between the Lakes sub-basin for three time periods: 1972, 1990 and 1999.

M. R. between Lakes	1972	1990	1999
Urban	0.0	0.5	0.6
Citrus	0.0	0.0	0.0
Other Agriculture	0.0	3.0	3.8
Uplands	61.0	46.9	47.0
Wetlands	35.0	46.0	45.5
Mines	0.0	0.0	0.0
Water	4.0	3.6	3.1

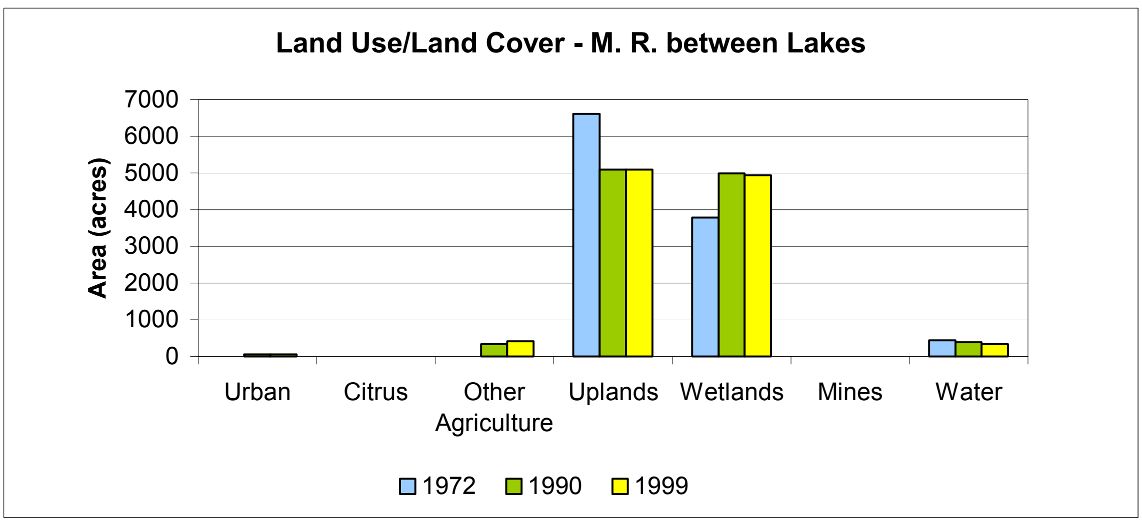


Figure 2-21. Land use/ cover in the Myakka River between the Lakes sub-basin in 1972, 1990 and 1999.

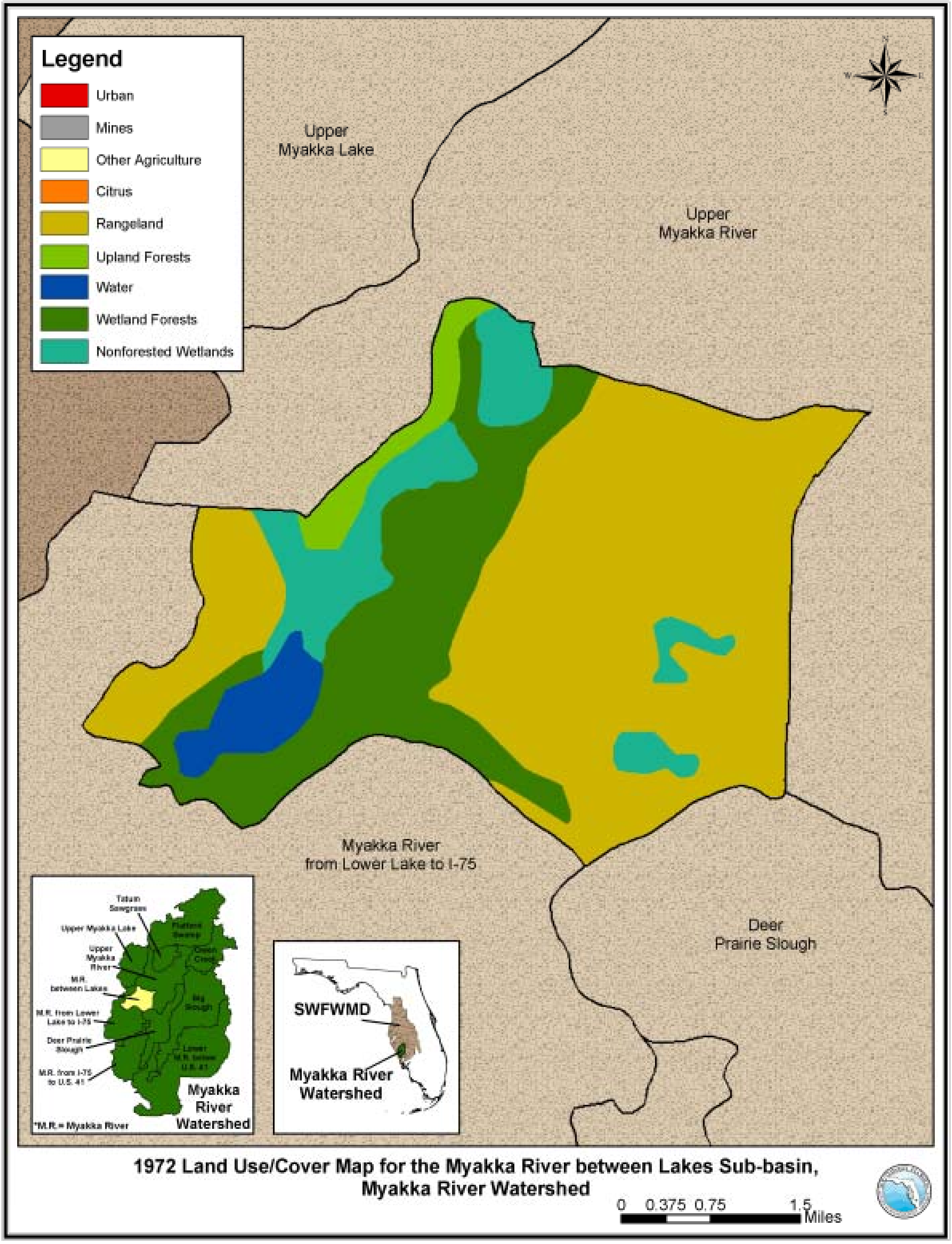


Figure 2-22. 1972 Land use/cover map of the Myakka River between the Lakes sub-basin.

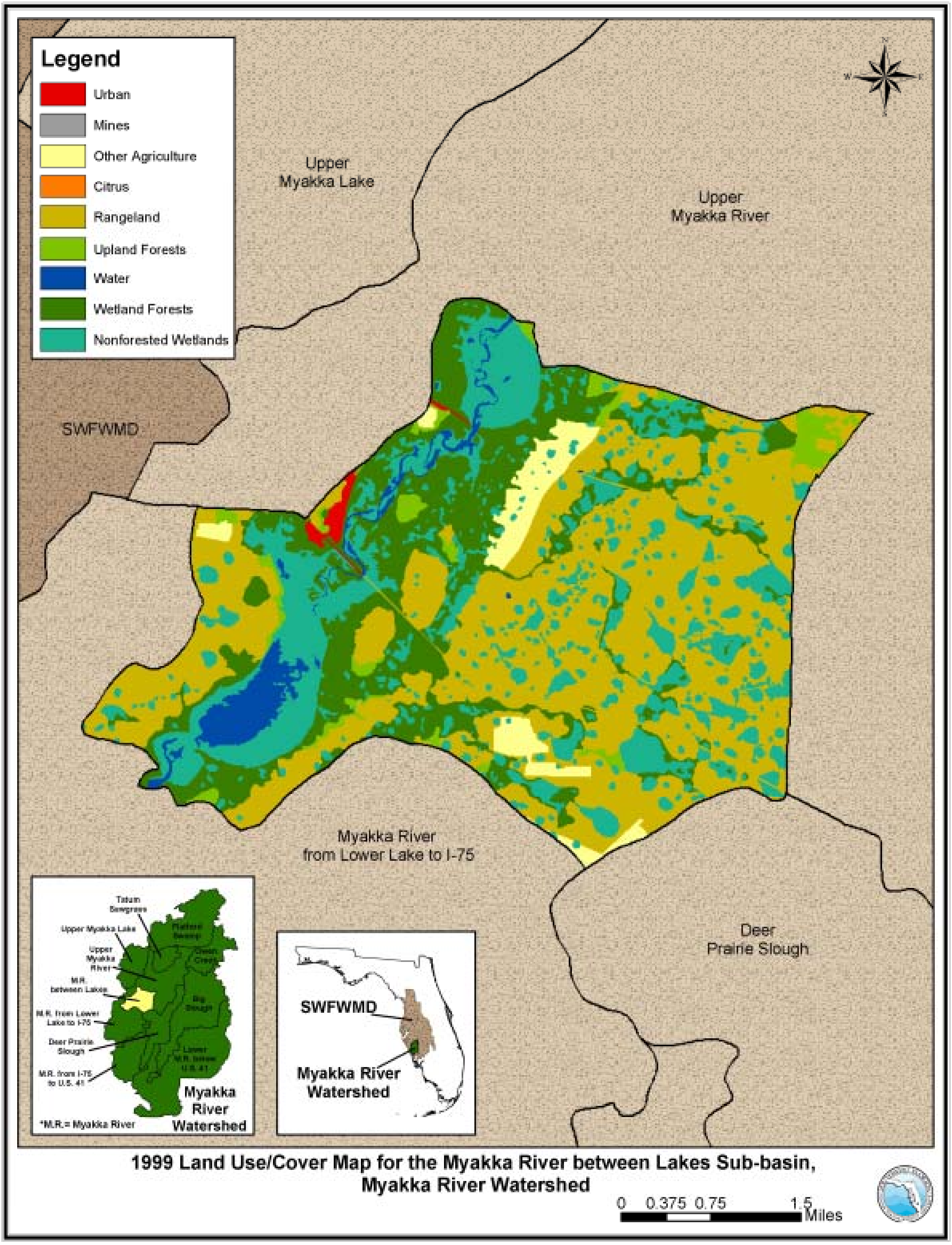


Figure 2-23. 1999 Land use/cover map of the Myakka River between Lakes sub-basin.

2.4 *Hydrology*

2.4.1 Overview

Unlike neighboring watersheds (e.g., Peace River and Alafia River) significant declining trends in flows in the Myakka River have not been documented. Hammett (1990) used the lack of a significant declining trend, in part, as evidence that climate was not the major factor controlling flow declines in neighboring watersheds, especially the Peace River. Kelly (2004), however, argued that there was a decline in Myakka River wet season flows similar to neighboring watersheds, and that the lack of a declining trend based on mean annual flows was more easily explained by offsetting dry-season flow increases. Kelly (2004) attributed flow declines largely to climate and increasing flows to anthropogenic factors. This is a primary assumption inherent in the minimum flow analyses used for the upper segment of the Myakka River and will be discussed in some detail in the following analysis.

The effect of the Atlantic Multidecadal Oscillation (AMO; see Enfield et al. 2001) on climate and river flows is considered briefly in this chapter, and its relevance and importance to developing MFLs in general and on the upper Myakka River in particular is discussed. We conclude that climate is a major factor that must be considered when developing baseline or benchmark periods for evaluating flow reductions and establishing MFLs. The chapter concludes with a discussion of the development of seasonal flow blocks that are utilized for minimum flow development.

2.4.2 Florida River Flow Patterns and the Atlantic Multidecadal Oscillation

> *"It would be reasonable to assume that given a fairly constant climate, the amount of water flowing down a river's course each year would vary evenly about an average value."* (Smith and Stopp 1978)

Smith and Stopp's statement reflects the typical paradigm with respect to the impact of climate on river flow. As a result, little attention has been paid to the potential for a climate change (oscillation) to affect river flows, and thus any change (trend) in flow other than expected annual variability has typically been assumed to be anthropogenic.

While much of Florida has a summer monsoon, the north to northwest portion of the state experiences higher flows in the spring similar to most of the southeast United States. Spatial and temporal differences in flows for southeastern rivers were highlighted by Kelly (2004) who used a graphical approach. By constructing plots of median daily flows (in cubic feet per second), seasonal flow patterns were clearly illustrated, and by dividing mean daily flows by the upstream watershed area, flows could be compared between watersheds of varying size. One of the more interesting features evident from this analysis was the existence of a distinctly bimodal flow pattern (Figure 2-24, bottom panel) which characterizes a number of streams in a rather narrow geographic band that extends from the Georgia-Florida border in the northeastern part of the state, where the St. Mary's River discharges into the Atlantic Ocean, towards the mouth of the Suwannee River in the Big Bend area. Rivers south of this line (most of peninsular Florida) exhibit highest flows in the summer (Figure 2-24, top panel), while those north of the line exhibit highest flows in the spring (Figure 2-24, middle panel).

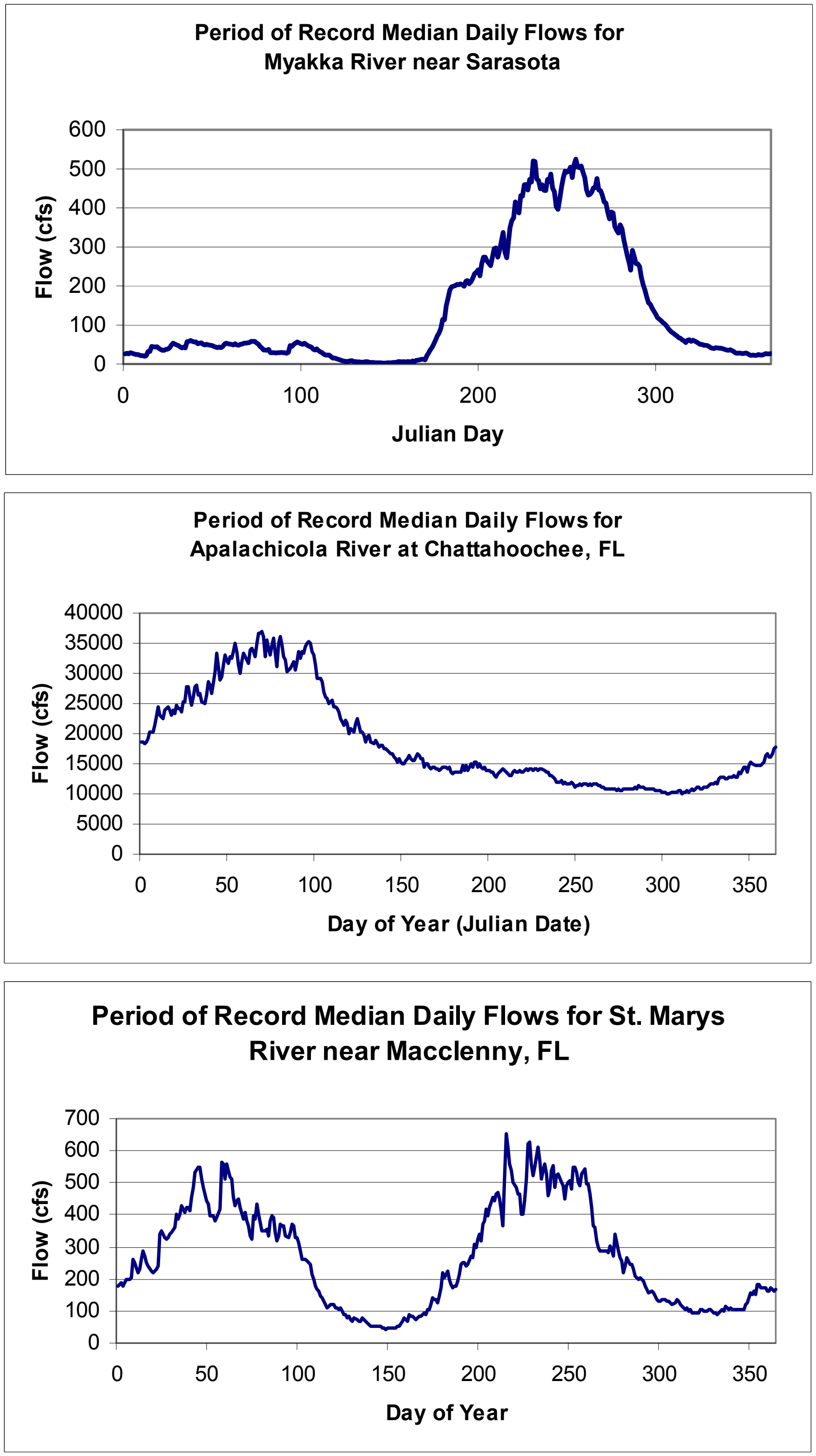


Figure 2-24. Examples of three river flow patterns: the Southern River Pattern (upper panel), the Northern River Pattern (center panel) and Bimodal River Pattern (bottom panel).

2.4.2.1 Multidecadal Periods of High and Low Flows

Citing Enfield et al. (2001), Basso and Schultz (2003) noted that the Atlantic Multidecadal Oscillation (AMO) offered an apparent explanation for observed rainfall deficits throughout central Florida. Although the SWFWMD and others (Hammett 1990, Hickey 1998) have discussed the lack of tropical storm activity and deficit rainfall in recent decades, the mechanism or mechanisms that would account for such differences were unknown. Based on an emerging body of research, climatologists now believe that multidecadal periods of warming and cooling of the North Atlantic Ocean's surface waters ultimately affect precipitation patterns across much of the United States. What is particularly interesting is that unlike most of the continental United States, there is for most of Florida a positive (rather than negative) correlation between rainfall and prolonged periods of North Atlantic Ocean sea surface warming (Enfield et al. 2001). While periods of warmer ocean temperature generally resulted in less rainfall over most of the United States, there are some areas, including peninsular Florida, where rainfall increased.

Since river flows are largely rainfall dependent, variation in rainfall should result in variations in river flows. To be consistent with the conclusions of Enfield et al. (2001) regarding the AMO and rainfall and with Basso and Schultz (2003) who examined long-term variations in rainfall in west-central Florida, Kelly (2004) reasoned that in Florida, flows would be highest at streamflow gage sites when sea surface temperatures in the North Atlantic are in a warm period (i.e., positively correlated). At the same time most of the continental United States would be expected to be in a period of lower flows. Conversely, the majority of continental gage sites would be expected to exhibit higher flows during AMO cool periods and much of peninsular Florida would be expected to be in a period of low flows.

Based on these hypotheses, Kelly (2004) examined flow records for multidecadal periods corresponding to warming and cooling phases of the AMO for numerous gage sites within the District, the state, and the southeastern United States to discern if increases and decreases in river flows were consistent with AMO phases. He concluded that flow decreases and increases in the northern part of the state and flow increases and decreases in peninsular Florida are consistent with the AMO and the reported relationship with rainfall. When rivers in peninsular Florida were in a multidecadal period of higher flows (1940 to 1969), rivers in the north to northwestern part of the state were in a low flow period. Conversely rivers in peninsular Florida exhibited generally lower flows (1970 to 1999) when rivers in the northern portion of the state exhibited higher flows. Examination of streams with a bimodal flow pattern offered particularly strong supporting evidence for a distinct difference in flows between northern and southern rivers, since differences between pre- and post 1970 flows that occurred during the spring were similar to differences noted for northern river flows while differences in summer flows were similar to flow changes that occurred in southern rivers.

2.4.3 Myakka River Flow Trends

2.4.3.1 Gage Sites and Periods of Record

Flow analyses in the Myakka River watershed focused on two USGS gage sites (Figure 2-1). The two sites are referenced by the USGS as the Myakka River near Sarasota gage and the Myakka River at Myakka City gage. The Myakka River near Sarasota gage has the longer flow record of the two, extending from 1936 to present. The USGS gage near Myakka City has a much shorter period of record. Flows at this site were monitored for a short time beginning in February 1963 to September 30, 1966, and have been monitored daily from October 1, 1977 to present.

2.4.3.2 Myakka River Flows

The upper Myakka River is defined as that segment of the river upstream of Lower Myakka Lake, and its flow is measured by the USGS Myakka River near Sarasota, FL gage. The lower or estuarine portion of the Myakka River is the subject of a separate MFL determination to be completed in 2006. Despite its shorter record, there is good agreement between flows measured at the two gage sites in the upper watershed. Figure 2-25 compares mean daily flows for the two sites after normalizing by watershed area (i.e., values expressed as cfs per square mile).

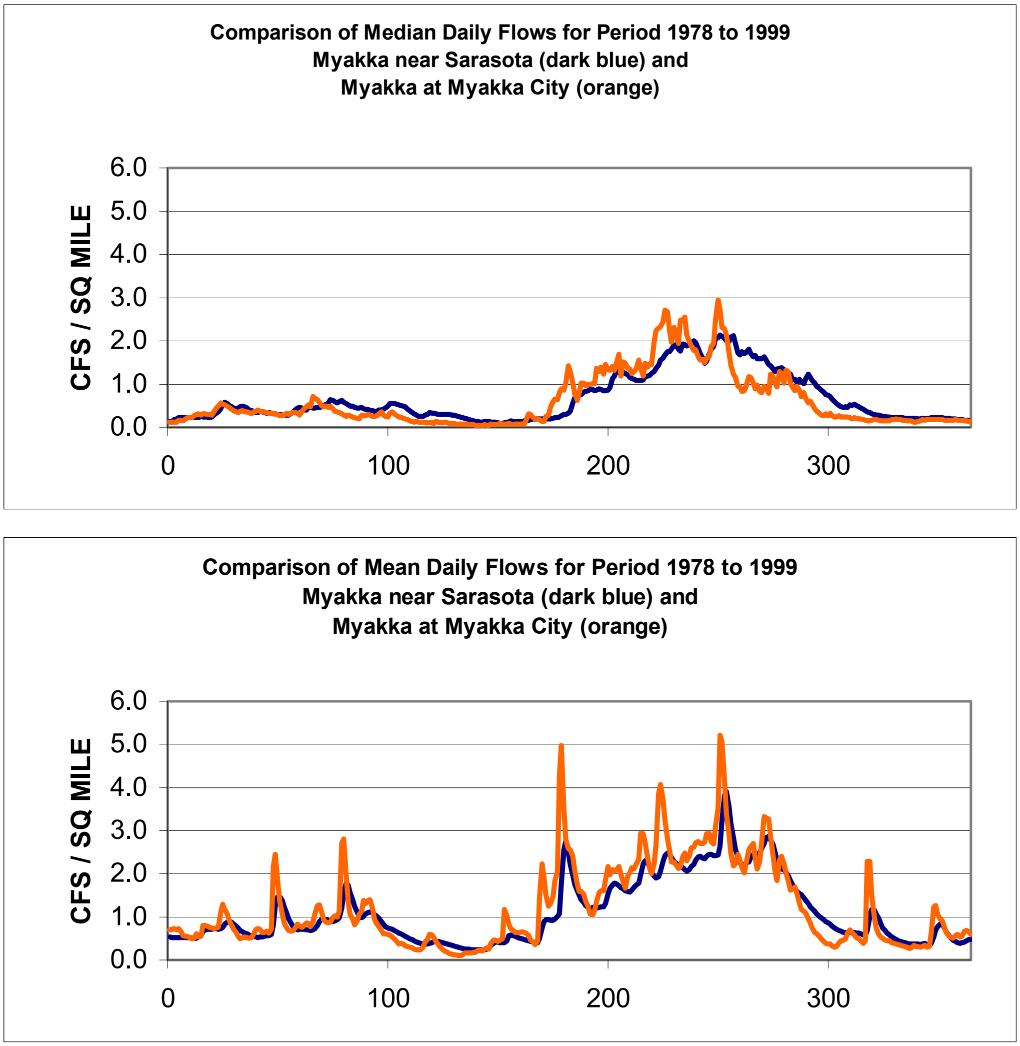


Figure 2-25. Comparison of median and mean daily flows at the Myakka River near Sarasota site with the Myakka River at Myakka City gage site. Comparisons are made based on flow records collected over the same time period in consideration of the shorter flow record for the Myakka City site.

A report by Hammett (1990) and its implications with respect to anthropogenic impacts on stream flow, particularly as measured at the Arcadia gage of the Peace River, have lead to considerable debate over impacts to Peace River flows (see Garlanger 2002, SWFWMD 2002, SDI 2003). Keeping in mind that Hammett (1990) was examining flow data only through 1985, she stated and then concluded, "If rainfall were the controlling factor, then all streamflow stations in the area would show similar trends, which is not the case." While we concur with the opening phrase of her statement, we do not agree with the resulting conclusion. Hammett used the Kendall's tau test to evaluate whether a site demonstrated a significant declining trend in flow, and applied an alpha level of 0.1 to her analysis. Simply stated, if the alpha level at a site was greater than

0.1, then no trend was assumed. Since flows at the Peace River at Arcadia, FL gage met her criterion for significance with its alpha level at exactly 0.1 (see Table 16 in Hammett 1990), a significant trend was indicated. Both Charlie Creek and Horse Creek exhibited relatively low alphas, 0.17 and 0.11, respectively; however, neither site met the criterion for statistical significance, and it was apparently assumed that they did not exhibit similar flow trends. No flow plots similar to the Arcadia plot in Hammett's report were generated for either of these sub-basins. If this had been done a different conclusion may have been reached.

One might anticipate flows in the Myakka River or Joshua Creek (a tributary to the Peace River which enters downstream of the Arcadia gage) to exhibit flow trends similar to the Peace River at Arcadia. The fact that they do not compare as favorably as might be expected is attributable more to anthropogenic flow increases in the Myakka River and Joshua Creek rather than to anthropogenic flow decreases in the Peace River. The lack of agreement in flow trends among some of these sites is the result of anthropogenic factors acting on those sites.

In recent years, there has been a dramatic increase in dry season flow in the upper Myakka River, one of the sites to which Hammett (1990) compared the Arcadia gage flows. The Myakka River near Sarasota gage site shows an increasing trend in low flow beginning in the late 1970s (Figure 2-26, upper panel). It is believed that this increasing flow trend is due largely to agricultural practices. Consistent with the AMO discussion presented earlier, we should not expect to see increasing flow trends during the 1980s and midway into the 1990s; however, significant increases are apparent, and these increases are of sufficient magnitude to noticeably affect median flows (Figure 2-26, fourth panel). Comparison of flow trends between multiple decades clearly shows an increase in low flows in the upper Myakka River basin during the typical lower flow months (November through May). There was more than 100% increase in median daily flows during the lower flow months when the period 1940 to 1969 is compared with the period 1970 to 1999. A comparison of high flow months between these two time periods, however, shows a 23% decrease in flows (based on median daily flows; see Figure 2-27 and Table 2-9).

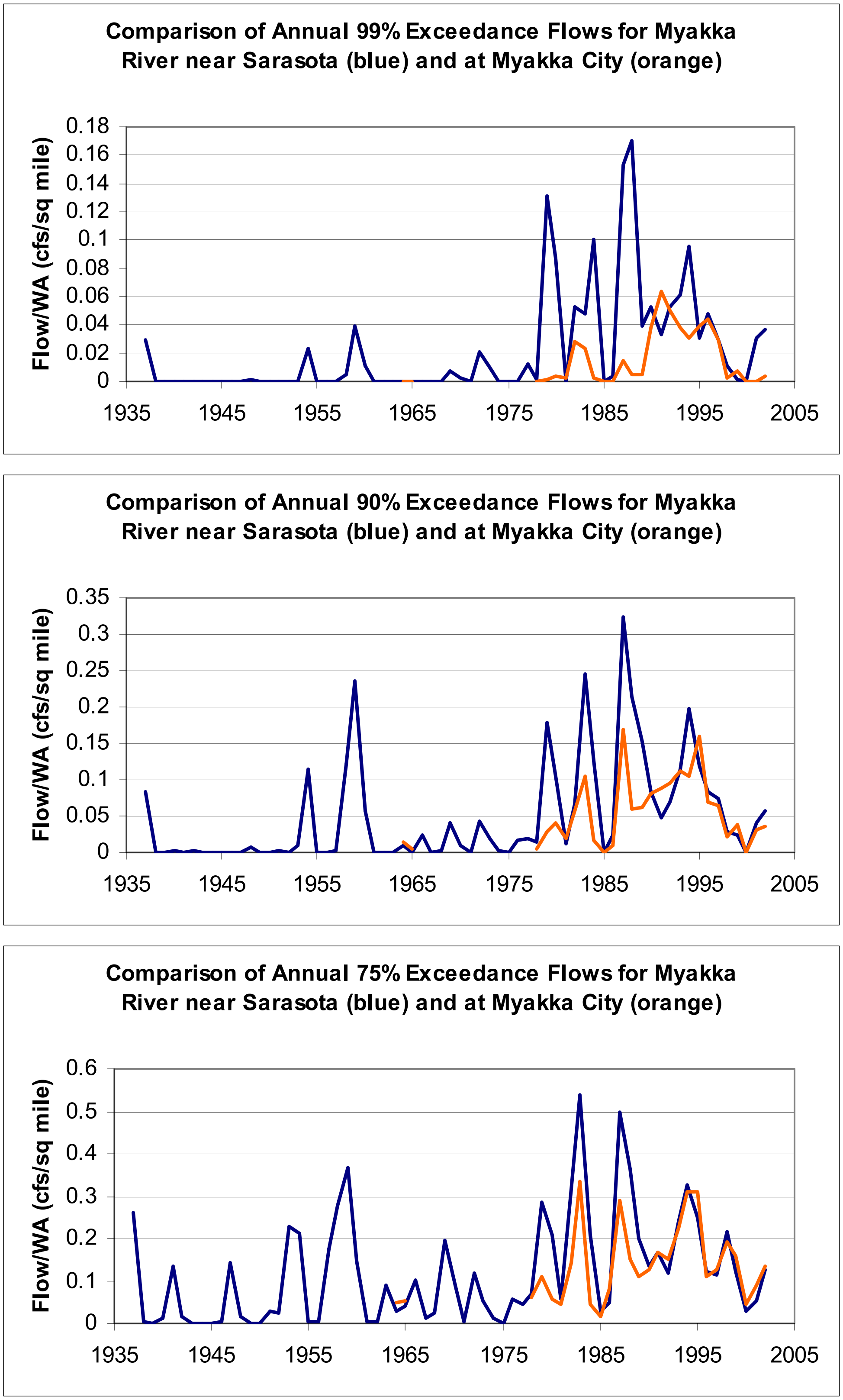
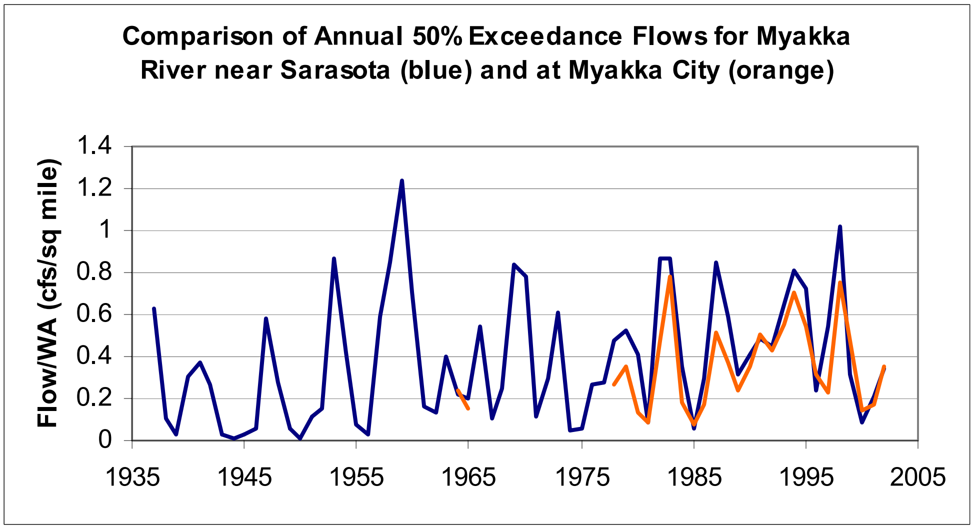
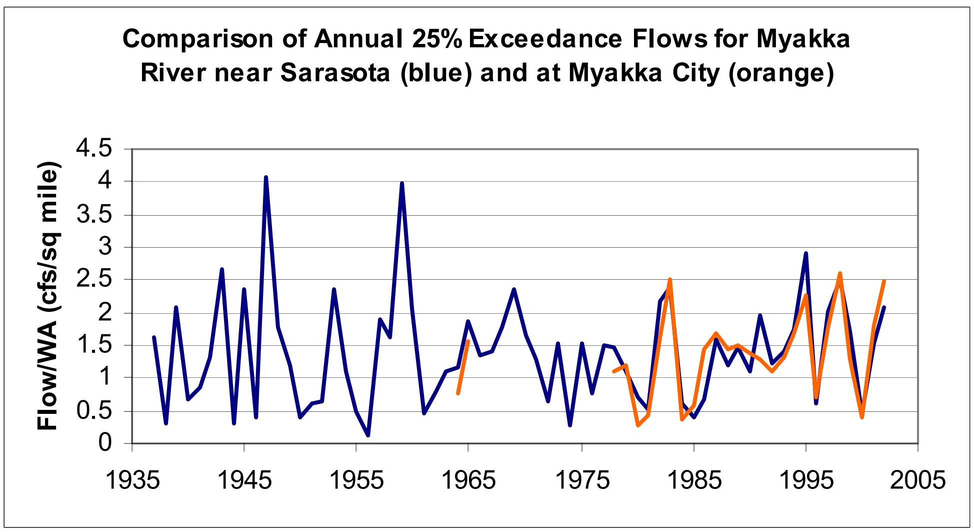


Figure 2-26. Comparison of select normalized (to watershed area) annual percent exceedance flows for the Myakka River near Sarasota gage and at the Myakka City gage.





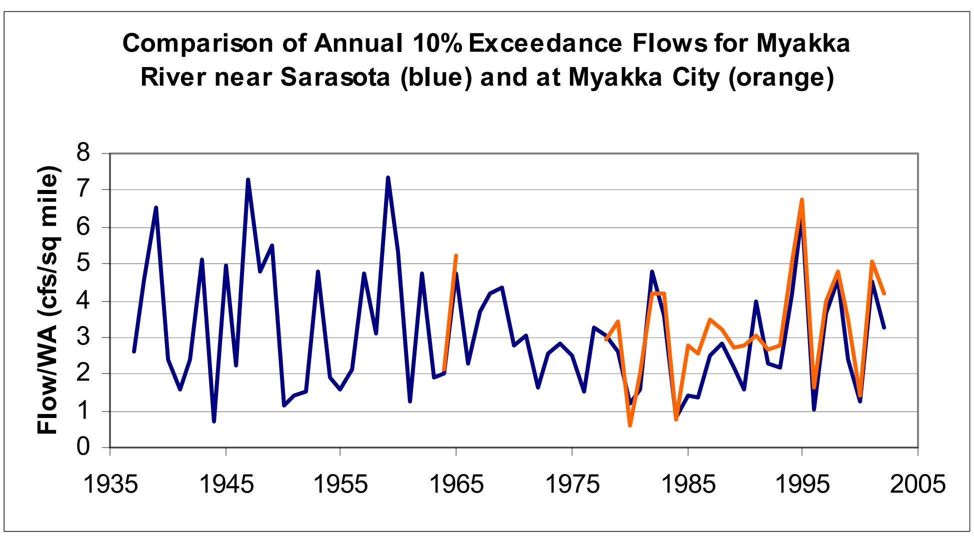
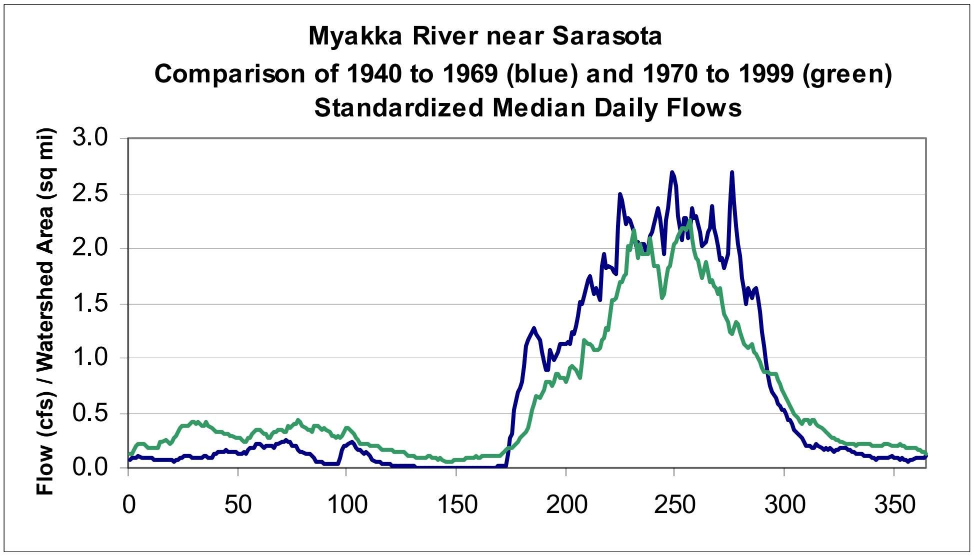


Figure 2-26 (continued). Comparison of select normalized annual percent exceedance flows for the Myakka River near Sarasota gage and at the Myakka City gage.



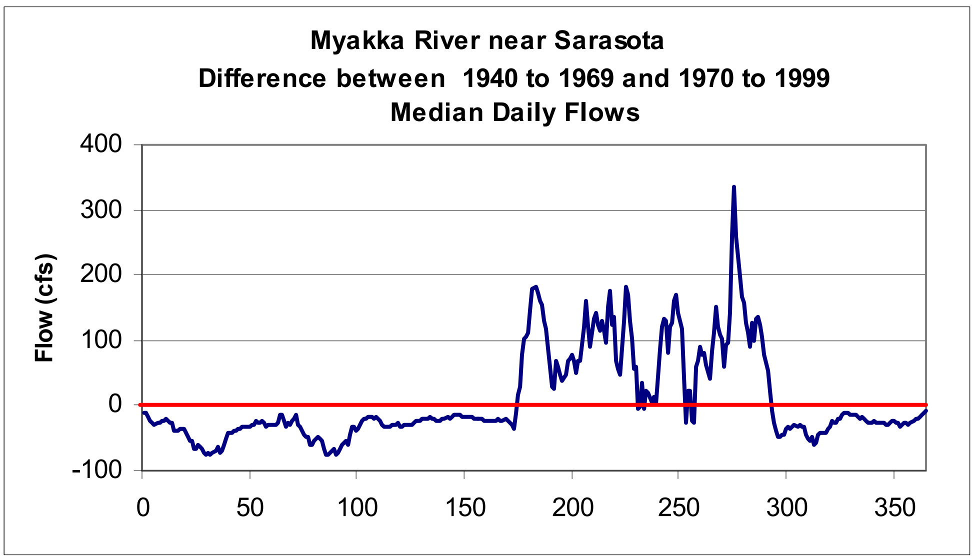


Figure 2-27. Comparison of median daily flows for the Myakka River near Sarasota for two time periods (1940 to 1969 and 1970 to 1999).

Table 2-9. Comparison of changes in median daily flow for the Myakka River near Sarasota gage for two time periods (1940 to 1969 and 1970 to 1999). Changes are expressed for the entire annual cycle and for three seasonal flow "blocks" as discussed in the text.

# USGS 02298830 MYAKKA RIVER NEAR SARASOTA FL				
	Block 1	Block 2	Block 3	Year
Mean of 40 to 69 Daily Median Flow/WA:	0.03	0.14	1.69	0.64
Mean 40 to 69 Daily Median Flow (inches)	0.06	0.93	7.75	8.74
Percentage of annual flow	0.72	10.62	88.66	100.00
Mean of 70 to 99 Daily Median Flow/WA:	0.12	0.30	1.30	0.60
Mean 70 to 99 Daily Median Flow (inches)	0.30	1.95	5.95	8.20
Percentage of annual flow	3.63	23.73	72.64	100.00
Mean of 40 to 69 Daily Mean Flow/WA:	0.27	0.43	2.63	1.14
Mean of 40 to 69 Mean Daily Flow in inches	0.67	2.79	12.05	15.50
Percentage of annual flow	4.32	17.97	77.71	100.00
Mean of 70 to 99 Daily Mean Flow/WA:	0.37	0.67	1.96	1.05
Mean of 70 to 99 Mean Daily Flow in inches	0.93	4.36	9.00	14.30
Percentage of annual flow	6.54	30.52	62.95	100.00
Percent Change between periods	Block 1	Block 2	Block 3	Year
40 to 69 versus 70 to 99 Median Daily Flows	-370.12	-109.77	23.13	6.17
40 to 69 versus 70 to 99 Mean Daily Flows	-39.67	-56.59	25.31	7.79

A Comparison of Mean Annual and Median Annual Flows for the Myakka River at Sarasota

Hammett (1990) found no statistically significant trend in mean annual flows for the Myakka River at Sarasota for the period of record based on a Kendall's tau analysis. A similar analysis of data from 1937 through 2002 yielded similar results. The slope of the trend line is very close to zero (p-value = 0.9559; see Figure 2-28). [NOTE: It should be noted that rather than using a calendar year or USGS water year, the analysis cited here was done on a Southern River Pattern Water Year (SRPWY) which begins on April 20th rather than January 1 of the year in question. While we feel that this is the most appropriate way to analyze these data, most past evaluations (e.g. Kelly 2004, Hammett 1990) were done on the basis of the calendar year. This explains why some annual means and medians may not be exactly the same when comparing reports.]

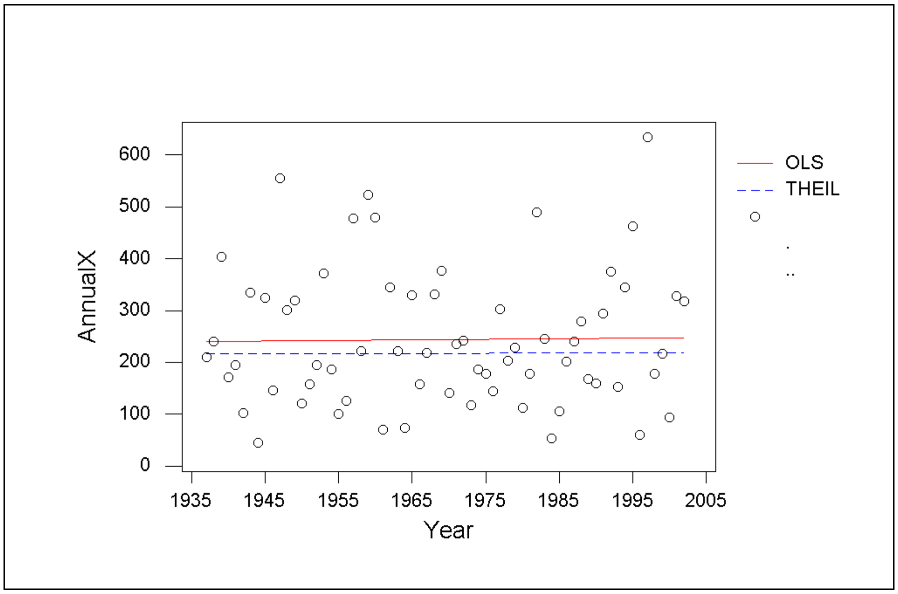


Figure 2-28. Graphical results of Kendall's tau test of mean annual flows for the Myakka River near Sarasota for the period of 1937 to 2002. The red line is the Ordinary Least Squares line, and the blue line is the Kendall's tau Thiel line. The p value was 0.9559.

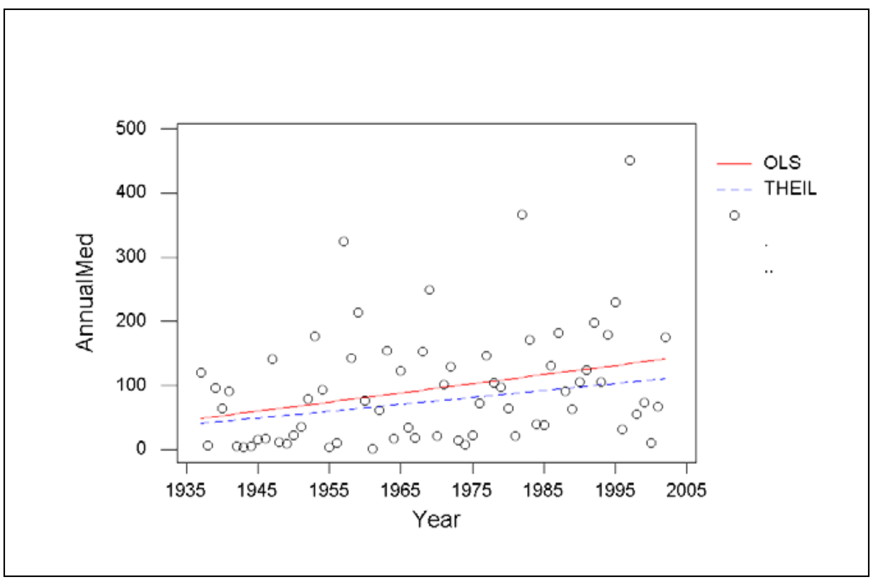


Figure 2-29. Graphical results of Kendall's tau test of median annual flows for the Myakka River near Sarasota for the period 1937 to 2002. The red line is the Ordinary Least Squares line, and the blue line is the Kendall's tau Thiel line. The p value was 0.00429.

Interestingly, there has been a statistically significant increasing trend in the median annual flows for the Myakka River near Sarasota for the same period of record (see Figure 2-29). The p value for this Kendall's tau analysis of median annual flows for the period 1937 to 2002 was 0.00429. When comparing means and medians for two thirty year periods (1940 to 1969 and 1970 to 1999), it was found that the mean annual flow decreased from 252 cfs to 231 cfs; at the same time, however, the median annual flow increased from 78 cfs to 116 cfs (a 38 cfs or 25 mgd increase). Considering that we would have expected flows to naturally decline between the two periods based on the AMO (see Kelly 2004), much if not all of the flow increase is believed to be related to agricultural water use and management in the watershed.

2.4.3.3 Step Trend in River Flows

Kelly (2004) argued, similarly to McCabe and Wolock (2002), that there was a step change in river flow volumes related to climatic change associated with the Atlantic Multidecadal Oscillation (AMO). This is shown graphically for the Peace River at Arcadia, FL gage site in Figure 2-30. The upper panel of the figure shows the results of a Kendall's tau regression of mean annual flows at the site versus time for the period 1940 to 1999. The Kendall's tau p-value was 0.0269 with a slope of –8.825 cfs/yr indicating a statistically significant declining trend. However, using 1970 as a break-point and repeating the analysis for the periods from 1940 to 1969 and 1970 to 1999 (periods corresponding to warm and cool-water phases of the AMO) indicated that there were no significant trends for either period. As can be seen in the middle panel of Figure 2-30, there was not a statistically significant trend in mean annual flows for the period 1940 to 1969; p = 0.8028, slope = –1.947. In the lower panel, Kendall's tau analysis for the period 1970 to 1999 also showed no significant trend; p = 0.5680, slope = 3.759. A Mann-Whitney test for differences between mean annual flows for the two multidecadal time periods indicated that flows at the Arcadia gage site were significantly greater (p=0.0035) during the earlier period (1940 to 1969) as compared to the more recent period (1970 to 1999). Similar results were found for other area rivers and are noted (Tables 2-10 and 2-11), providing evidence for a step change in Peace River flows rather than a monotonic trend as suggested by Hammett (1990). To paraphrase slightly McCabe and Wolock (2002), the identification of an abrupt decrease in peninsular Florida streamflow rather than a gradual decreasing trend is important because the implications of a gradual trend is that the trend is likely to continue into the future whereas the interpretation of a step change is that the climate system has shifted to a new regime that will likely remain relatively constant until a new shift or step change occurs.

The Myakka River, and to a lesser extent the Little Manatee River, are notable exceptions to the expected step trend in river flows (Tables 2-10 and 2-11). It is believed that in both watersheds, the expected flow decrease does not appear when mean annual flows are examined because the low flows are augmented, effectively countering the climatic-driven decline.

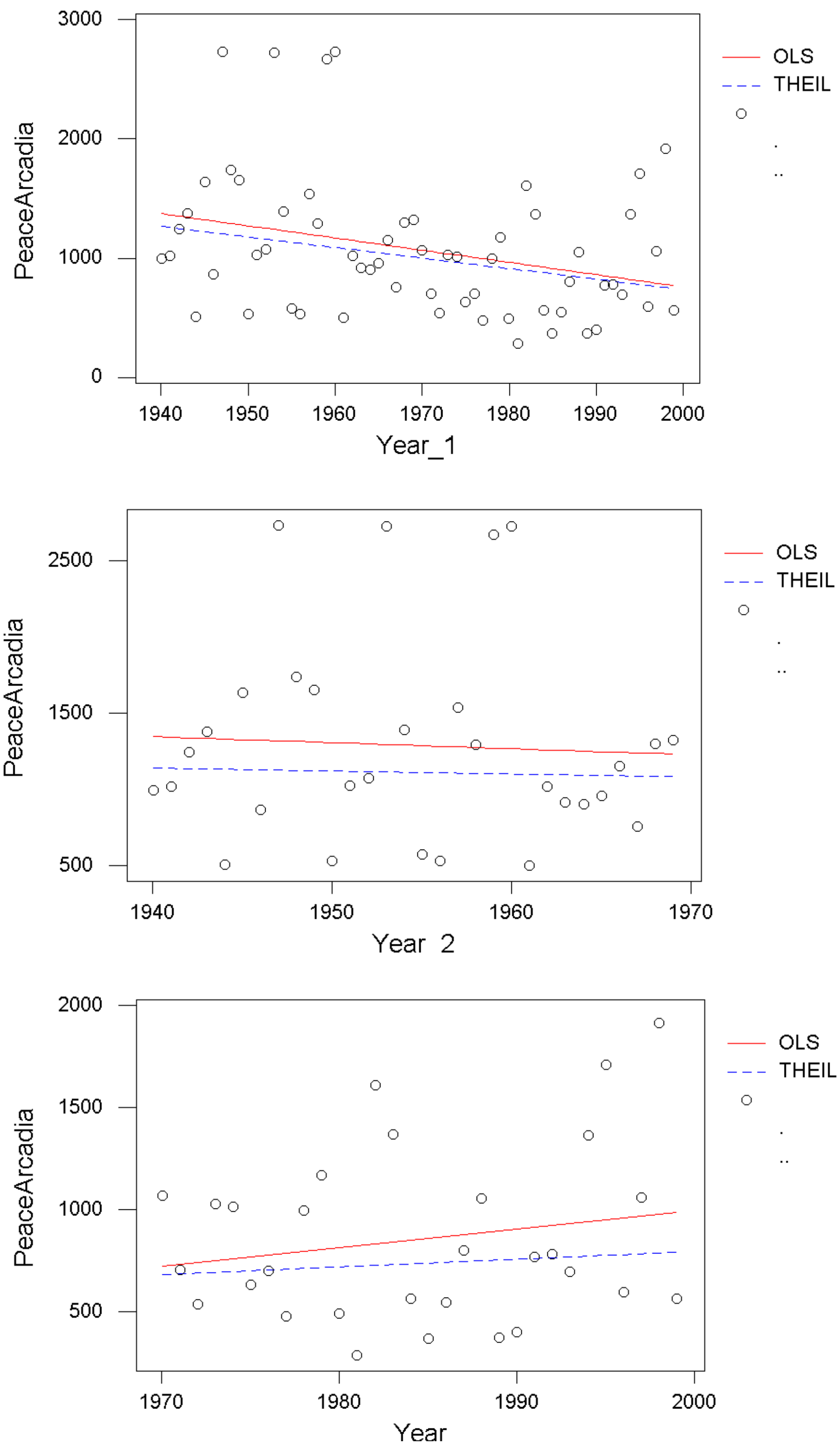


Figure 2-30. Graphical results of Kendall's tau test of mean annual flows for the Peace River at Arcadia for the period 1940 to 1999 (upper panel), 1940 to 1969 (middle panel), and 1970 to 1999 (lower panel). The red line is the Ordinary Least Squares line, and the blue line is the Kendall's tau Thiel line.

Table 2-10. Results of Kendall's tau test of mean annual flows (XannQ) for selected gage sites and selected time periods. P values < 0.1 are highlighted in bold; those associated with flow decreases are shaded yellow, those that indicate flow increases are shaded blue. Table is an excerpt from a table in Kelly (2004).

Site Name	1940 to 1999				1940 to 1969				1970 to 1999			
	XAnnQ	MedAnnQ	Slope	p	XAnnQ	MedAnnQ	Slope	p	XAnnQ	MedAnnQ	Slope	p
Alafia River at Lithia	336	309	-2.122	**0.0653**	388	375	3.796	0.3353	284	268	0.1081	1.0000
Hillsborough River near Tampa	454	387	-6.3982	**0.0003**	632	516	3.149	0.6947	276	264	0.1813	0.9147
Hillsborough River at Zephyrhills	248	209	-1.223	**0.0419**	292	247	1.189	0.6427	202	187	1.703	0.4754
Little Manatee River near Wimauma	171	159	-0.331	0.6324	184	178	0.3341	0.9431	158	139	2.318	**0.0867**
Myakka River near Sarasota	251	227	0.4538	0.5966	261	215	1.721	0.5680	241	228	4.405	0.1435
Peace River at Arcadia	1073	1006	-8.825	**0.0268**	1289	1113	-1.947	0.8028	856	738	3.759	0.5680
Peace River at Bartow	228	183	-2.425	**0.0075**	295	241	-1.367	0.6427	161	145	3.335	0.2251
Peace River at Zolfo Springs	614	547	-6.376	**0.0031**	751	636	-3.084	0.4754	477	422	1.231	0.8305
Withlacoochee River at Croom	428	372	-0.5033	**0.0228**	531	431	1	0.7752	325	330	-0.3577	0.9147
Withlacoochee River near Holder	1008	885	-8.9686	**0.0055**	1206	1028	1.153	0.9147	810	742	-9.271	0.3008
Withlacoochee River at Trilby	322	270	-2.5065	**0.0672**	401	340	2.069	0.4537	244	244	1.301	0.8027

XAnnQ = Mean Annual Flow (cfs)
MedAnnQ = Median Annual Flow (cfs)

Table 2-11. Results of Mann-Whitney tests for flow differences between mean annual flows at selected gage sites for two multidecadal time periods (1940 to 1969 and 1970 to 1999). P values of 0.1 or less are highlighted in bold; p values that indicate a flow decrease between periods are shaded yellow. Excerpt of table from Kelly (2004).

Site Name	1940 to 1969 median	n	1970 to 1999 median	n	Test	p
Alafia River at Lithia	374.9	30	268.1	30	Pre>Post	**0.0054**
Hillsborough River at Zephyrhills	247	30	187	30	Pre>Post	**0.0021**
Hillsborough River near Tampa	516	30	264	30	Pre>Post	**0.0000**
Little Manatee River near Wimauma	178	30	139	30	Pre>Post	**0.0954**
Myakka River near Sarasota	215	30	228	30	Pre>Post	0.4094
Peace River at Arcadia	1113	30	738	30	Pre>Post	**0.0035**
Peace River at Bartow	241	30	145	30	Pre>Post	**0.0003**
Peace River at Zolfo Springs	636	30	422	30	Pre>Post	**0.0007**
Withlacoochee River at Croom	431	30	330	30	Pre>Post	**0.0033**
Withlacoochee River at Trilby	339	30	244	30	Pre>Post	**0.0054**
Withlacoochee River near Holder	1038	30	742	30	Pre>Post	**0.0023**

2.4.4 Benchmark Periods

Climate-based differences in flows associated with ocean warming and cooling phases of the AMO suggest that two benchmark periods should be utilized for evaluating minimum flow criteria. A benchmark period from 1940 through 1969 corresponds to a warm phase of the AMO, and is correlated with a multidecadal period of higher rainfall and increased river flows; the period from 1970 through 1999 corresponds to a cool phase of the AMO, and is correlated with a multidecadal period of lower rainfall and lower river flows.

Several approaches could be used to develop minimum flows and levels given that two benchmark flow periods have been identified. If permitting or allowing consumptive water use is conducted on a fixed-quantity basis (e.g., 50 million gallons per day) a conservative approach for protecting the ecology and aquatic resources of river systems would be to use the drier period as the benchmark period, since this would yield the lowest withdrawal recommendation. This approach would prevent significant harm from withdrawals during the low flow benchmark period, and provide greater protection during the period of higher flows. If, however, permits are issued on a percent-of-flow basis (e.g., 10% of the preceding day's flow is available for use), the most conservative approach would be to base permitting on the benchmark period that produces the lower percent-of-flow reduction associated with the criterion or key resources identified for protection from significant harm. This would allow the recommended percent-of-flow reduction to be used in either benchmark period while affording protection to the key resource(s) during both flow periods. A third option would be to adjust either the fixed quantity or percent-of-flow withdrawal restrictions according to the current AMO period or phase. From a water supply perspective, this would probably be the most desirable approach, since it would allow the maximum amount of water to be withdrawn irrespective of the multidecadal phasing of the AMO. This option, however, would be difficult to apply since there is currently no method for determining when a step change to a new climatic regime has occurred, except in hindsight.

Based on the difficulty of determining when a step change in flows has occurred and given that there are several advantages to the "percent-of-flow" approach (e.g., maintenance of the seasonality and distribution of flows in the natural flow regime) over the fixed-quantity approach, we have developed minimum flow criteria that are based on percent-of-flow reductions. We anticipate that on most rivers under most circumstances that these criteria will be based on the most restrictive flow reductions associated with analyses involving two benchmark periods, from 1940 through 1969 and from 1970 through 1999. However, unlike the middle Peace River (Kelly et al. 2005a) and the Alafia River (Kelly et al. 2005b), the use of two benchmark periods for the Myakka River becomes problematic not because of a declining flow trend, but because of anthropogenic increases in flow. We believe that the entire flow record for the multidecadal period extending from 1940 to 1969 can be used as a benchmark period for evaluating flow reductions during the wetter climatic oscillation (i.e., AMO warm period). However, the multidecadal period extending from 1970 to 1999 should not be used as a benchmark period except perhaps during the rainy season (Block 3 as defined below) for evaluating flow reductions during the drier (i.e., AMO cool period) climatic oscillation. Because of apparent anthropogenic flow increases associated with agricultural activity within the watershed, there is no clear picture regarding what flows in the drier multidecadal period should be. It should be expected that flows in the wetter period in the absence of anthropogenic effects (even during Blocks 1 and 2 as described below) would be higher than in the drier period; however, this was not the case for the Myakka River. It is, therefore, proposed that percentage reductions developed for the wetter period (1940 to 1969) should be applied regardless of climatic phase (wetter or drier period), since flows for much of the year have increased due to anthropogenic causes (especially for Block 1 and Block 2 as discussed below) in the drier (1970 to 1999) period.

2.4.5 Seasonal Flow Patterns and the Building Block Approach

For most rivers in the SWFWMD, there is a repetitive annual flow regime that can be described on the basis of three periods. These three periods are characterized by low, medium, and high flows and for the purpose of developing minimum flows and levels, are termed Block 1, Block 2, and Block 3, respectively. To determine when these blocks may be expected to occur seasonally, we evaluated flow records for several rivers in the region.

For this analysis, flow records for long-term gage sites including the Myakka River near Sarasota, the Alafia River at Lithia, the Hillsborough River at Zephyrhills, the Peace River at Arcadia, and the Withlacoochee River at Croom were reviewed. The mean annual 75 and 50 % exceedance flows and average median daily flows for two time periods (1940 to 1969 and 1970 to 1999), corresponding to climatic phases associated with the Atlantic Multidecadal Oscillation were examined. On a seasonal basis, a low flow period, Block 1, was defined as beginning when the average median daily flow for a given time period fell below and stayed below the annual 75% exceedance flow. Block 1 was defined as ending when the high flow period, or Block, 3 began. Block 3 was defined as beginning when the average median daily flow exceeded and stayed above the mean annual 50% exceedance flow. The medium flow period, Block 2, was defined as extending from the end of Block 3 to the beginning of Block 1.

With the exception of the gage site on the Withlacoochee River, there was little difference in the dates that each defined period began and ended, irrespective of the time period evaluated (Table 2-12). For the Alafia, Hillsborough, Myakka, and Peace Rivers, Block 1 was defined as beginning on Julian day 110 (April 20 in non-leap years) and ending on Julian day 175 (June 24). Block 3 was defined as beginning on Julian day 176 (June 25) and ending on Julian day 300 (October 27). Block 2, the medium flow period, extends from Julian day 301 (October 28) to Julian day 109 (April 19) of the following calendar year. Using these definitions: Blocks 1, 2, and 3 are 65, 176 and 124 days in length, respectively (Table 2-13).

The three flow blocks were utilized for development of minimum flows for the upper Myakka River and are evident in hydrographs of median daily flows for the Sarasota gage site (Figure 2-31). Lowest flows, which are typically confined to the river channel, occur during Block 1. Highest flows, which are often sufficient for inundating the river floodplain, occur during Block 3, although high flows may also occur during Block 2. Medium flows occur during Block 2.

Table 2-12. Beginning Julian days for the Wet and Dry periods (Blocks 1 and 3) and ending date for the Wet period at five different gage stations in the SWFWMD.

	Begin Dry (Block 1)	Begin Wet (Block 3)	End Wet (Block 3)
Alafia at Lithia	106	175	296
Hillsborough at Zephyrhills	112	176	296
Myakka at Sarasota	115	181	306
Peace at Arcadia	110	174	299
Withlacoochee at Croom	130	208	306
Mean w/o Withlacoochee	110	176	300
Mean with Withlacoochee	114	183	301

Table 2-13. Beginning and ending calendar dates for annual flow Blocks 1, 2, and 3 for the Alafia, Hillsborough, Myakka and Peace Rivers for non-leap years. Calendar dates apply for both non-leap years and leap years.

	Start Date (Julian Day)	End Date (Julian Day)	Number of Days
Block 1	April 20 (110)	June 24 (175)	65
Block 2	October 28 (301)	April 19 (109)	176
Block 3	June 25 (176)	October 27 (300)	124

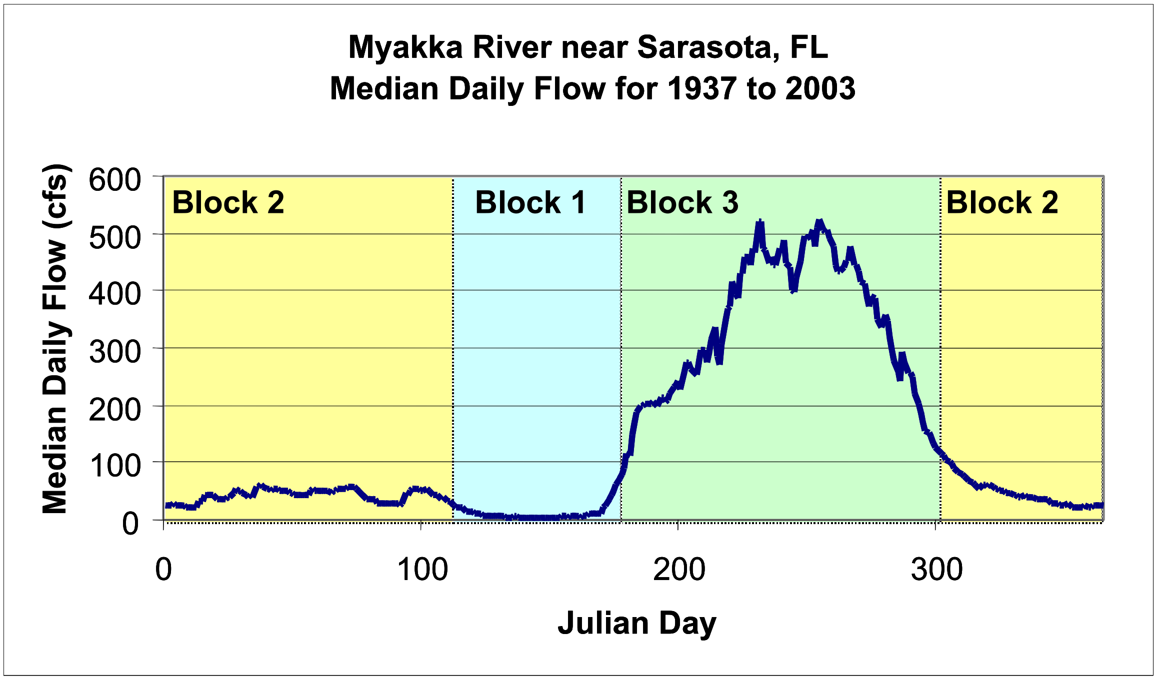


Figure 2-31. Median daily flows for 1937 through 2003 at the USGS Myakka River near Sarasota, FL Gage site and seasonal flow blocks (Blocks 1, 2 and 3) for the upper Myakka River.

2.5 Water Chemistry

2.5.1 Water Quality Data

Although flow can affect water quality, it is not expected that the adoption and achievement of minimum flows in the Myakka River will necessarily lead to substantial changes in water quality. However, it is appropriate to review the water quality of the Myakka River to fully appreciate how land use changes may have affected the system.

Long-term water quality changes were evaluated using USGS data gathered at gage sites on the Myakka River (near Sarasota and at Myakka City) (see Appendix WQ). Comparison of water quality data with flow records was made for evaluation of possible relationships between flow and land use. In addition, comparisons were made with gage sites on other river systems, specifically the Peace River near Arcadia.

For the following analyses, available water quality data for selected gages were retrieved from the USGS on-line database. While some data are available on a number of water quality parameters, analysis was restricted to those parameters for which it was felt that a sufficient number of observations existed for inspection of trends. The USGS has long-term flow and water quality data for a number of gage sites throughout the District. Flow records at many sites exceed 50 to 60 years, and some of these have water quality records of 40 years or more. Except for special studies of relatively short duration, water quality at most USGS sites was typically monitored on a quarterly basis at best.

Data for each parameter discussed in the following sections of this chapter are typically presented in three plots: a time-series plot, a plot of the parameter versus flow, and a plot of the residuals obtained from a LOWESS regression of the parameter versus flow. The last plot was used to evaluate if a parameter's loading has increased or decreased over time irrespective of flow. The results of a Kendall's tau analysis on the residuals were used to help determine if apparent increasing or decreasing trends in a parameter were statistically significant.

2.5.2 Macronutrients: Phosphorus and Nitrogen

Concentrations of the two major macronutrients, phosphorus and nitrogen, have been monitored for some time at mainstem gage sites. The exact chemical form of the nutrient monitored has changed over time (e.g., total nitrate, dissolved nitrate, nitrite+nitrate, etc.), however, for purposes of the discussion that follows and for trend analysis, values for some constituents were combined to provide a sufficient number of data points for analysis.

2.5.2.1 Phosphorus

Phosphorus has over the years been variously reported by the USGS as total phosphorus, dissolved phosphate, and as ortho-phosphate. For our analyses, it was assumed that dissolved phosphate and ortho-phosphate are essentially equivalent. Although some of the older data were reported as mg/l phosphate, all values were converted and expressed as mg/l phosphorus (P).

Friedemann and Hand (1989) determined the typical ranges of various constituents found in Florida lakes, streams and estuaries. Based on their finding, 90% of all Florida streams exhibited total phosphorus concentrations less than 0.87 mg/l P. The Myakka River would fall in this category; however, there has been a statistically significant increase in phosphorus concentration irrespective of flow (based on Kendall's tau analysis of residuals; Figure 2-32). There is a rather marked increased in phosphorus concentrations beginning in the late 1970s; this increasing trend begins at approximately the same time that low flows began to increase in the Myakka River. It appears probable that increasing phosphorus concentrations are related to the increase in land converted to row crop agriculture.

2.5.2.2 Nitrogen

Nitrogen has most often been reported by the USGS as either nitrate or nitrate+nitrite. For our analyses, it was assumed that total nitrate, dissolved nitrate, and nitrate+nitrite are essentially equivalent, unless both were reported. In this case, the highest concentration was used for data analysis. Total Kjeldahl nitrogen, total organic nitrogen, ammonia nitrogen and total nitrogen are not considered here, because considerably fewer observations were generally made for these parameters.

There was a statistically significant decreasing trend in nitrate-nitrite nitrogen based on an analysis of residuals after regression against flow (Table 2-14). There is a readily noticeable difference in nitrate-nitrite concentrations pre and post 1970 (Figure 2-33); however, we can offer no explanation for this apparent decline.

2.5.3 Potassium and Trend Analysis of Selected Chemical Constituents

One of the more interesting and unanticipated findings of the analysis of gage site water quality data on the Peace River (SWFWMD 2002) was an apparent increasing trend in dissolved potassium (Figure 2-34). Statistical analysis revealed that the trend was significant and unrelated to increases or decreases in flow, indicating an increasing rate of loading from the watershed. It was speculated that the trend was most likely attributable to increasing fertilizer application within the watershed. An increasing trend in dissolved potassium is also clearly evident for the Myakka River (Figure 2-35).

A number of water quality parameters at the Myakka River near Sarasota site showed significant increasing trends irrespective of flow (e.g., conductance, Figure 2-36). These are not considered in detail, but plots of many of these are included in Appendix WQ. It is speculated that some of these trends (e.g., conductance, calcium, chloride, hardness, magnesium, sodium and sulfate) may be related to anthropogenic groundwater inputs (irrigation), since many of the observed increases over time are in constituents that are typically higher in groundwater than in surface water (Table 2-14).

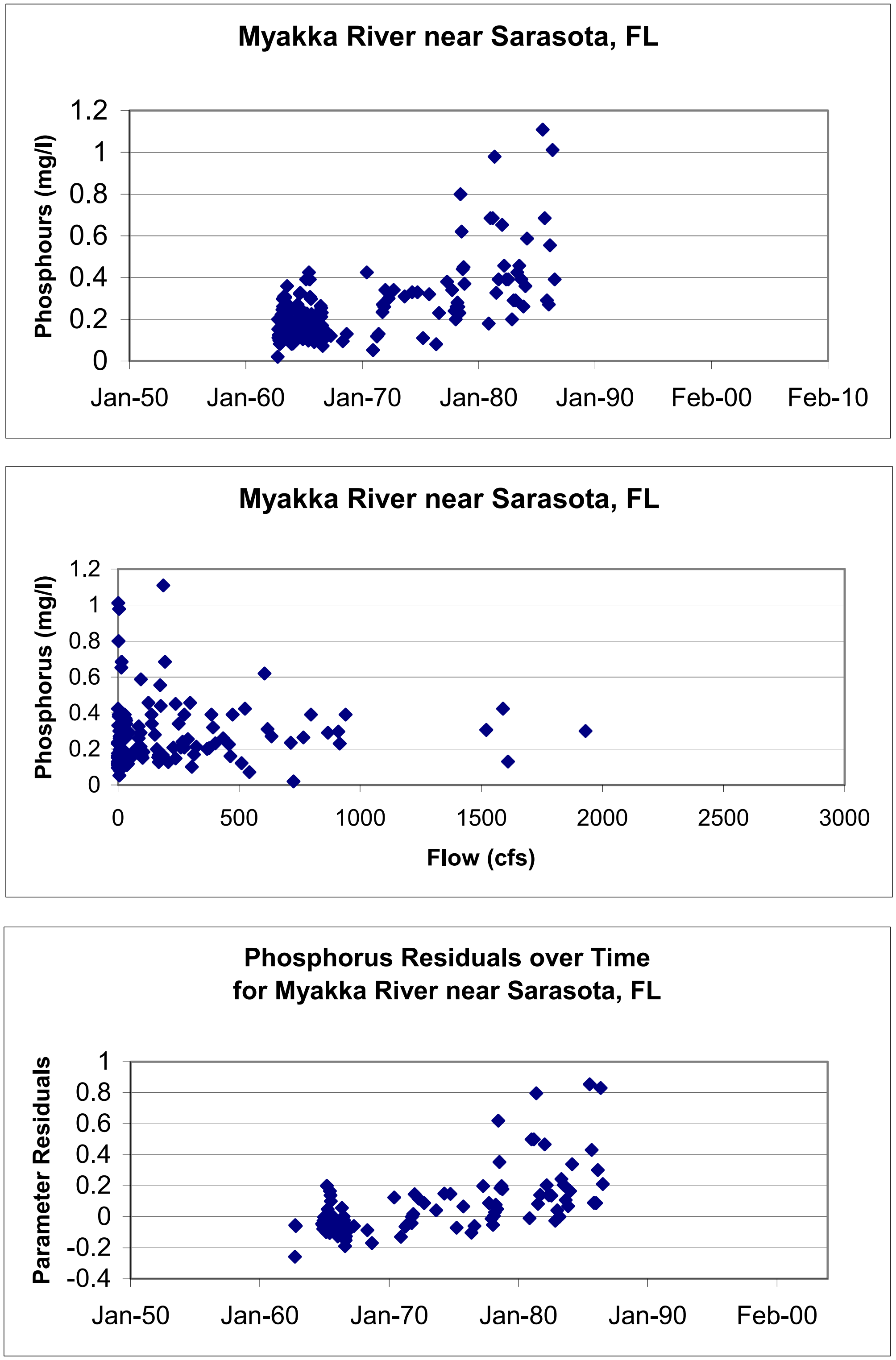
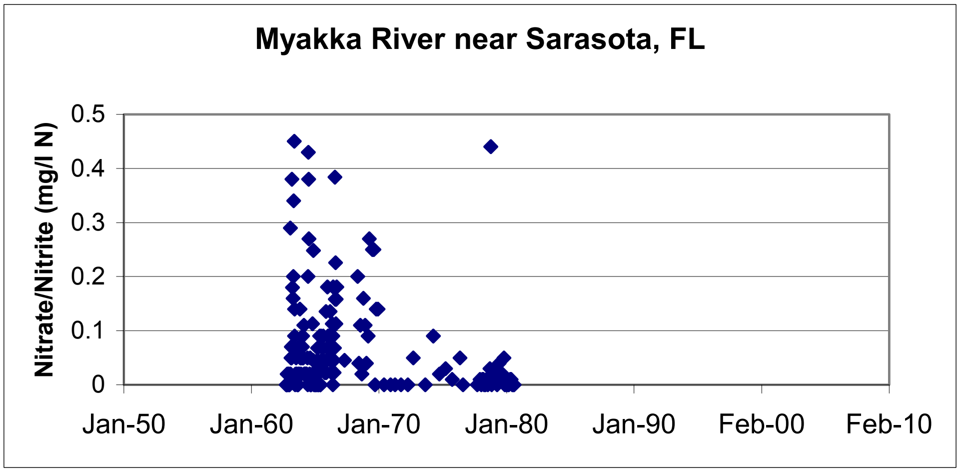
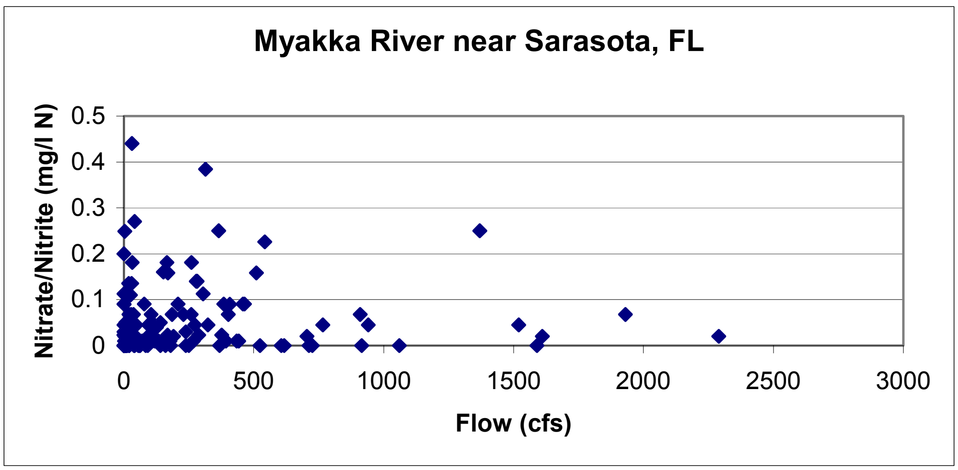


Figure 2-32. Phosphorus concentrations in water samples collected by the USGS at the Myakka River near Sarasota gage. Upper plot is time series plot; middle plot is concentration versus flow; and the bottom plot is time series plot of residuals of phosphorus concentration regressed against flow.





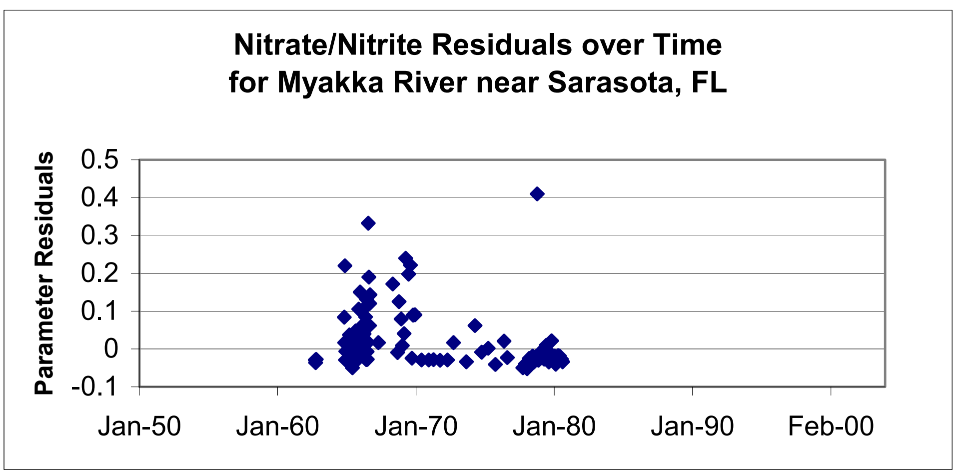


Figure 2-33. Nitrate or Nitrate/Nitrite concentrations in water samples collected by the USGS at the Myakka River near Sarasota gage. Upper plot is time series plot; middle plot is concentration versus flow; and the bottom plot is time series plot of residuals of nitrate or nitrate/nitrite concentration regressed against flow.

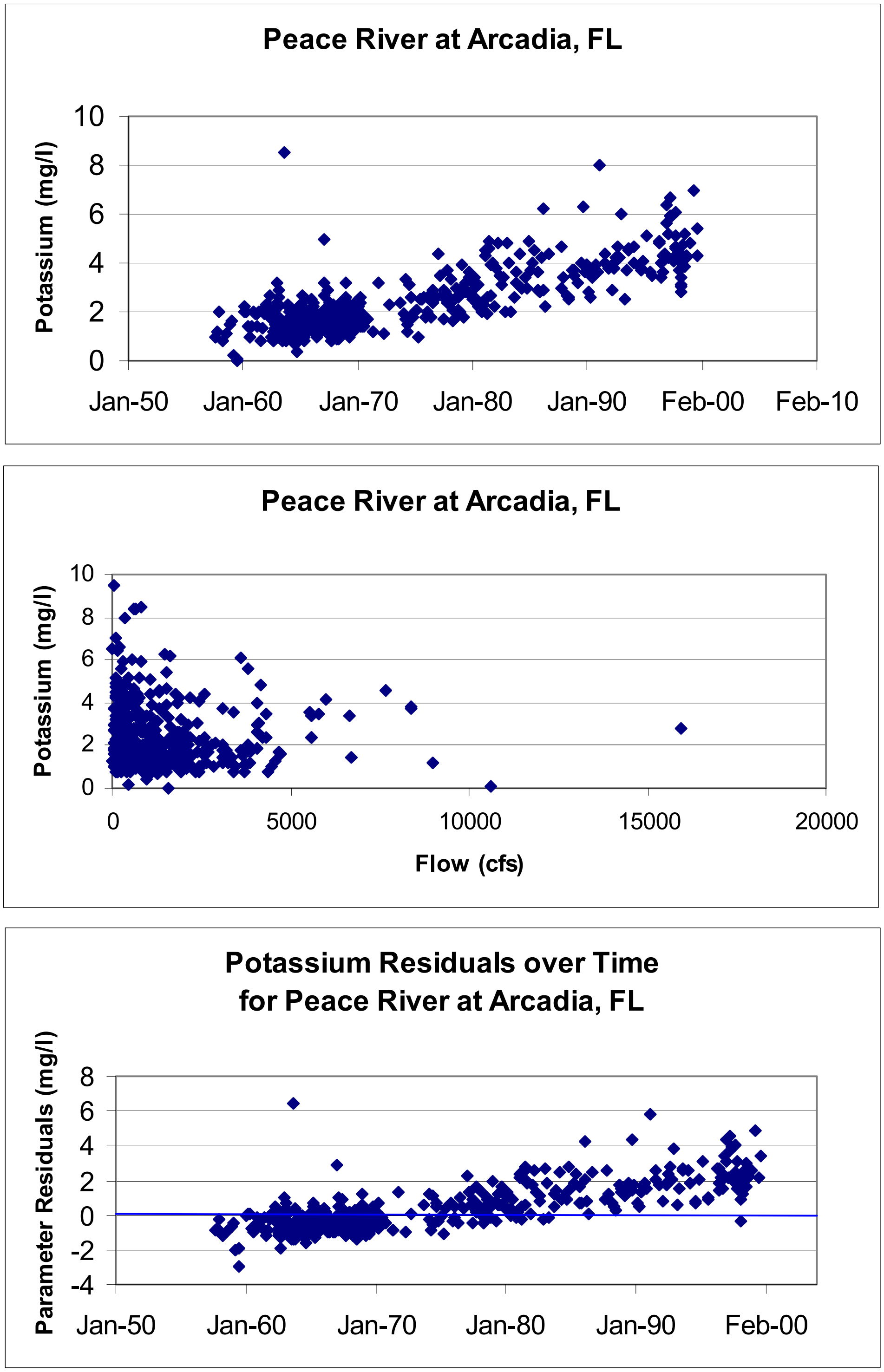
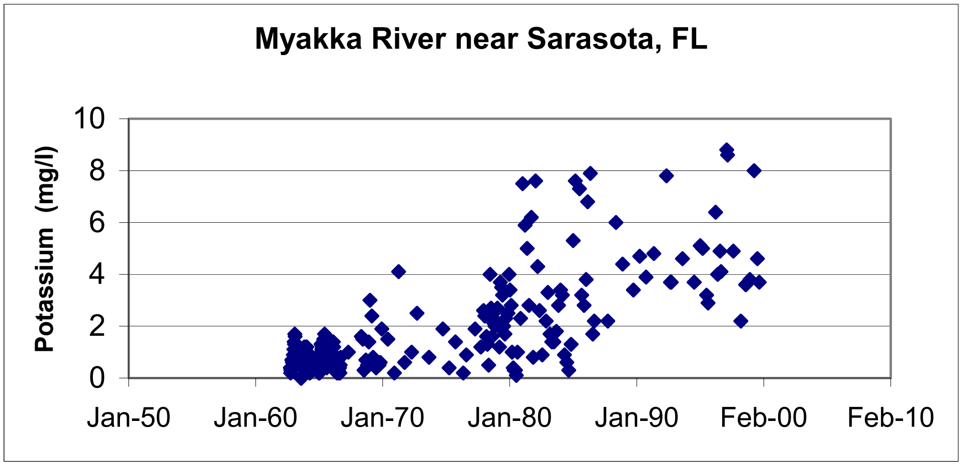
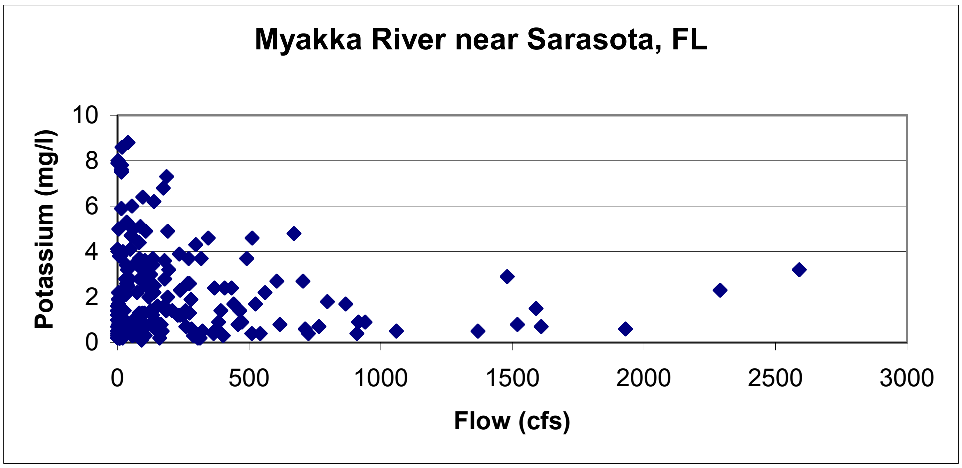


Figure 2-34. Potassium concentrations in water samples collected by the USGS at the Peace River at Arcadia gage. Upper plot is time series plot; middle plot is concentration versus flow; and the bottom plot is time series plot of residuals of potassium concentration regressed against flow.





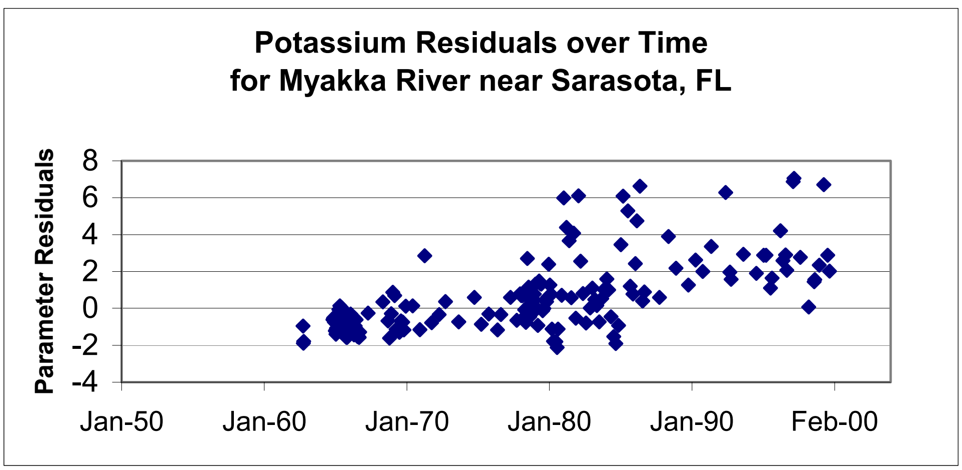


Figure 2-35. Potassium concentrations in water samples collected by the USGS at the Myakka River near Sarasota gage. Upper plot is time series plot; middle plot is concentration versus flow; and the bottom plot is time series plot of residuals of potassium concentration regressed against flow.

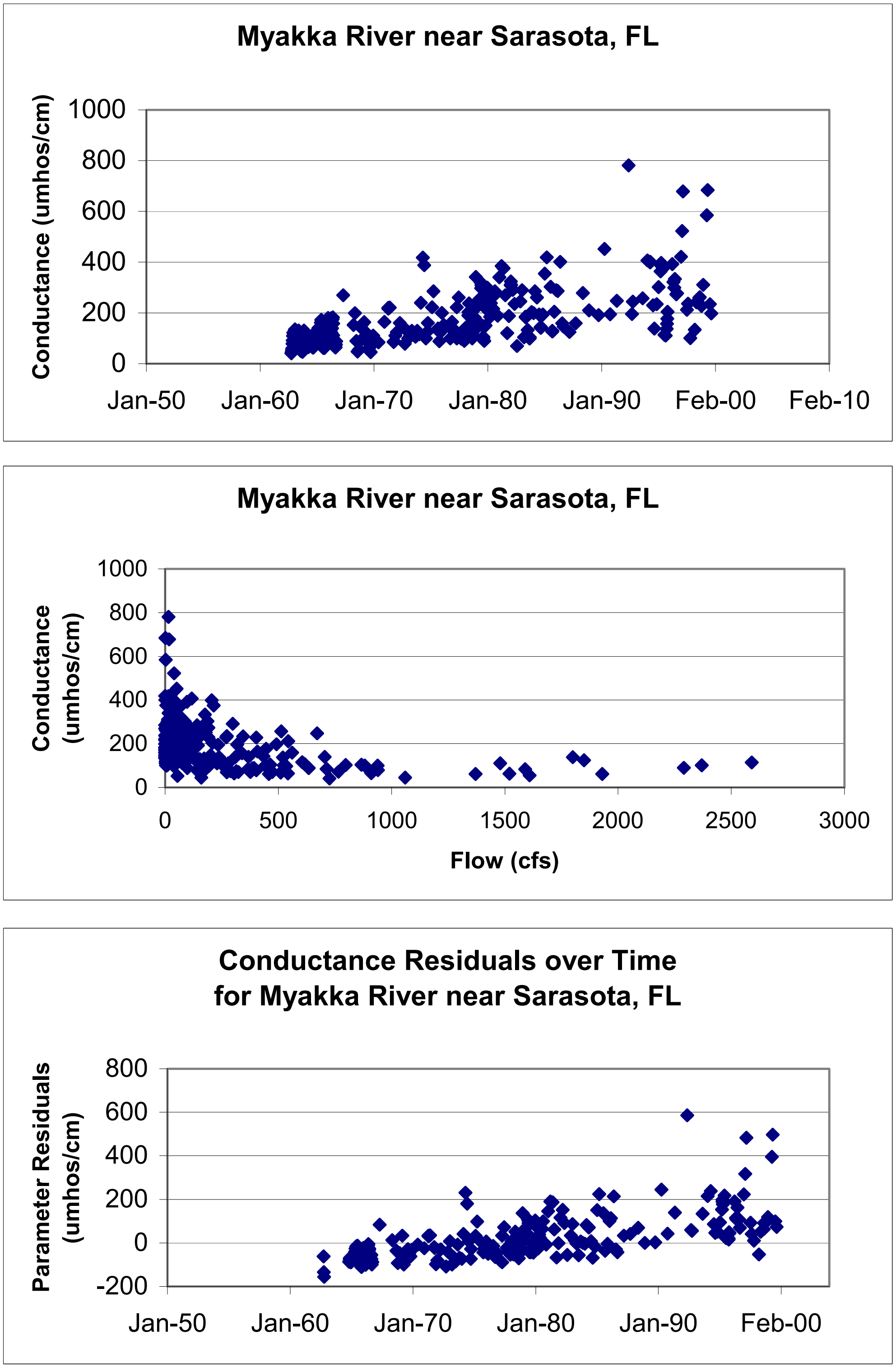


Figure 2-36. Conductance in water samples collected by the USGS at the Myakka River near Sarasota gage. Upper plot is time series plot; middle plot is concentration versus flow; and the bottom plot is time series plot of residuals of conductance regressed against flow.

Table 2-14. Results of Kendall's tau analysis on residuals for various parameters regressed against flow for the Myakka River near Sarasota gage. Yellow shading indicates a statistically significant decreasing trend, while blue shading indicates a statistically significant increasing tend.

MYAKKA RIVER AT SARASOTA

Parameter Residual	Residual Median	n	p Value	intercept	slope
Conductance	-10.0000	248	0.00000	-424.30800	0.014563
Dissolved Oxygen	0.0350	120	0.50922	1.46821	-0.000047
pH	-0.0083	215	0.00416	0.63905	-0.000023
NOx	-0.0069	129	0.06248	0.04895	-0.000002
Phosphorus	-0.0171	127	0.00000	-0.73127	0.000029
Calcium	-1.0090	193	0.00000	-36.99860	0.001267
Chloride	-0.3290	198	0.00001	-9.87780	0.000342
Fluoride	0.0045	197	0.00027	0.17920	-0.000006
Hardness	-2.9100	146	0.00000	-187.61700	0.007340
Magnesium	-0.4650	193	0.00000	-19.95630	0.000686
Potassium	-0.2810	193	0.00000	-8.17683	0.000277
Silica	0.0850	192	0.77540	-0.23801	0.000011
Sodium	0.0070	192	0.00000	-7.44218	0.000262
Sulfate	-3.7800	191	0.00000	-135.29300	0.004629

Chapter 3 Goals, Ecological Resources of Concern and Key Habitat Indicators

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

3.1 Goal – Preventing Significant Harm

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

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

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

3.2 Resources and Area of Concern

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

3.3 Resource Management Goals and Key Habitat Indicators

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

Resource management goals for the Myakka River addressed by our minimum flows analysis include:

1) maintenance of minimum water depths in the river channel for fish passage and recreational use;
2) maintenance of water depths above inflection points in the wetted perimeter of the river channel to maximize aquatic habitat with the least amount of flow;
3) protection of in-channel habitat for selected fish species and macroinvertebrate assemblages;
4) inundation of woody habitats including snags and exposed roots in the stream channel; and
5) maintenance of seasonal hydrologic connections between the river channel and floodplain to ensure floodplain structure and function.

These goals are consistent with management goals identified by other researchers as discussed in Chapter 1. The rationale for identifying these goals and the habitats and ecological indicators associated with the goals are addressed in subsequent sections of this chapter. Field and analytical methods used to assess hydrologic requirements associated with the habitats and indicators are presented in Chapter 4, and results of the minimum flows and levels analyses are presented in Chapter 5.

3.3.1 Fish Passage and Recreational Use

Ensuring sufficient flows for the passage or movement of fishes is an important component of the development of minimum flows. Maintenance of these flows is expected to ensure continuous flow within the channel or river segment, allow for recreational navigation (e.g., canoeing), improve aesthetics, and avoid or lessen potential negative effects associated with pool isolation (e.g., high water temperatures, low dissolved oxygen concentrations, localized phytoplankton blooms, and increased predatory pressure resulting from loss of habitat/cover). Tharme and King (1998, as cited by Postel and Richter 2003) in developing a "building block" approach for South African rivers listed the retention of a river's natural perenniality or nonperenniality as one of eight general principles for managing river flows. For many rivers within the District, flows and corresponding water depths adequate for fish passage are currently or were historically maintained by baseflow during the dry season (Figure 3-1). For example, in the upper Peace River, historical flows were sufficient for maintaining a naturally perennial system and flow was sufficiently high during the low flow season to permit passage of fish along most of the river segment (SWFWMD 2002). Recent flows in the upper Peace River have not, however, been sufficient for fish passage much of the time. Historic flows in other District rivers, such as the Myakka River were probably intermittent, historically, but have increased in recent years. Evaluation of flows sufficient for fish in support of minimum flows development may, therefore, involve consideration of historic or recent flow conditions with respect to perenniality and the likelihood of fish passage being maintained naturally (i.e., in the absence of consumptive water use).

3.3.2 Wetted Perimeter Inflection Point

A useful technique for evaluating the relation between the quantity of stream habitat and the rate of streamflow involves an evaluation of the "wetted perimeter" of the stream bottom. Wetted perimeter is defined as the distance along the stream bed and banks at a cross section where there is contact with water. According to Annear and Conder (1984), wetted perimeter methods for evaluating streamflow requirements assume that a direct relationship between wetted perimeter and fish habitat exists in streams. By plotting the response of wetted perimeter to incremental changes in discharge, an inflection can be identified in the resulting curve where small decreases in flow result in increasingly greater decreases in wetted perimeter. This point on the curve represents a flow at which the water surface recedes from stream banks and fish habitat is lost at an accelerated rate. Stalnaker et al. (1995) describe the wetted perimeter approach as a technique for using "the break" or inflection point in the stream's wetted perimeter versus discharge relation as a surrogate for minimally acceptable habitat. They note that when this approach is applied to riffle (shoal) areas, "the assumption is that minimum flow satisfies the needs for food production, fish passage and spawning."

We view the wetted perimeter approach as an important technique for evaluating minimum flows and levels near the low end of the flow regime. Studies on streams in the southeast have demonstrated that the greatest amount of macroinvertebrate biomass per unit reach of stream occurs on the stream bottom (e.g., Benke et al. 1985). Although production on a unit area basis may be greater on snag and root habitat, the greater area of stream bottom along a reach makes it the most productive habitat under low flow conditions. The wetted perimeter inflection point in the channel provides for large increases in bottom habitat for relatively small increases of flow. This point is defined as the "lowest wetted perimeter inflection point" or LWPIP. It is not assumed that flows associated with the LWPIP meet fish passage needs or address other wetted perimeter inflection points outside the river channel. However, identification of the LWPIP permits evaluation of flows that provide the greatest amount of inundated bottom habitat in the river channel on a per-unit flow basis.

3.3.3 In-Channel Habitats for Fish and Macroinvertebrates

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

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

3.3.4 Woody Habitats

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

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

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

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

3.3.5 Hydrologic Connections Between the River Channel and Floodplain

Although not historically addressed in most minimum flow determinations, floodplains have long been recognized as seasonally important riverine habitat. A goal of the SWFWMD's minimum flows and levels approach is to ensure that the hydrologic requirements of biological communities associated with the river floodplain are met during seasonally predictable wet periods. Periodic inundation of riparian floodplains by high flows is closely linked with the overall biological productivity of river ecosystems (Crance 1988, Junk et al., 1989). Many fish and wildlife species associated with rivers utilize both instream and floodplain habitats, and inundation of the river floodplains greatly expands the habitat and food resources available to these organisms (Wharton et al. 1982, Ainsle et al.

1999, Hill and Cichra 2002). Inundation during high flows also provides a subsidy of water and nutrients that supports high rates of primary production in river floodplains (Conner and Day 1979, Brinson et al. 1981). This primary production produces large amounts of organic detritus, which is critical to food webs on the floodplain and within the river channel (Vannote et al. 1980, Gregory et al. 1991). Floodplain inundation also contributes to other physical-chemical processes that can affect biological production, uptake and transformation of macro-nutrients (Kuensler 1989, Walbridge and Lockaby 1994).

Soils in river floodplains exhibit physical and chemical properties that are important to the overall function of the river ecosystem (Wharton et al. 1982, Stanturf and Schenholtz 1998). Anaerobic soil conditions can persist in areas where river flooding or soil saturation is of sufficient depth and duration. The decomposition of organic matter is much slower in anaerobic environments, and mucky or peaty organic soils can develop in saturated or inundated floodplain zones (Tate 1980, Brown 1990). Although these soils may dry out on a seasonal basis, typically long hydroperiods contribute to their high organic content. Plant species that grow on flooded, organic soils are tolerant of anoxic conditions and the physical structure of these soils (Hook and Brown 1973, McKevlin et al. 1998). Such adaptations can be an important selective mechanism that determines plant community composition. Because changes in river hydrology can potentially effect the distribution and characteristics of floodplain soils, soil distributions and their relationship to river hydrology are routinely investigated as part of minimum flows and levels determinations for District rivers.

Compared to instream evaluations of MFL requirements, there has been relatively little work done on river flows necessary for meeting the requirements of floodplain species, communities or functions. Our work on the Peace and Alafia Rivers suggests that direct and continuous inundation of floodplain wetlands by river flows is in many cases not sufficient to meet the published inundation needs of the dominant species found in the wetlands. There are probably several reasons for this apparent inconsistency. Some floodplain systems likely include seepage wetlands, dependent on hydrologic processes other than direct inundation from the river. Other wetlands may occur in depressional areas where water is retained after subsidence of river flows.

The District's approach to protection of flows associated with floodplain habitats, communities and functions involves consideration of the frequency and duration of direct connection between the river channel and the floodplain. As part of this process, plant communities and soils are identified across the river floodplain at a number of sites, and periods of inundation/connection with the river are reconstructed on an annual or seasonal basis. These data are used to characterize the frequency and duration of direct connection/ inundation of these communities to or by the river and to develop criteria for minimum flow development.

Figure 3-1. Example of low flow in a riffle or shoal area. Many potential in-stream habitats such as limerock (foreground), snags, sandbars, and exposed roots are not inundated under low flow conditions.

Chapter 4 Technical Approach for Establishing Minimum Flows and Levels for the Myakka River

4.1 Overview

Methods used to determine the minimum flow requirements for the fresh water portion of the Myakka River between Myakka City and S.R. 72 are described in this chapter. The approach outlined for the river involves identification of a low flow threshold and development of prescribed flow reductions for periods of low, medium and high flows (Blocks 1, 2 and 3). The low flow threshold is used to identify a minimum flow condition and is expected to be applicable to river flows throughout the year. The prescribed flow reductions are based on limiting potential changes in aquatic and wetland habitat availability that may be associated with changes in river flow during Blocks 1, 2 and 3.

4.2 Transect Locations and Field Sampling of Instream and Floodplain Habitats

The Myakka River was designated as the portion of the river from the USGS at Myakka City gage (02298608) near State Road 70 spanning a drainage area of approximately 125 sq. miles to the USGS near Sarasota gage (02298830) crossing State Road 72 with a drainage area of approximately 229 sq. miles (Figure 4-1). Sampling included characterization of cross-sectional physical, hydrologic and habitat features. Four types of cross-sectional information were collected, including data used for HEC-RAS modeling, Physical Habitat Simulation (PHABSIM) modeling, instream habitat assessment, and floodplain vegetation/soils assessments. HEC-RAS cross-sections were established to develop flow and inundation statistics for the other cross-section sites based on existing flow records for the USGS gage site at Sarasota.

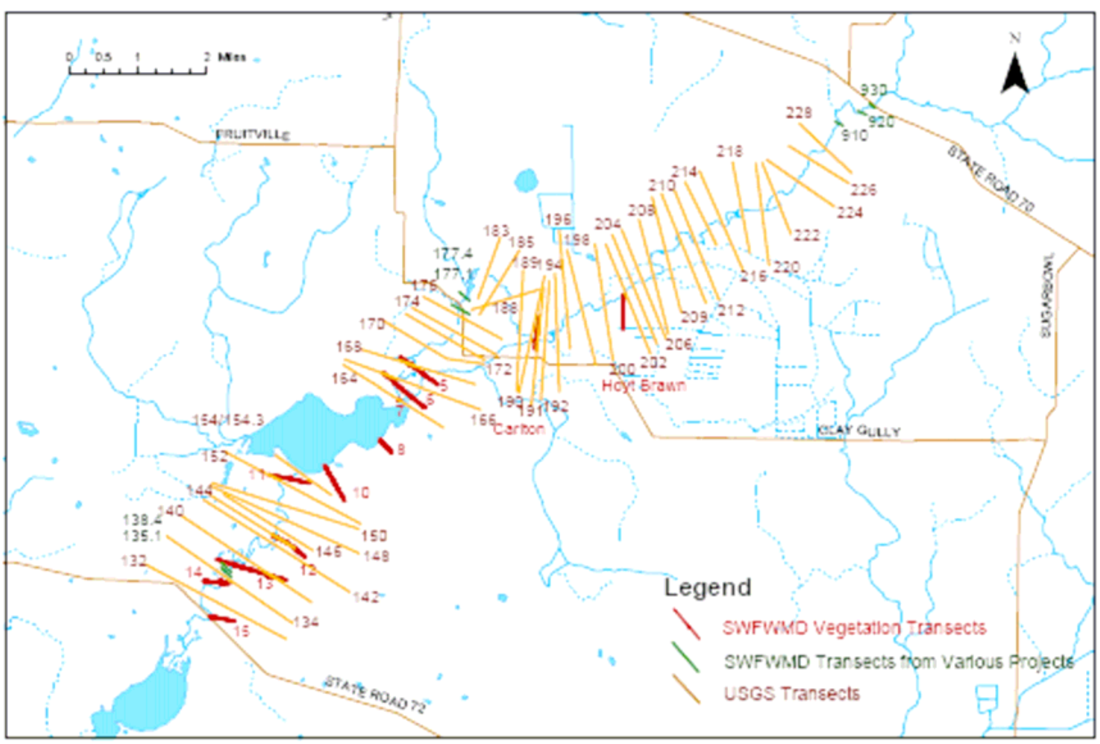


Figure 4-1. Study corridor for the Myakka River. Vegetative cross-sections are in red, USGS cross-sections are in orange and additional SWFWMD cross-sections are shown in green.

4.2.1 HEC-RAS Cross-Sections

Cross-section channel geometry data used to generate a HEC-RAS model for the Myakka River were adopted from previously established USGS channel cross-sections (Hammett et al. 1978) for the study area and from additional sites identified by District staff. The locations of 43 USGS cross-sections, 7 cross-sections from other SWFWMD projects, and 9 vegetative sites surveyed by the District and utilized in the HEC-RAS model are shown in Figure 4-1. Shoals, representing high spots that could restrict flow and result in loss of hydraulic connection, present barriers to fish migration, or hamper recreational canoeing were also identified by District staff in April 2002. Cross-section elevations and channel geometry data were obtained for two shoals and these data were combined with the USGS cross-section data for development of the HEC-RAS model.

4.2.2 PHABSIM Cross-Sections

Physical Habitat Simulation (PHABSIM) cross-sections, designed to quantify specific habitats for fish and macroinvertebrates at differing flow conditions, were established at five sites identified on the Myakka River. Two were situated at a shoal site while the other three represented either deep/ narrow or deep/wide sections of the river. The northernmost sites were located upstream of Upper Myakka Lake (at two shoal sites and a deep/narrow section site). The southernmost sites (consisting of two deep/wide section sites) were situated in the portion of the river between Upper and Lower Myakka Lake.

PHABSIM analysis required acquisition of field data concerning channel habitat composition and hydraulics. At each PHABSIM site, tag lines were used to establish a cross-section across the channel to the top of bank on either side of the river. Water velocity was measured with a Marsh-McBirney Model 2000 flow meter at two or four-foot intervals along each cross-section. Stream depth, substrate type and habitat/cover were recorded along the cross-sections. Other hydraulic descriptors measured included channel geometry (ground elevations), water surface elevations across the channel and water surface slope determined from points upstream and downstream of the cross-sections. Data were collected under a range of flow conditions (low, medium and high flows) to provide the necessary information needed to run the PHABSIM model for each stream reach.

4.2.3 Instream Habitat Cross-Sections

Cross-sections for assessing instream habitats were examined at nine sites on the Myakka River. Triplicate instream cross-sections, from the top of bank on one side of the channel through the river and up to the top of bank on the opposite channel, were established at each site perpendicular to flow in the channel. One of the three cross-sections at each site was situated along the floodplain vegetation transect line. Replicates were located 50 ft upstream and downstream. A total of 27 instream cross-sections were sampled (9 cross-sections x 3 replicates at each site).

For each instream habitat cross-section, the range in elevation and linear extent (along the cross-section) for the following habitats were determined:

- bottom substrates (which included sand, mud, or bedrock);
- exposed roots;
- snags or deadwood;
- aquatic plants;
- wetland (herbaceous or shrubby) plants; and
- wetland trees.

4.2.4 Floodplain Vegetation Cross Sections

For cross-section site selection, the river corridor was stratified using criteria described by PBS&J (2005). Twelve representative floodplain vegetation cross-sections were established perpendicular to the river channel within dominant

National Wetland Inventory (NWI) vegetation types (Figures 4-2 and 4-3). Cross-sections were established between the 0.5 percent exceedance levels on either side of the river channel, based on previous determinations of the landward extent of floodplain wetlands in the river corridor. Ground elevations were determined at 50-foot intervals along each cross-section. Where changes in elevation were conspicuous, elevations were surveyed more intensively. Transects were initially selected based on NWI vegetation classifications. For example, PFO1/FO3C and PFO3/FO1C made up a large portion of the study corridor, indicating different combinations of palustrine, forested, broad-leaved deciduous and evergreen, seasonally flooded communities. While these classes were adequate for identifying floodplain boundaries, they were considered too broad for the intent of community characterizations in this study.

To characterize forested vegetation communities along each cross-section, changes in dominant vegetation communities were located and used to delineate boundaries between vegetation zones. Boundaries between communities were identified in the field using a combination of indicators, including, but not limited to:

- general community type (e.g., wetland to upland)
- species cover (e.g., popash to oak, obligate wetlands to facultative wetlands)
- elevation (e.g., scarp presence)
- soils (e.g., hydric or nonhydric)

Subsequently, a general method of vegetation class nomenclature was developed based on species dominance (below).

- Vegetation classes with greater than 40 percent tree cover were designated based on dominant tree species (Cowardin et al. 1979) (e.g., popash swamp or oak/popash)
- Marshes (trees comprised less than 40 percent of the total cover) were designated based on dominant herbaceous species, (e.g., *Panicum* marsh)

Vegetation classes were further refined based on importance values (IVs) of tree species, an index that combines relative density, frequency, and basal area of tree species (Mueller-Dombois and Ellenberg 1974).

At each change in vegetation zone, plant species composition, density, basal area and diameter at breast height (for woody vegetation with a dbh greater than 1 inch) were recorded. A minimum of three plots was sampled within each vegetation zone and the point-centered-quarter (PCQ) sampling method (Cottam and Curtis 1956, Mueller-Dombois and Ellenberg 1974 as cited in PBS&J 2005) was used to characterize the vegetation. Density, basal area, and IV were calculated for each tree species, by transect and vegetation class. Vegetation classes and IVs of tree species in each class are listed in Table 5-2, in general order from wetlands to uplands.

Soils along the floodplain vegetation cross-sections were evaluated for the presence of hydric or flooding indicators, as well as saturation and/or inundation condition. At least three soil cores were examined to a minimum depth of 20 inches within each vegetation zone at each cross section. Soils were classified as upland (non-hydric), hydric or non-hydric with the presence of flooding indicators. Special consideration was placed on locating elevations of the upper and lower extent of muck soils (> 8 inches in thickness) at cross-sections where they occurred.

Ground elevation data were used to compare vegetation and soils within and among cross-sections. For some comparisons, vegetation elevations were normalized to the lowest channel elevations at the cross-section to account for differences in absolute elevations among the cross-sections. The HEC-RAS floodplain model (see Section 4.2.1) was used to determine corresponding flows at the Sarasota gage that would be necessary to inundate specific floodplain elevations (e.g., median vegetation zone and soils elevations).

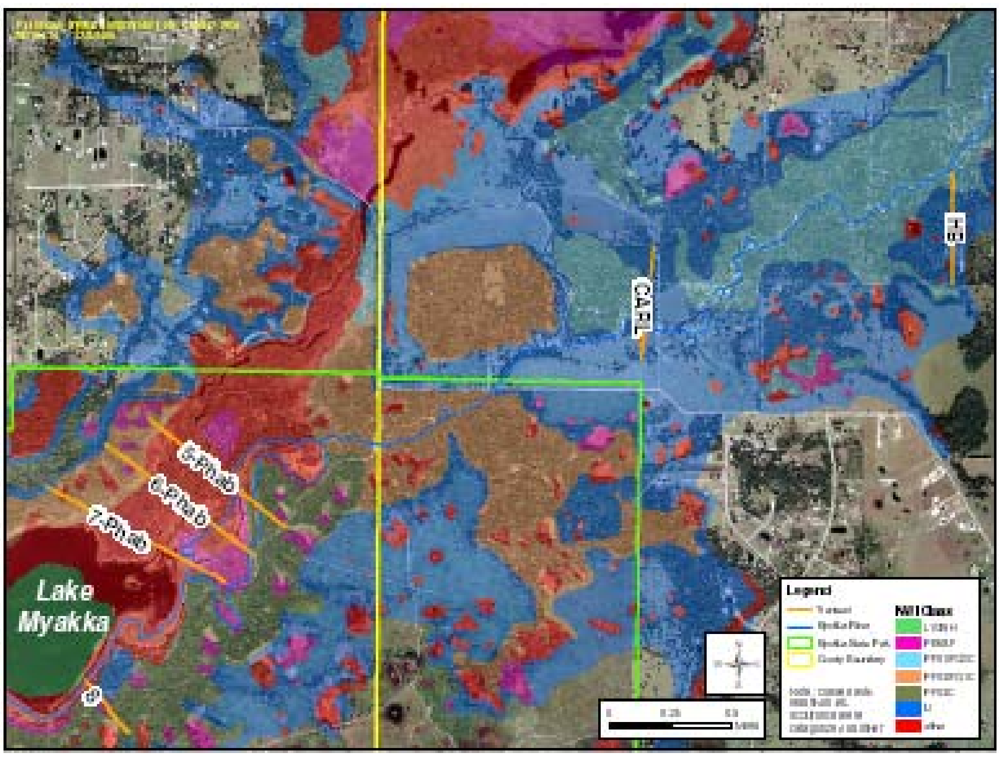


Figure 4-2. Upstream vegetation cross-section locations and NWI classes on the Myakka River.

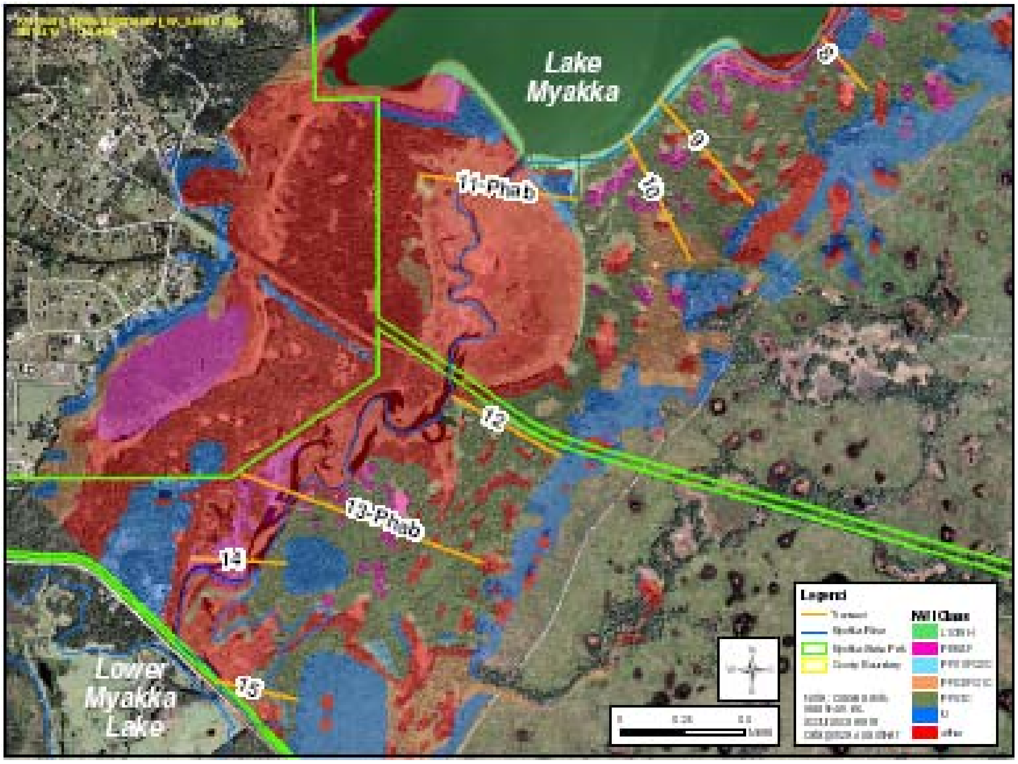


Figure 4-3. Downstream vegetation cross-section locations and NWI classes for the Myakka River.

4.3 Modeling Approaches

A variety of modeling approaches were used to develop minimum flows and levels for the Myakka River. HEC-RAS models were developed to characterize flows at all study sites. Physical Habitat Simulation (PHABSIM) modeling was used to characterize potential changes in the availability of fish habitat and macroinvertebrate habitat. Recent and Long-term Positional Hydrographs (RALPH) plots/analyses were used to examine inundation durations for specific habitats or floodplain elevations and to also examine changes in inundation patterns that could be expected with changes to the flow regime.

4.3.1 HEC-RAS Modeling

The HEC-RAS model is a one-dimensional hydraulic model that can be used to analyze river flows. Version 3.1.1 of the HEC-RAS model was released by the U.S. Army Corps of Engineers Hydrologic Engineering Center in November 2002 and supports water surface profile calculations for steady and unsteady flows, including subcritical, supercritical, or mixed flows. Profile computations begin at a cross-section with known or assumed starting condition and proceed upstream for subcritical flow or downstream for supercritical flow. The model resolves the one-dimensional energy equation. Energy losses between two neighboring cross sections are computed by the use of Manning's equation in the case of friction losses and derived from a coefficient multiplied by the change in velocity head for contraction/expansion losses. For areas where the water surface profile changes rapidly (e.g., hydraulic jumps, bridges, river confluences), the momentum equation is used (US Army Corps of Engineers 2001).

We used the HEC-RAS model and available flow records for the USGS Myakka River at Myakka City and Myakka River near Sarasota gages to simulate flows at cross-section sites within the Myakka River study area. Data required for performing HEC-RAS simulations included geometric data and steady flow data. Geometric data used for our analyses consisted of connectivity data for the river system, cross-section elevation data for 53 USGS cross-sections, 7 cross-sections from other SWFWMD projects, and 9 vegetative sites surveyed by the District, reach length, energy loss coefficients due to friction and channel contraction/expansion, stream junction information, and hydraulic structure data, including information for bridges, culverts, etc. (Figure 4-1). Required steady-flow data included the USGS gage records, boundary conditions, and peak discharge information.

Calculations for subcritical flow begin downstream where a boundary condition is applied. For the Myakka River, a known water-surface elevation, calculated from a stage-discharge relationship at the Myakka River near Sarasota gage**,** was used as a downstream boundary condition. The energy equation is then solved between the first and second (most downstream) cross sections. Once this is achieved, the model repeats this process working its way upstream balancing the energy equation (or momentum equation if appropriate) between adjacent cross-sections until the most upstream cross-section is reached.

Model accuracy is evaluated by comparing calculated water-surface elevations at any gage location with a stage-discharge relationship derived from historic data for the location. The model is calibrated by adjusting factors in the model until calculated results closely approximate the observed relationship between stage and flow. While expansion and contraction coefficients can be altered, the major parameter altered during the calibration process is typically Manning's roughness coefficient (n), which describes the degree of flow resistance. Flow resistance is a function of a variety of factors including sediment composition, channel geometry, vegetation density, depth of flow and channel meandering. Generally, the model is considered calibrated when model results are within 0.5 ft of the established stage-discharge relationship at the upstream gage site(s) (Murphy et al. 1978; Lewelling 2003). For the Myakka River model, the rating curve for the Myakka River at Myakka City gage site was used to calibrate calculations for the river segment between the Myakka City gage and the Myakka River near Sarasota gage site.

The Myakka River HEC-RAS model calculates profiles for a total of 16 steady flow rates. They are the 90, 85, 80, 75, 65, 60, 50, 40, 35, 25, 20, 15, 10, 5, 1 and 0.5 upper percentiles of historical flow data measured in the river. The boundary conditions were specified with known water surface elevations for each flow rate at the downstream boundaries. In other words, rating curves (obtained from USGS) at the downstream boundaries were used as the boundary conditions.

Accuracy of the step-backwater analysis for the Myakka River was determined by comparing the model output with the upstream gage at Myakka City. The HEC-RAS model was considered calibrated when the calculated water surface elevations were within plus or minus 0.5 ft. This is in keeping with standard USGS practices where the plus or minus 0.5 ft, is based on the potential error range using the 1-ft aerial contour maps (Lewelling 2004). The U.S. Geological Survey, Water-Resources Investigations Report 78-65 titled Magnitude and Frequency of Flooding on the Myakka River, Southwest Florida was the study from which a majority of the cross-sections used in the HEC-RAS model were obtained (Hammett et al. 1978). It is unverifiable from this report what error was associated with the cross-sections and at what level of departure from the stage relation curve the model was considered calibrated. However, a USGS report done in the same year on the neighboring Peace River used the same plus or minus 0.5 ft which seems to be the standard applied to USGS step backwater calculations (Murphy et al. 1978). Though some of our cross-sections have been surveyed with a greater accuracy, the majority of the modeled cross-sections are still from the original report and thus the plus or minus 0.5 ft standard to determine calibration was used. The greatest error associated with the model is likely to be the accuracy of the cross-sectional data. It is unknown what kind of error is associated with the cross section data taken from the USGS quads.

No long-term gage records exist between the Myakka gage near Sarasota and the Myakka City gage site. However, to validate the model the District intends to study the inundation of wetlands along river corridors where MFL studies have occurred. This is intended to include staff gages in both the wetlands and the river channel. This will allow verification of the rivers connection with the wetland or the partial independence of the wetland hydrology. This will also serve to verify the model by collecting upstream gage heights.

The HEC-RAS model was run using all flows to determine stage vs. flow and wetted perimeter versus flow relationships for each cross-section. These relationships were also used to determine inundation characteristics of various habitats at instream habitat and floodplain vegetation cross-sections. The peer review panel assessing the "Upper Peace River; An Analysis of Minimum Flows and Levels" found HEC-RAS to be an "appropriate tool" for assessing these relationships and determined this to be a "scientifically reasonable approach" (Gore et al. 2002).

4.3.2 Physical Habitat Simulation (PHABSIM) Modeling

It is suggested that the District consider use of procedures which link biological preferences for hydraulic habitats with hydrological and physical data (Gore et al. 2002). Specifically, Gore et al. (2002) endorsed use of the Physical Habitat Simulation (PHABSIM), a component of the Instream Flow Incremental Methodology (Bovee et al. 1998) and its associated software for determining changes in habitat availability associated with changes in flow. Following this recommendation, the PHABSIM system was used to support development of minimum flows for the Myakka River.

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

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

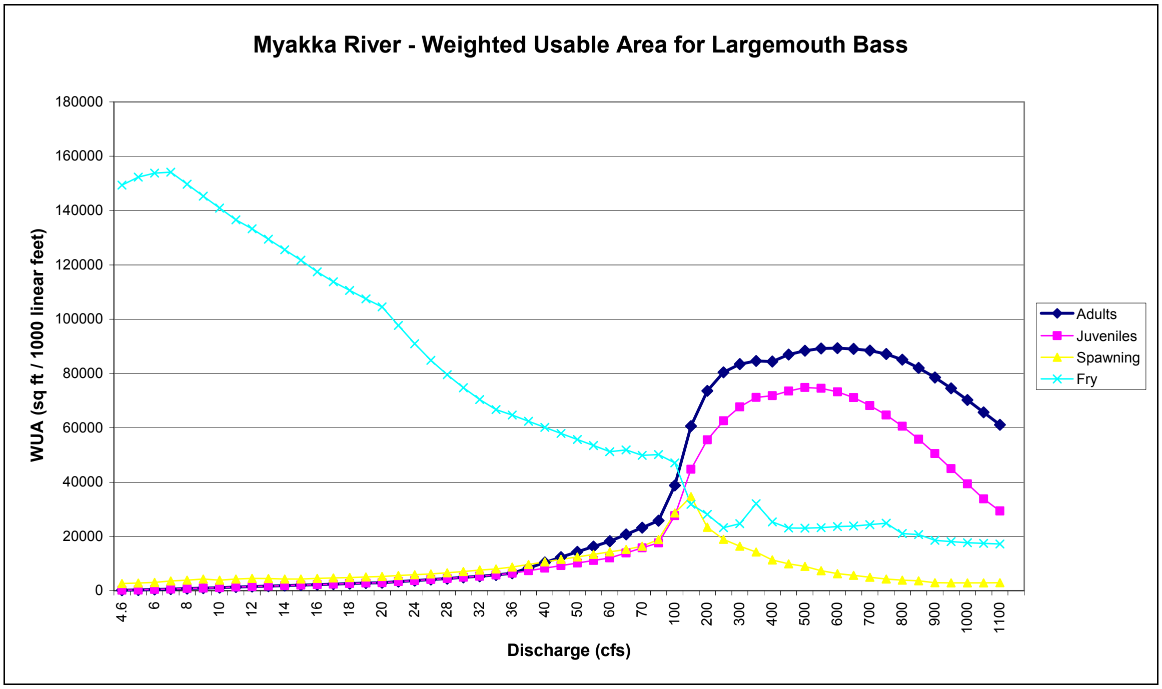


Figure 4-4. Weighted usable area (WUA) versus discharge for three life history stages (fry, juvenile, adult) and spawning activity of largemouth bass in the Myakka River.

PHABSIM analysis does not prescribe an acceptable amount of habitat loss for any given species or assemblage. Rather, given hydrologic data and biological preferences, it establishes a relationship between hydrology and WUA and allows examination of habitat availability in terms of the historic and altered flow regimes. Determining from these data the amount of loss, or deviation from the optimum, that a system is capable of withstanding is based on professional judgment. Gore et al. (2002) provided guidance regarding this issue, suggesting that "most often, no greater than a 15% loss of available habitat" is acceptable. For the purpose of minimum flows and levels development, we have defined percent-of-flow reductions that result in greater than a 15% reduction in habitat from historic conditions as limiting factors. Figure 4-5 shows an example of habitat gain/loss plots, which display changes in WUA (habitat) relative to flow reductions of 10 to 40%.

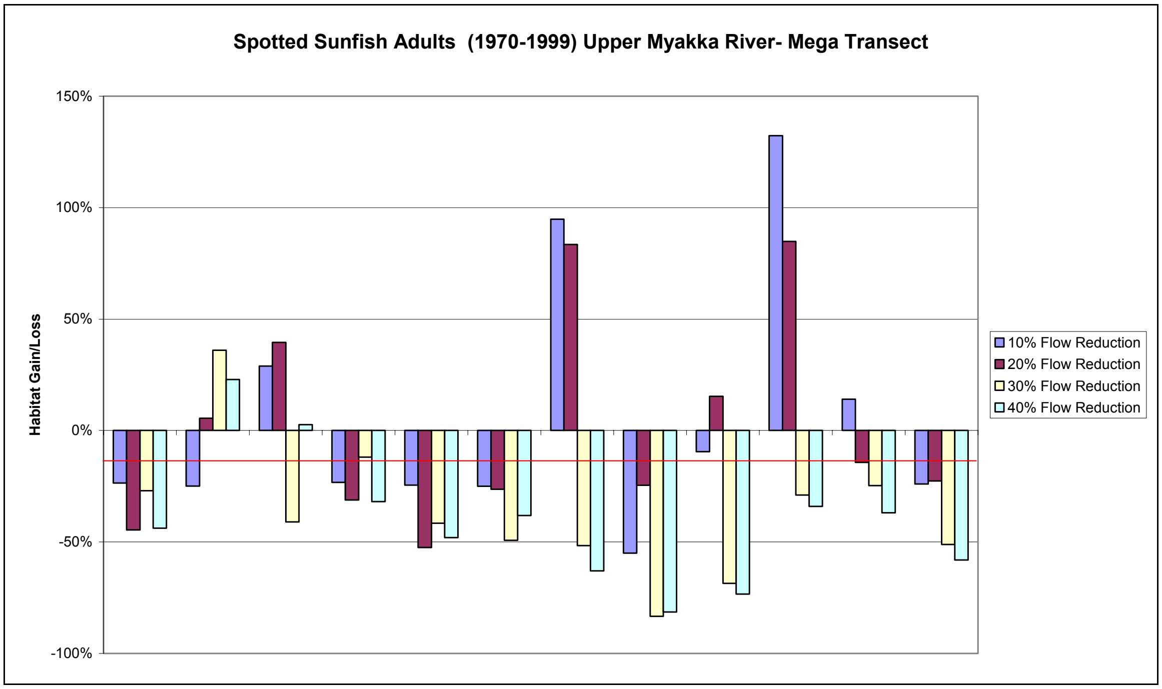


Figure 4-5. Example of a plot of habitat gain/loss relative to flow reductions of 10, 20, 30, and 40 %. Habitat loss is shown for spotted sunfish adults in the Myakka River based on historic flow records from 1970 to 1999.

4.3.2.1 Development of Habitat Suitability Curves

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

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

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

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

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

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

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

Per recommendation of the peer review panel for the middle Peace River, the District, over the long-term, intends to evaluate and develop additional habitat suitability curves for species of interest. For example curves could be refined for the spotted sunfish, new curves could be developed for species representative of feeding guilds, wading birds, and listed species.

4.3.3 Recent and Long-term Positional Hydrograph/Analyses

Recent and Long-term Positional Hydrographs (RALPH) analysis is used to identify the number of days during a defined period of record that a specific flow or level (elevation) was equaled or exceeded at individual river cross-sections, including streamflow gaging sites (Figure 4-6). The plots and associated spreadsheets are developed using measured elevations for habitats or other features and HEC-RAS model output. RALPH plots also allow examination of how future changes in flow could affect the number of days of inundation during a particular span of time (Figure 4-7). For the purpose of developing minimum flows and levels, percent-of-flow reductions that result in greater than a 15% reduction in habitat from historic conditions are characterized as limiting factors.

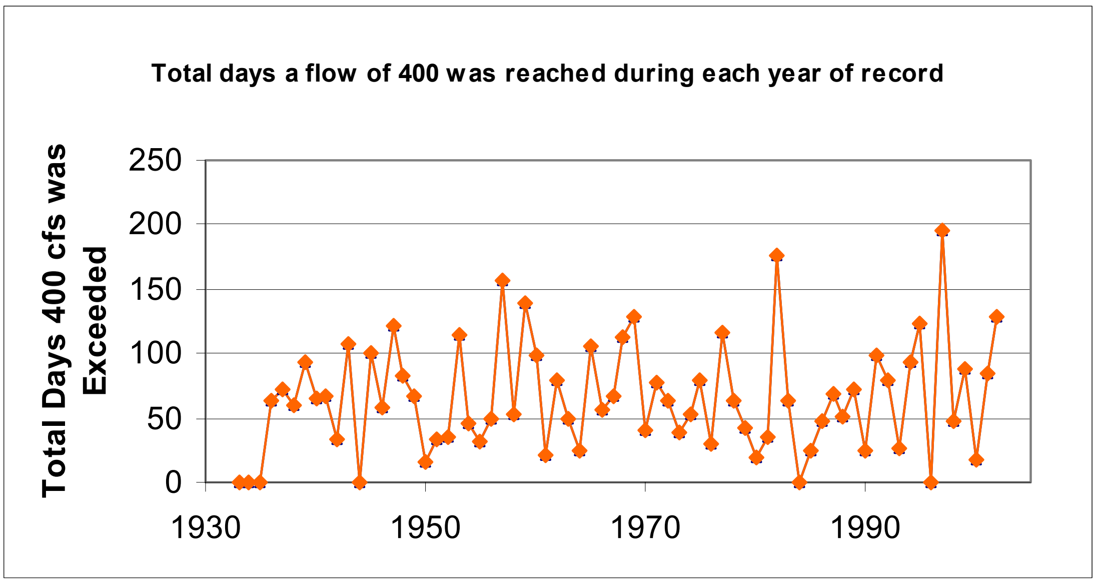


Figure 4-6. RALPH plot of the number of days during the southern river pattern (SRP) water year that 400 cfs is exceeded at the USGS Myakka River near Sarasota gage site.

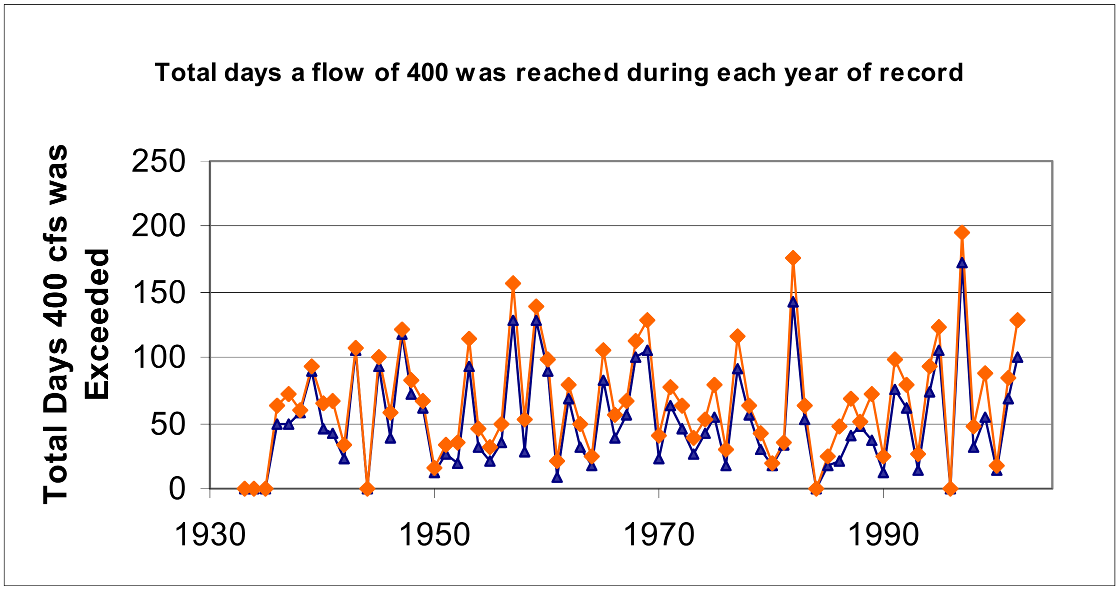


Figure 4-7. RALPH plot of the number of days during the southern river pattern water year that 400 cfs is exceeded at the USGS Myakka River near Sarasota gage site (orange line) compared with the number of days that inundation would have occurred if there had been a 20% reduction in river flows (blue line).

4.4 Seasonal Flow and Development of Blocks 1, 2, and 3

For development of minimum flows and levels for the Myakka River, we identified three seasonal blocks corresponding to periods of low, medium, and high flows. Lowest flows occur during Block 1, a 65-day period that extends from April 20 to June 24 (Julian day 110 to 175). Highest flows occur during Block 3, the 124-day period that immediately follows the dry season. This is the period when the floodplain is most likely to be inundated on an annual basis; although high flows can occur at other times. The remaining 176 days constitute an intermediate or medium flow period, which is referred to as Block 2 (Table 4-1).

Table 4-1 Beginning and ending calendar dates (and Julian days) for seasonal flow Blocks 1, 2, and 3 for the Myakka River.

Block	Start date (Julian Day)	End Date (Julian Day)	Number of Days
1	April 20 (110)	June 24 (175)	65
2	October 28 (301)	April 19 (109)	176
3	June 25 (176)	October 27 (300)	124

4.5 Low Flow Threshold

Protection of aquatic resources associated with low flows is an important component of the minimum flows and levels implementation. To accomplish this goal, it is necessary to develop a low flow threshold which identifies flows that are to be protected in their entirety (i.e*.,* flows that are not available for consumptive-use). To determine this threshold, two low flow standards are developed. One is based on the lowest wetted perimeter inflection point; the other is based on maintaining fish passage along the river corridor. The low flow threshold is established at the higher of the two flow standards, provided that comparison of that standard with historic flow records indicates that the standard is reasonable. Although flows less than the low flow threshold may be expected to occur throughout the year, they are most likely to occur during Block 1.

4.5.1 Wetted Perimeter Standard

Output from multiple runs of the HEC-RAS model were used to generate a wetted perimeter versus flow plot for each HEC-RAS cross-section of the Myakka River corridor (see Figure 4-8 as an example and Appendix WP for all plots). Plots were visually examined for inflection points, which identify flow ranges that are associated with relatively large changes in wetted perimeter. The lowest wetted perimeter inflection point (LWPIP) for flows up to 200 cfs was identified for each cross-section. Inflection points for flows higher than 200 cfs were disregarded since the goal was to identify the LWPIP for flows contained within the stream channel. Many cross-section plots displayed no apparent inflection points between the lowest modeled flow and 200 cfs. These cross-sections were located in pool areas, where the water surface elevation may exceed the lowest wetted perimeter inflection point even during low flow periods. For these cross-sections, the LWPIP was established at the lowest modeled flow. Flows associated with the LWPIP at each cross-section were converted to flows at the USGS Myakka River near Sarasota, FL gage using relationships from HEC-RAS model. The LWPIP flows are used to develop a wetted perimeter standard for the gage site.

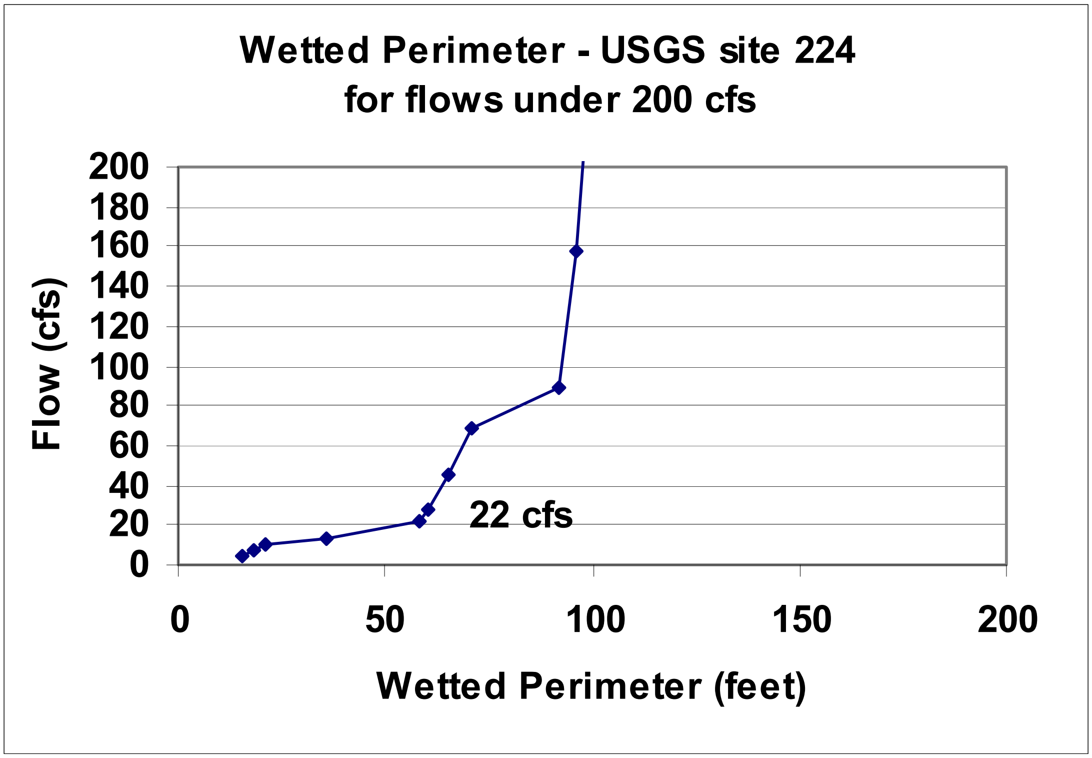


Figure 4-8. Wetted perimeter versus discharge at HEC-RAS transect number 224 in the Myakka River corridor. Wetted perimeter values for modeled flows up to 200 cfs are shown and the Lowest Wetted Perimeter Inflection Point (LWPIP) is identified.

4.5.2 Fish Passage

For development of minimum flows, it is desirable to maintain longitudinal connectivity along a river corridor, to the extent that this connectivity has historically occurred. To secure the benefits associated with connectivity and sustained low flows, a 0.6-ft fish-passage criterion was used to develop a low flow standard for the Myakka River. The fish-passage criterion has been used by the District for development of proposed minimum flows and levels for the upper Peace (SWFWMD 2002), Alafia (SWFWMD 2005a) and middle Peace (Kelly et al. 2005b) rivers and was found to be acceptable by the panel that reviewed the proposed upper Peace River flows (Gore et al. 2002). Further, Shaw et al. (2005) also found that “the 0.6-ft standard represents best available information and is reasonable”.

Flows necessary for fish-passage at each HEC-RAS cross-section were identified using output from multiple runs of the HEC-RAS model. The flows were determined by adding the 0.6-ft depth fish-passage criterion to the elevation of the lowest spot in the channel and determining the flow necessary to achieve the resultant elevations. At many cross-sections, the minimum channel elevation plus 0.6-ft resulted in a water surface elevation lower than the elevation associated with the lowest modeled flow. These cross-sections were located in pool or run areas, where fish passage could occur during periods of little or no flow. For these sites, the flow requirement for fish passage was established at the lowest modeled flow.

Ultimately, regressions between the stage at each cross-section and the flow at the USGS Sarasota gage were used to determine flows at the Sarasota gage that corresponded to the target fish-passage elevation at the cross sections (Figure 4-9). The flow at the Sarasota gage that was sufficient to provide for fish passage at all HEC-RAS cross sections at all sampled cross-sections was used to define the fish passage, low flow standard.

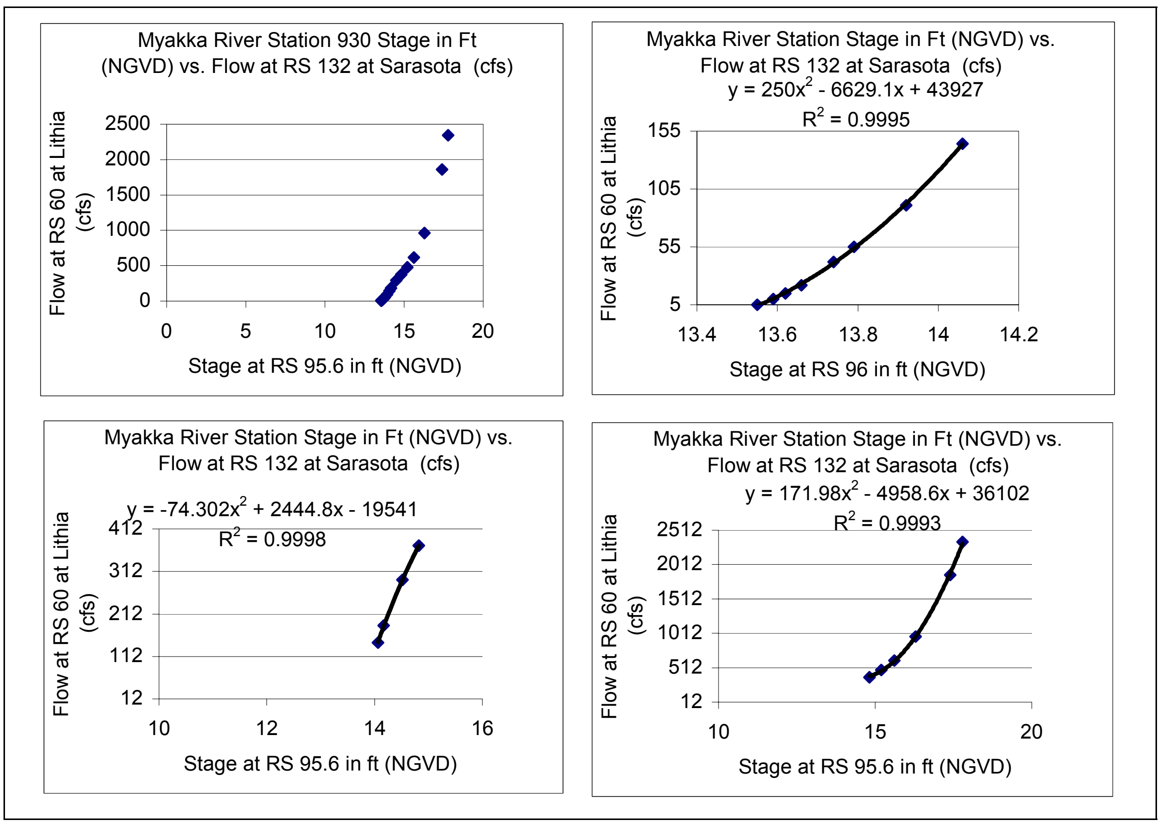


Figure 4-9. Stage flow relationships between HEC-RAS cross-section 132 and flow at the USGS Sarasota gage derived from the HEC-RAS model of the Myakka River. The upper-left plot shows the relationship derived for the entire range of flows evaluated. The other three show relationships used to develop regression equations for selected portions of the flow range.

4.6 Prescribed Flow Reduction for Block 1

When flows exceed the low flow threshold during Block 1, it may be that some portion of the flows can be withdrawn for consumptive use without causing significant harm. To establish these quantities, the availability of aquatic habitat for selected fish species and macroinvertebrate populations for low flow periods can be estimated using the Physical Habitat Simulation Model (PHABSIM).

4.6.1 PHABSIM – Application for Block 1

PHABSIM was used to evaluate potential changes in habitat associated with variation in low flows in the Myakka River. For the analyses, historic time series data from the Sarasota gage site for two benchmark periods, from 1940 through 1969 and from 1970 through 1999 was used. Simulations were conducted for various life-history stages of spotted sunfish, largemouth bass, bluegill, and for macroinvertebrate diversity at four sites on the Myakka River. Flow reductions during Block 1, (i.e., from April 20 to June 24) that resulted in no more than a 15% reduction in habitat from historic conditions for either benchmark period were determined to be limiting factors. These factors were used to derive prescribed flow reductions, which identify acceptable flow requirements for the Sarasota gage site during Block 1 when flows exceed the low flow thresholds.

4.7 Prescribed Flow Reduction for Block 2

During Block 2, flows are typically higher than in Block 1 (Figure 4-9), but are still dominated by in-channel events. Minimum flows and levels are established for Block 2 for flows that exceed the low flow threshold using PHABSIM to evaluate potential habitat losses, and through the use of HEC-RAS model output and RALPH plots and analyses to evaluate potential changes in the inundation of woody habitats. Results from the PHABSIM analysis and woody habitat analyses define limiting factors, the most conservative of which is used to develop a prescribed flow reduction for Block 2.

4.7.1 PHABSIM – Application for Block 2

PHABSIM was used to evaluate potential changes in habitat associated with variation in medium flows. For the analyses, we used historic time series data collected at the Sarasota gage site from 1940 through 1969 and 1970 through 1999. Simulations were conducted for various life-history stages of spotted sunfish, largemouth bass, bluegill, and macroinvertebrate diversity at four sites on the Myakka River. Maximum flow reductions that resulted in no more than a 15% reduction in habitat from historic conditions during Block 2, which runs from October 28 to April 19 of the following calendar year, were determined to be limiting factors. These factors were considered for development of prescribed flow reductions that identify acceptable flow requirements for the Sarasota gage site during Block 2 when flows exceed the low flow thresholds.

4.7.2 Snag and Exposed Root Habitat Analyses – Application for Block 2

Mean elevations of snag and exposed root habitats were determined for nine instream habitat cross-sections in the Myakka River corridor. Flows at the cross-section sites and corresponding flows at the Sarasota gage that would result in inundation of the mean habitat elevations at each cross-section were determined using the HEC-RAS model. RALPH plots/analyses were used to determine the number of days that the mean elevations for the snag or root habitat were inundated. Flow records from two benchmark periods (1940 through 1969 and 1970 through 1999) were examined to identify percent-of-flow reductions that would result in no more than a 15% loss of habitat defined as a reduction of no more than 15% of the number of days of inundation from direct river flow for the entire year, after prescribed flow reductions for Blocks 1 and 3 were applied. Although we acknowledge that a 15% change in habitat availability based on a reduction in spatial extent of habitat may not be equivalent to a 15% change in habitat availability based on number of days a particular habitat is inundated, the peer review panel for the middle Peace River MFL felt, "that the 15% threshold selected for preventing significant harm is appropriate" (Shaw et al. 2005). Loss of days of direct connection with river flows was evaluated for the entire year since woody habitats in the river are expected to be inundated during periods of high flow (Block 3) and may also be inundated by flows occurring during Block 1 in some years. The percent-of-flow reductions derived for Block 2 flows at the gage site were considered to be limiting factors and evaluated for development of prescribed flow reductions for Block 2 for the Myakka River near Sarasota gage and for two benchmark periods, from 1940 through 1969 and from 1970 through 1999.

4.8 Prescribed Flow Reduction for Block 3

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

Highest flows, including out-of-bank flows, are most likely to occur during Block 3, which for the Myakka River extends from June 25 to October 27. Minimum flows developed for this period are intended to protect ecological resources and values associated with the floodplain by maintaining hydrologic connections between the river channel and the floodplain and maintaining the natural variability of the flow regime. This goal is accomplished through the HEC-RAS modeling and use of RALPH plots/analyses to evaluate floodplain feature inundation patterns associated with channel-floodplain connectivity. Based on these analyses, a prescribed flow reduction for Block 3 can be developed.

4.8.1 Floodplain Connection Analyses – Application for Block 3

The HEC-RAS model output and RALPH plots/analyses were used to evaluate floodplain inundation patterns associated with river flows at the 12-floodplain vegetation cross-sections and associated flows at the Sarasota gage site. Inundation of elevations associated with floodplain features, including vegetation zones and soils, was evaluated to establish percent-of-flow reductions that would result in no more than a 15% reduction in the number of days of inundation during Block 3, based on flows during two benchmark periods (1940 through 1969 and 1970 through 1999). The percent-of-flow reductions were considered to be limiting factors and used for development of prescribed flow reductions for the Sarasota gage site during Block 3. Although we acknowledge that a 15% change in spatial extent of habitat may not be equivalent to a 15% change in habitat availability based on the number of days a particular habitat is inundated, the peer review panel for the middle Peace River MFL felt "that the 15% threshold selected for preventing significant harm is appropriate" (Shaw et al. 2005).

Chapter 5 Results and Recommended Minimum Flows

5.1 Overview

Results from modeling and field investigations on the Myakka River were assessed to develop minimum flow criteria/standards for ensuring that ecological functions associated with various flows and levels are protected from significant harm. A low flow threshold based on historic flows is recommended for the USGS Myakka River near Sarasota gage site, along with prescribed flow reductions for Blocks 1, 2, and 3. Based on the low flow threshold and prescribed flow reductions, short-term and long-term minimum flow compliance standards are identified for establishing minimum flows and levels for the Myakka River

5.2 Low Flow Thresholds

The low flow threshold defines flows that are to be protected in their entirety (i.e., flows that are not available for consumptive-use) throughout the year. The low flow threshold is established at the higher of two flow standards, which are based on maintaining fish passage and maximizing wetted perimeter for the least amount of flow in the river channel. The low flow must also be historically appropriate. For the Myakka River, the low flow threshold was developed for the USGS Myakka River near Sarasota, FL gage site.

5.2.1 Fish Passage Standards

Flows necessary to reach a maximum water depth of 0.6 foot to allow for fish passage at each cross-section in the HEC-RAS model of the Myakka River between the gage site at Myakka City and the gage site near Sarasota are shown in Figure 5-1. At most cross-sections, the minimum water surface elevation that would allow for fish passage was lower than the elevation associated with the lowest modeled flow. These cross-sections were located in pool or run areas, where fish passage would be possible during low flow periods.

Inspection of the data indicated that flows equal to or greater than 32 cfs at the Sarasota gage would be sufficient for fish passage at all sampled sites except one which requires 186 cfs. This cross section is located at the weir at the outfall of Upper Myakka Lake. At this location there are six culverts present which allow fish passage at lower flows. A flow of 32 cfs was therefore used to define the fish passage standard for the Sarasota gage site on the Myakka River. This standard flow is sufficient to maintain constant flow in the river and would minimize problems such as low dissolved oxygen levels that may be associated with low flow or stagnant conditions.

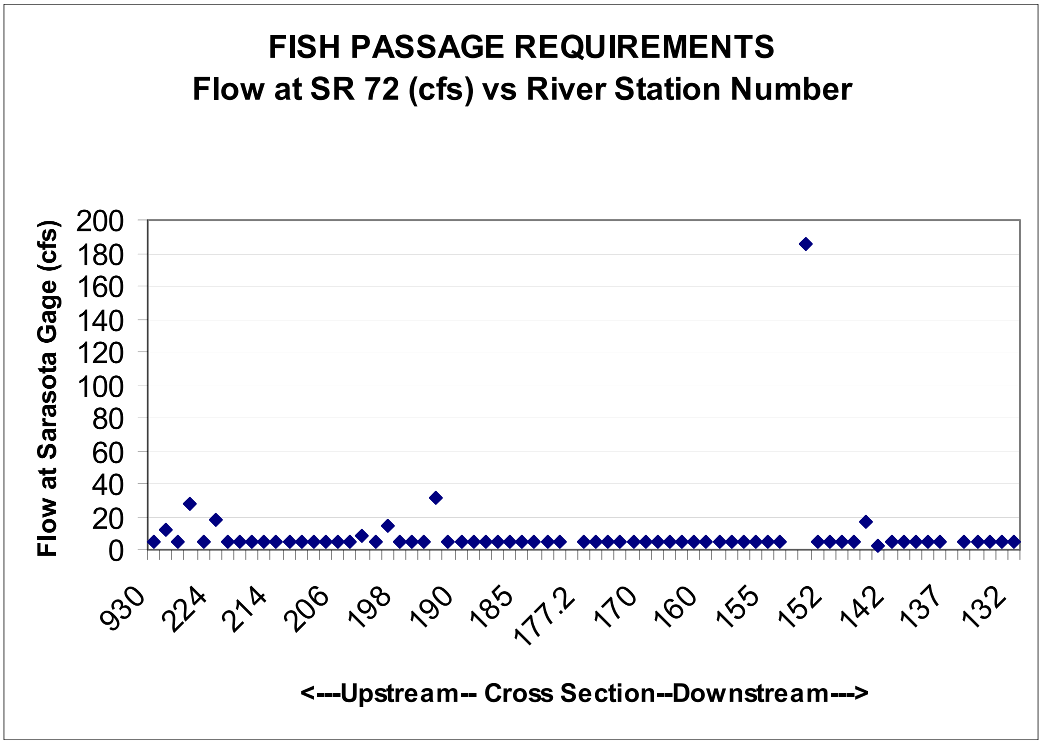


Figure 5-1. Plot of flow required at the Myakka River near Sarasota gage to inundate the deepest part of the channel at each HEC-RAS cross-section in the Myakka River to a depth of 0.6 ft.

5.2.2 Wetted Perimeter Standards

Wetted perimeter plots (wetted perimeter versus local flow) and the lowest wetted perimeter inflection point (LWPIP) were developed for each HEC-RAS cross-section of the Myakka River between the gage sites at Sarasota and Myakka City based on modeled flow runs (see Appendix WP for all plots). The LWPIP was below the lowest modeled flow for numerous sites, especially towards the downstream end of the study corridor (Figure 5-2). The highest flows required to inundate LWPIPs correspond to local flows of 54 and 52 cfs, at site 138.4 and 150, respectively. The local flows of 54 and 52 cfs at cross-section 138.4 and 150 correspond to a flow of 55 cfs at the Sarasota gage which is just downstream of site 138.4. A flow of 55 cfs at the Sarasota gage would, therefore, be sufficient to meet the local LWPIP flows at all sampled cross-sections. These two sites, though the highest, do not depart greatly from the range of LWPIPs seen throughout the study corridor. Based on these considerations, the wetted perimeter flow standard for the Myakka River between the gage sites at Myakka City and near Sarasota was established at 55 cfs at the Sarasota gage.

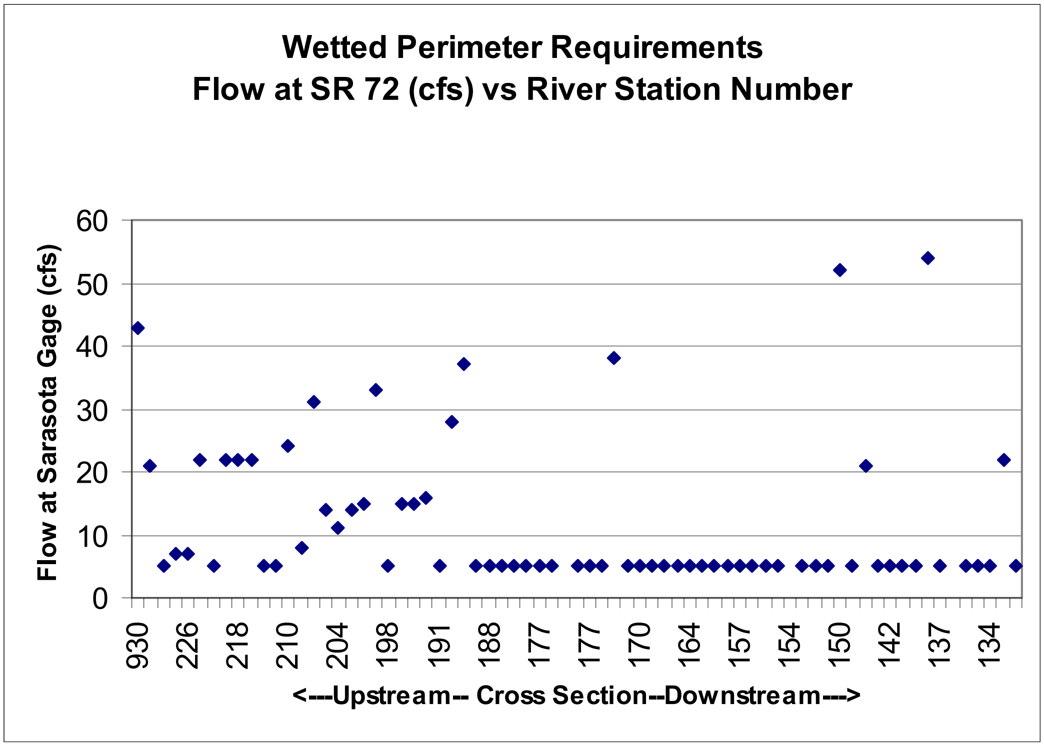


Figure 5-2. Plot of local flow required to inundate the lowest wetted perimeter inflection point at each HEC-RAS cross-section. Local flows are shown for site 132 (the Sarasota gage) to sites at the Myakka city gage (site 930).

5.2.3 Low Flow Threshold

Recall from Chapter 1 that South African researchers stated, "a river's natural perenniality or nonperenniality should be retained" (Postel and Richter 2003). Examining Figure 5-3 it is evident that during the period from 1940 to 1969 flows at the gage site went to near zero at least half the time during much of the Block 1 period. Examination of the period of record data shows that the median year between 1940 and 1969 had 47 days of no flow, while the average year for the same period had 55 days of no flow. The median year between 1970 and 1999 had zero days of no flow, while the average year for the same period had only 12 days of no flow. This change is inconsistent with other rivers in the District and with the expectation generated by the AMO (Kelly 2004). As discussed in Chapter 2, there has been an increase in low flows in the Myakka River. This increase has resulted in a previously non-perennial river becoming perennial.

Historic flows went to zero on a regular and consistent basis. It would be inappropriate to impose a low flow threshold, which limited withdrawals based on the protection of a fish passage or wetted perimeter standard that was regularly unmet by naturally occurring historic flows. Therefore, a low flow threshold of 0 cfs is recommended to be established at the USGS Myakka River near Sarasota, FL gage site.

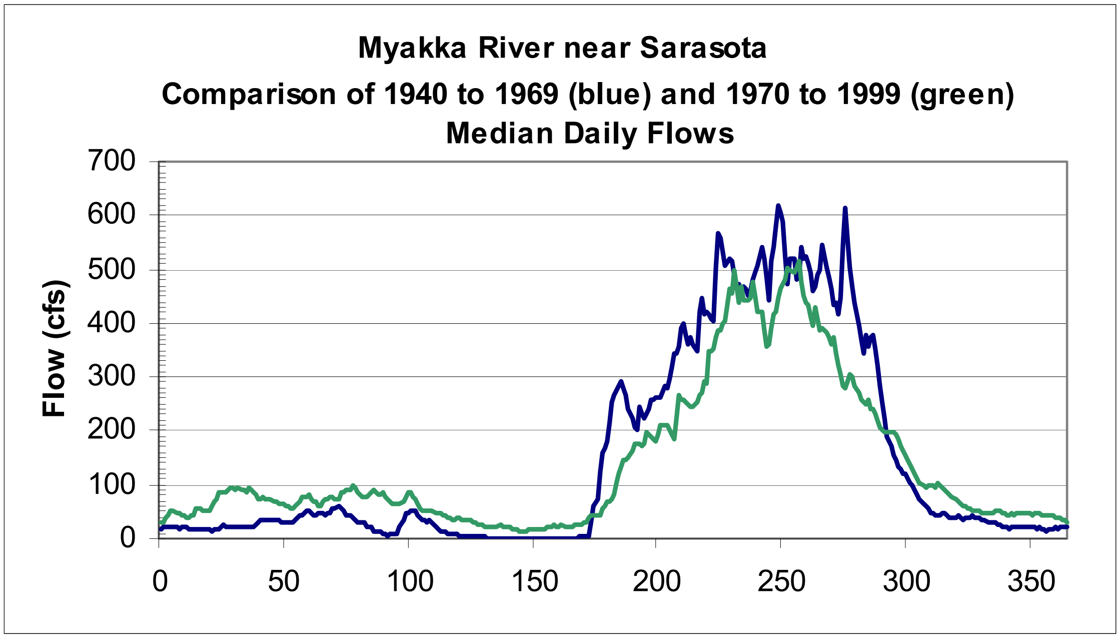


Figure 5-3. Comparison of median daily flows from 1940 to 1969 with median daily flows for 1970 to 1999 at the Myakka River near Sarasota gage site.

5.3 Prescribed Flow Reduction for Block 1

A prescribed flow reduction for Block 1 at the Myakka River near Sarasota gage sites was based on review of limiting factors developed using PHABSIM to model potential changes in habitat availability for several fish species and macroinvertebrate diversity. During Block 1, which runs from April 20 through June 24, the most restrictive limiting factors identified for the PHABSIM cross-section sites were habitat suitability for adult and juvenile largemouth bass and adult spotted sunfish. Based on the 1940 through 1969 benchmark period adult spotted sunfish exhibit a 15% loss of habitat when flows are reduced by 18%. In both benchmark periods, simulated reductions in historic flow greater than 15% resulted in more than 15% loss of available habitat for adult largemouth bass and a 14% reduction in flow resulted in a 15% loss of habitat for juvenile largemouth bass (Figure 5-4, Figure 5-5, and Appendix PHABSIM). Examining the lowest percent flow reduction allowed During Block 1 and averaging the lowest each

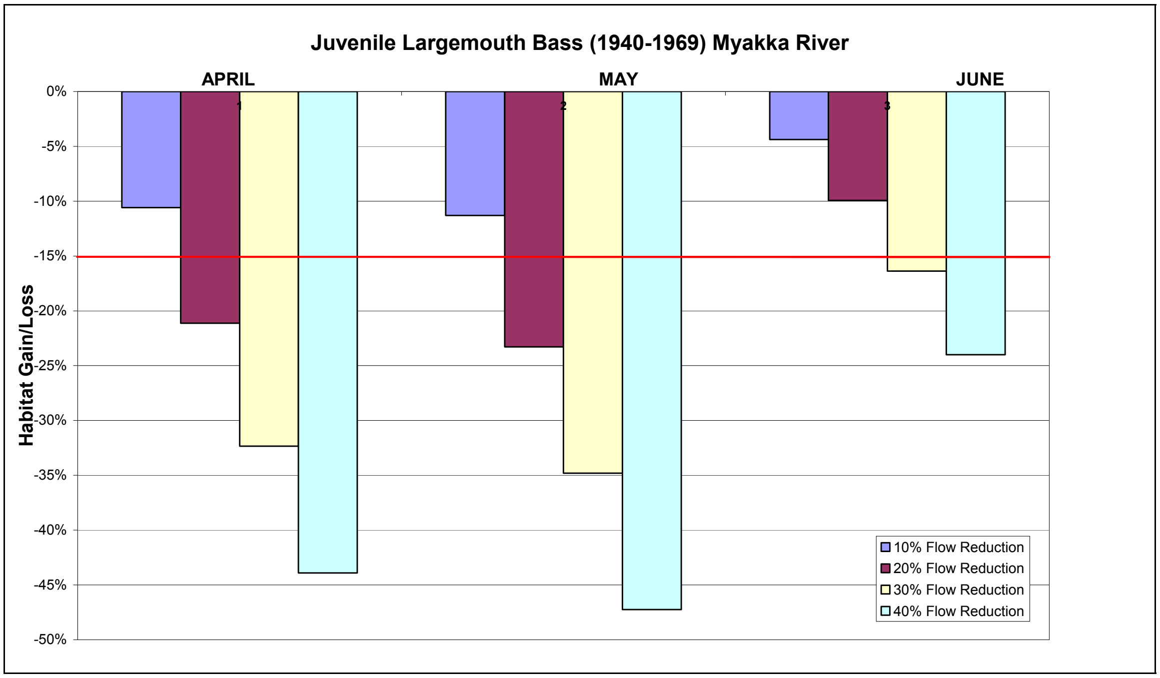


Figure 5-4. Predicted habitat gain/loss for juvenile largemouth bass during April, May and June based on the flow record for the Myakka River near Sarasota gage site from 1940 to 1969.

	Apr	May	June
◆ Mean	24	25	28
Minimum	15	14	18
Maximum	36	36	36
N	12	17	10

Figure 5-5. Summary of PHABSIM results for the Myakka River near Sarasota gage. Predicted habitat gain/loss for all species which limited flow reduction to less then 50% during April, May and June based on the flow record for the Myakka River near Sarasota gage site and both benchmark periods.

month resulted in a prescribed flow reduction of 15% for Block 1 at the Myakka River near Sarasota gage.

5.4 Short-Term Compliance Standards for Block 1

Short-Term Compliance Standards represent a flow prescription that can be utilized for evaluating minimum flows compliance on a short-term basis, for example, based on measured daily flows. For the USGS Myakka River near Sarasota, FL gage site, the following Short-Term Compliance Standards are proposed for Block 1, which begins on April 20 and ends on June 24:

1) The low flow threshold is 0 cfs;

2) A 15% reduction of all flows measured at the USGS Myakka River near Sarasota, FL gage is available for consumptive use.

The second standard was developed to permit compliance with the Block 1 prescribed flow reduction without violation of the low flow threshold.

5.5 Prescribed Flow Reductions for Block 3

The prescribed flow reductions for Block 3 flows at the Myakka River near Sarasota gage site was based on review of limiting factors developed using the Myakka River HEC-RAS model and RALPH analyses. Factors assessed included changes in the number of days that river flows were sufficient for inundation of identified floodplain features, including river banks, floodplain vegetation zones, floodplain wetted perimeter inflection points and hydric soils. Change in the number of days specific flows occurred was assumed to be a good indication of potential changes in inundation patterns for floodplain features, including those that were not identified. During Block 3, which runs from June 25 to October 27 for the Myakka River, it was determined that a stepped reduction in historic flows was appropriate and would allow for consumptive uses and habitat protection. During Block 3 when flows are less than the 15% exceedance flow (577 cfs), based on the time period from 1940 to 1969, a 16% reduction in historic flows can be accommodated without exceeding a 15% loss of days of connection. When flows exceed the 15% exceedance flow (577 cfs) more than an 8% reduction in historic flows resulted in a decrease of 15% or more in the number of days that flows would inundated floodplain features. Using these limiting conditions, the prescribed flow reduction for Block 3 for the Myakka River near Sarasota gage site was defined as an 8% reduction in flows when flows exceed 577 cfs and a 16% reduction in flows when flows are below 577 cfs, provided that no withdrawal results in failure to comply with the low flow threshold.

5.5.1 Inundation of Floodplain Features

Floodplain profiles, as shown for cross section (transect) 6 in Figure 5-6, were developed for the twelve floodplain vegetation cross sections (see Appendix RH). Distances across the floodplain (cross section or transect lengths) ranged from 1297 to 5518 ft. Local (cross-section site) flows needed to overflow the river's banks ranged from 29 to 2447 cfs (see Appendix RH for channel bank and other floodplain feature elevations and associated flows). Mean flow at the Sarasota gage that corresponded to the flow necessary for exceeding the elevation of the lowest bank on either side of the river averaged 311 cfs; flows at the gage that would be sufficient for the river to overflow both banks averaged 566 cfs (Table 5-3).

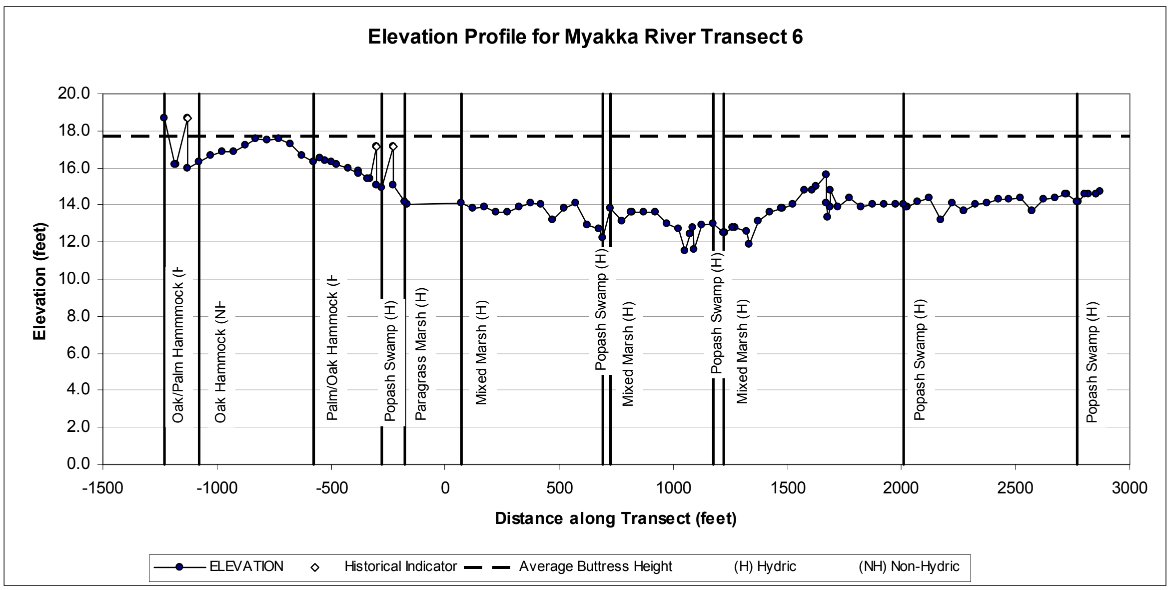


Figure 5-6. Elevation profile for floodplain vegetation cross-section (transect) 6. Distances (cumulative length) are shown centered on the middle of the river channel. Floodplain features relative to elevation shown include occurrence of vegetation zones, hydric and non-hydric soils, historical and seasonal hydrologic indicators and buttress heights.

Ten major vegetation zones or community types within the river floodplain and their respective median elevations were identified at the twelve floodplain vegetation cross-sections on the Myakka River (Table 5-1). Detailed descriptions of the vegetation zones or classes, which include Mixed Marsh, Panicum Marsh, Paragrass Marsh, Popash Swamp, Oak/Popash Wet Hammock, Oak/Palm Wet Hammock, Palm/Oak Dry Hammock, Cabbage Palm Dry Hammock, Saw Palmetto/Oak Upland and Saw Palmetto Upland are provided in PBS&J (2005). Woody species composition and dominance were significantly different between the ten vegetation classes identified along the Myakka River study transects based on importance values (IVs) of tree species, an index that combines relative density, frequency, and basal area of tree species (Table 5-2).

Table 5-1. **Median elevations (NGVD) of vegetation classes by transect along the upper Myakka River. Shaded cells indicate community absence on a transect.**

	Upstream Transects			→					**Downstream Transects**			
Vegetation Class	**HB**	**CARL**	**5**	**6**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Panicum Marsh	25	.	16.1	.	.	16.1	.	.	13.7	13.7	12.3	.
Mixed Marsh	.	.	.	14		13.5	12.7	.	.	.	.	.
Paragrass Marsh	.	.	15.7	14.9		.	15.6	14.4	13.6	13.3	12.2	12.1
Popash Swamp	.	.	15.4	14.4	14.7	15.4	.	.	.	13.8	13.55	13.1
Oak/Popash Wet Hammock	23.8	.	.	.	.	.	.	.	.	.	.	13. 5
Oak/Palm Wet Hammock	.	20.8	16.5	.	15.8	16.6	16	.	15.4	14.7	13.6	.
Palm/Oak Dry Hammock	.	18	15.6	16.2	16.4	.	16.5	.	.	15.1	14.2	.
Cabbage Palm Dry Hammock	.	.	16	16	.	17.36	.	.	.	15.9	.	.
Saw Palmetto/Oak Upland	26.2	20.2	17.3	.	17	.	16.9	.	.	16.1	.	15.3
Saw Palmetto Upland	26.6	.	.	.	.	.	.	.	16.6	16.8	.	.

Table 5-2. Importance values for tree species in vegetation zones for the Myakka River floodplain.

Wetland Status	Plant Species	Vegetation Classes for Transects along the upper Myakka River (shaded cells indicate species absence)										
		Mixed Marsh	Paragrass Marsh	Panicum Marsh	Popash Swamp	Oak/ Popash	Oak/ Palm	Palm/ Oak	Cabbage Palm	Saw Palmetto /Oak	Saw Palmetto	Total IV (Rank)
OBL	*Carya aquatica*					23.6						23.6 (10)
OBL	*Cephalanthus occidentalis*	51.8	41.7	20.1	7.1		1.3			1.7		123.7 (6)
OBL	*Fraxinus caroliniana*		39	49.1	208.3	71.6	17.3	7.6	22.3			415.1 (3)
OBL	*Gleditsia aquatica*		42.6		5.9		2.6	2.5	10.5			64.2 (8)
OBL	*Ilex cassine*						1.3					1.3 (15)
OBL	*Persea palustris*			19.7	2.3							22.0 (11)
OBL	*Salix caroliniana*	248.2			10.4	15.2						273.8 (4)
FACW	*Acer rubrum*			63.7	7.04	15.2		3.5		1.73		91.1 (7)
FACW	*Pinus elliottii*			6.3			3.4			10.8		20.4 (12)
FACW	*Quercus laurifolia*		100.3	59.3	32.3	120.4	163.4	112.2	46.5	180.6		815 (2)
FACW	*Quercus myrtifolia*			25.6						1.7		27.3 (9)
FAC	*Lyonia fruticosa*			7.3						4.5		11.7 (13)
FAC	*Myrica cerifera*		6.9							1.7		8.6 (14)
FAC	*Sabal palmetto*			49	26.6	54.1	110.9	162.2	220.7	92.8	188.5	974.1 (1)
UPL	*Quercus virginiana*							12		4.6	111.5	128.2 (5)

Although not all zones were identified at all sites, the vegetation zones were typically distributed along an elevation gradient when normalized to channel elevation. Marshes and swamps (Mixed, Panicum, Paragrass and Popash) tend to occupy the lowest elevations. This was followed by Wet Hammock (Oak/Palm) and Dry Hammocks (Palm/Oak, Cabbage Palm). Upland vegetation represented by Saw Palmetto and Oak occupied the highest median elevations (Figure 5-7). The Oak/Popash Wet Hammock vegetation zone was not included in this analysis because this community type occurred in Sites 15 and HB. These sites were discarded because of recently modified channel elevations due to dredging for waterway navigation near the bridge as well as farming activities. Inundation of the highest floodplain vegetation class that is seasonally inundated (such as the oak/palm wet hammock) would require flows ranging from 352 to 1679 cfs as measured from the USGS Sarasota gage (see Appendix RH). Inundation of the median elevation associated with the floodplain swamp and marsh vegetation zones (Paragrass Marsh, Panicum Marsh, Mixed Marsh, and Popash Swamp) would occur when flows at the USGS Sarasota gage would range from 100 cfs to 847 cfs (Appendix RH). Mean flows required to inundate these low-lying marsh and swamp vegetation zones ranged from 331 to 625 cfs as measured from the USGS Sarasota gage (Table 5-3). Mean flows required to inundate the wet hammock vegetation zones (Oak/Popash and Oak/Palm) range from 467 to 863 cfs as recorded from the USGS Sarasota gage (Table 5-3).

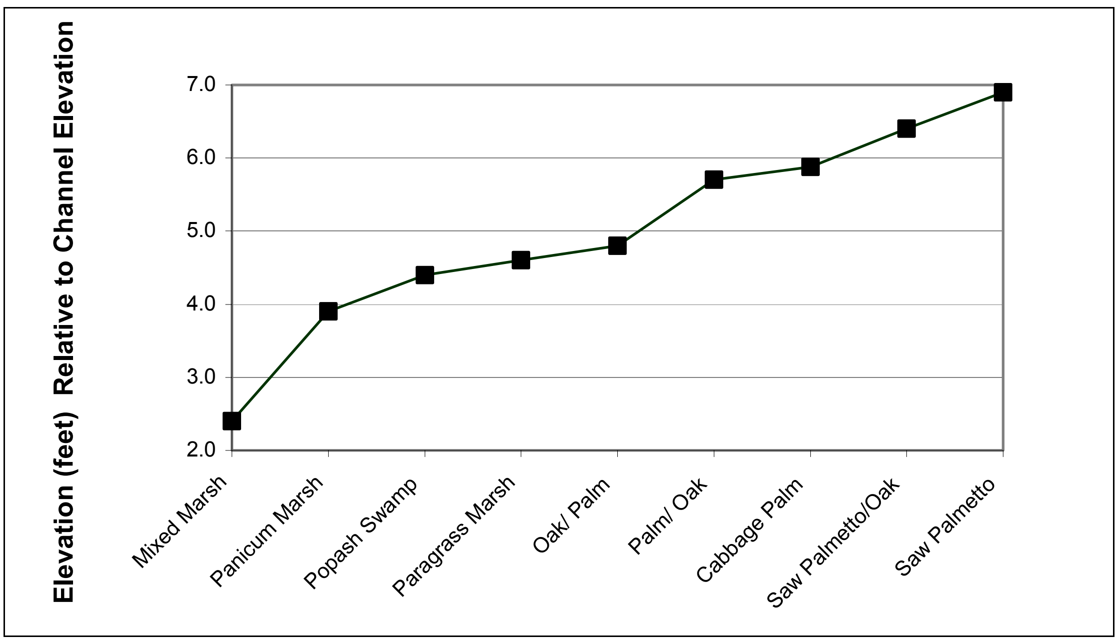


Figure 5-7. Median elevations of vegetation classes along the upper Myakka River relative to channel elevations. Data from Transect 15 and HB were excluded due to anthropogenic disturbances noted at the transect sites.

Hydric and muck soils were identified in all twelve sampled vegetation cross-section sites (Figure 5-8). Where they occurred, hydric soils and muck were consistently associated together and occurred at lower elevations compared to nonhydric and non-mucky soils especially at transects associated with marshes and swamps located at Myakka River State Park. Based on output from the HEC-RAS floodplain model, mean flows measured from the USGS Sarasota gage would range from 637 to 694 cfs and this would be necessary to inundate the median hydric and mucky soil elevations (Table 5-3).

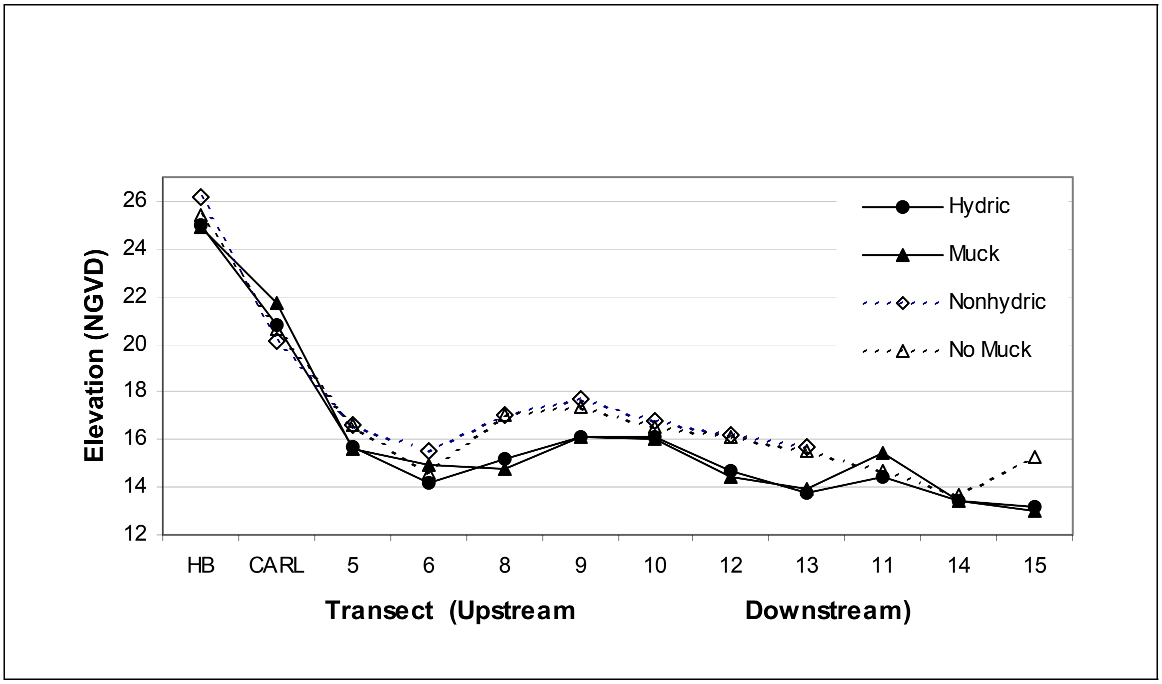


Figure 5-8. Median elevations (NGVD) of hydric, muck, non-hydric and non-muck soils along the Myakka River.

Floodplain wetted perimeter plots (patterned after the wetted perimeter plots used for identification of the Lowest Wetted Perimeter Inflection Point) were developed for each floodplain vegetation cross section (see Appendix RH). The plots were developed to show the linear extent of inundated floodplain (wetted perimeter) associated with measured floodplain elevations, including the median elevations of the floodplain vegetation classes. For example, Figure 5-9 shows a floodplain wetted perimeter plot for floodplain vegetation cross-section (transect) 6. Based on the plot, 2166 linear feet of floodplain would be inundated when the river is staged at the median elevation of the Mixed Marsh vegetation zone. Flows necessary to inundate the first major slope change beyond the top of the stream bank at each transect were evaluated using the HEC-RAS model. Average corresponding flows of 463 cfs at the USGS Sarasota gage would be necessary to inundate the lowest major inflection point associated with maximizing floodplain inundation levels for the minimum amount of river flow (see Appendix RH). Correspondingly, if more flow were allowed to inundate the floodplain, the next major breakpoint in the wetted perimeter would require an average of about 827 cfs as measured by the USGS Sarasota gage (Table 5-3).

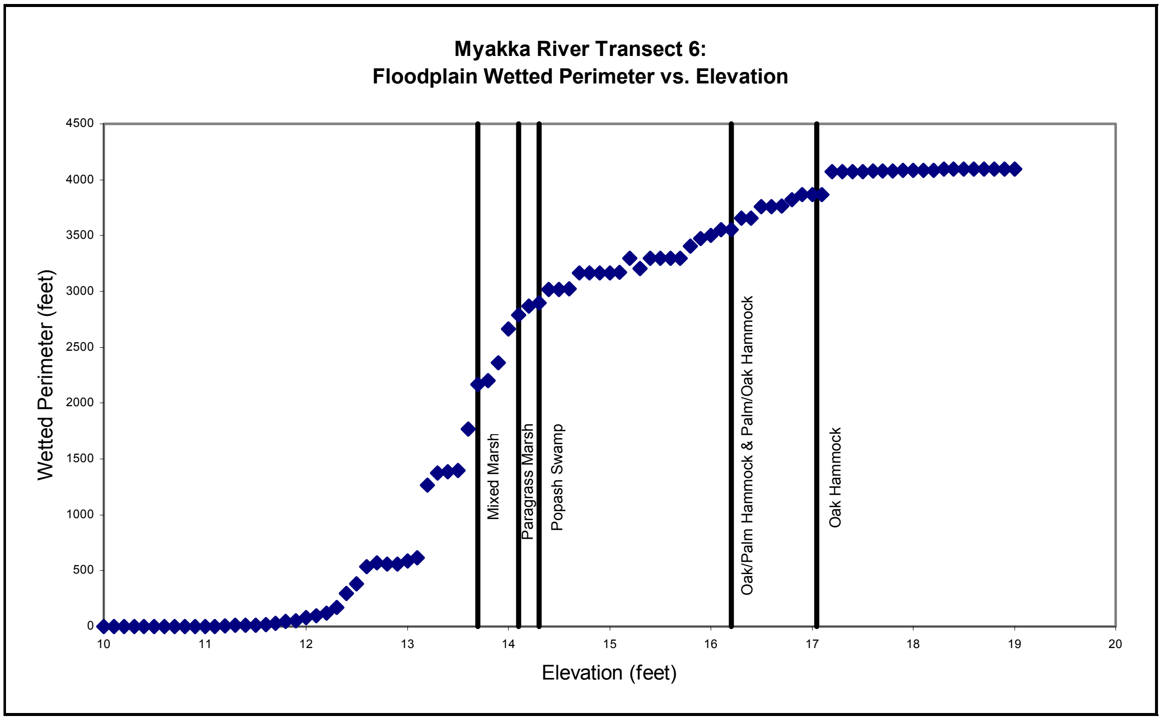


Figure 5-9**.** Floodplain wetted perimeter versus elevation at floodplain cross-section 6 (transect 6). Vertical bars indicate median elevations of floodplain vegetation zones recorded at the site.

Table 5-3. Mean (+SD) flows at the Sarasota gage required to inundate selected floodplain features and maximum reductions associated with less than a 15% reduction in the number of days of flow sufficient to inundate the feature. Reductions were based on flow records for 1940 to 1969 and 1970 to 1999.

Floodplain Feature	Number of floodplain transects containing feature (N)	Mean (+SD) Flow Required for Inundation	Percent-of-Flow Reduction 1940 to 1969	Percent-of-Flow Reduction 1970 to 1999
Lowest Bank Elevation to inundate one side of the river floodplain	12	311 (265)	15%	8%
Lowest Bank Elevation to inundate both sides of river floodplain	9	566 (681)	16%	11%
Median Elevation of Oak-Palm Wet Hammock	8	863 (410)	13%	8%
Median Elevation of Oak-Popash Wet Hammock	2	467 (189)	16%	9%
Median Elevation of Popash Swamp	7	354 (92)	20%	15%
Median Elevation of Paragrass Marsh	8	332 (152)	21%	15 %
Median Elevation of Mixed Marsh	3	33 (57)	72%	68%
Median Elevation of Panicum Marsh	6	625 (435)	16%	11%
Median elevation of mucky soils	12	694 (577)	15%	10%
Median elevation of hydric soils	12	636 (468)	16%	11%
First major low inflection point on wetted perimeter	12	463 (297)	17%	11%
First major high inflection point on wetted perimeter	12	827 (927)	15%	9%

Changes in flow at the Sarasota gage during Block 3 that are expected to result in no more than a 15% reduction in the number of days of inundation of the mean elevation of selected floodplain features are listed in Table 5-3. The percent-of-flow changes, which were determined, using RALPH analyses, ranged from 8-15% for 1970 to 1999 and from 13-21% for 1940 to 1969. The one exception to this was mixed marsh, which occurred at three vegetative cross-sections (see Appendix RH). At one cross-section, a flow of 100 cfs was required to inundate the median elevation of the marsh. At the other two the median elevation was below the lowest modeled flow and so the flow required approached 0 cfs. Examination suggests that higher flows might require a slightly more restrictive standard than some of the indicators associated with low flows in the table.

To further investigate limiting factors associated with the Myakka River floodplain, a RALPH analysis of percent-of-flow reductions that would result in a 15% loss of the number of days river flows reached a given flow was produced (Figures 5-10). Plots ranged from 100 to 2,000 cfs at the Myakka River near Sarasota gage site. The low end of the plotted flows reflects the approximate 50% exceedance flow for the period of record, a flow that is used to define the beginning of Block 3. The high end of the plotted flow range was selected to exclude rare flow events (approximately the 1% exceedance) that would be expected to occur for relatively short durations; durations for which 15% changes would be difficult to evaluate. To develop the plot, the 1940 to 1969 benchmark period was used. The 1970 to 1999 benchmark period resulted in generally lower numbers but the flow record was considered to be augmented (see Chapter 2).

Figure 5-10 indicates that for flows of approximately 1000 cfs or greater, flow reductions that result in a 15% reduction in the number of days the flow is achieved tend to stabilize around 7% for the Sarasota gage site. This percent-of-flow reduction is comparable to the values derived for flows at the Sarasota site, from 1970-1999, that would inundate dominant vegetation zones, mucky soils, and top of bank elevations (Table 5-3). Collectively, these data indicate that up to a 7% reduction in the flows necessary to inundate floodplain features of the middle Myakka River, including those we have not identified, will result in a 15% or less reduction in the number of days the features are inundated. However, the plots also show that there are flows which occur during Block 3 which do not require reductions be limited to 7% to avoid a 15% reduction in the number of days a flow is achieved. Using the 15% exceedance of 577 cfs at the Sarasota gage as a cutoff, we can apply a stepped prescription, which allows a 7% reduction in flows when flows exceed 577 cfs, and a 16% reduction in flows when flows are below 577 cfs (Figure 5-10). While other multiple steps could be made, or an algorithm applied to determine the percent flow reduction allowed, the single step provides a conservative means assuring that unidentified factors are likely to be protected and that water not needed to protect from significant harm is available for consumptive use. Unidentified factors could include either unidentified vegetative zones or inundation to various depths of zones which have been identified. If the 1970 to 1999 benchmark period was used, the stepped flow restriction would likely have been 7% above about 525 cfs and 12% below 525 cfs.

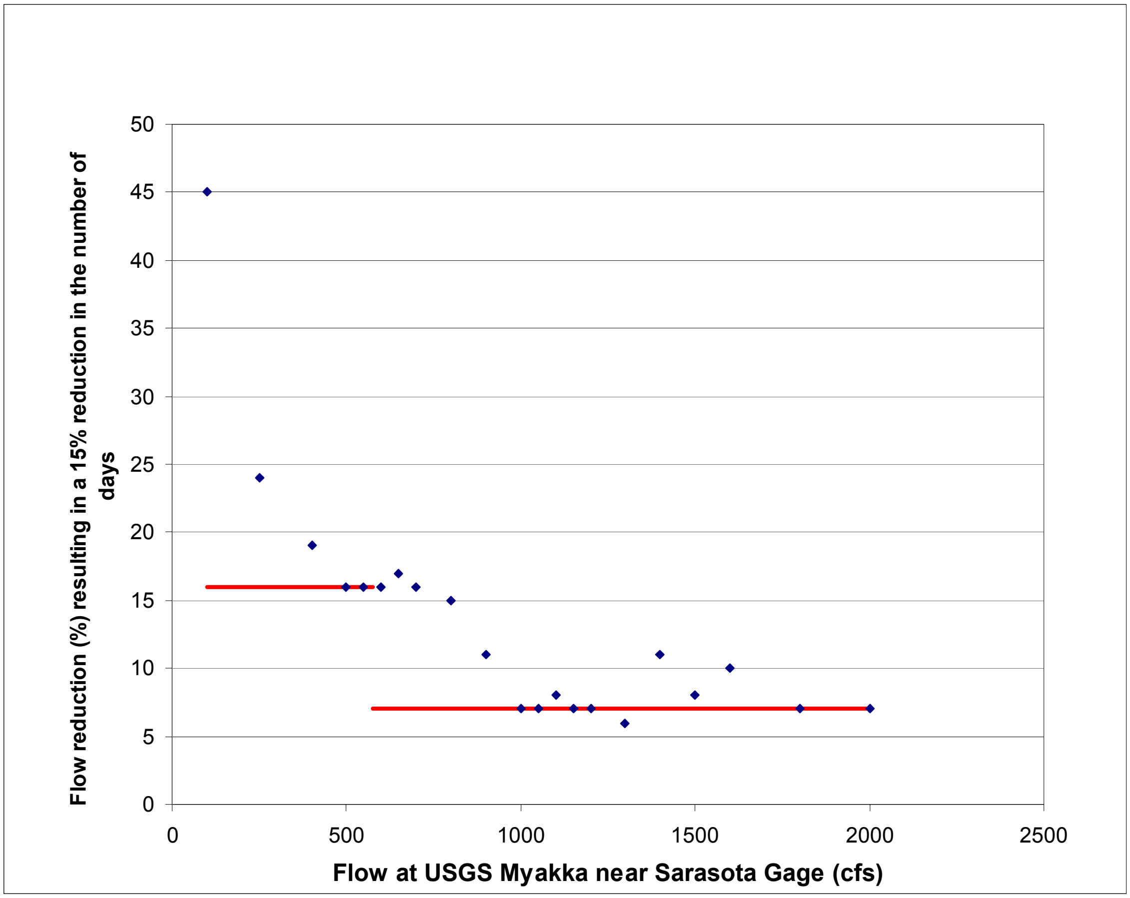


Figure 5-10. Percent-of-flow reductions that result in a 15% reduction in the number of days flows at the USGS Myakka River near Sarasota gage are achieved, based on flow records from 1940 through 1969.

5.6 Short-Term Compliance Standards for Block 3

Short-Term Compliance Standards represent a flow prescription that can be utilized for evaluating minimum flows compliance on a short-term basis, for example, based on measured daily flows. During Block 3, which for the Myakka River begins on June 25 and ends on October 27, standards were developed for the Myakka River near Sarasota gage site.

For the USGS Myakka River near Sarasota, FL gage site, the following Short-Term Compliance Standards are proposed for Block 3:

1) A 16% reduction of all flows between 0 cfs and 577 cfs measured at the Myakka River near Sarasota gage are available for use; and

2) A 7% reduction of all flows above 577 cfs measured at the Myakka River near Sarasota gage is available for use.

The two standards were developed through RALPH analysis to assure no greater than a 15% loss of days of a given flow is being achieved.

5.7 Prescribed Flow Reduction for Block 2

A prescribed flow reduction for Block 2 flows at the Myakka River near Sarasota gage site was based on a review of limiting factors developed using PHABSIM to model potential changes in habitat availability for several fish species and macroinvertebrate diversity, and use of RALPH analyses to specifically evaluate changes in inundation patterns of woody habitats. The prescribed flow reductions were established by calculating the percent-of-flow reduction which would result in no more than a 15% loss of habitat availability during Block 2 or no more than a 15% reduction in the number of days of inundation of exposed root habitat over the entire year, after prescribed flow reductions for Blocks 1 and 3 were applied. PHABSIM analyses yielded the most conservative percent-of-flow reductions. PHABSIM results were therefore used to establish a prescribed flow reduction of 5% for the Sarasota gage site.

5.7.1 Application of PHABSIM – Block 2

PHABSIM analyses were used to model potential changes in habitat availability for several fish species and macroinvertebrate diversity during Block 2, which runs from October 28 through April 19. Reductions in historic flow greater than about 5% resulted in more than a 15% loss of available habitat for spotted sunfish adults (Figure 5-11, and Figure 5-12). This percent-of-flow reduction was considered for use in the development of a prescribed flow reduction for Block 2 at the Sarasota gage site.

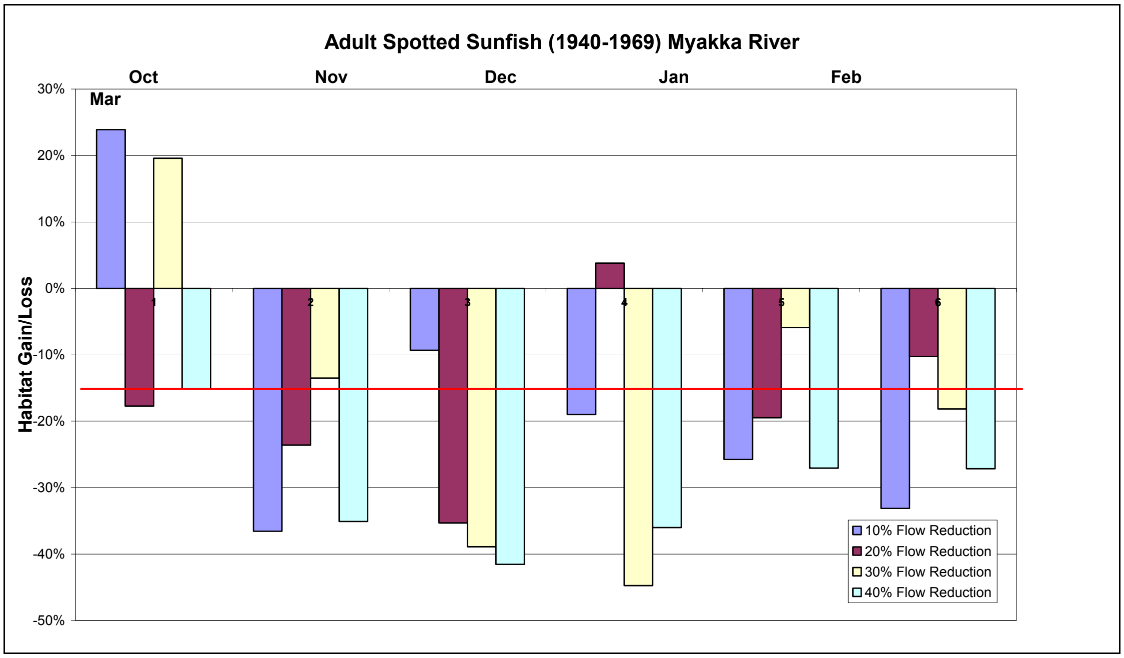
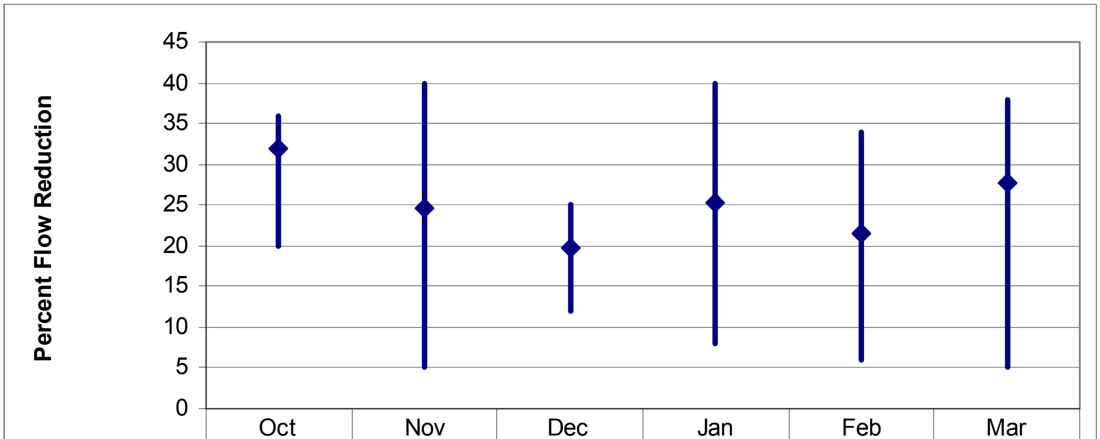


Figure 5-11. Predicted habitat gain/loss for spotted sunfish adults based on the flow record at the Sarasota gage from 1940 to 1969 and flow reductions of 10, 20, 30, and 40 percent.



	Oct	Nov	Dec	Jan	Feb	Mar
◆ Mean	32	25	20	25	22	28
Minimum	20	5	12	8	6	5
Maximum	36	40	25	40	34	38
N	6	12	10	9	8	8

Figure 5-12. Summary of PHABSIM results for the Myakka River near Sarasota gage. Predicted habitat gain/loss for all species which limited flow reduction to less than 50% for October through March based on the flow record for the Sarasota gage and both benchmark periods.

5.7.2 Instream Habitats

Bottom habitats, such as sand and mud were the dominant instream habitats, based on the linear extent of the habitat along the nine instream habitat cross-sections (Figure 5-13). Wetland plant habitat was also abundant. Exposed roots, snags and wetland trees comprised substantially less of the linear habitat. Relative elevations of the habitats were consistent among the cross-sections (Figures 5-14). Wetland trees were typically situated near the top of the banks with wetland plants and exposed roots occurring at slightly lower elevations. Snags were found in association with the bottom habitats. The occurrence of exposed roots at relatively high elevations is important because inundation of this habitat results in inundation of habitats located at lower elevations. Maintaining a mosaic of aquatic and wetland habitats provides the greatest potential for stream productivity and ecosystem integrity (Pringle et al. 1988).

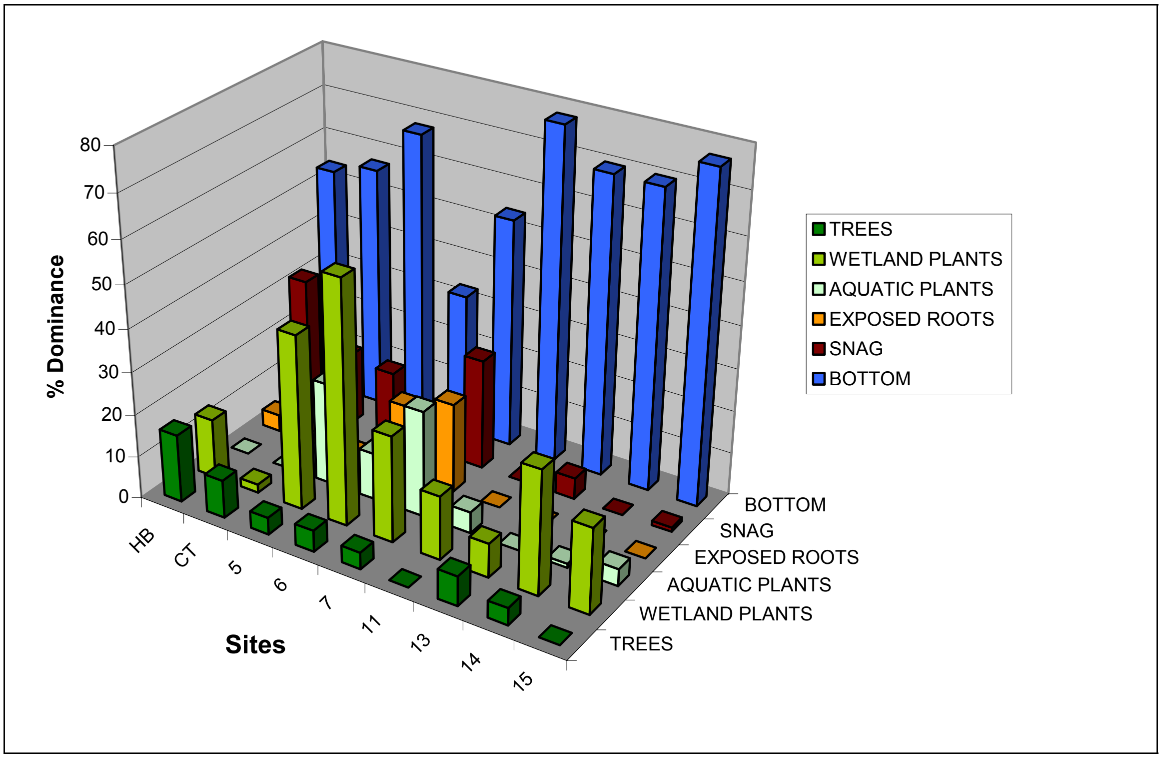


Figure 5-13. Percent dominance of instream habitats based on linear extent of the habitats along nine cross-sections in the Myakka River corridor.

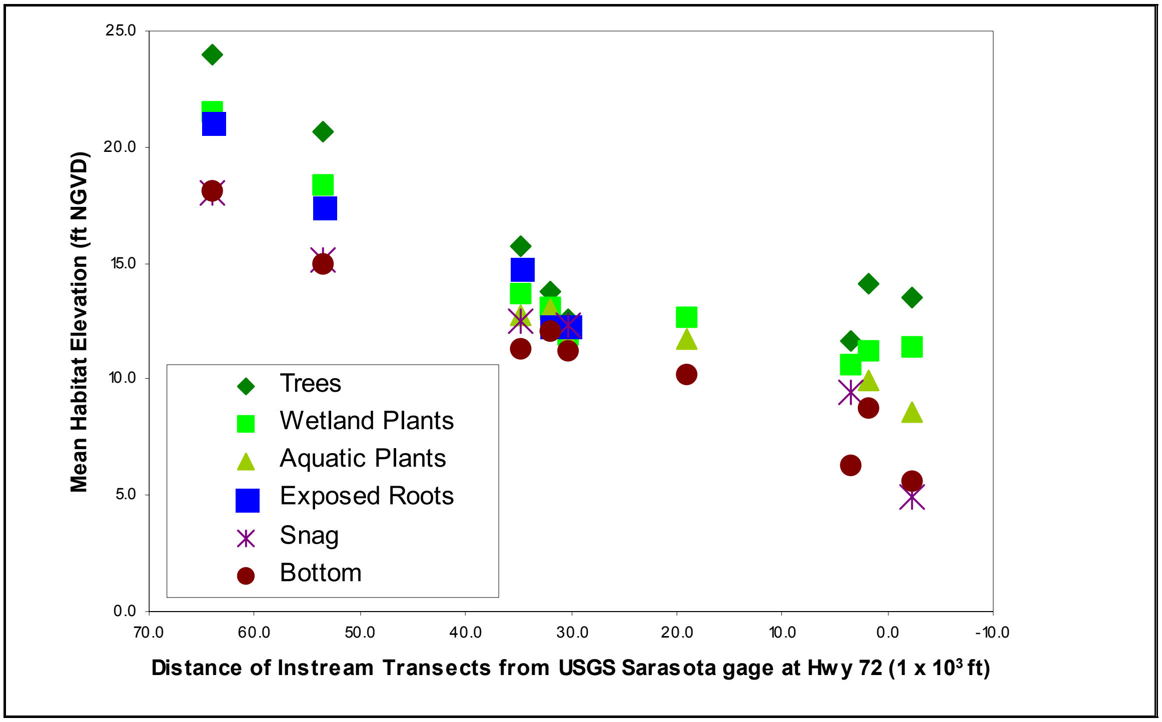


Figure 5-14. Mean instream habitat elevations at nine cross-section sites on the Myakka River.

5.7.3 Flow Relationships with Woody Instream Habitats

Based on the ecological importance of woody habitat, and its potential for use in development of a medium flow standard, inundation patterns were examined for exposed root and snag habitats at the nine Myakka River instream habitat cross-sections (Table 5-4). Flows at the Sarasota gage site that would be required to inundate exposed root habitat at the sites upstream of the gage ranged from 61 to 348 cfs. Snag habitat occurred at six of the sites, but flows required for inundation of the mean snag elevation were lower than the lowest modeled-flow at all but two sites. Those two sites required flows of 97 and 193 cfs for inundation.

Based on historic flow records for the gages, inundation of woody habitats in the Myakka River is expected during Block 2, and would therefore also occur during Block 3 when flows are higher. Flows sufficient to inundate the habitat may also occur in Block 1 during some years. Because these important habitats may be inundated during all three seasonal blocks, we determined percent-of-change flow reductions for inundation of the habitats during Block 2 using prescribed flow reductions developed for Blocks 1 and 3. Percent-of-flow reductions during Block 2 were derived for each gage site by calculating the flow reduction that would result in no more than a 15% loss of days of inundation of woody habitat over the entire year, after the flow reductions for Block 1 and Block 3 were applied. Using RALPH plots/analyses and flow records from 1970 through 1999, we decreased the flows in Blocks 1 and 3 by 15% and 16% respectively, and evaluated percent-of-flow reductions for Block 2 which combined with these prescribed flow reductions would not violate the habitat availability criterion. Because the flow requirement at the Sarasota gage to inundate exposed roots were all below the Block 3 step of 523 cfs, a flow reduction of 16% was used for Block 3 rather than the high flow step reduction of 8%. The same method was applied to the 1940 to 1960 benchmark. The 1970 through 1999 period resulted in more restrictive criteria and are thus utilized as the more conservative approach. Based on these criteria, percent-of-flow reductions of 10 to 42% were identified for woody habitats at sites upstream of the Sarasota gage.

Table 5-4. Mean elevation of instream woody habitats (exposed roots and snags) at nine instream habitat cross-section sites, corresponding flows at the Myakka River near Sarasota gage site required for inundation of the mean elevations, and maximum percent-of-flow reductions associated with less than a 15% reduction in the number of days flow is sufficient to inundate the mean habitat elevations.

Habitat	Site	Mean Elevation (± S.D.) (ft NGVD)	Flow at Gage (cfs) Required for Inundation	Gage	Percent-of-Flow Reduction 1940-1969	Percent-of-Flow Reduction 1970-1999
Exposed Root	HB	21.1 (2.4)	174	Sarasota	39%	28%
Exposed Root	CT	17.4 (3.3)	348	Sarasota	21%	10%
Exposed Root	5	14.8 (0.8)	170	Sarasota	39%	30%
Exposed Root	6	12.3 (1.0)	61	Sarasota	52%	42%
Exposed Root	7	12.3 (0.7)	NA[a]	Sarasota	NA[a]	NA[a]
Exposed Root	12	NA[b]	NA[b]	Sarasota	NA[b]	NA[b]
Exposed Root	13	NA[b]	NA[b]	Sarasota	NA[b]	NA[b]
Exposed Root	14	NA[b]	NA[b]	Sarasota	NA[b]	NA[b]
Exposed Root	15	NA[b]	NA[b]	Sarasota	NA[b]	NA[b]
Snag	HB	18 (1.6)	NA[a]	Sarasota	NA[a]	NA[a]
Snag	CT	15.1 (0.9)	97	Sarasota	43%	34%
Snag	5	12.5 (1.9)	193	Sarasota	39%	24%
Snag	6	NA[b]	NA[b]	Sarasota	NAb	NA[b]
Snag	7	12.3 (0.7)	NA[a]	Sarasota	NAa	NA[a]
Snag	12	NA[b]	NA[b]	Sarasota	NA[b]	NA[b]
Snag	13	9.4 (1.5)	NA[a]	Sarasota	NA[a]	NA[a]
Snag	14	NA[b]	NA[b]	Sarasota	NA[b]	NA[b]
Snag	15	4.9 (0.6)	NA[a]	Sarasota	NA[a]	NA[a]

NA[a] Flows required to inundate the habitat were below modeled flows.
NA[b] Snag habitat not found at the cross-section sites.

5.7.4 Selection of the Prescribed Flow Reductions for Block 2

Percent-of-flow reductions associated with PHABSIM modeling and RALPH analyses associated with inundation of woody habitats were compared for identification of prescribed flow reductions. Prescribed flow reductions were established for the Myakka River near Sarasota gage site based on percent-of-flow reductions derived from PHABSIM analyses. These analyses indicated that up to a 5% reduction in flow would be acceptable for the Sarasota gage site, while analyses of the inundation of woody habitat yielded less restrictive percent-of-flow reductions. The more conservative standard is applied as the short term compliance standard during Block 2.

5.8 Short-Term Compliance Standards for Block 2

Short-Term Compliance Standards represent a flow prescription that can be utilized for evaluating minimum flows compliance on a short-term basis, for example, based on measured daily flows. During Block 2, which for the Myakka River begins on October 28 and ends on April 19 of the subsequent year, the standards were developed for the Myakka River near Sarasota gage site.

For the USGS Myakka River near Sarasota, FL gage site, the following Short-Term Compliance Standard is proposed for Block 2:

1) A 5% reduction of all flows above 0 cfs measured at the Sarasota gage is available for use.

This standard was developed to assure that the prescribed flow reduction for Block 2 does not lead to a violation of the more conservative of the Block 2 standards, in this case, the PHABSIM standard.

5.9 Compliance Standards and Proposed Minimum Flows for the Myakka River near Sarasota

We have developed short-term compliance standards that comprise a flow prescription for preventing significant harm to the Myakka River. Compliance standards were developed for three blocks that represent periods of low (Block 1), medium (Block 2) and high (Block 3) flows at the Myakka River near Sarasota USGS gage sites (Table 5-5). During Block 1, which runs from April 20 to June 24, the allowable withdrawal from the Myakka River for consumptive-use is 15% of the natural daily flow as measured at the USGS Myakka River near Sarasota gage. During Block 2, which extends from October 28 of one year to April 19 of the next year, withdrawals of up to 5% of the natural daily flow at the Sarasota gage site, may be allowed. During Block 3, which extends from June 25 to October 27, withdrawals should be limited to a stepped flow reduction of 16% and 7% of natural flows, with the step occurring at 577 cfs at the Sarasota gage (Figure 5-15).

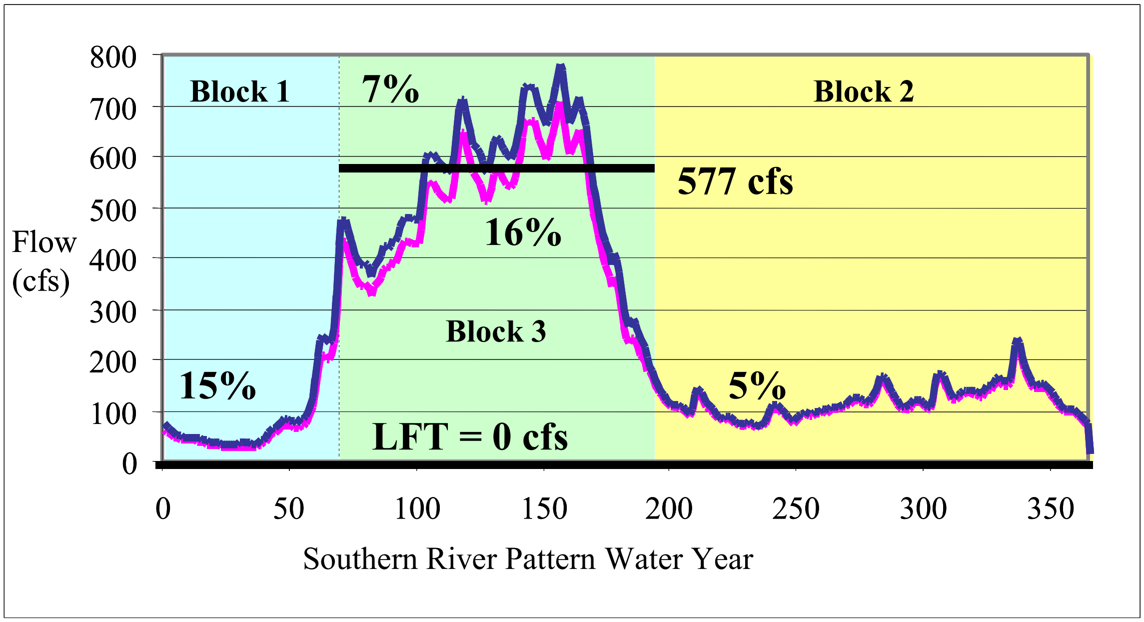


Figure 5-15. Median daily flow plotted for each day of the southern river pattern water year with short-term compliance standards for Blocks 1, 2 and, 3.

Because climatic variation can influence river flow regimes, long-term compliance standards for the Myakka River near Sarasota gage site were developed. The standards are hydrologic statistics that represent flows that may be expected to occur during long-term periods when short term-compliance standards are being met. However, it is also important that the long-term compliance standards be generated from flow records which represent a period devoid of significant anthropogenic impacts. As discussed in Chapter 2, the long-term flow trends for the Myakka River are not consistent with the AMO (Figure 2-27). Specifically, the 1970-1999 period displays an elevated flow record and, is therefore, not suitable for the development of long-term compliance standards. To accommodate for the increased flow, the long-term compliance standards should either be generated using only the 1940-1969 record, a period free from significant anthropogenic impacts or the flow record for 1970-1999 must be corrected so that a non-augmented flow record is approximated. Staff was able to generate estimates of the increased flows in the Myakka River for Blocks 1 and 2 for the period from 1970-1999. For Blocks 1 and 2 the flows in the Myakka River are estimated to be elevated by 22.5 and 26 cfs, respectively. Because the effects of augmentation are small relative to average flows in Block 3, no estimates of augmentation flow were made for Block 3. The estimated corrections for Block 1 and 2 were applied to the period of record from 1970 through 1999 and a new flow record was generated. This flow record was used to generate long-term compliance standards.

The long-term compliance standards were generated using the corrected flow record, prescribed flow reductions and the low flow threshold for the three seasonal blocks. For the analyses, the entire flow record was altered by the maximum allowable flow reductions in accordance with the prescribed flow reduction and the low flow threshold. Hydrologic statistics for the resulting altered flow data sets, including five and ten-year mean and median flows, were calculated. In all cases, the resulting mean and median flows occurred before 1970, during the period for which the flow record was not altered. The resulting statistics integrate duration and return frequency components of the flow regime for long-term (five or ten-year) periods, and were used to establish the long-term compliance standards.

For flows in the Myakka River at the USGS Sarasota gage, long-term compliance standards were established at the minimum five and ten-year mean and median flows (Table 5-5). Standards were developed for evaluating flows on an annual basis and for the seasonal blocks corresponding to periods of low (Block 1), medium (Block 2) and high (Block 3) flows. Because these long-term compliance standards were developed using the short-term compliance standards and the historic flow records, it may be expected that the long-term standards will be met if compliance with short-term standards is applied to the river's natural flow.

Because of the non-perennial nature of the natural flows in the Myakka River, a low flow threshold of 0 cfs was established. This initially creates the impression that the short-term compliance standards are simpler on the Myakka River than other rivers for which the District has established freshwater MFLs (Kelly et al. 2005a, 2005b). However, this is not the case, since the short-term compliance standards on the Myakka River have been developed using historic flows and are specifically to be applied to the natural flow regime. During roughly the past three decades, the Myakka River has experienced a period of flow augmentation. The excess flow in the river alters the historical flow regime by creating a perennial river where one did not historically exist. The compliance standards, both short and long term, have been derived, as much as possible, from non-augmented flow records. This means that any water in the river exceeding the natural flow is available for withdrawal prior to the restrictions of the short-term compliance standards, and that this should not result in the violation of a long-term compliance standard.

The amount of water augmenting the Myakka River should be available for withdrawal prior to enforcement of short-term compliance standards. The amount of water determined to be augmenting the natural flow should be based on the best available data. Currently, we conservatively estimate that the median amount of water available during Block 1 is 22.5 cfs and during Block 2 is 26 cfs. During Block 3 the volume of the augmentation is relatively small compared to mean flows so we advocate applying the short-term compliance standards for the total flow. It is important to acknowledge that augmented flows are likely to change over time, and in the future, augmentation might increase the flow less than currently estimated. Block specific 5-year medians should be compared with the 1940-1969 5-year medians as a starting point to determine how much excess water may be withdrawn prior to the implementation of the short-term compliance standards. Ultimately, this approach should lead to a conservative estimate of augmented flows because the 1940-1969 base line represents the wetter cycle of the AMO. This means that had we had an accurate 1970-1999 natural flow record, it should have produced lower flows than the 1940-1969 record. By basing the median amount of augmentation on a comparison with a wet cycle, we will at times underestimate the amount of the augmented flow. This is consistent with other District MFL assumptions, which are conservative with respect to instream flows.

Collectively, the short and long-term compliance standards proposed for the USGS gage sites near Sarasota comprise the District's proposed minimum flows and levels for the Myakka River. The standards are intended to prevent significant harm to the water resources or ecology of the river that may result from water use. Since future structural alterations could potentially affect surface water or groundwater flow characteristics within the watershed and additional information pertaining to minimum flows development may become available, the District is committed to revision of the proposed levels, as necessary.

Table 5-5. Proposed Minimum Flows for the Myakka River, including short-term and long-term compliance standards for the USGS Myakka River near Sarasota, FL gage site.

Period	Effective Dates	Short-Term Compliance Standards		Long-Term Compliance Standards	
		Flow on Previous Day	Daily Flow Available for Consumptive Use	Hydrologic Statistic	Flow (cfs)
Annually	January 1 to December 31	<0 cfs >0 cfs	0% of flow Seasonally dependent (see below)	10-Yr Mean 10-Yr Median 5-Yr Mean 5-Yr Median	172 12 149 5
Block 1	April 20 to June 24	<0 cfs >0 cfs	0% of flow 15% of flow	10-Yr Mean 10-Yr Median 5-Yr Mean 5-Yr Median	23 0 4 0
Block 2	October 28 to April 19	<0 cfs >0 cfs	0% of flow 5% of flow	10-Yr Mean 10-Yr Median 5-Yr Mean 5-Yr Median	28 4 15 3
Block 3	June 25 to October 27	<0 cfs >0 cfs and <577 cfs >577 cfs	0% of flow 16% of flow 7% of flow	10-Yr Mean 10-Yr Median 5-Yr Mean 5-Yr Median	324 181 241 133

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APPENDIX A – Peer Review

The District is committed to submitting major documents concerning minimum flows and levels to voluntary peer review process. Appendix A is a copy of the peer review report generated by this process for the Myakka River.

A Review of

"Alafia River Minimum Flows and Levels Freshwater Segment including Lithia and Buckhorn Springs"

March 21, 2005 Draft

and

"Proposed Minimum Flows and Levels for the Upper Segment of the Myakka River, from Myakka City to SR72"

August 10, 2005 Draft

by

Ecological Evaluation Section
Resource Conservation and Development Department
Southwest Florida Water Management District

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September 2005

EXECUTIVE SUMMARY

This is a summary of the Scientific Peer Review Panel's ("Panel") evaluation of the scientific and technical data, assumptions, and methodologies used by the Southwest Florida Water Management District (District) in the development of two proposed minimum flows and levels (MFLs): the Alafia River freshwater segment including Lithia and Buckhorn Springs ("Alafia Report," SWFWMD 2005b) and the Myakka River upper segment from Myakka City to SR 72 ("Myakka Report", SWFWMD 2005c).

The Peer Review Panel has attempted to provide a critical review of the methods, data, and conclusions of the District. Overall, the Panel endorses the District's approach for setting MFLs in the Alafia and Myakka rivers, and we find no serious flaws or errors in the methodology or findings documented in the reports. Assumptions of the approach are well documented and are reasonable given the amount and quality of data available. Tools and methods of analysis employed in this effort are appropriately used and utilize best available information. Conclusions in the reports are based on an impressive field data collection effort and sound application of findings from the scientific literature and previous investigations by District staff. The District has done a commendable job of incorporating the suggestions of past peer review, including those for the Upper and Middle Peace River MFLs (Gore et al. 2002, Shaw et al. 2005), including use of seasonal building blocks and the application of the Instream Flow Incremental Methodology. The District has also continued to apply and refine several concepts that were endorsed by previous peer review panels (Gore et al. 2002; Shaw et al. 2004). The Panel has provided suggestions for relatively minor changes or additions to the reports for the Alafia and Myakka rivers that we feel will improve the repeatability of the methods, better justify the conclusions and ensure that resource protection goals are satisfied for overlooked species or unusual flow conditions.

The Panel finds particular merit with and strongly endorses several concepts incorporated in the Alafia and Myakka River MFLs. These include:

- Identifying ***benchmark periods*** based on different phases of the Atlantic Multidecadal Oscillation (AMO) for identifying the most protective minimum flows
- Applying ***multiple, independent approaches*** to identify the most protective minimum flows in each seasonal block
- Specifying minimum flows in terms of allowable ***percent flow reductions*** that vary by season and flow conditions

The Panel recommends that the District continue to refine these concepts and that they should routinely be incorporated when setting future MFLs for rivers in Southwest Florida.

The draft report for setting MFLs for the Alafia River includes the first effort by the SWFWMD to set MFLs for major springs in a basin, Lithia and Buckhorn springs. The panel expressed concern regarding the District's decision to use for these springs only one of the methods employed to develop allowable flow reductions for the rivers and to set a single flow reduction for the entire year instead of for the three seasonal blocks that were used for the rivers. The panel recognizes the logic of using an annual standard, but noted that there is substantial interannual variability in the discharge from both springs and that there may be merit in reducing permitted withdrawals from the springs in times of lower discharge. The panel suggests that thought be given to more restrictive withdrawals when the springs are discharging at less that 20% of long-term annual means. Although the panel supports the extension of PHABSIM and other riverine instream flow methods to spring systems, we recommend that the District research and consider alternative approaches for setting MFLs in Lithia and other major Floridan Aquifer springs that focus on the unique aquatic habitat provided by these systems. The review team supports the decision by the District to defer setting a prescribed flow reduction for Lithia Springs until MFLs for the Alafia estuary are developed.

The sole modification made to the District's basic MFL approach to deal with the issue of agricultural flow augmentation in the Myakka River was to employ a single benchmark period instead of two periods as was done for the Alafia River. The panel supports this modification and believes it to be reasonable and consistent with the District's overall approach. However, it should be noted that this approach does little to prevent flows from being augmented above natural background levels, nor does it correct the current flow augmentation problem in the watershed. Setting MFLs also may require that historic minimum flows be retained in intact rivers or returned in rivers with significant flow augmentation.

We applaud the District's commitment to periodic reassessment of the MFLs for the Alafia and Myakka rivers and other water bodies as structural alterations or changes in watershed conditions occur. We strongly recommend, however, that the District begin now to develop the process and methodology by which such reassessment would occur, and we suggest that such a process should be based on an adaptive management framework.

INTRODUCTION

The Southwest Florida Water Management District (SWFWMD) under Florida statutes provides for peer review of methodologies and studies that address the management of water resources within the jurisdiction of the District. The SWFWMD has been directed to establish minimum flows and levels (designated as MFLs) for priority water bodies within its boundaries. This directive is by virtue of SWFWMD's obligation to permit consumptive use of water and a legislative mandate to protect water resources from *significant harm*. According to the Water Resources Act of 1972, *minimum flows* are defined as “the minimum flow for a given watercourse shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area” (Section 373.042 F.S.). A *minimum level* is defined as “the level of groundwater in an aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area.” Statutes provide that MFLs shall be calculated using the *best available* information.

The process of analyzing minimum flows and levels for the Alafia and Myakka rivers is built upon the analyses previously performed on the Upper Peace River (SWFWMD 2002), peer reviewed by Gore et al. (2002), and more recently, on the Middle Peace River (SWFWMD, 2005a), peer reviewed by Shaw et al. (2005). The Alafia and Myakka MFL methodologies incorporate many of the recommendations of these earlier peer reviews, as well as key improvements developed by District staff. Establishment of minimum flows and levels generally is designed to define thresholds at which further withdrawals would produce significant harm to existing water resources and ecological conditions if these thresholds were exceeded in the future.

This review follows the organization of the Charge to the Peer Review Panel and the structure of the draft report. It is the job of the Peer Review Panel to assess the strengths and weaknesses of the overall approach, its conclusions, and recommendations. This review is provided to the District with our encouragement to continue to enhance the scientific basis that is firmly established for the decision-making process by the SWFWMD. Combined comments and recommendations are given for the basic approach for analyzing and setting MFLs in both rivers, followed by separate comments on aspects unique to each river; i.e., approaches for setting MFLs for springs in the Alafia River and for dealing with agricultural flow augmentation that occurs in the Myakka River. Extensive editorial comments and suggestions to improve the draft reports on the Alafia and Myakka rivers are provided in the Appendices.

1.0 THE CHARGE

The charge to the Peer Review Panel contains five basic requirements:

1. Review the District’s draft documents used to develop provisional minimum levels and flows for the Alafia and Myakka rivers.
2. Review documents and other materials supporting the concepts and data presented in the draft document.
3. Participate in an open (public) meeting at the District’s Tampa Service Office for the purpose of discussing directly all issues and concerns regarding the draft report with a goal of developing this report.

4. Provide to the District a written report that includes a review of the data, methodologies, analyses, and conclusions outlined in the draft report.
5. Render follow-up services where required.

We understand that some statutory constraints and conditions affect the District's development of MLFs and that the Governing Board may have also established certain assumptions, conditions and legal and policy interpretations. These *givens* include:

1. the selection of water bodies or aquifers for which minimum levels have initially been set;
2. the determination of the baseline from which "significant harm" is to be determined by the reviewers;
3. the definition of what constitutes "significant harm" to the water resources or ecology of the area;
4. the consideration given to changes and structural alterations to watersheds, surface waters, and aquifers, and the effects and constraints that such changes or alterations have had or placed on the hydrology of a given watershed, surface water, or aquifer; and
5. the adopted method for establishing MFLs for other water bodies and aquifers.

In addition to the draft report and appendices, various types of supplementary data provided by the District also were examined as part of this review.

2.0 RESULTS OF THE PEER REVIEW

2.1 Common Approach for Setting MFLs for Alafia and Myakka Rivers

MFL Benchmarks and Resource Protection Goals

Benchmarks and the Atlantic Multidecadal Oscillation (AMO)

The reports use the five elements listed by Beecher (1990) as guidelines for developing minimum flows and levels (MFLs). These are a good set of guidelines. One guideline, the use of a benchmark period, needs to be coupled to the growing understanding of climate variability, the AMO, and river flow regimes in Florida. The draft report by Kelly (SWFWMD 2004) does an excellent job in demonstrating how various benchmark periods can yield very different answers with regards to flow regime when the AMO is in different modes. The analysis of AMO and streamflow relationships for Florida

(SWFWMD 2004) was previously peer reviewed and the findings of the draft report were strongly endorsed by the reviewers (Shaw et al. 2004). In Florida, the status of the AMO needs to be considered when MFLs are being set, especially given the strong influence of the AMO on streamflow patterns, and when regulatory and other measures are being considered to sustain adequate flows and levels (Enfield et al. 2001). The District has fully embraced the climate-streamflow issue in developing the MFLs for the Alafia and Myakka rivers by evaluating and identifying limiting flow conditions for two separate benchmark periods (based on different phases of the AMO) for each approach described in the report. Recommended low-flow thresholds and percent flow reduction criteria are based on the most limiting of these benchmark periods to ensure adequate protection during periods when less rainfall and lower streamflow prevail. The peer review panel strongly endorses this approach and recommends that similar approaches should routinely be incorporated when setting MFLs for all rivers in Florida. In addition, knowledge of AMO-streamflow relationships gained by District staff should be widely disseminated to water managers throughout Florida and other parts of the eastern United States.

For the Alafia, the report provides convincing evidence (using water quality data and comparison of median daily flow hydrographs from different sub-basins on a flow per unit watershed area basis) that flow increases in low to median flows around 1960 were caused by increases in mining related discharges. Subsequent decreases in the same range of flows in the 1970s were attributed to a combination of curtailment of mining discharges and climate. This is similar to arguments made regarding the hydrologic effects of climate vs. mining in the middle Peace River basin (SWFWMD 2005a). One minor omission in the discussion of flow trends is a statement regarding whether increasing trends detected in the discharge of Lithia and Buckhorn springs are consistent with the expected effects of the AMO.

In the Myakka Report, convincing evidence is presented that dry season (low to median) and mean annual flows on the Myakka River have increased substantially since the late 1970s and that this trend is not caused by climate but instead by increases in discharge (irrigation return flows and runoff) from agricultural operations near the headwaters. Additional studies of agricultural flow augmentation in the Flatford Swamp area are cited to support this inference. The District's decision to determine minimum flows and levels in the Myakka River based only on the 1940-69 benchmark period (the period unaffected by agricultural flow augmentation) is reasonable and prudent given the inability to precisely quantify flow augmentation effects and separate them from effects caused by AMO-induced climate cycles. For a water body that naturally experiences no-flow conditions during the dry season, we consider this approach adequately protective even though the benchmark period selected represents the wetter phase of the AMO for southern rivers like the Myakka.

Building Block Approach

The SWFWMD has employed a building block approach in establishing MFLs for the Alafia and Myakka rivers (Gore et al. 2002, Postel and Richter 2003). The assumptions behind building block methods are based upon simple ecological theory. Organisms and communities occupying a river have evolved and adapted their life cycles to flow conditions over a long period of pre-development history (Stanford et al. 1996, Bunn and Arthington 2002). Thus, with limited biological knowledge of specific flow requirements, the best alternative is to maintain or recreate the hydrological conditions under which communities had existed prior to disturbance of the flow regime or allocation of instream flows. Building-block models are the "first-best-approximation" of adequate conditions to meet ecological needs. More often than not, resource agencies have hydrographic records for long periods of time, while little or no biological data are available.

Hydrological variability is the critical template for maintaining ecosystem integrity. The use of this natural variability as a guide for ecosystem management has been widely advocated (e.g. Richter et al. 1996, Bunn and Arthington 2002). Although variability is a key to ecosystem maintenance, some sort of predictability of variation must be maintained. It must be realized that survival of aquatic communities is contained within the envelope of natural variability (Resh et al. 1988). In addition to the seasonal pattern of flow, such conditions as time, duration and intensity of extreme events, as well as the frequency and predictability of droughts and floods, may also be significant environmental cues. Also, the frequency, duration, and intensity of higher and lower flows can affect channel morphology and riparian vegetation, and thus change aquatic habitat. Indeed, the rate of change of these conditions must also be considered (Poff and Ward 1989, Davies et al. 1994, Richter et al. 1996, 1997).

Hydrological variability is a critical component of the flow regime, and three blocks are defined from the average long-term annual hydrograph. Block 1 considers the low flow period that occurs during the spring dry season, Block 2 considers the baseflow period during the cooler portion of the year when evapotranspiration rates are often at their lowest levels, and Block 3 considers the high flow period during the summer/fall wet season. This is a valid approach for setting MFLs because it accounts for expected seasonal variability during a typical year. By contrast, MFLs focused solely upon low flow conditions are inadequate for protecting important river and riparian ecosystem functions that occur at other times of the year, and which are often critical to the viability of aquatic organisms. The building block approach is based upon predictably varying hydrological conditions and is a rigorous and defensible approach for the establishment of protective MFLs for the Alafia and Myakka rivers. It also has the advantage of insuring a flow regime with the range of variability essential to the maintenance of stream and river structure and function.

One potential weakness of using building blocks with fixed beginning and ending dates that was identified in the peer review for the Middle Peace River is that some important ecosystem functions may receive inadequate protection if an atypical or unusual water year occurs (Shaw et al. 2005). For example, during strong El Niño cycles, Florida often receives more intense rains and higher stream flows during the winter and spring months, which are assumed to be low-flow periods according to the building block concept. Conversely, less than average rainfall and stream flow may occur during the summer. This can result in an annual hydrograph that is seasonally reversed from the pattern assumed by the District's building blocks. In response to this concern, District staff have modified the building block approach so that the low flow threshold applies throughout the year instead of only during the low flow period (Block 1). This improvement is incorporated in the building block approach for both the Alafia River and Myakka River MFLs.

Preventing Significant Harm – 15% Change in Habitat

The draft Alafia and Myakka reports continue the District's practice of using a 15% change in habitat availability as the threshold for defining significant harm. This value was originally chosen based on the peer review report by Gore et al. (2002) for MFLs for the Upper Peace River (SWFWMD 2002) and, strictly speaking, applied to common professional practice when interpreting the results of PHABSIM analyses. The application of the 15% change threshold was expanded somewhat in the District's report on the Middle Peace River MFLs to define significant harm as either a 15% change in the area of available habitat (spatial change) or a 15% change in the number of days habitat is accessible to fish and other aquatic organisms (temporal change) (SWFWMD 2005a). This expanded interpretation also is used for the Alafia River and Myakka River MFLs. It should be acknowledged, however, that a 15% change in habitat availability based on a reduction in spatial extent of habitat (as was used in the PHABSIM analyses) may not be equivalent to a 15% change in temporal availability of habitat, and it is recommended that this issue be more fully investigated in the future. Nevertheless, the peer review panel for the Middle Peace found that use of the 15% threshold is reasonable and prudent (Shaw et al. 2005), especially given the absence of clear guidance in statute or in the scientific literature on levels of change that would constitute significant harm. We acknowledge that percentage changes reported in the literature have ranged from 10-33% in other applications designed to prevent significant harm. The present panel affirms the use of the 15% threshold in the Alafia and Myakka rivers for similar reasons. However, over the long term, it is critical that this presumption be further investigated and validated and/or refined through the collection of additional site-specific data as part of a larger adaptive management program.

Analytical Tools Used to Develop MFLs
HEC-RAS

The Hydrologic Engineering Centers River Analysis System (HEC-RAS) model is used for estimating one-dimensional steady-state water surface profiles in setting

MFLs for the Alafia and Myakka rivers. HEC-RAS is a model developed by the US Army Corps of Engineers Hydrologic Engineering Center and is widely used, having previously replaced the HEC-2 model as the standard program for water surface profile calculations. The newest generation of the model (version 3.1.1) was used with a range of flows from the USGS stream flow gages to determine stage versus flow and wetted perimeter versus flow for numerous cross sections on the Alafia and Myakka rivers. This model has a history of being used to estimate minimum flows (Gore and Mead 2002).

The HEC-RAS model also was used in establishing MFLs for the Upper Peace (SWFWMD 2002). The concern expressed in the peer review of the Upper Peace report was that the hydraulic model needed to be linked to a biotic habitat model. This has been done with subsequent riverine MFLs, including the Alafia and Myakka, by use of the Physical Habitat Simulation (PHABSIM) model with key biota from these rivers, and is also used in the fish passage and wetted perimeter analysis and with RALPH analyses of woody habitat and floodplain plant communities. This is an appropriate linking of models and makes for a more robust determination of MFLs.

The peer review panel deems the HEC-RAS model to be an appropriate tool for assessing flow-stage relationships in the Alafia and Myakka rivers. Some problems were encountered when applying the model to cross-sections that did not extend sufficiently far into the floodplain to handle wet season flows, but it appears that these issues were handled appropriately. A more thorough discussion of precision and accuracy issues related to the use of HEC-RAS and the methods of determining cross section elevations is provided in the Myakka Report, perhaps in response to peer review suggestions for the middle Peace report. We recommend that similar discussion be added to the Alafia Report. We support the District's intent to further validate the accuracy of models and the effectiveness of its MFLs by investigating inundation of floodplain wetlands along river corridors where MFLs have been established.

PHABSIM

The Instream Flow Incremental Methodology (IFIM) (Bovee et al. 1998) and its software, the Physical Habitat Simulation (PHABSIM) requires hydrological data plus the additional effort of determining the physical habitat requirements of target biota. There are five major hydraulic conditions that affect the distribution and ecological success of riverine biota. These are suspended load, bedload movement, turbulence, velocity profile, and substratum interactions (near bed hydraulics). Singly, or in combination, changes in these conditions can alter distribution of biota and disrupt community structure. The interactions of these hydraulic conditions upon the morphology and behavior of the individual organisms govern the distribution of aquatic biota. The IFIM attempts to describe these interactions using a relatively simple but appropriate modeling technique.

Traditionally, the IFIM technique has focused on habitat availability of target fish species. Gore and Nestler (1988) believe that habitat suitability curves can be thought of as surrogates for basic niches. Statzner et al. (1988) and Gore and

Bryant (1990) have demonstrated that different macroinvertebrate life stages also require different hydraulic conditions to achieve completion of life cycles, just as fish species have very different spawning, incubation, and maintenance requirements. Recently, Gore et al. (2001) demonstrated that inclusion of macroinvertebrate criteria often dramatically altered decisions on flow allocations versus those based upon analysis of fish species alone. By the same token, we recommend that the District evaluate whether additional habitat suitability curves should be developed and PHABSIM analyses be conducted for other species that may be more sensitive to hydrological change than the three common centrarchid fishes identified in the Middle Peace report. These other species might include key invertebrates in the rivers of the District.

Changes in velocity distribution and substrate/cover characteristics at regular intervals, combined with stage/discharge relationships, provide the calibration data for PHABSIM. Habitat suitability curves were developed for spotted sunfish (*Lepomis punctatus*), largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), and macroinvertebrate community diversity (Gore et al. 2001, Stuber et al. 1982). These are appropriate species for consideration in rivers of the southern Florida peninsula and their selection is validated by data presented on fish abundance in the appendices to the MFL reports. Helpful information on the methods used for aquatic invertebrate and fish community assessment was included in Chapter 4 of the Alafia report, but was absent from the Myakka report. It is not clear whether such assessments were only conducted for the Alafia or whether the same assessments were carried out for the Myakka but the information was left out of the Myakka report. The need for continued development and refinement of habitat suitability curves for these species and other species of concern remains a necessary long-term goal (as noted below), but the peer review panel affirms that the best available information was used in the PHABSIM modeling for the Alafia and Myakka rivers. This strengthens the specific recommendations for MFLs made in the report.

Over the long term, we recommend that the District focus research on evaluating and potentially developing habitat suitability information on additional species or groups of species that may be more sensitive to changes in hydrological regimes. Of particular concern would be any listed, imperiled, or endemic species, species tracked by the Florida Natural Areas Inventory (FNAI) (e.g., ironcolor shiner, present in both the Alafia and upper Myakka rivers), wading birds and fish species with preferences for stream edges or banks that might be the first places to feel the effects of reduced flows. Similarly, it may be useful to develop better habitat suitability information for certain exotic species present in these rivers (e.g., blue tilapia (*Oreochromis aureus*)) to ensure that reduced flows do not *improve* habitat conditions for such species or facilitate their invasion of new habitat. Additional species of concern in the Alafia and Myakka rivers that may not be directly amenable to the PHABSIM approach include several species of rare plants inhabiting the floodplain (FNAI Element Occurrence Database, 2005).

RALPH PLOTS AND ANALYSES

Recent and Long-Term Positional Hydrographs (RALPH) plots and analyses were used in the reports to identify the number of days from a defined period of record when flows or levels associated with a specific aquatic habitat or floodplain feature were equaled or exceeded. These analyses were applied at various river cross-sections and enable a quantitative assessment of how flow reductions of a certain magnitude would affect the number of days that certain flow characteristics would be met or exceeded. Examples are given in the reports. As a means of analysis and graphical visualization, the panel feels that the RALPH plots are an important enhancement to the presentation of MFLs for riverine systems, and we recommend that the District continue to utilize and refine this tool for future MFL development.

Habitat Criteria and Characterization Methods Used to Develop MFLs

FISH PASSAGE

Fish passage was used to estimate flows sufficient to permit fish movement throughout the Alafia and Myakka rivers. Flows of this magnitude would also likely permit recreation (i.e., canoeing). A fish passage criterion of 0.6 ft was used based in part on size data from large-bodied fishes in Florida streams and minimum fish passage depths used in other instream flow settings elsewhere in the U.S. This criterion has been used to develop previous minimum flow plans (SWFWMD 2002) and has been found acceptable by peer reviewers (Gore et al. 2002).

This notwithstanding, fish passage depths in the range of 0.5-0.8 ft were originally derived from requirements of migratory salmonids in cool, well oxygenated waters of the western U.S. The adequacy of these standards for use in Florida's warmwater streams has been questioned by resource managers (HSW Engineering, Inc. 2004). Although no definitive research has yet been conducted on this issue (Hill and Cichra 2002), it is the emerging consensus that minimum depth criteria used in Florida need to be re-evaluated to ensure that they adequately prevent negative effects associated with low flows in warmwater ecosystems, including high water temperatures, low dissolved oxygen, algal blooms and increased predatory pressure, in addition to mere physical passage of fish. The peer review panel recommends that the District engage with researchers studying fish passage depths for warmwater streams and actively work to develop minimum fish passage criteria that are more suitable for warmwater aquatic ecosystems, and which go beyond the issue of simple physical passage to address other negative impacts of low flows.

Flows adequate to maintain the fish passage criterion were estimated at stream cross sections using output from the HEC-RAS model. Water depth at the deepest part of the channel was used to establish the criterion. The peer review panel feels that the continued use of the 0.6-ft standard represents best available information and is reasonable and consistent with overall SWFWMD water allocation policy. However, the use of river stages estimated using HEC-RAS, which the authors of the Myakka Report acknowledge as having a calibration accuracy of ± 0.5 ft., in combination with a fish passage criterion of 0.6 ft and linear regressions between modeled stages and flows, raises questions regarding the level of uncertainty that exists in the derived low-flow prescriptions.

As a final note, one of the water resource functions that the low-flow prescriptions are intended to protect is recreational use of the river. This goal is alluded to in Section 3.3.1 of both reports, but the issue is never discussed or developed further. Apparently, the assumption is made that fish passage criteria serve as surrogates for recreational use. While the panel feels that 0.6 ft is most likely an adequate depth that will permit canoeing during low flow periods, this issue and discussion of appropriate minimum depth criteria should be further developed. If it is being assumed that recreation is mostly passive (e.g., canoeing) and that the low flow threshold based on fish passage or wetted perimeter analysis will also protect flows and levels for recreation, then this should be explicitly stated and justified in the report. The justification, if possible, should cite figures on boating usage, minimum depths and widths needed for safe and enjoyable passage of canoes or other craft and include analysis demonstrating that those conditions would be satisfied by the proposed low flow thresholds.

DAYS OF FLOODPLAIN INUNDATION

Low gradient rivers, like the Alafia and (especially) the Myakka, have extensive floodplains. Floodplains support complex and diverse plant communities, whose distribution is determined by small changes in microtopography and average length of annual inundation or hydroperiod. Plant communities are often adapted to the average annual flow regime and decline if flood frequency is altered. Extensive floodplains are often critical to many forms of aquatic life. River biota migrate onto floodplains for foraging and spawning during floods. In addition, periodic flooding stimulates biogeochemical transformations in floodplain soils, which benefit both floodplain and riverine productivity.

The District has recognized the critical role of floods in proposing minimum flows for the Alafia and Myakka rivers. Extensive vegetation and elevation surveys were used to characterize the structure and floristic composition of floodplains. HEC-RAS and RALPH plots/analysis were used to determine floodplain inundation patterns based on historical benchmark periods. This information was then used to estimate percent of flow reductions for Block 3 that would result in no more than a 15% reduction in the number of days of floodplain inundation. The analysis suggested that a stepped approach to water allocation during Block 3 would meet the established criteria.

The peer review panel feels that consideration of high flows and patterns of floodplain inundation is commendable. The use of a 15% reduction in the number of days of inundation is an appropriate criterion for water allocation and is consistent with the working definition of significant harm used throughout the report.

Inclusion of information on the methods used for identifying and characterizing floodplain plant communities and soils in the Alafia and Myakka reports is helpful and represents a significant improvement in the readability of these reports and interpretation of results. We commend District staff for incorporating these and other changes, which were recommended in previous peer reviews, in these reports.

SNAG AND ROOT INUNDATION

Woody substrates (snags and exposed roots) are a critical habitat in most low gradient southeastern streams. Woody substrates are often the most productive habitat (on a unit area basis). Wood also provides shelter for freshwater fishes and basking sites for aquatic herpetofauna. Submerged wood also is important in biogeochemical transformation because biofilms develop on submerged wood, carbon and nutrient processing are enhanced and overall stream metabolism is increased.

The District estimated the mean elevation of woody substrates using instream habitat cross-sections in the Alafia and Myakka rivers. Then, an estimate of the average frequency of inundation was determined using the two benchmark periods. Data from the most recent period (1970-1999) were used because it was more conservative (i.e., it was during a period of lower stream flow). This was compared with previously prescribed flow reductions in Blocks 1 and 3 to determine the overall effect on woody substrate inundation. These analyses were used to help determine the allowable flow allocation during Block 2 and then estimate flow allocations that would result in no more than a 15% reduction in days of inundation over the entire year.

The peer review panel agrees with the District that woody substrates are a critical habitat in the Alafia and Myakka rivers and that their duration of inundation should be considered in flow allocation strategies. The approach adopted by the District is reasonable and consistent with other recommendations made in the report.

COMPLIANCE STANDARDS AND PROPOSED MINIMUM FLOWS

The peer review panel endorses the District's proposed minimum flows for the Alafia and Myakka rivers and finds them to be based on sound science and best available information, subject to our comments and recommendations above. We believe that the consideration of two separate benchmark periods based on distinct climate regimes (at least for the Alafia) and multiple assessment methods and habitat criteria for identifying the limiting flow reductions in each seasonal block gives additional confidence in the District's work and lends credibility to the results. We recommend that a similar methodological framework be adopted for developing all future MFLs. We commend the District for specifying minimum flows in terms of allowable percent flow reductions for different seasonal blocks and a low-flow threshold applicable at all times of the year. This "percent of flow approach" (as it is called by instream flow analysts) combined with seasonal building blocks has been recognized as one of the best ways of protecting multiple functions and values of river systems under a wide range of flow conditions (Postel and Richter 2003). The proposed short and long-term compliance standards proposed in the report are pragmatic and logical means of implementing the findings of the report in a regulatory context.

The review panel does have a concern about the wording of the second short-term compliance standards for Block 2 and Block 3 of the draft Alafia River report. The wording for the short-term compliance standard for Block 1 reads "When flows are between 59 cfs and 66 cfs measured at the USGS Lithia Gage, all flows above 59 cfs are available for use." The wording for Block 2 states "All flows between 59 cfs and 64.2 cfs measured at the Lithia gage are available for use." The wording for Block 3 states "All flows between 59 cfs and 69 cfs measured at the Lithia gage are available for use." We believe that the present wording for the second short-term compliance standard for Block 2 and 3 could be construed to mean that all water can be extracted from the river when flows are between the stated ranges for Block 2 and Block 3. The wording for Block 1 is clearer. The panel suggests that the wording for Block 2 read "When flows are between 59 and 64.2 cfs measured at the USGS Lithia Gage, all flows above 59 cfs are available for use." Similarly, wording for Block 3 should read "When flows are between 59 cfs and 69 cfs measured at the USGS Lithia Gage, all flows above 59 cfs are available for use." This way of stating the standard would preclude confusion as to whether all the flow or only part of the flow is available for reduction in these windows of river discharge. We also applaud the District's commitment to periodic reassessment of the MFLs for the Alafia and Myakka rivers and other water bodies as structural alterations or substantial changes in watershed conditions occur. We strongly recommend, however, that the District begin now to develop the process and methodology by which such reassessment would occur. Specifically, we recommend that an adaptive management framework be adopted for evaluating compliance with MFLs, taking corrective action to reduce water withdrawals and triggering MFL reassessments when necessary. Such a framework should include ongoing evaluation of the effectiveness of the MFLs based on long-term monitoring of key ecosystem and water resource values the MFLs are intended to protect and periodic assessment of whether key assumptions inherent in the MFL development are still satisfied.

2.2 Minimum Flows and Levels for Lithia and Buckhorn Springs

The draft report for setting MFLs for the Alafia River includes the first effort by the SWFWMD to set MFLs for major springs in a basin. In both cases, the head springs themselves are highly altered from natural conditions, with Lithia Springs serving as a recreational swimming facility and Buckhorn Springs as a water supply pumping facility. Consequently, the MFL approach for these systems focused on protecting the ecological resources of the spring runs (including Buckhorn Creek). Of the various methods employed for developing minimum flow prescriptions for the Alafia and other rivers (e.g., fish passage, snag and root inundation, wetted perimeter, PHABSIM), the decision was made, presumably on the basis of data availability, to apply only the PHABSIM methodology to the spring runs. The use of multiple corroborative methods for setting MFLs in streams is a strength of the District's overall approach, and the panel suggests that additional and more careful explanation is needed in the report to better justify employing only one of these methods to the spring systems, especially given the fact that the PHABSIM results for Lithia Springs are ultimately discounted.

Allowable prescribed flow reductions are to be set on an annual basis for Lithia Springs and Buckhorn Springs Main rather than for three designated blocks with different hydrological characteristics, as is done for the rivers. The review team recognizes the logic of using an annual standard, but there is substantial interannual variability in the discharge from both springs and there may be merit in reducing permitted withdrawals from the springs in times of lower discharge. For example, the range of daily discharges from Lithia Springs Major is 7 to 70 cfs and from 4 to 22 cfs for Buckhorn Springs Main during the period of available record. The review team suggests that thought be given to more restrictive withdrawals when the springs are discharging at less that 20% of long-term annual means. For springs with more constant flow regimes, there would be less of a need for a low discharge threshold at which to reduce withdrawals and a set annual percentage could be applied.

The decision was made to not develop a prescribed flow reduction for Lithia Springs Major at this time. This decision was based on the ongoing MFLs being developed by the District for the estuarine portion of the Alafia River. MFLs for the estuary may be partially dependent on flows from Lithia Springs, and the review team supports the decision by the District to defer setting a prescribed flow reduction until the issue of setting MFLs for the Alafia estuary is resolved.

The panel also recommends that the District research and consider alternative approaches for setting MFLs in Lithia and other major Floridan Aquifer springs. Although we generally support the extension of PHABSIM and other methods for setting minimum flows in rivers to spring systems like Lithia, it should be recognized that springs are unique aquatic ecosystems that are quite different from the blackwater systems that otherwise prevail in Florida. For example, Odum's classic study of Silver Springs identified unique characteristics of the aquatic habitat of springs, including high water clarity and light penetration, high mass turnover rates and flow velocities and steady-state production, some of which might be affected by changes in spring flow (Odum, 1957). This unique environment, while perhaps not supporting a large number of rare or spring obligate species, may in fact provide physiological refuge or serve important habitat needs of more common species that goes beyond a simple stage-habitat relationship. One factor to consider in setting MFLs for springs is the frequency of incursion of riverine conditions (i.e., more highly colored water with different chemical, temperature and other properties) into portions of the spring and spring run habitat as spring flows are reduced. St. Johns Water Management District used the frequency and extent of incursions of cold river water into portions of the spring run utilized as winter habitat for manatee to assess its proposed MFL for Volusia Blue Spring. An analogous approach could be developed for springs in the SWFWMD, focusing on fish or invertebrate habitat, or in cases where ecological values are minimal, focusing on impacts to recreational use, water quality or aesthetics. It is not clear whether the manatee should be considered in setting an MFL for Lithia Springs. The report includes no discussion of whether this species presently or historically utilized the spring, despite the fact that a known manatee aggregation occurs at the TECO Big Bend power plant a short distance downstream.

Another possible factor to consider for springs that are heavily utilized for recreation is the relationship between depth of flow in the spring run and extent of trampling of submerged aquatic vegetation. Observations of springs in north Florida suggest that as water levels decline, damage to vegetation (and associated fauna such as snails) becomes more extensive as swimmers become waders and move into areas of the spring run previously too deep for wading. Such relationships are, for example, built into the limits on recreational use implemented at Ichetucknee Springs.

The percentage of maximum reduction of discharge for Buckhorn Springs Main is proposed as no more than a 15% reduction of mean daily flow from the average from the previous month (corrected for withdrawals). PHABSIM analyses were used to assess habitat changes from various flow reductions, and the analyses suggested a 15% flow reduction on average was most appropriate to meet a less than 15% reduction in habitat for various life history stages for dominant fish species in Buckhorn Creek downstream of the main spring. This is consistent with the criteria used in setting minimum flows and levels for rivers administered by the SWFWMD, and the review panel agrees that this is an appropriate target to use to meet the criteria of no significant harm to the spring and creek. Again, there is significant month-to-month variability in spring discharge, and a reduced or no reduction policy might be considered for times when spring discharge is at the lower one or two deciles of mean annual long-term discharge.

2.3 Approach for Addressing Flow Augmentation in the Myakka River

The sole modification made to the District's basic MFL approach to deal with the issue of agricultural flow augmentation in the Myakka River was to employ a single benchmark period instead of two periods as was done for the Alafia River and Middle Peace River MFLs. As noted above, the panel supports this modification and believes it to be reasonable and consistent with the District's overall approach. However, it should be noted that this modified MFL approach, focusing as it does on *low* flow thresholds and prescriptions for flow *reductions,* does little if anything to prevent flows from being *augmented* above natural background levels, nor does it correct the current flow augmentation problem in the watershed.

Flow augmentation and a change from intermittent to perennial flow conditions can affect wetland and riparian plant communities. For example, wetland hardwoods in the area around Flatford Swamp on the Myakka may be showing increased mortality due to increased duration of flooding from flow augmentation. Bunn and Arthington (2002) point out that the loss of wet-dry cycles can reduce growth and survival of native aquatic macrophytes and set the stage for increased invasion of non-native species. Setting MFLs also may require that historic minimum flows be retained in intact rivers or returned in rivers with significant flow augmentation.

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APPENDIX B - Staff Response to Peer Review

Introduction

Overall the peer review committee endorsed the Districts approach to establishing minimum flows and levels on the Myakka River. Specifically the peer review committee noted that the assumptions of the approach are well documented and are reasonable, the tools and methods of analysis employed are appropriate and utilize best available information, and the conclusions in the report are based on an impressive field data collection effort and sound application of findings from the scientific literature. In short they found "no serious flaws or errors in the methodology or findings documented in the report" (Cichra et al. 2005, Appendix A). The Panel also found particular merit with and strongly endorses several novel concepts including;

- Identifying ***two separate benchmark periods*** based on different phases of the Atlantic Multidecadal Oscillation (AMO) . . .
- Applying ***multiple, independent approaches*** to identify the most protective minimum flow in each seasonal block. . .
- Specifying minimum flows in terms of allowable ***percent flow reductions*** that vary by season and flow conditions.

However, the panel did supply some direction for improving the report, and much of that direction has already been incorporated into this report.

1. *It should be acknowledged, however, that a 15% change in habitat availability based on a reduction in spatial extent of habitat (as was used in PHABSIM analyses) may not be equivalent to a 15% change in habitat availability based on number of days a particular habitat is inundated.*

   The District acknowledges this and is currently performing a comparison of temporal and spatial loss of habitat. The results are under review but preliminarily indicate that on the Myakka River flow reduction required to effect a 15% spatial loss are greater then those required to effect a 15% temporal loss (Munson and Delfino in review).

2. *Over the long term, we recommend that the District focus research on evaluating and potentially developing habitat suitability information on additional species or groups of species that may be more sensitive to change in the hydrologic regime.*

The District agrees and had, prior to this recommendation, arranged with Dr. James Gore of the University of South Florida to develop additional habitat suitability curves specific to southwest Florida species.

3. *Although no definitive research has yet been conducted on this issue, it is the emerging consensus that minimum depth criteria used in Florida needs to be re-evaluated to ensure that they adequately prevent negative effects associated with low flows in warm water ecosystems.*

   To address this issue the District is identifying locations on rivers where such research can occur, and staff is proposing the deployment of data logging equipment under low flow conditions to collect data necessary to further investigate this issue.

4. *While the panel feels that 0.6 ft is most likely an adequate depth that will permit canoeing during low flow periods, this issue and discussion of appropriate minimum depth criteria should be further developed.*

   The District will continue to review the literature regarding minimum depth requirements for canoeing and other recreational activities, and incorporate this information into future minimum flow analysis and reports.