Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek

Southwest Florida Water Management District

April 2010 – Final Report and Appendix 1

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Acknowledgement

This report was produced in collaboration with the staff of Janicki Environmental, Inc. (JEI), under contract to the Southwest Florida Water Management District (SWFWMD). The Shell Creek statistical model was developed by JEI, and the coupled 2-D, 3-D hydrodynamic model of the lower Peace River system was developed by Dr. Xinjian Chen of the SWFWMD. Dr. Tony Janicki, Keith Hackett, Steve Grabe, and Kate Malloy were the primary contributors for JEI, and Marty Kelly, Mike Heyl, Sid Flannery, and Xinjian Chen were the primary contributors from the SWFWMD. The final report benefited from the constructive comments and criticisms of the peer review panel that reviewed the draft report for the SWFWMD. Members of the panel included Drs. Paul Montagna (Texas A&M Univ.), Joe Boyer (Florida International Univ.) and Ben Hodges (Univ. of Texas). The report also benefited from comments received by various members of the Peace River Manasota Water Supply Authority's Hydrobiological Monitoring Program's peer review panel, the Charlotte Harbor Estuary Program, and by Carollo Engineers and HSW Engineering, consultants to the City of Punta Gorda.

Preface

An earlier draft MFL document was prepared for independent scientific peer review and made available for public inspection and comment. This draft report was presented to the Governing Board of thse SWFWMD at their July 2007 Board meeting and placed on the District's web site. After receiving the peer review panel's comments and comments from others, a second report dated April 9, 2009 was prepared and this version was posted on the District's web site. The Governing Board at its June 2009 Board meeting initiated rule making regarding the proposed minimum flows as presented in this report; however, they delayed rule adoption at the request of the Charlotte Harbor National Estuary Program (CHNEP) and others pending further review and discussion. As a result of additional analyses and discussions with various stakeholders several important modifications were made to the MFLs that were proposed in the April 9, 2009 report. These modifications are discussed in greater detail within the body of this report, but can be summarized as follows:

1) a change in the recommended Low Flow Threshold from 90 cfs to 130 cfs based on the sum of the combined flows to the lower Peace River as measured at USGS gauges located on Horse Creek, Joshua Creek and the Peace River near Arcadia;

2) the establishment of a flow trigger (i.e., 625 cfs) in seasonal Blocks 2 and 3 which must be exceeded before higher flow percentage withdrawals can be made;

3) the establishment of a maximum diversion capacity (i.e., 400 cfs) which limits the total amount of water that can be diverted from the river;

4) and a provision calling for a re-evaluation of the MFLs within 5-years of rule adoption.

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 lower segment of the Peace River, defined as the reach of the river from the United States Geological Survey Peace River at Arcadia gauge downstream to Charlotte Harbor. This reach includes the total inflow from the Peace River at Arcadia gauge, Joshua Creek at Nocatee gauge, and Horse Creek near Arcadia gauge. Additionally, minimum flows are proposed for Shell Creek, which extends downstream from the City of Punta Gorda dam (Hendrickson Dam) to the confluence of Shell Creek with the Lower Peace River.

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 the extent to which 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 evaluating flows in the middle segment of the Peace River. It has also been demonstrated that flow declines in the Lower Peace River can be ascribed to both climatic variation and anthropogenic effects.

Seasonal blocks corresponding to periods of low, medium, and high flows, previously defined for the development of minimum flows in the middle Peace River, were used to establish minimum flows for both the Lower Peace River and Shell Creek. Short-term minimum flow compliance standards for the sum of the flows from the Peace River at Arcadia, Joshua Creek at Nocatee, and Horse Creek near Arcadia, as well as for the Shell Creek flows, were developed for each of these seasonal periods using a "building block" approach. The concept of defining “building blocks” to establish MFLs is to get the “right flow at the right time.”

Definition of the minimum flow regime often includes a low flow threshold. The low flow threshold is defined to be a flow that serves to limit withdrawals, with no withdrawals permitted unless the threshold is exceeded. After examination of the relationships between flow and several habitat variables, including salinity, chlorophyll *a*, and dissolved oxygen (DO) in Shell Creek, no clear, defensible, low flow threshold was identified for Shell Creek.

After review of numerous criteria, the most protective criterion selected for Shell Creek was maintenance of the two ppt salinity zone. This biologically-relevant salinity helps to maintain the integrity of fish and benthic community structures in Shell Creek. Based on this criterion, the minimum flows in Shell Creek were defined for each block as the

percentage of the Shell Creek dam flow that can be withdrawn. The allowable percent reductions in flow are:

- Block 1 (April 20 to June 25) = 16% of the flow
- Block 2 (October 27 to April 19) = 29% of the flow
- Block 3 (June 26 to October 26) = 38% of the flow

It should be noted, that if there is no inflow to the reservoir above the dam, then there is no minimum flow required below the dam.

The minimum flow regime for the Lower Peace River included a low flow threshold. Models were developed to relate flows to ecological criteria in the Lower Peace River, but there were no breakpoints or inflections in these relationships at low flows, thus it was concluded that a low flow threshold based on ecological criteria was not necessary. However, the PRMRWSA plant withdraws water from the Lower Peace River for potable water supply. It is important to maintain freshwater at the PRMRWSA withdrawal point because saline water hinders the treatment process for the plant. Therefore, an operational criterion of maintaining freshwater at the PRMRWSA plant was chosen as an acceptable criterion. An empirical analysis yielded a low flow threshold of 130 cfs for the sum of the flows from Peace River at Arcadia, Joshua Creek at Nocatee, and Horse Creek near Arcadia in order to maintain freshwater at the PRMRWSA plant.

The salinity criteria selected for the Lower Peace River were two, five, and 15 ppt. These biologically-relevant salinities help to maintain the integrity of fish, benthic, and vegetation community structures in the Lower Peace River. In addition to examining the extent of the biologically-relevant salinities river-wide, a more spatially-specific assessment of salinity within a portion of the Lower Peace River was also deemed critical. Studies have shown that a specific area in the river has a significantly abundant and diverse fish community and salinities in this area are typically in the range of 8 to 16 ppt. Therefore, the volume of water meeting the appropriate salinity range (8 to 16 ppt) in this area was also analyzed.

Based on these criteria, the minimum flows in the Lower Peace River were defined for each block as the percentage of the total combined flow above 130 cfs from Peace River at Arcadia, Joshua Creek at Nocatee, and Horse Creek near Arcadia that can be withdrawn. The allowable percent reductions in flow are:

- Block 1 (April 20 to June 25) = 16% of the flow
- Block 2 (October 27 to April 19) = 16% of the flow when the combined flow is at or below 625 cfs, and 29% of the flow above 625 cfs
- Block 3 (June 26 to October 26) = 16% of the flow when the combined flow is at or below 625 cfs, and 38% of the flow above 625 cfs.

In all cases, however, the maximum amount of flow that can be diverted from the river based on the combined flows of the three gauges shall not exceed 400 cfs on any given day.

Finally, it is recommended that the MFL for the lower Peace River be MFL be re-evaluated within 5 years after rule adoption.

1 PURPOSE AND BACKGROUND OF MINIMUM FLOWS AND LEVELS

1.1 Overview

The Southwest Florida Water Management District (District) is responsible for permitting the consumptive use of water within the District's boundaries. Within this context, the Florida Statutes (Section 373.042) mandate that the District protect water resources from “significant harm” through the establishment of minimum flows and levels (MFLs) for streams and rivers within its boundaries. In establishing MFLs for the Lower Peace River (LPR) and Shell Creek (SC), the District evaluated potential flow scenarios and their associated impacts on the downstream ecosystem. The determination of minimum flows is a rigorous technical process in which extensive physical, hydrologic, and ecological data are analyzed for the water body in question.

This chapter provides an overview of how the District applied legislative and water management directives in the determination of minimum flows for the LPR and SC. The rationale and basic components of the District approach are also summarized. Greater details regarding the District's technical approach, including data collection efforts and analyses to determine minimum flows, are provided in subsequent chapters.

1.2 Legislative Directives

Section 373.042, F.S. defines the minimum flow for a surface watercourse as *“the limit at which further withdrawals would be significantly harmful to water resources or ecology of the area”.* Section 373.042, F.S. defines the minimum level of an aquifer or surface water body to be “*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*”. It is generally interpreted that ecological resources are included in the water resources of the area mentioned in the definition of minimum water levels. The establishment of MFLs for flowing watercourses can incorporate both minimum flows and minimum water levels. However, because of the dominant effect of tides on water levels in the Lower Peace River and Shell Creek, the establishment of MFLs for these watercourses involved only a flow component, and the term minimum flows is used throughout this report with regard to MFLs for the Lower Peace River and Shell Creek.

Section 373.042 F.S. further states that "*minimum flows and levels are to be established based upon the best information available. When appropriate, minimum flows and levels shall be calculated to reflect seasonal variations. The department and the governing board shall also consider, and at their discretion may provide for, the protection of nonconsumptive uses in the establishment of minimum flows and levels*."

Guidance regarding nonconsumptive uses of the water resource to be considered in the establishment of MFLs is provided in the State Water Resources Implementation Rule (Chapter 62-40.473, Florida Administrative Code), which states that "*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 materials*
- *(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*

Florida Statues further state that "*When establishing minimum flows and levels pursuant to 373.042, the department or governing board shall consider 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, provided that nothing in this paragraph shall allow significant harm as provided by s. 373.042(1) caused by withdrawals*" (Section 373.0421(1)(a) F.S.). In essence, the District is to evaluate and account for existing structural alterations on a watercourse when assessing the potential for withdrawals to cause significant harm.

The statutes also state "*The Legislature recognized that certain water bodies no longer serve their historic hydrologic functions. The Legislature also recognizes that recovery of these water bodies to historic hydrologic conditions may not be economically or technically feasible, and such recovery effort could cause adverse environmental or hydrologic impacts. Accordingly, the department of governing board may determine that setting a minimum flow or level for such a water body based on its historic condition is not appropriate"* (Section 373.0421(1)(b).

Given these legal directives, the basic function of MFLs is to ensure that the hydrologic requirements of natural environmental systems are met and not harmed by excessive water withdrawals. The establishment of MFLs is therefore very important to water supply planning and regulation, since it affects how much water from a watercourse is available for withdrawal. Accordingly, the methods, data and analyses on which MFLs are determined should be comprehensive and technically sound. For this reason, the District is committed to voluntary, independent scientific peer review of MFL documents. The purpose of this report is to document the scientific and technical data and methodologies that were used to develop minimum flow recommendations for the LPR and SC.

1.3 Conceptual Approach to Establishing Minimum Flows

In keeping with the intent of legislation pertainng to MFLs, the District first considered the status of the existing physical, hydrologic, and ecological characteristics of the Lower Peace River and Shell Creek system in its determination of minimum flows. Although the Peace River Manasota Regional Water Supply Authority maintains an offstream diversion facility on a slough connected to the river near river kilometer 30, the channel of the Lower Peace River contains no man-made structures that impede the river's flow, thus existing structural alterations were not a factor in the determination of minimum flows for the LPR.

The City of Punta Gorda maintains a low elevation dam on Shell Creek, located approximately ten kilometers upstream of the confluence of the creek with the Lower Peace River. Although this dam presents a barrier to the upstream migration of fish and other aquatic organisms in Shell Creek, there is flow over the dam nearly all the time and a complete salinity gradient that includes fresh and oligohaline waters occurs below the dam under most hydrologic conditions. Given the location of the dam and these hydrobiological characteristics of Shell Creek, the District evaluated the flow record over the dam as the hydrologic variable of concern, correcting this record for withdrawals by the City to reconstruct a baseline flow record for the evaluation on minimum flows for Shell Creek. The presence of the dam was otherwise not considered in the assessment of baseline conditions. However, the City may make withdrawals from water storage in the impoundment behind the dam as long as reductions in the baseline flows in the creek do not result in significant harm to the downstream ecosystem.

Based on these considerations, the District applied the percent-of-flow method to determine minimum flows for the LPR and SC. The percent-of-flow method allows water users to take a percentage of streamflow at the time of the withdrawal. The percent-of-flow method has been used for the regulation of water use permits since 1989, when it was first applied to withdrawals from the Lower Peace River.

The LPR and SC are two of a series of tidal river estuaries in which the percent-of-flow method will be used to establish minimum flows during 2008 and 2009 (Lower Alafia, Myakka, Anclote, Weeki Wachee and Little Manatee Rivers). The method is oriented for use on unimpounded rivers that retain a largely natural flow regime (Flannery et al. 2002). The percent-of-flow method has been applied to determine and adopt minimum flows for a series of unimpounded freshwater streams in the District, including the freshwater reaches of the Alafia River, the Myakka River, and the middle reach of the Peace River.

A goal of the percent-of-flow method is that the natural flow regime of the river be maintained, albeit with some flow reduction for water supply. Natural flow regimes have short-term and seasonal variations in the timing and volume of streamflow that reflect the drainage basin characteristics of the river in question and the climate of the region. In recent years, there has been considerable progress in the field of freshwater stream ecology and flow management in identifying the physical and biological processes that are linked to and dependent upon natural flow regimes (Poff *et al.* 1997, Instream Flow Council 2002, Postel and Richter 2003). As summarized in the District's MFL report for the freshwater reach of the Alafia River, these processes include geomorphic and biological processes. The geomorphic processes are related to sediment transport and channel maintenance. The biological processes are related to fish passage, the inundation of instream and floodplain habitats, and maintenance of adequate water levels and velocities to provide habitat suitable for the growth and reproduction of fishes and invertebrates (SWFWMD 2004).

As with freshwater stream ecology, management issues regarding freshwater inflows to estuaries have received considerable attention in recent decades. A national symposium on inflows to estuaries was held in 1980 (Cross and Williams 1981), and a special issue of the journal *Estuaries* devoted to freshwater inflows was produced by the Estuarine Research Federation in 2002 (Montagna *et al.* 2002), which included the paper by Flannery *et al.* (2002). Since its introduction, the District's percent-of-flow method has received attention as a progressive method for water management in the national technical literature (Alber 2002, Postel and Richter 2003, and the National Research Council 2005), and its use for water supply planning and regulation has been established regionally in District documents (SWFWMD 1992, 2001, 2006).

1.4 Content of Remaining Chapters

This general introduction is followed by eight additional chapters. In these chapters, the technical information that was used to evaluate the minimum flows for the LPR and SC is described. In Chapter 2 the physical and hydrological characteristics of the LPR and SC watersheds have been described. In Chapter 3 the spatial and temporal variation in physical and water quality characteristics of the LPR and SC are discussed. Chapter 4 contains a description of the benthic macroinvertebrate community of the LPR and SC. The characteristics of the LPR and SC fish communities are described in Chapter 5. In Chapter 6, relationships between flow and water quality constituents are explored. In addition, relationships between flow and salinity are examined for model simulation data in Chapter 7. Major conclusions of this study along with the District’s minimum flow recommendations for the LPR and SC are presented in Chapter 8. Chapter 9 identifies the literature cited in the report. Correspondence related to the proposed MFLs, including the independent scientific peer review report, is included in the Appendix 1.

2 DESCRIPTION OF THE LOWER PEACE RIVER AND SHELL CREEK

A brief description of the LPR and SC and their associated watersheds is presented in this section.

2.1 Physical Characteristics of the LPR Watershed

Three major tributaries drain to Charlotte Harbor, the Peace and Myakka Rivers in the north, and the Caloosahatchee River in the south (Figure 2-1). The Peace River basin is approximately 2,350 square miles and extends from the headwaters in Polk County to the river mouth in Charlotte Harbor (PBS&J 1999a). The Peace Creek Drainage Canal and Saddle Creek join near Bartow, FL to form the Peace River (Hammett 1990). The River flows south for approximately 75 miles through Polk, Hardee, De Soto, and Charlotte Counties. The Peace River represents a major source of fresh water to Charlotte Harbor, as its watershed comprises nearly half of the total 4,670 square miles of the Greater Charlotte Harbor watershed (Stoker *et al.* 1992). Streamflows in the Peace and Myakka Rivers are unregulated, except for one low-water dam in the upper Myakka basin and one in SC. Therefore, discharges from the Peace and Myakka Rivers tend to correspond to rainfall patterns in the respective basins. Streamflow in the Caloosahatchee River is also influenced by rainfall in the basin, but discharge to the harbor is regulated by Franklin Lock (Stoker 1992).

Hammett (1990) estimated that total freshwater inflow to Charlotte Harbor from the three major tributaries, the coastal area, and direct rainfall at between 5,700 and 6,100 cfs. Hammett (1990) estimated the average inflows to Charlotte Harbor from the various sources as:

- Caloosahatchee River - 1,900 to 2,100 cfs,
- Peace River (including Shell Creek) - 2,010 cfs,
- Myakka River - 630 cfs,
- Direct rainfall - 1,030 cfs, and
- Coastal area - 200 to 400 cfs.

The Peace River, with approximately three-times the freshwater flow as the Myakka River, is a major influence on the freshwater inflow to upper Charlotte Harbor. The physical and hydrologic characteristics of the LPR watershed, including an assessment of trends in freshwater inflows to the LPR estuary will be discussed in the following sections. Additional information pertaining to the portion of the Peace River upstream of Arcadia can be found in SWFWMD (2002, 2005a).

The LPR is defined as the portion of the river below the USGS gauge (02296750) at Arcadia (Figure 2-2). Upstream from Arcadia the channel of the Peace River is very well defined (Hammett 1990). Downstream from Arcadia the LPR flood plain widens and the channel becomes more braided approximately 20 miles above the river mouth.

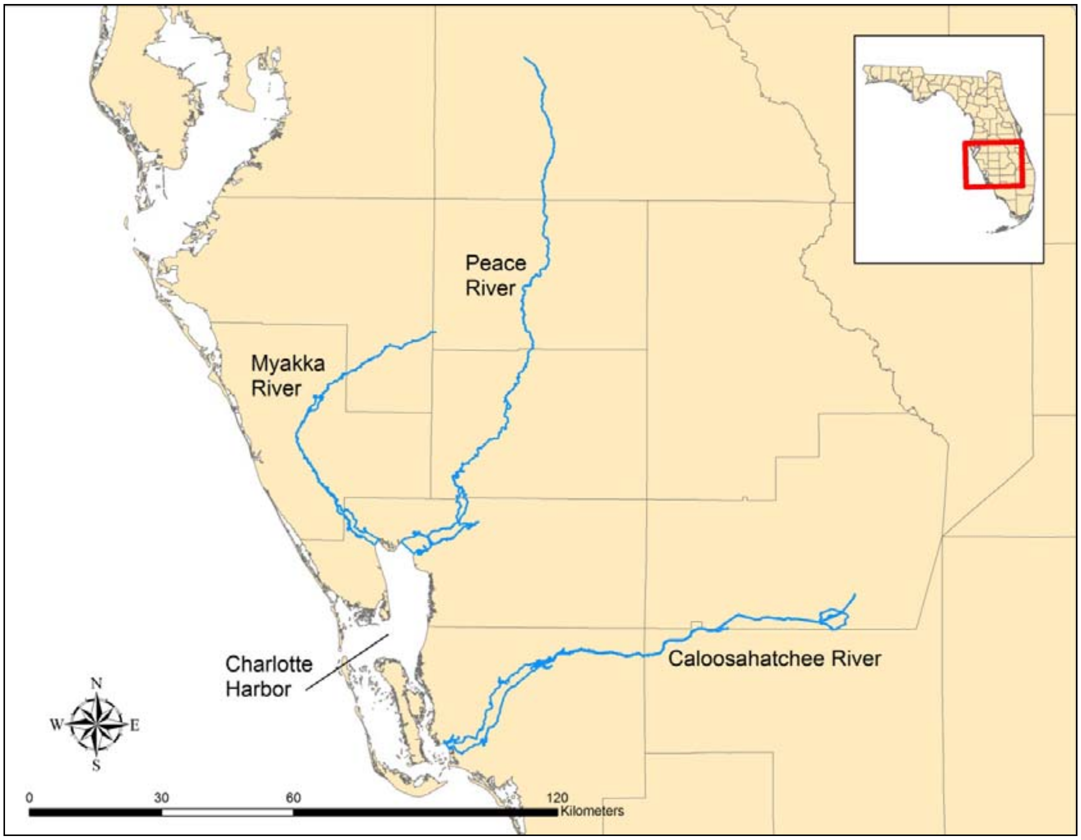


Figure 2-1. **Map of Charlotte Harbor and Major Tributaries.**

The portion of the watershed that drains to the river downstream of Arcadia represents approximately 42% (990 mi^2) of the entire Peace River watershed. There are three major tributaries that flow into the LPR: Joshua Creek, Horse Creek, and SC (Figure 2-2). Of these three tributaries, SC is the largest at 434 mi^2, Horse Creek is the second largest at 245 mi^2, and Joshua Creek is the smallest at 121 mi^2.

The LPR river kilometer system and the Peace River Manasota Regional Water Supply Authority (PRMRWSA) Hydrobiological Monitoring Program (HBMP) fixed location water quality sampling stations are presented in Figure 2-3. Mixed semi-diurnal tides (two high waters and two low waters of unequal height each day) occur in the Peace River (Stoker 1992). The tidal reach of the Peace River extends from the mouth upstream to approximately river kilometer 42 (26 miles). The location of the freshwater-saltwater interface (where salinity is 0.5 ppt) moves upstream and downstream daily with the tide and seasonally with volume of freshwater inflow (Stoker 1992), with the exception of extreme droughts, the location of freshwater-saltwater interface usually fluctuates within the lowermost 30 kilometers of the river channel (PBS&J 1999b).

LPR land use is depicted in Figure 2-4. Wetlands buffer the river channel and the remaining dominant land uses are agricultural, pasture and range land, and urban development (near the mouth of the river). PBS&J (2007) summarized changes in land use in the Peace River basin between 1940 and 1999 (Table 2-1).

Table 2-1. Land Use in the Peace River Watershed: 1940s – 1999 (Reproduce from PBS&J 2007).

Land Use	Acres (Percent) in Land Use Class		
	1940s	1979	1999
Developed			
Improved Pasture	39,640 (2.8)	356,925 (25.6)	379,346 (27.2)
Intense Agriculture	107,115 (7.7)	191,496 (13.7)	229,832 (16.5)
Mined lands	7,495 (0.5)	64,437 (4.6)	143,487 (10.3)
Urban Land Use	14,659 (1.0)	73,049 (5.2)	133,571 (9.6)
Undeveloped			
Native Upland Habitat	834,311 (59.7)	419,449 (30.0)	242,849 (17.4)
Wetlands	354,674 (25.4)	249,255 (17.8)	218,232 (15.6)
Water			
Lakes and open water	33,779 (2.4)	35,432 (2.5)	43,027 (3.1)
Other Water	5,011 (0.4)	6,641 (0.5)	6,338 (0.5)
Total	1,396,683 (100)	1,396,683 (100)	1,396,683 (100)

Soils within the watershed (Figure 2-5) are primarily classified as B/D (mix of moderate infiltration rate and very slow infiltration rate) and D (very slow infiltration rate and high runoff potential). Class D buffers the river channel, with isolated areas of Class A (high infiltration rate and low run off potential) further from the channel but still within the floodplain.

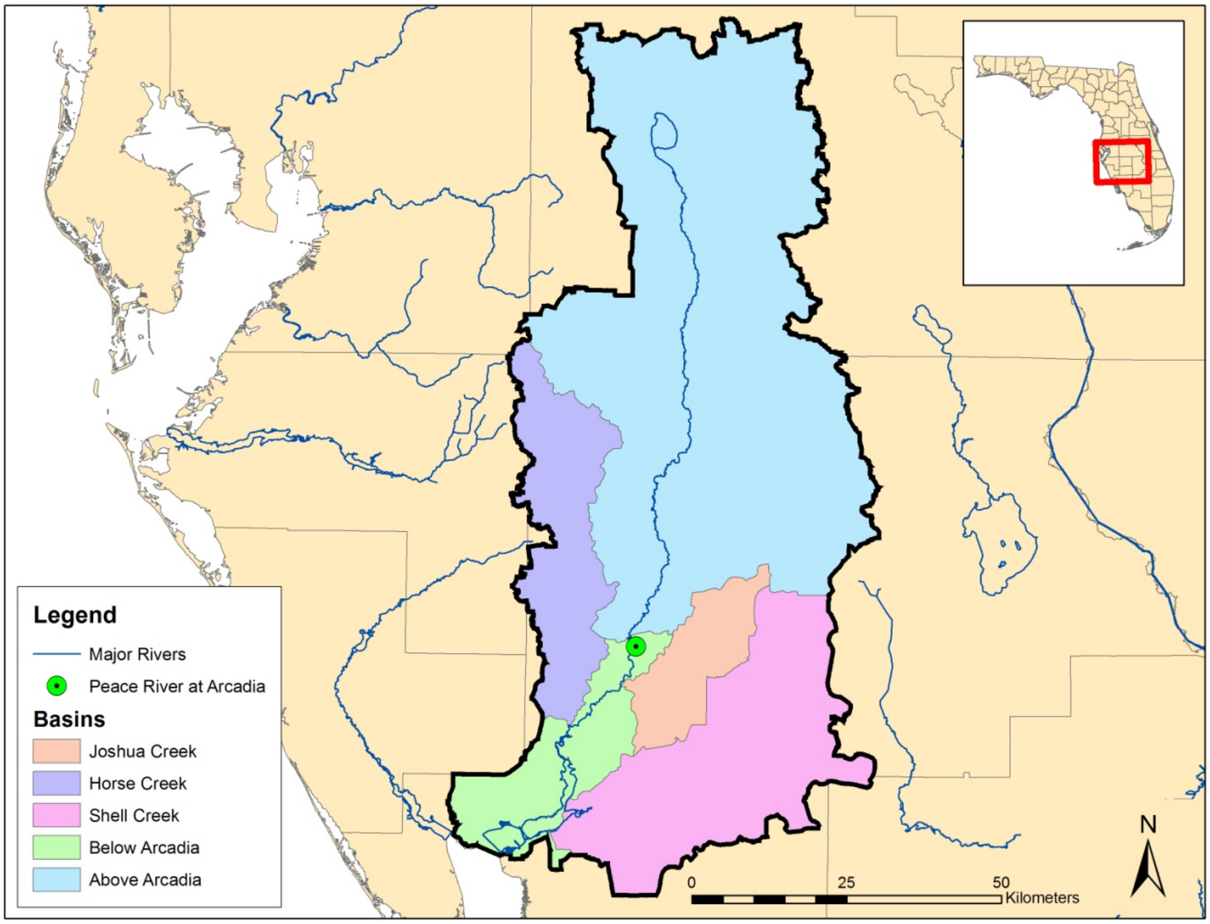


Figure 2-2. Map of Peace River Watershed including Watersheds of LPR Tributaries.

As previously mentioned, the LPR consists of the portion of the river from Arcadia, FL to the mouth of the Peace River where it flows into Charlotte Harbor. The following sections describe the physical characteristics of the LPR as well as the hydrology of the system.

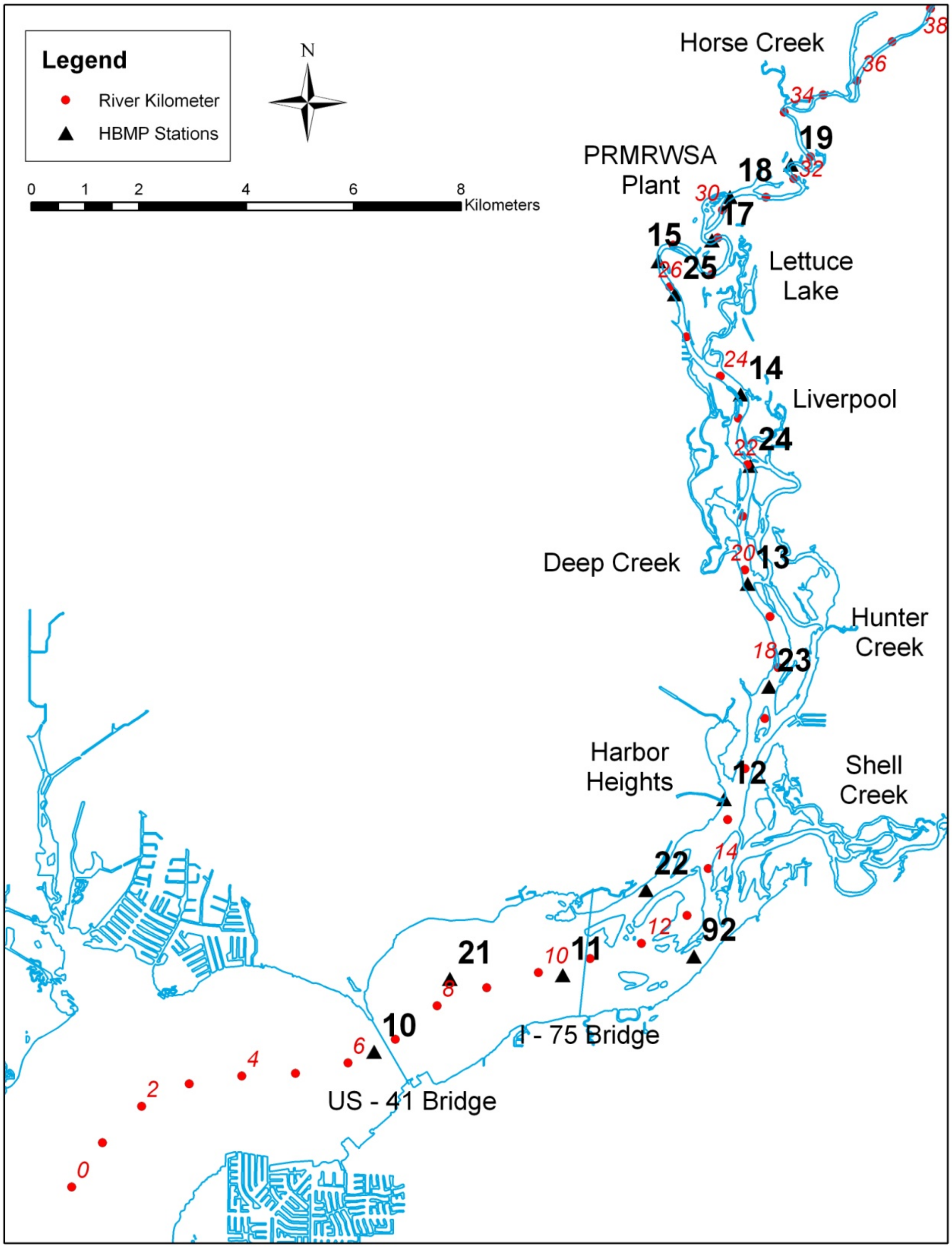


Figure 2-3. Location of the river kilometer system and location of HBMP fixed location stations in the Lower Peace River.

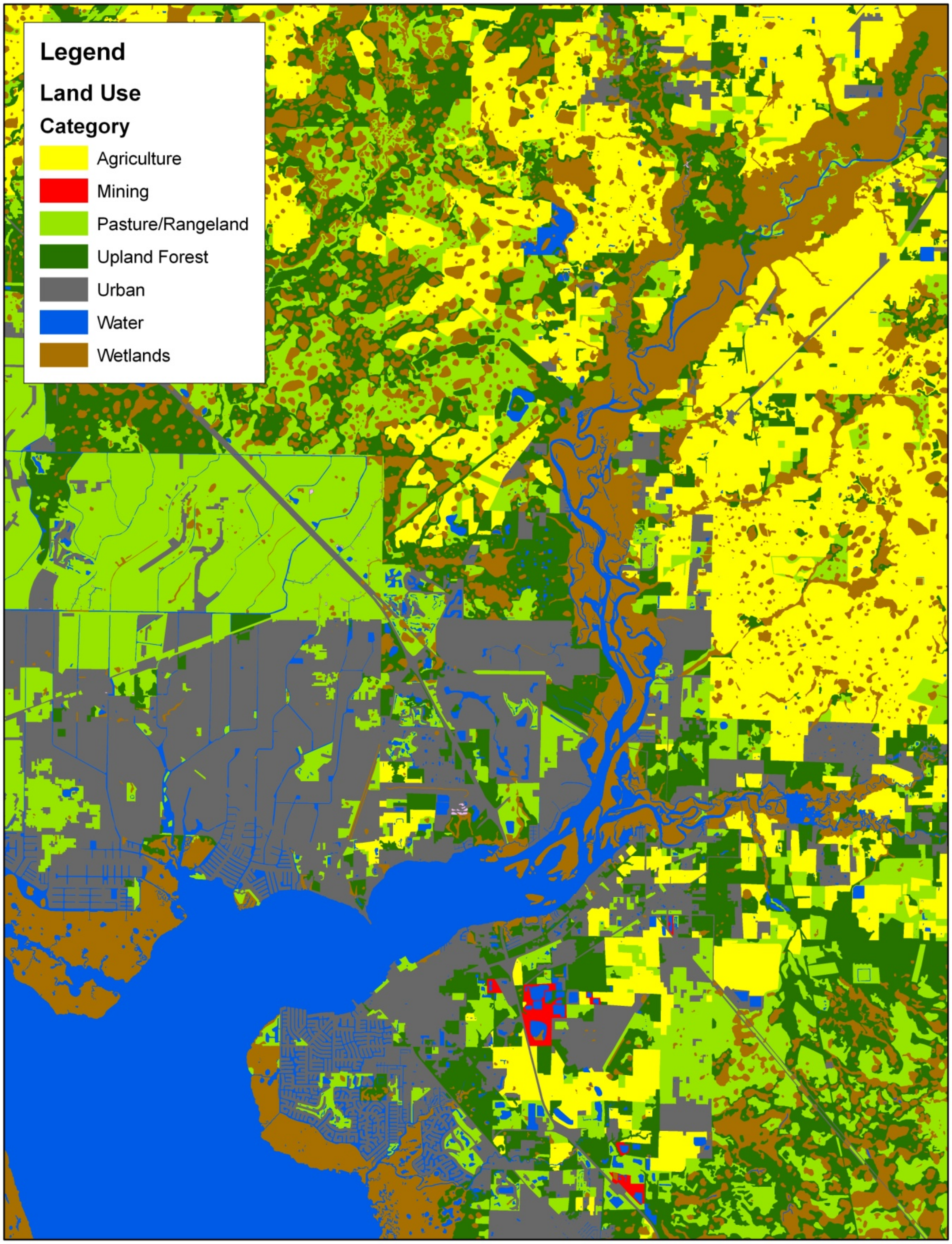


Figure 2-4. **Land use map of the Lower Peace River Watershed (Source: SWFWMD 1999).**

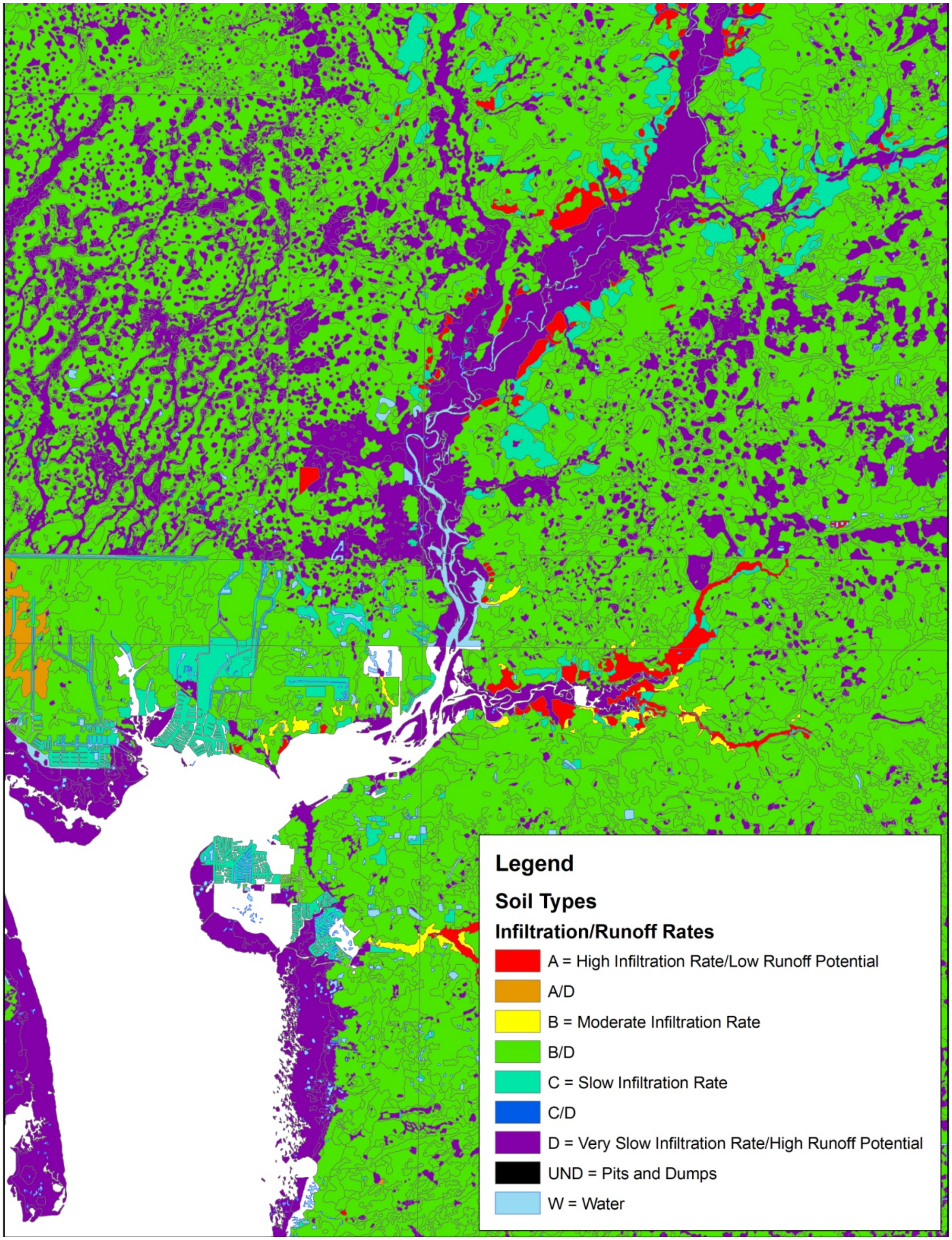


Figure 2-5. Soil types in the Lower Peace River watershed. (Source: SWFWMD 2002).

2.1.1 Bathymetry and Morphometry

The morphology of a riverine system can influence the biology of the system in several ways. The shape of the river affects current speed, and also sediment composition. Sediment composition has obvious impacts for benthic dwelling organisms. Additionally, the shape of the river determines the volume of water, which can affect habitat zonation and availability. Information on morphology and bathymetry in the LPR are available from PBS&J (1998), Mote Marine Lab (2002), and Wang (2004).

The bathymetry of the LPR is shown in Figure 2-6 (Wang 2004). Generally depths are less than four meters throughout the whole river, and are less than three meters in most areas. The greatest depths of around six meters are seen downstream near the mouth of the river.

2.1.2 Shoreline Vegetation

Shoreline vegetative communities (including wetlands) are important components of riverine and estuarine systems. Vegetation communities along tidal rivers south from Tampa Bay, such as the LPR, display a transition from the tidal freshwater forested wetlands and marsh communities upstream, to brackish and salt marsh communities in the mid to lower segments, to mangroves near the river mouths (Estevez et al. 1991). Descriptive information on the vegetation communities located along the Lower Peace River were available from a 1994 vegetation map (FMRI 1998), HBMP monitoring reports prepared for the PRMRWSA (PBS&J 1999b, 2004) and a study of wetland splant species distribution on sevens rivers in the SWFWMD by Clewell et al. (2002). The general distribution of major vegetative communities along the lower river was mapped by FMRI (1998) and is shown in Figure 2-7.

Bottomland Hardwood and Mixed Wetland Forests

Bottomland hardwoods are a type of wetland forest that includes a diverse assortment of hydric hardwood species that are typically found along rivers. Generally they occur on rich alluvial silt- and clay-rich sediments deposited by river overflow. Bottomland hardwood forests are the dominant vegetative community along the Lower Peace River upstream of river kilometer 22. Common tree species in these forest included bald cypress (*Taxodium distichum*), water hichkory (*Carya aquatica*), ash (*Fraxinus caroliniana*) and red maple *(Acer rubrum)*.This forest type is influenced by periodic overflow from the river during high flows, and more frequently, tidal water level fluctuations that occur in this part of the river. Though classified as bottomland hardwoods by FMRI (1998), these forests are more properly classified as tidal freshwater forested wetlands using the terminology applied by Conner et al (2007). Excessive salt penetraton into this part of the river could affect the health and distribution of these forested wetlands. FMRI (1998) also identified mixed wetland forests downstreram of kilometer 22. These forests are found at higher elevations and include habitats that can be considered uplands (FMRI 1998). Common tree and shrub species within these mixed wetland forests included sabal palm (*Sabal palmetto*), wax myrtle (*Myrica cerifica*), oaks (*Quercus* spp.) and saltbush (*Baccharis halmifolia*).

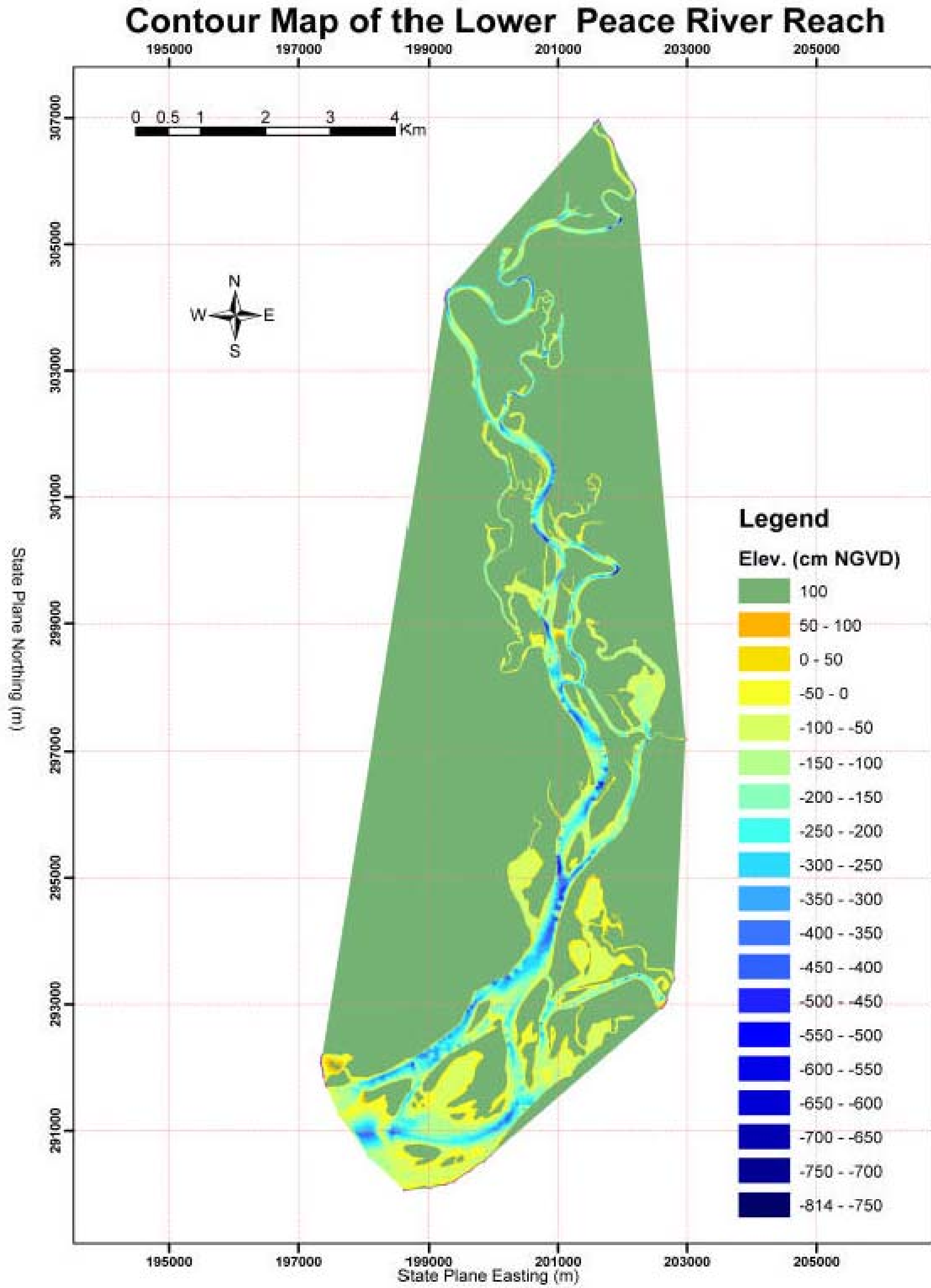


Figure 2-6. Bathymetry of the Lower Peace River (from Wang 2004).

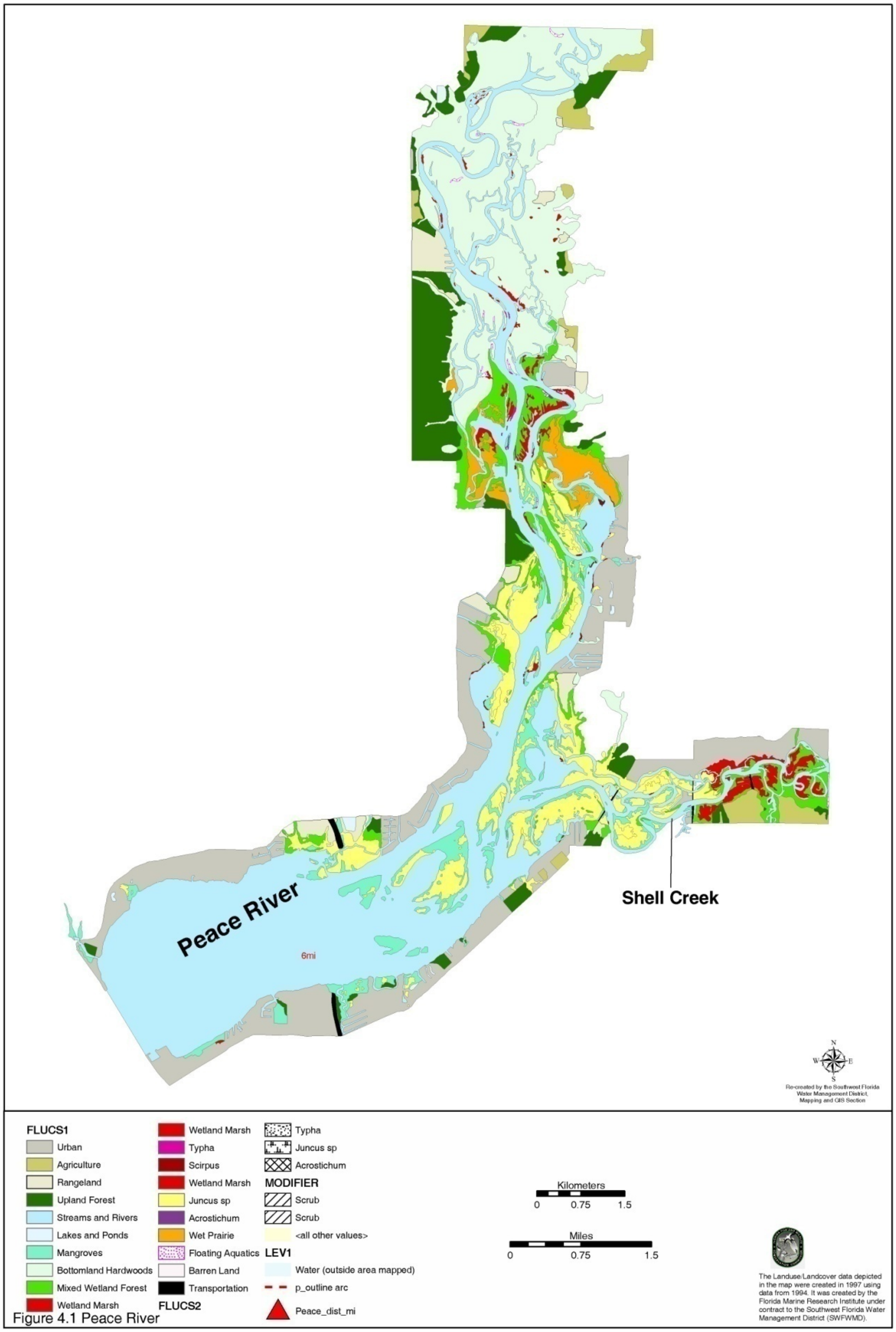


Figure 2-7. Depiction of Lower Peace River Vegetation (from FMRI 1998).

Tidal Marshes

Tidal marshes provide important habitat for numerous species of fishes and crustaceans. Extensive studies have been conducted in salt marshes, while tidal fresh-water and oligohaline marshes are less studied (Figure 2-8). However, existing studies have concluded tidal fresh-water and oligohaline marshes also provide valuable habitat for fishes, crustaceans, and birds (McIvor *et al.* 1989, Odum *et al.* 1988, FFWCC 2005, Shellenbarger and Jones 2007). These marshes serve several functions for these species, such as providing extended foraging ground, temporary refuge from predation, or essential nursery habitat. The habitat value of tidal marshes for nektonic organisms in estuaries has been documented for various geographic areas, including Texas, Louisiana, Georgia, the Carolinas, New Jersey and Delaware (Able *et al.* 2001, Yozzo and Smith 1998, Rozas and Reed 1993, Rozas and Hackney 1984).

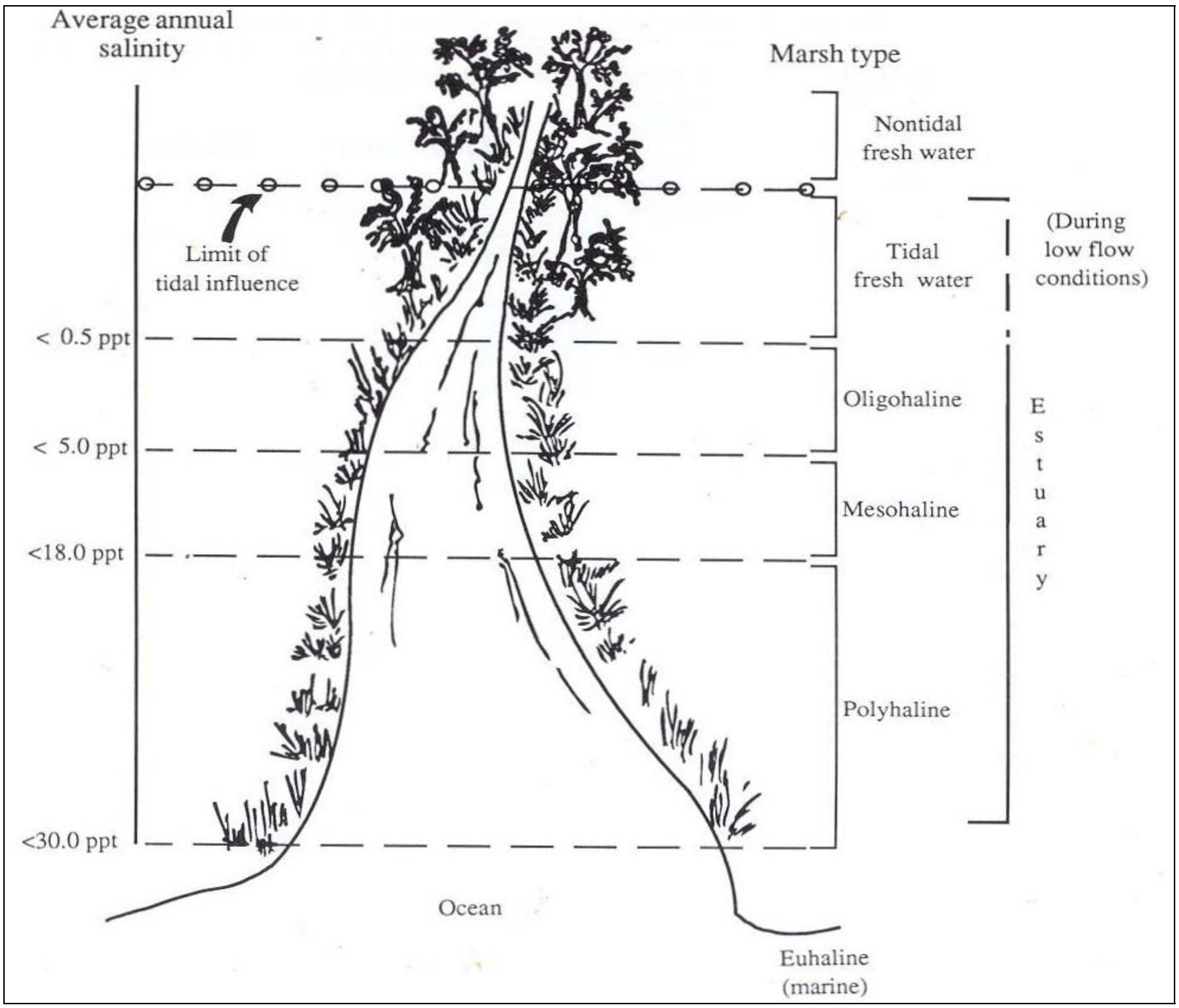


Figure 2-8. Marsh types present in a tidal river system, classified by surface salinity (from Odum *et al.* 1984).

“Oligohaline saltmarsh” was identified as a priority target habitat for conservation in the northern Gulf of Mexico by Beck *et al.* (2000). The oligohaline marsh is characterized by salinities between 0.5 and 5 ppt. As salinities decrease, diversity increases because more species are able to tolerate the conditions. Several species of bulrush (*Scirpus* spp.), as well as cattail (*Typha domingensis*), leatherfern (*Acrostichum danaefolium*) and sawgrass (*Cladium jamaicense*) are considered representative of oligohaline marshes. Many species is oligohaline marshes are freshwater plants that can tolerate low salinities.

Another intertidal wetland community is the tidal fresh-water marsh. Dominant plants include sawgrass, bulrushes, wild rice (*Zizania aquatica*), cattail, arrowhead (*Sagitaria latifolia),,* water parsnip (*Sium suave*), pickerelweed (*Pontedaria cordata*), spatterdock (*Nuphar luteum*), and other fresh-water emergent marsh plants (Clewell *et al.* 1999, Clewell *et al.* 2002). Overall, tidal freshwater marshes have the highest plant diversity of the various tidal marsh community types (Clewell *et al.* 1999). The general structure and function of tidal fresh-water marsh communities were described by Odum *et al.* (1984). The fisheries habitat value of tidal freshwater marshes is likely equivalent to those of downstream, higher salinity marshes (Odum *et al.* 1984). Beck *et al.* (2000) identified “tidal fresh marshes” as a high priority Habitat Target for conservation in the northern Gulf of Mexico. The tidal fresh-water marsh is generally characterized by salinities <0.5 ppt, though infrequent salt incursions may occur.

Saltmarshes dominated by black needlerush (*Juncus roemerianus*) occur downstream of fresh and oligohaline marshes on the Lower Peace River (Figure 2-7). Saltmarshes are characterized by somewhat higher salinity, frequently in the mesohaline (5 to 18 ppt) salinity range (Stout 1984, Clewell et al. 2002). Plant species that intergrade along the boundary between oligohaline marshes and saltmarshes on the Lower Peace River include sawgrass, black needlerush, bulrushes, cordgrasses, and lance-leaved arrowhead (PBS&J 2004, Clewell *et al.* 2002). As with the tidal freshwater marsh communities, few studies have been made on these low-salinity brackish wetlands in Florida. These low-salinity marshes, in association with their complex of tidal creeks, are known to provide critical nursery habitat for many fishes of commercial or recreational importance (Rozas and Hackney 1984, Comp and Seaman 1985), particularly during the juvenile stages.

Mangroves

Mangroves are tropical trees that occur in brackish and saltwater environments, typically near the mouths of tidal rivers. While mangroves can physiologically grow in freshwater, mangrove communities only become established in salt water systems, because of the absence of competition from freshwater species (Odum *et al.* 1982). Red and white mangroves *(Rhizophora mangle* and *Laguncularia racemosa)* commonly occur around New Harbor Heights and their dominance increases towards the mouth of the river (Figure 2-7).

2.1.3 Rainfall

In peninsular Florida, there is typically a June through September high rainfall season. Superimposed on this general seasonal cycle are the effects of larger scale events, notably the El Niño-Southern Oscillation (ENSO) and the Atlantic Multidecadal Oscillation (AMO) (Kelly 2004; Kelly and Gore 2008). Typically El Niño years are wetter than La Niña years (Schmidt and Luther 2002). However, El Niño effects during the summer wet season are somewhat attenuated by the seasonal occurrence of thunderstorms. Mean monthly rainfall at the Arcadia gauge exhibits the typical June-September rainfall peak and lower values during the remainder of the year (Figure 2-.9). Long-term trends for rainfall in the basin are shown in Figure 2-10. The total annual rainfall at Arcadia ranged from 29 to 80 inches, while the mean and median were 51.9 and 52.0 inches, respectively.

2.1.4 Freshwater Flows

Streamflow represents the sum of the contributions of groundwater, runoff, direct rainfall, and anthropogenic discharges (e.g., wastewater) minus the volume of water that is lost due to evapotranspiration, groundwater, and withdrawals. Long-term alteration of inflow characteristics can produce large changes in aquatic ecosystem structure and function. The physical, chemical, and biological properties of aquatic ecosystems are all affected by the magnitude and frequency of flow. Chemical and biological processes in estuaries are affected by changes in water residence time, which is a function of freshwater inflow. Similarly, the structure and function of biological communities associated with aquatic ecosystems depend in large part on the hydrologic regime (Poff and Ward 1989, 1990). In tidal rivers, freshwater flow is a critical determinant of the spatial and temporal variation in salinity. In turn, salinity is a critical determinant of the structure and function of the tidal river ecosystem and that of the estuary into which it flows.

There are four USGS gauges that record flows that enter the LPR, Peace River at Arcadia (USGS gauge 02296750), Horse Creek near Arcadia (USGS gauge 02297310), Joshua Creek at Nocatee (USGS gauge 02297100), and SC near Punta Gorda (USGS gauge 02298202). There is one permitted surface water withdrawal on the LPR at the Peace River Manasota Regional Water Supply Authority (PRMRWSA) plant and one by the City of Punta Gorda from the reservoir behind the Hendrickson Dam on SC. PRMRWSA began withdrawing water in 1980. The SC flows are described in section 2.2.2.3 while flows from other gauges and the PRMRWSA withdrawals are described below.

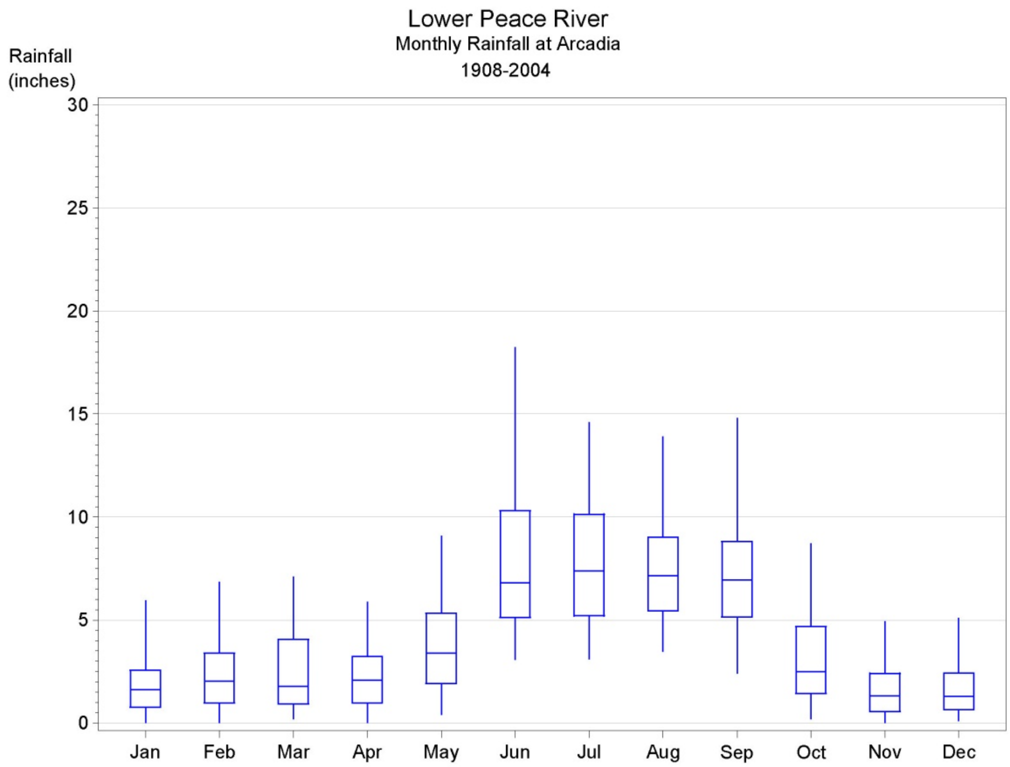


Figure 2-9. **Box and Whisker of monthly rainfall (total inches) at Arcadia, 1908-2004. Whiskers represent the 5th and 95th percentile monthly rainfall.**

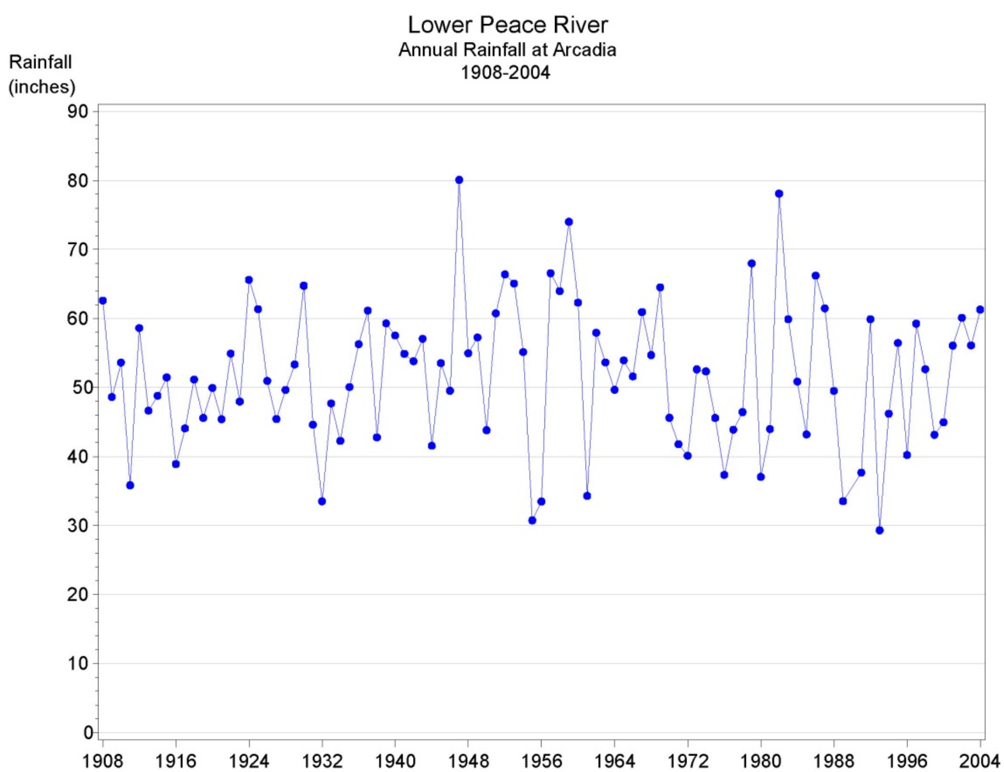


Figure 2-10. **Annual rainfall (inches) at Arcadia, 1908-2004.**

Flows have been measured at the Peace River at Arcadia gauge since 1932. The annual median flows from the Peace River at Arcadia gauge are presented in Figure 2-11. The annual median flows ranged from a minimum of 63 cfs in 2000 to a maximum of 1,740 cfs in 1953. A box and whisker plot of the daily flow from the Peace River at Arcadia gauge is presented in Figure 2-12. The seasonal pattern of higher flows from July to October and lower flows from November to June can be clearly seen. September is typically the month with the highest flows while May has the lowest flows. Finally, a flow duration curve of the daily flows from the Peace River at Arcadia gauge is shown in Figure 2-13. Daily flows ranged from 6 cfs to 34,700 cfs. The 25th percentile, median, and 75th percentile flows over the entire period of record were 205, 461, and 1,210 cfs, respectively.

The period of record for the Horse Creek near Arcadia gauge is 1950 to present. The annual median flows from the Horse Creek near Arcadia gauge are shown in Figure 2-14. The minimum annual median flow of 3 cfs occurred in 1974 and the maximum of 211 cfs in 1953. A box and whisker plot of the daily flow from the Horse Creek near Arcadia gauge is presented in Figure 2-15. As with the Peace River at Arcadia gauge, the seasonal pattern of higher flows from July to October and lower flows from November to June is clear. September is typically the month with the highest flows while May has the lowest flows. A flow duration curve of the daily flows from the Horse Creek near Arcadia gauge in shown in Figure 2-16. The daily flows ranged from 0 cfs to 10,700 cfs. The 25th percentile, median, and 75th percentile flows over the entire period of record were 10, 46, and 189 cfs, respectively.

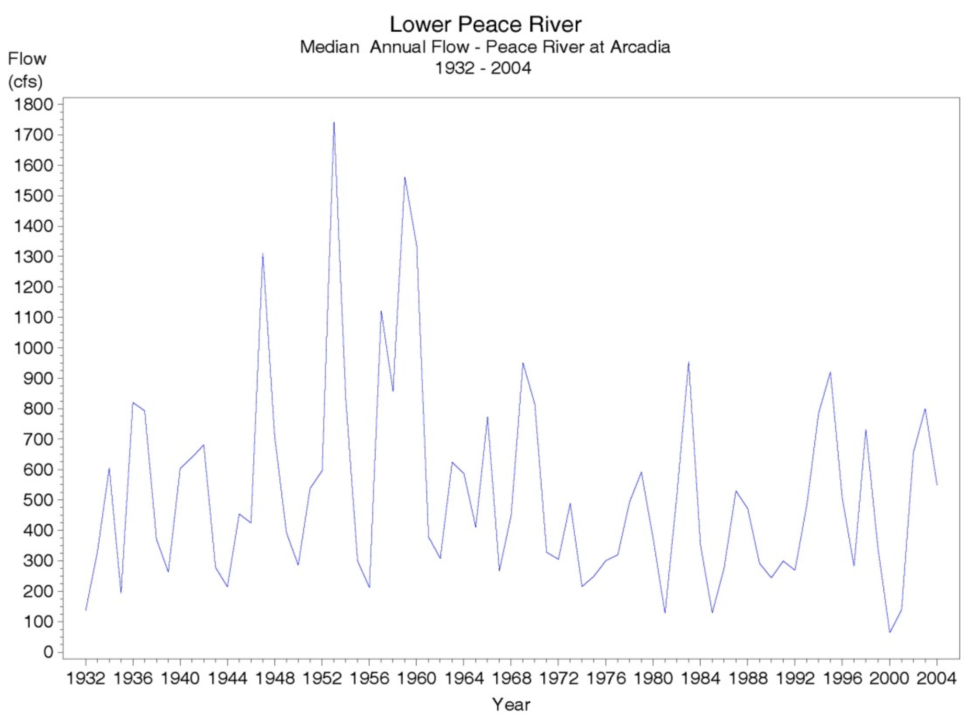


Figure 2-11. Time series of annual median flows (cfs) from the Peace River at Arcadia gauge (USGS 02296750) for the period 1932 to 2004.

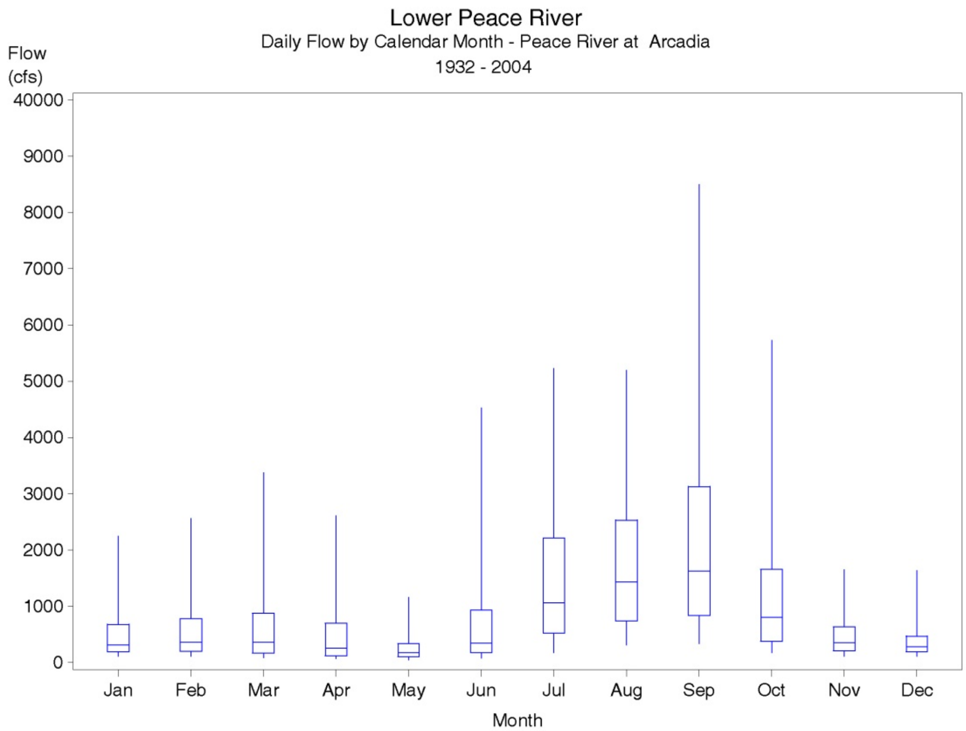


Figure 2-12. Box and whisker plot of daily flows (cfs) by calendar month from the Peace River at Arcadia gauge (USGS 02296750) for the period 1932 to 2004. Boxes represent the inter-quartile range while the whiskers represent the 5th and 95th percentiles.

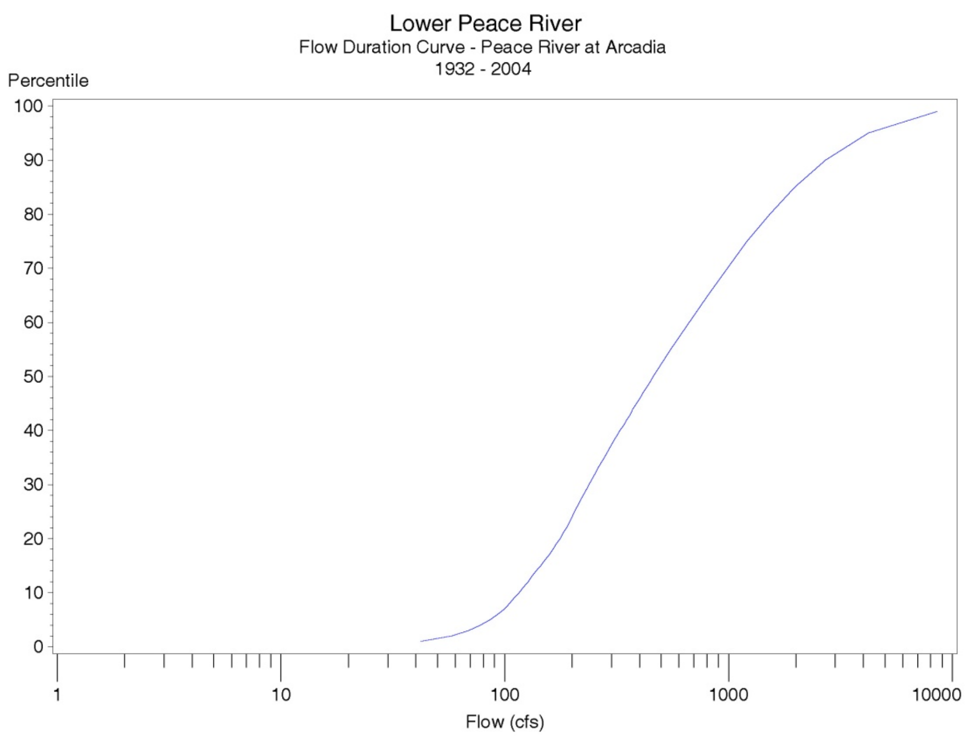


Figure 2-13. Flow duration curve of daily flows (cfs) from the Peace River at Arcadia gauge (USGS 02296750) for the period 1932 to 2004.

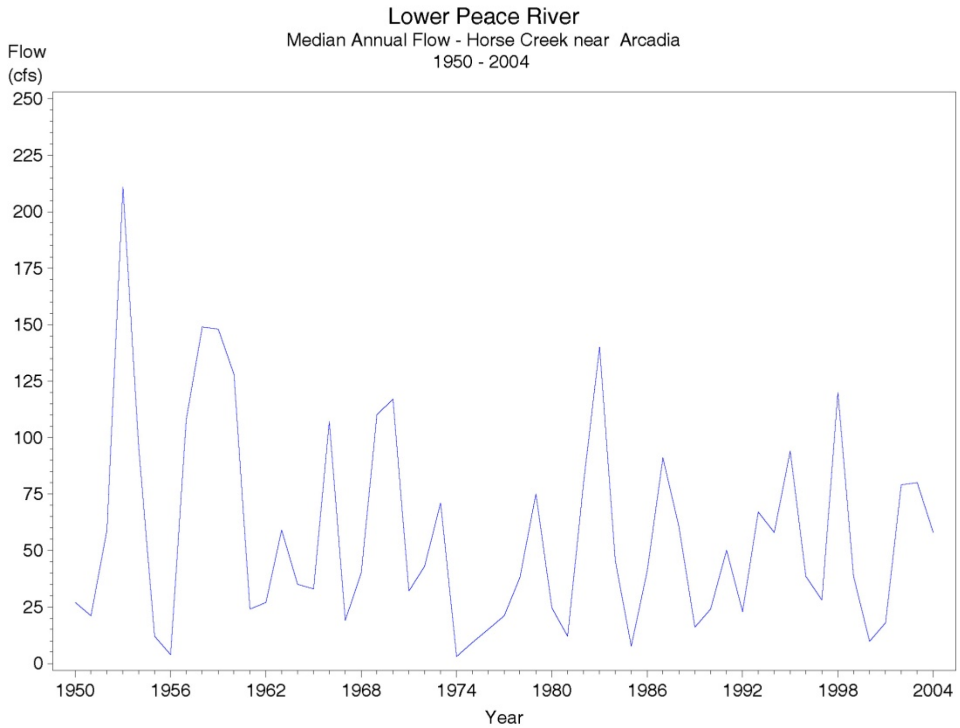


Figure 2-14. **Time series of annual median flows (cfs) from the Horse Creek near Arcadia gauge (USGS 02297310) for the period 1950 to 2004.**

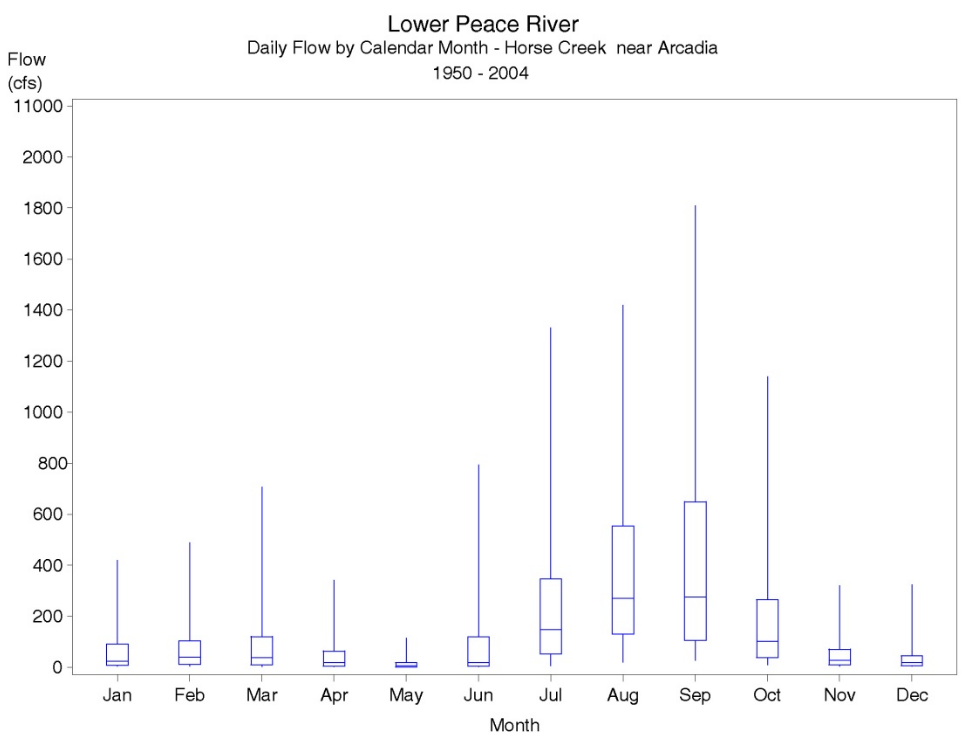


Figure 2-15. **Box and whisker plot of daily flows (cfs) by calendar month from the Horse Creek near Arcadia gauge (USGS 02297310) for the period 1950 to 2004. Boxes represent the inter-quartile range while the whiskers represent the 5th and 95th percentiles.**

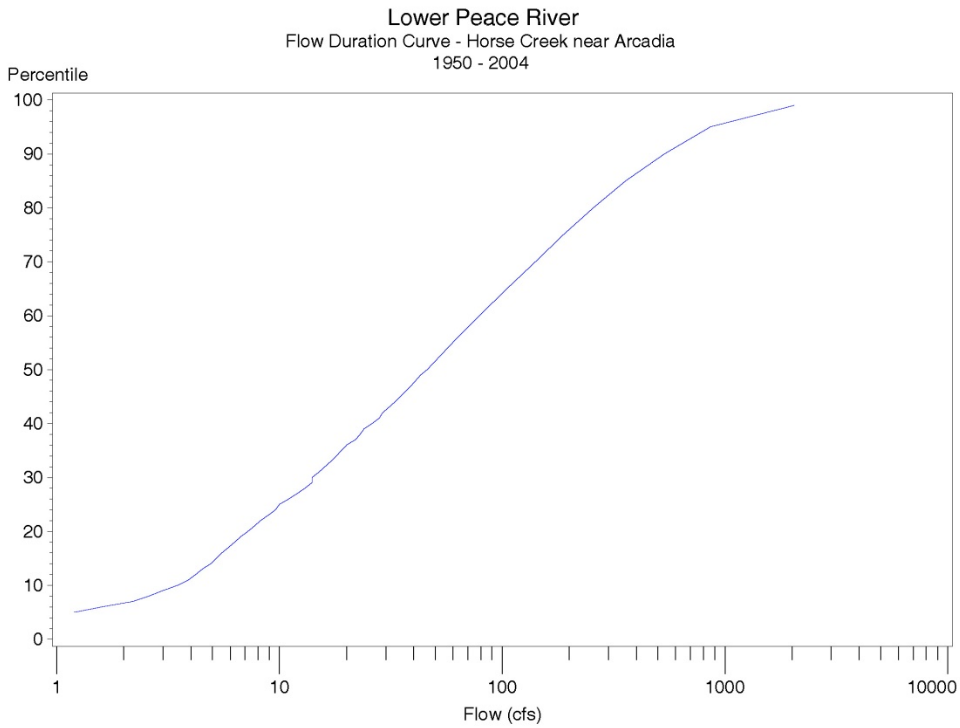


Figure 2-16. Flow duration curve of daily flows (cfs) from the Horse Creek near Arcadia gauge (USGS 02297310) for the period 1950 to 2004.

The period of record for the Joshua Creek at Nocatee gauge is from 1950 to 2004. The annual median flows from the Joshua Creek at Nocatee gauge are presented in Figure 2-17. The annual median flows ranged from a minimum of 2 cfs in 1956 to a maximum of 73 cfs in 1958. There is a trend of increasing flows in Joshua Creek (PBS&J 2007). A box and whisker plot of the daily flow from the Joshua Creek at Nocatee gauge is presented in Figure 2-18. The seasonal pattern of higher flows from July to October and lower flows from November to June can be seen clearly. September is typically the month with the highest flows while May has the lowest flows. Finally, a flow duration curve of the daily flows from the Joshua Creek at Nocatee gauge in shown in Figure 2-19. The daily flows ranged from 0 cfs to 7,910 cfs. The 25th percentile, median, and 75th percentile flows over the entire period of record were 10, 28, and 92 cfs, respectively.

The only major surface water withdrawal on the Peace River is maintined by the Peace River Manasota Regional Water Supply Authority (PRMRWSA), with the intake located on a slough connected to the west bank of the river approximately 19 miles upstream of the river mouth at Charlotte Harbor. The Water Use Permit (WUP #2010420.02) held by the PRMRWS is regulated using the percent-of-flow method. The WUP, as modified on 18 December 1998, permits:

- withdrawals from the river cannot exceed 10% of the preceding day flow as measured at the Peace River near Arcaida gauge

- withdrawals from the river cannot reduce the rate of flow as measured at Arcadia below 130 cfs (e.g., no withdrawals allowed when flows are below 130 cfs, only 5 cfs available for withdrawal if flow is 135 cfs at Arcadia)
- daily maximum withdrawals from the river cannot exceed a rate of 139 cfs (90 mgd),
- water supplies provided to PRMRWSA customers cannot exceed a monthly maximum rate of 59 cfs (38.1 mgd); and an annual average rate of 51 cfs (32.7 mgd).

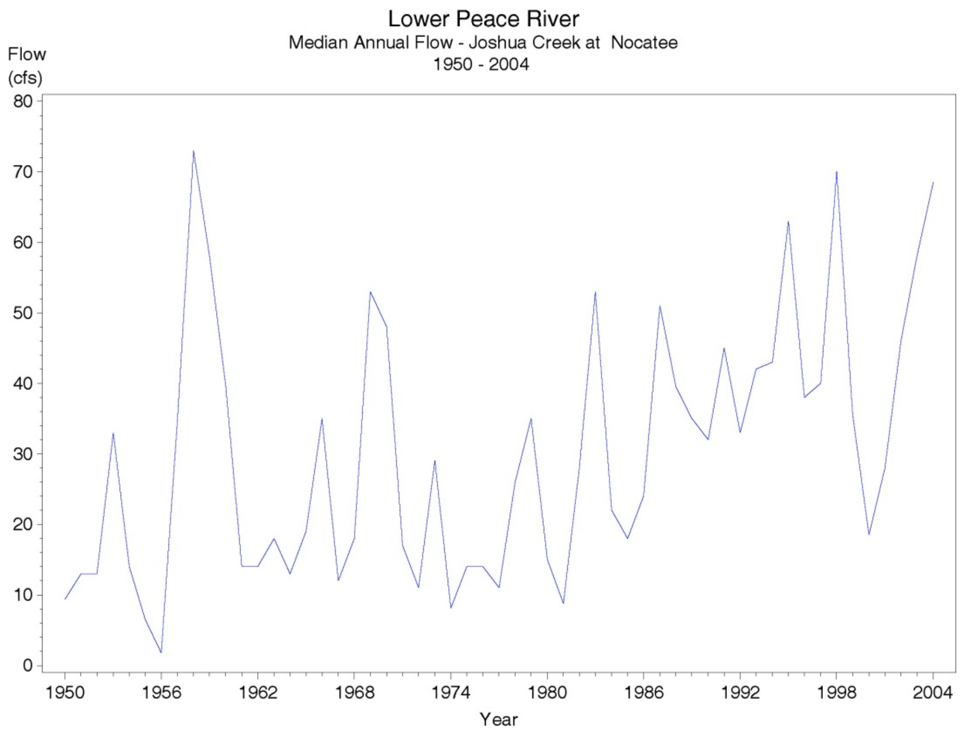


Figure 2-17. Time series of annual median flows (cfs) from the Joshua Creek near Nocatee gauge (USGS 02297100) for the period 1950 to 2004.

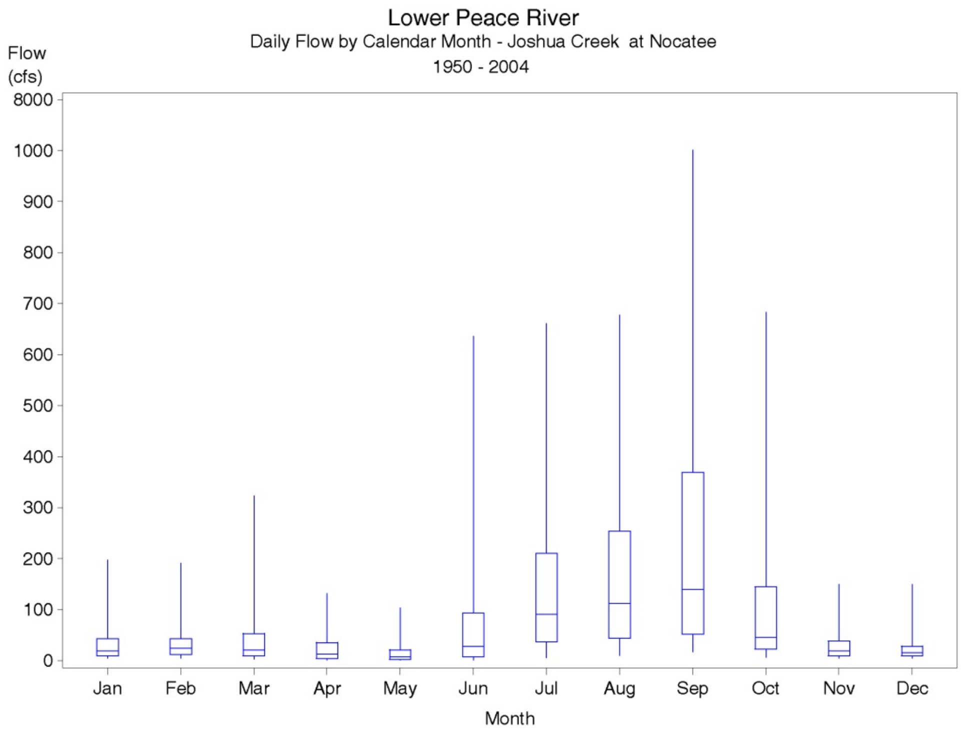


Figure 2-18. Box and whisker plot of daily flows (cfs) by calendar month from the Joshua Creek near Nocatee gauge (USGS 02297100) for the period 1950 to 2004. Boxes represent the inter-quartile range while the whiskers represent the 5th and 95th percentiles.

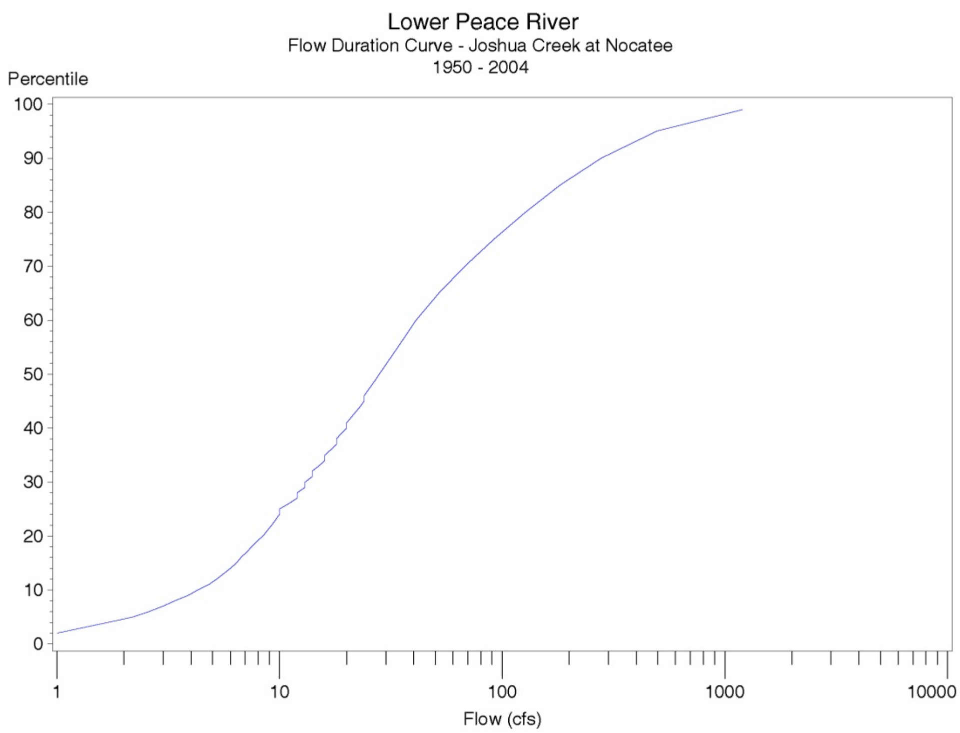


Figure 2-19. Flow duration curve of daily flows (cfs) from the Joshua Creek near Nocatee gauge (USGS 02297100) for the period 1950 to 2004.

The annual median withdrawals from the PRMRWSA plant are shown in Figure 2-20. The minimum annual median withdrawal was 0 cfs and it occurred in five years (1981, 1984, 1985, 2000, and 2001). The maximum median annual withdrawal was 26 cfs, and it occurred in 2003 and 2004. A box and whisker plot of the daily withdrawals from the PRMRWSA is presented in Figure 2-21. A seasonal cycle to the withdrawals is evident due to the permit being conditioned with a low flow threshold of 130 cfs and a 10% of flow limitation. The highest median withdrawal is in October and the lowest is in May—although the interquartile ranges for all months overlap.

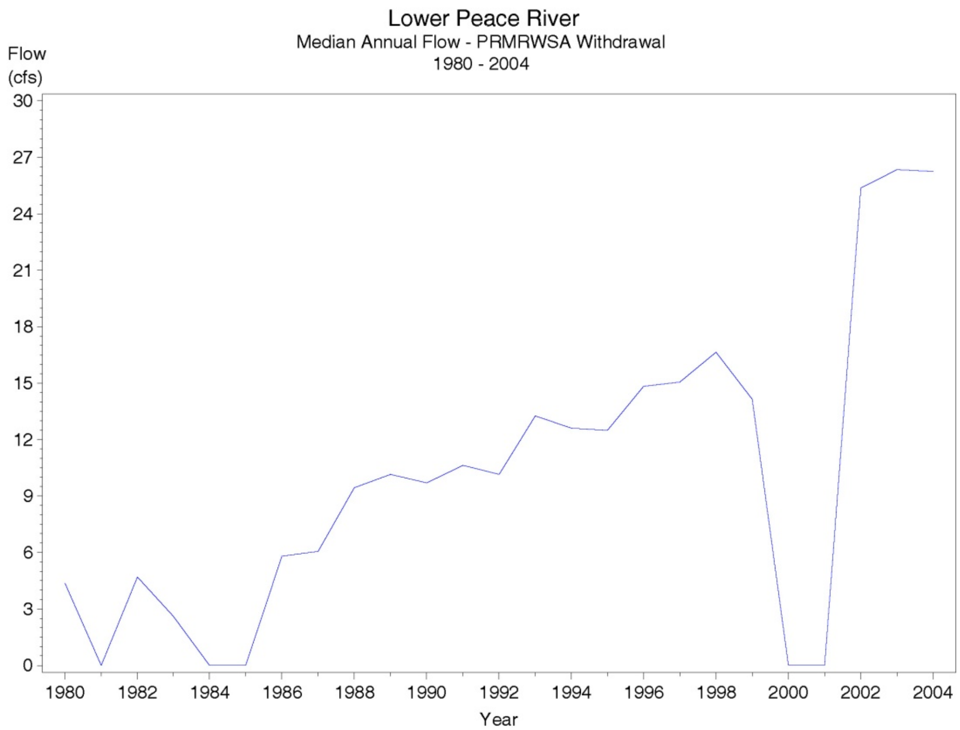


Figure 2-20. **Time series of annual median flows (cfs) from the PRMRWSA for the period 1980 to 2004.**

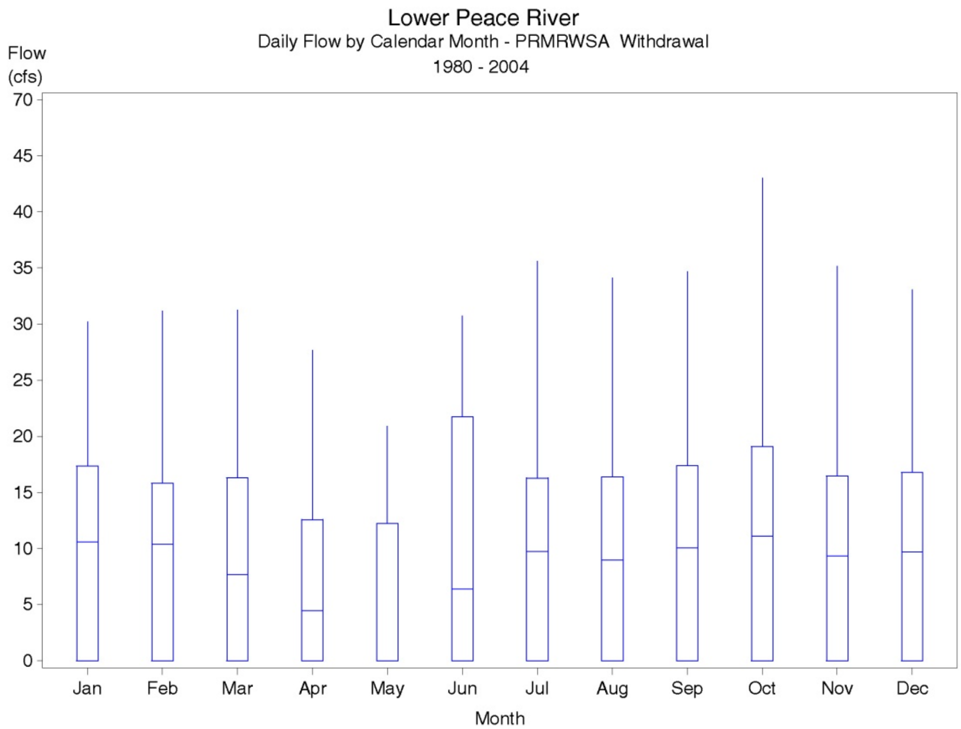


Figure 2-21. **Box and whisker plot of daily flows (cfs) by calendar month from the PRMRWSA for the period 1980 to 2004. Boxes represent the inter-quartile range while the whiskers represent the 5th and 95th percentiles.**

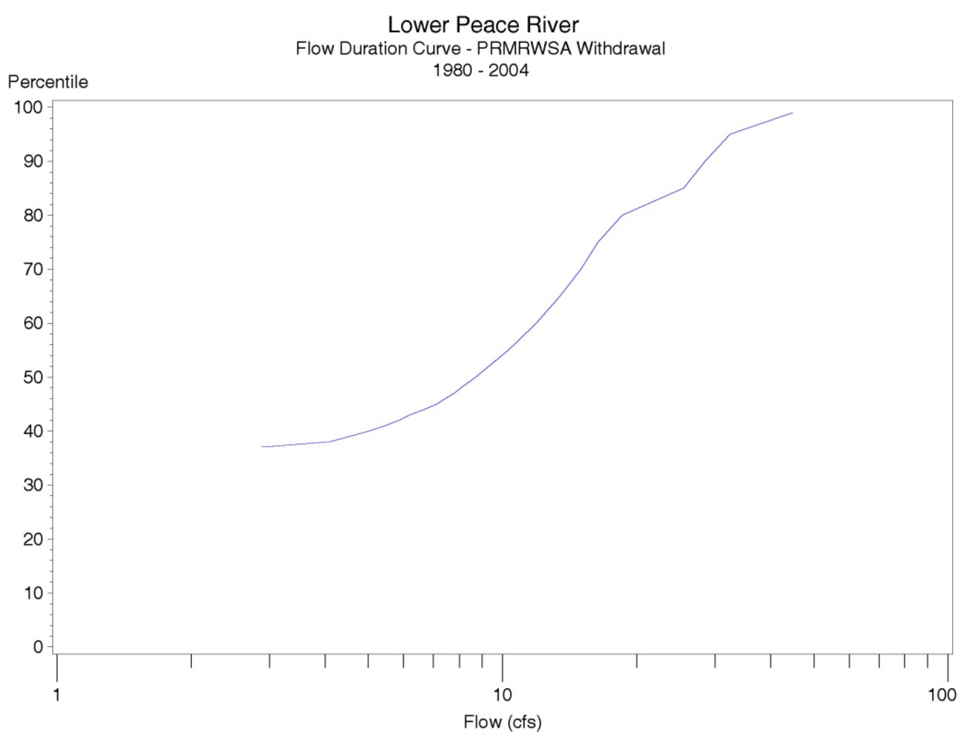


Figure 2-22. **Flow duration curve of daily flows (cfs) from the PRMRWSA for the period 1980 to 2004.**

A flow duration curve of the daily withdrawals from the PRMRWSA plant in shown in Figure 2-22. The daily withdrawals ranged from 0 cfs to 69 cfs. The 25th percentile, median, and 75th percentile flows over the entire period of record were 0, 9, and 16 cfs, respectively.

A number of studies have examined streamflow trends in the Peace River watershed, and the status and causes of flow trends in the watershed has been the source of considerable discussion (Peek 1951, Hammett 1990, Coastal Environmental 1996, Flannery and Barcelo 1998, SWFWMD 2002, 2005a, PBS&J 2007). In two of the more recent assessments,

Kelly (2004) and Kelly and Gore (2008) examined the impact of the Atlantic Multidecadal Oscillation (AMO) in Florida by looking at long-term variations in river flows. For the Peace River, flows at the Arcadia gauge were compared to flows from two major subbasins, Charlie Creek and Horse Creek. When normalized for watershed area (i.e., flows expressed as cfs/sq mile), Charlie Creek, Horse Creek and the Peace River at Arcadia show very similar flow patterns, both pre and post 1970. Plots for Peace River at Arcadia and Horse Creek are presented in Figures 2-23 and 2-24. When percent decreases in median daily flows where compared between periods, both Charlie and Horse Creeks showed almost identical flow declines to that observed for the Peace River at Arcadia. Kelly (2004) suggested that most of the flow decline observed between the two periods investigated must be attributable largely to climate. While declines in flow attributable to AMO were documented for the Peace River at Arcadia and Horse Creek near Arcadia gauges, the same was not seen at Joshua Creek (Figure 2-25). The increase in flows after 1980 seen at Joshua Creek was attributed to increased runoff due to increased agricultural activities in the basin (Kelly 2004).

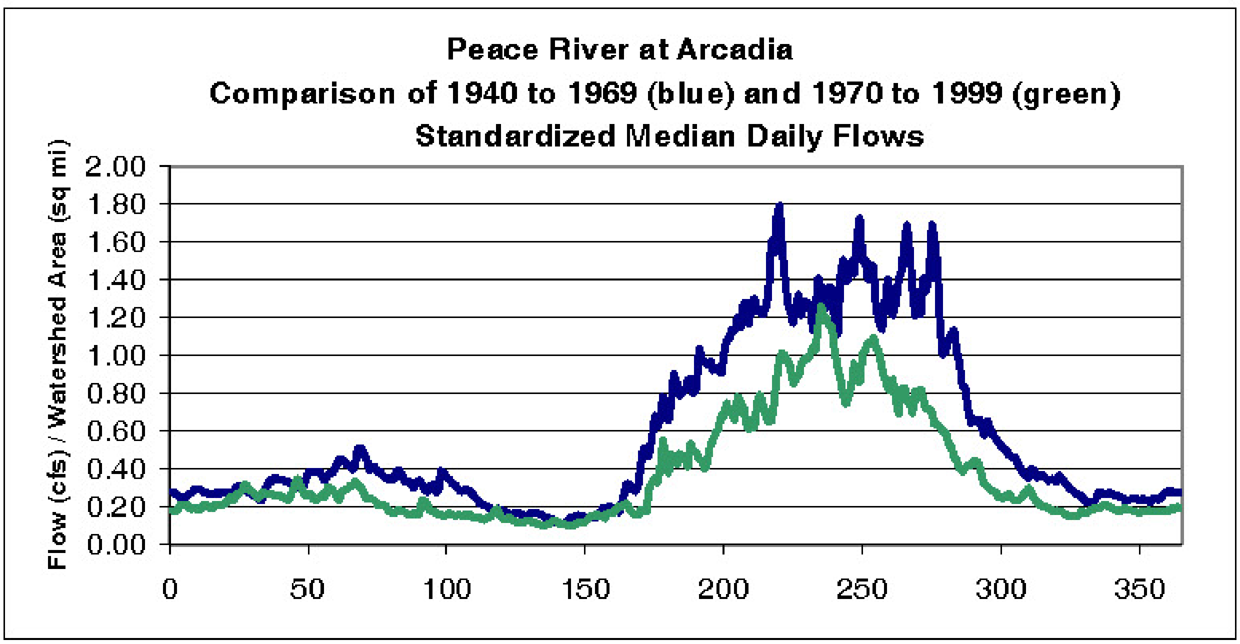


Figure 2-23. Median daily flow normalized for watershed area for the wet (1940-1969) and dry (1970-1999) AMO periods for the Peace River at Arcadia gauge. (Source: Kelly 2004)

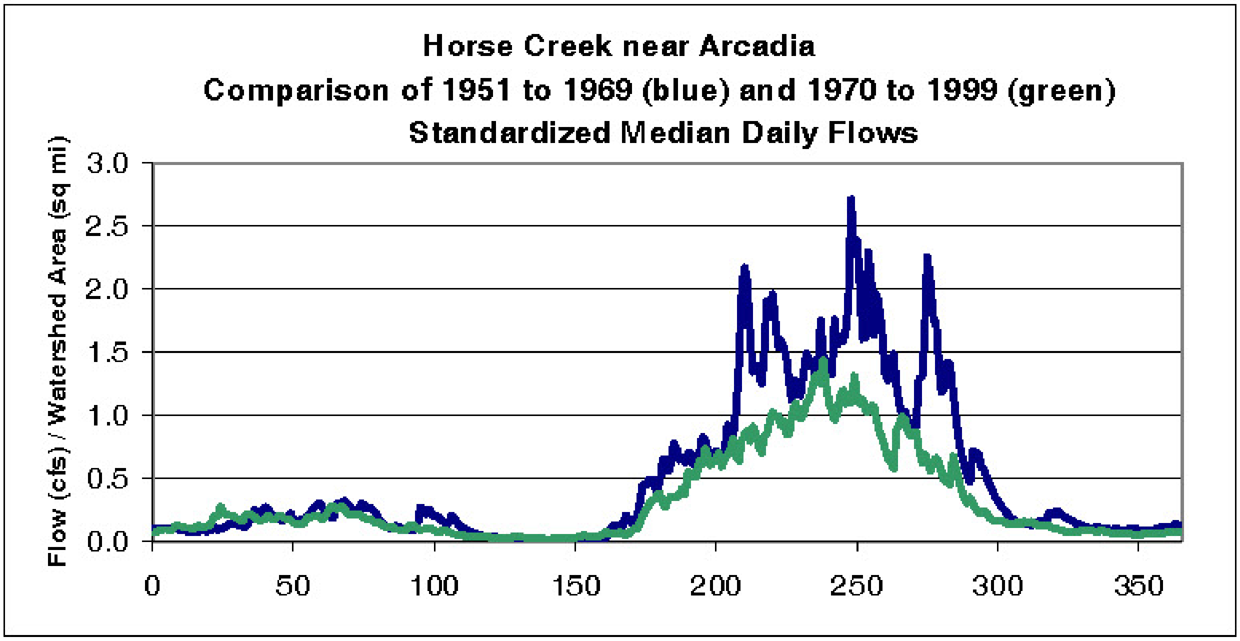


Figure 2-24. Median daily flow normalized for watershed area for the wet (1951-1969) and dry (1970-1999) AMO periods for the Horse Creek near Arcadia gauge. (Source: Kelly 2004)

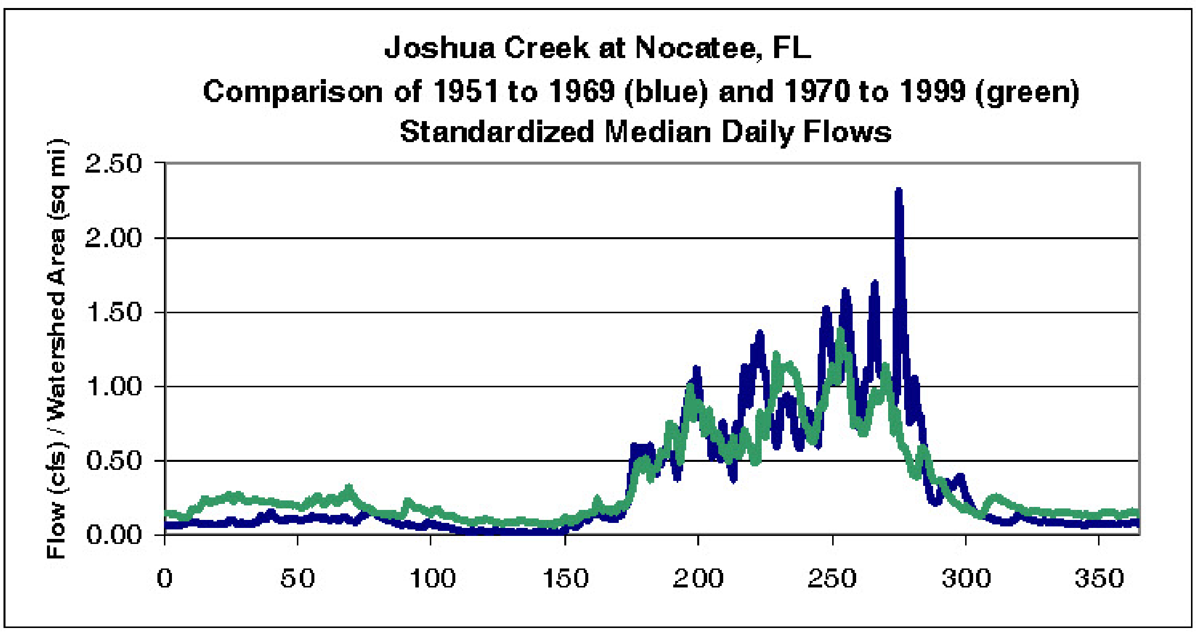


Figure 2-25. Median daily flow normalized for watershed area for the wet (1951-1969) and dry (1970-1999) AMO periods for the Joshua Creek near Arcadia gauge. (Source: Kelly 2004)

2.1.5 Sediment Characteristics

Sediments in the LPR during November 1998 ranged from mud-sized (<62 μ) to coarse sands (500-1000 μ) (Mote Marine Lab 2002). Mud-sized sediments were only found in Zone 3 (see Figure 4-3). Based upon median grain sizes, sediments in Zones 2, 3 and 4, Hunter Creek and Lettuce Lake were generally fine sands; medium sand-sized sediments were predominant in Zone 1 and Deep Creek.

2.2 Physical Characteristics of the Shell Creek Watershed

The portion of SC covered by the MFL extends from the mouth of SC to the SC dam, a distance of approximately 10 km (Figure 2-26). Land use throughout the watershed is presented in Figure 2-27. Wetlands buffer the channel of SC and the remaining land uses are a mix of agricultural, pasture and range land, and upland forest. Soils within SC (Figure 2-28) are primarily classified as A (high infiltration rate and low runoff potential) and D (very slow infiltration rate and high runoff potential).

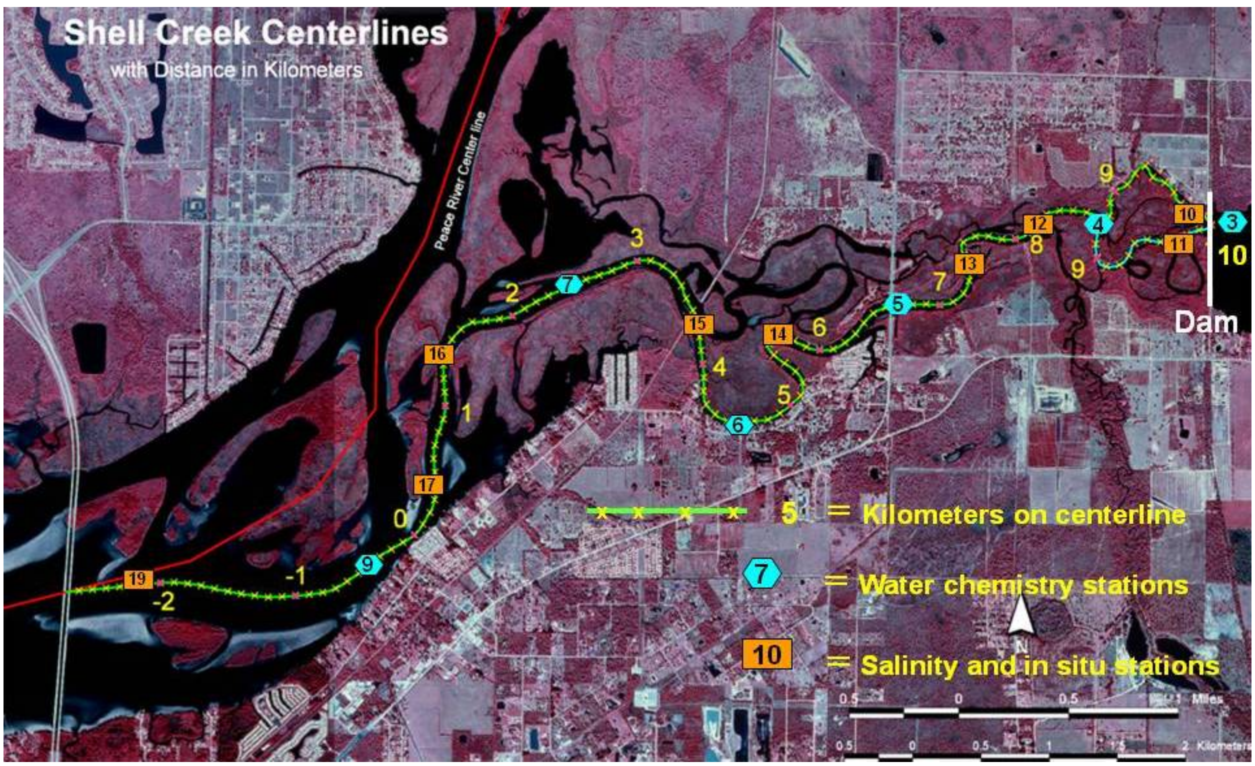


Figure 2-26. Map of SC with centerline kilometer and fixed HBMP in-situ vertical profie and water chemistry stations.

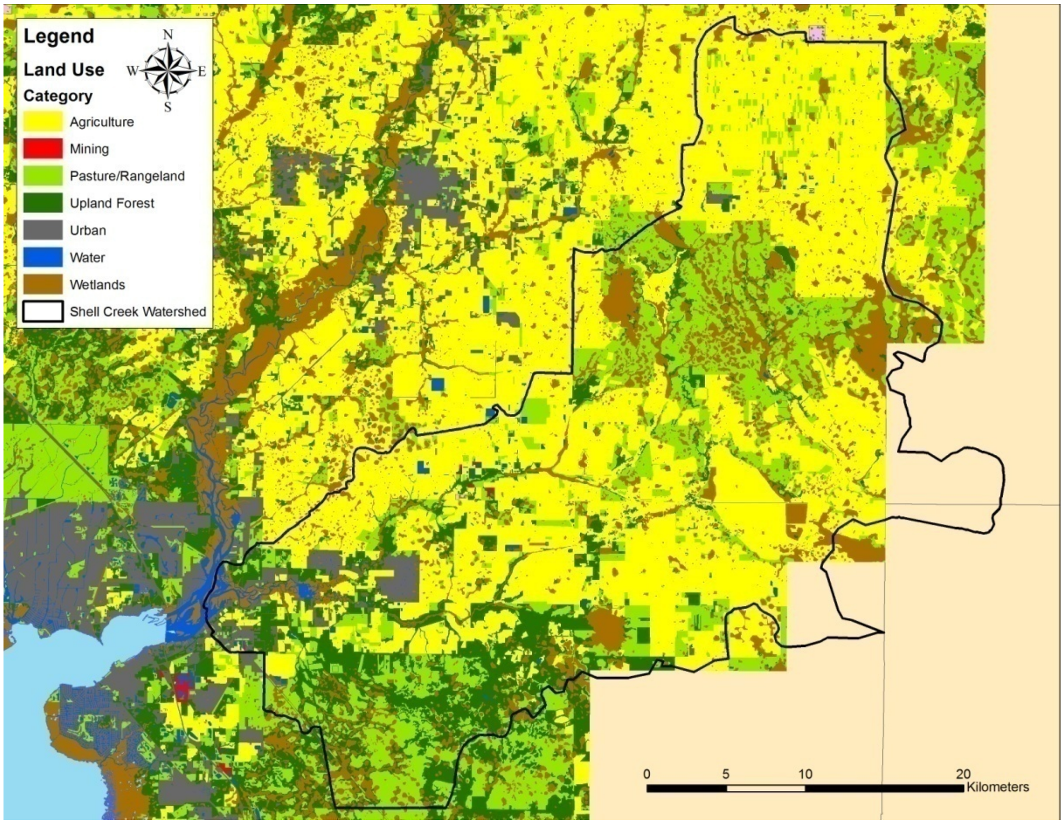


Figure 2-27. Land use map of the SC Watershed (source: SWFWMD 1999).

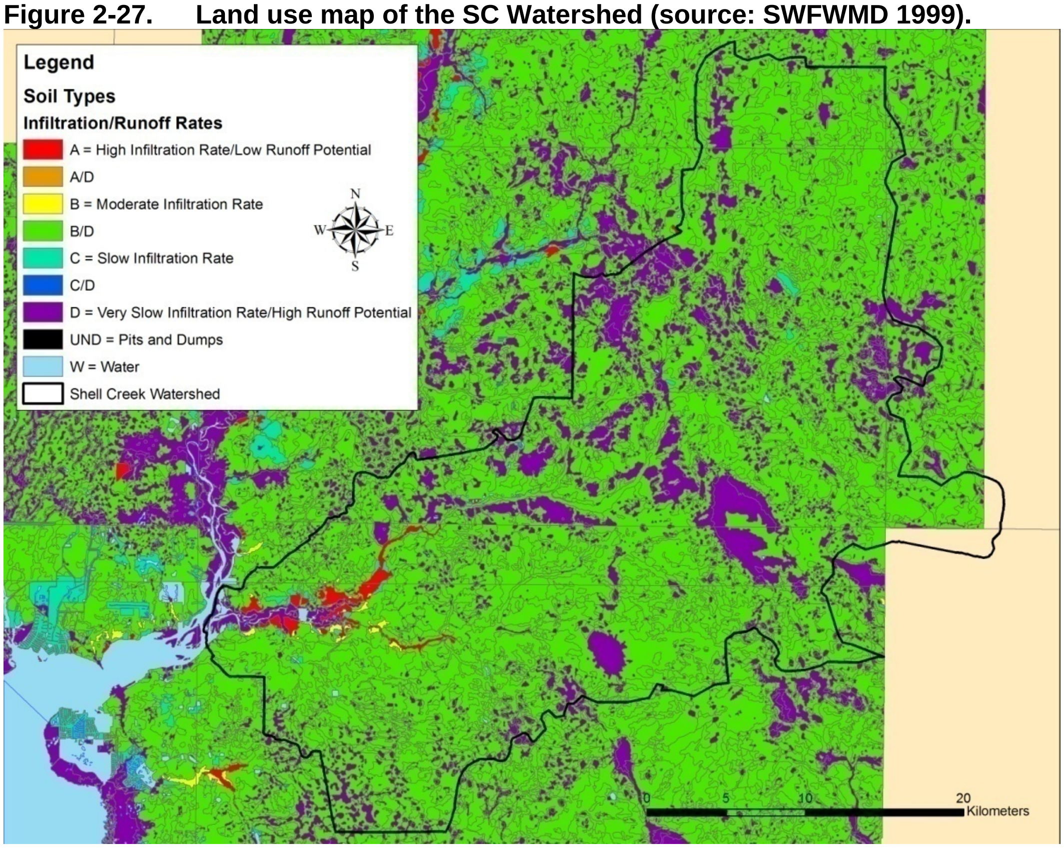


Figure 2-28. Soil types in the SC Watershed (source: SWFWMD 2002).

2.2.1 Bathymetry and Morphometry

The morphology of a riverine system can influence the biology of the system in several ways. The shape of the river affects current speed, and also sediment composition. Sediment composition has obvious impacts for benthic dwelling organisms. Additionally, the shape of the river determines the volume of water, which can affect habitat zonation and availability. Information on morphology and bathymetry in SC are available from PBS&J (1998), Mote Marine Lab (2002), and Wang (2004). Bathymetry in SC is primarily less than 2 meters deep (Figure 2-29).

2.2.2 Shoreline Vegetation

Shoreline vegetation communites on Shell Creek below the Hendrickson dam display shifts in species composition related to horizontal salinity gradients in the creek below the dam. Descriptive information on the vegetation communities located along SC was available from a 1994 vegetation map (FMRI 1998) and from a Shell Creek Gap Report prepared by PBS&J (2006). The general distribution of major vegetative communities along the lower river mapped by PBS&J (2006) are shown in Figure 2-30. A complete set of vegetation maps from PBS&J (2006) are presented in Appendix 2-1.

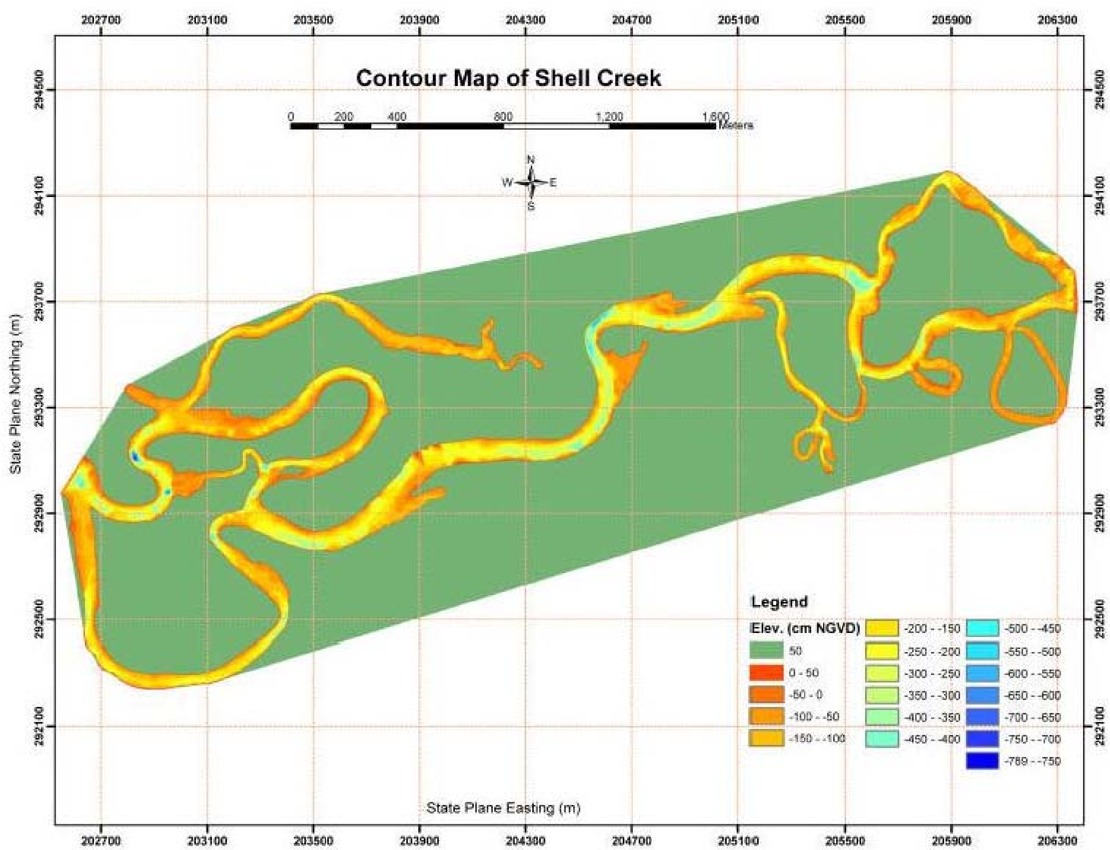


Figure 2-29. Bathymetry of tidally influenced portion of SC (from Wang 2004).

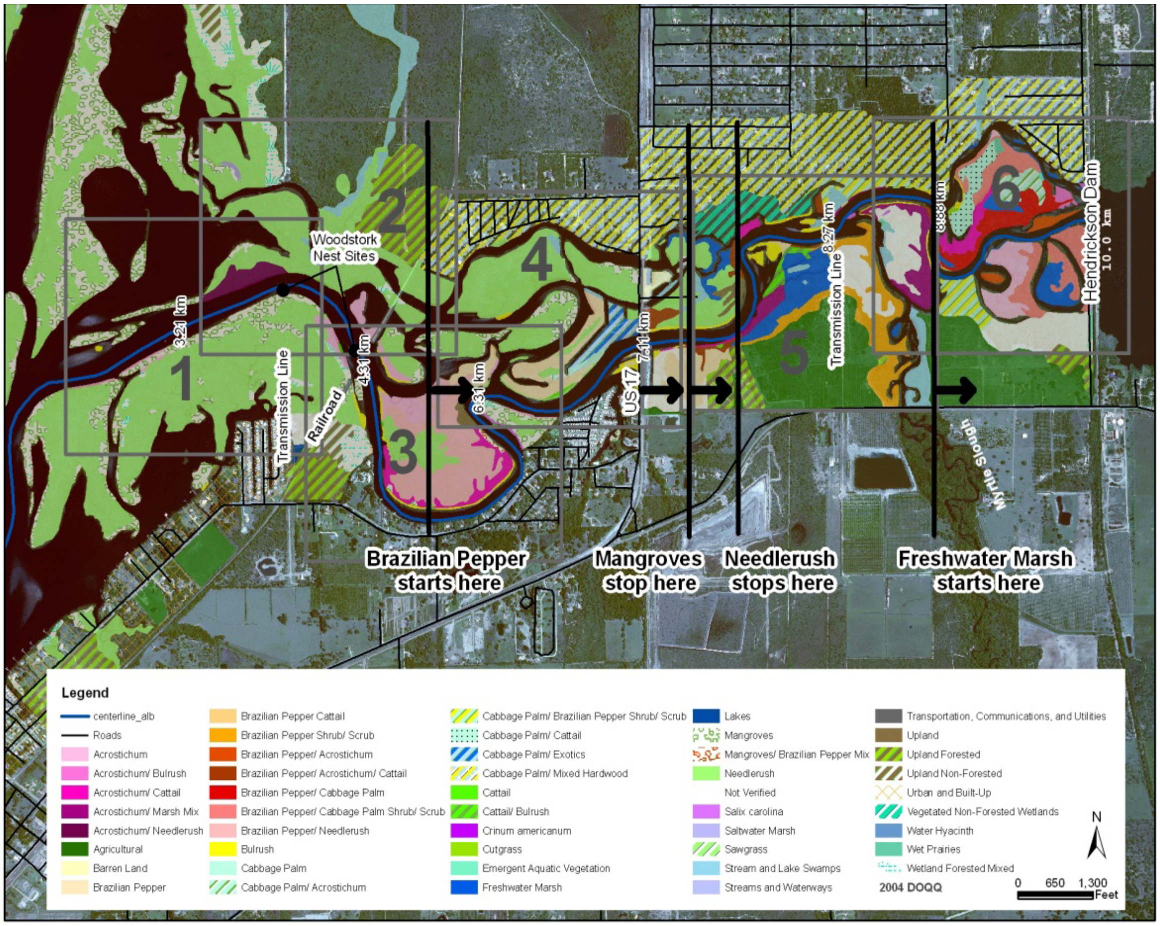


Figure 2-30. Map of SC Vegetation (from PBS&J 2006).

Saltmarshes with intermixed mangroves are common along the lower reaches of Shell Creek near the Peace River (Figures 2-6 and 2-30). Mangroves become increasingly less common upstream, with the most upstream mangrove trees found near kilometer 7.1 (Figure 2-30). Black needlerush extends slightly further upstream, with lower salinity oligohaline marsh species such as leatherfern (*Acrostichum danaefolium*) and cattail (*Typha dominguensis*), becoming dominant. Freshwater marsh communties are found within about 1 kilometer of the dam.

2.2.3 Rainfall

In peninsular Florida, there is typically a June through September high rainfall season. Superimposed on this general seasonal cycle are the effects of larger scale events, notably the El Niño-Southern Oscillation (ENSO) and the Atlantic Multidecadal Oscillation (AMO) (Kelly 2004). Mean monthly rainfall at Punta Gorda, FL exhibits the typical June-September rainfall peak and lower values during the remainder of the year (Figure 2-31). Long-term trends for rainfall in the basin are shown in Figure 2-32. The total annual rainfall at Punta Gorda ranged from 30 to 88 inches, while the mean and median were 50.7 and 50.3 inches, respectively.

2.2.4 Freshwater Flows

Freshwater inflow to the tidal reaches of Shell Creek is measured by the USGS at the Shell Creeek near Punta Gorda gauge (#02298202). It is important to note that this gauge measures flow over the spillway of the Hendrickson Dam and not inflow to the reservoir. Shell Creek also receives a small amount of unaged runoff that enters the creek below the dam.

The City of Punta Gorda withdraws water from the SC reservoir upstream of the SC dam, under the stipulatons of a Water User Permit issued by the Southwest Florida Water Management District (WUP #2000871.008). Flows reported by the USGS for the Shell Creek near Punta Gorda gauge reflect flow reductions resulting from the City's withdrawals. The current WUP allows for an average permitted withdrawal of 8.1 mgd (12.5 cfs) and a maximum peak monthly withdrawal of 11.7 mgd (18.1 cfs).
In contrast to withdrawals from the Peace River by the PRMRWSA, withdrawals from Shell Creeek are not regulated with regard to concurrent flows within the creek.

The period of record for the Shell Creek near Punta Gorda gauge is from 1966 to 2004. However, there is a break in the flow record from October 1987 to September 1994, when the USGS ceased rating measurements due to safety concerns at the reservoir spillway. The District used the 1987 USGS rating curve at the dam and daily mean water level measurements at the gauge to estimate daily flows for this missing period. The annual median flows from the Shell Creek near Punta Gorda gauge are presented in Figure 2-33. The annual median flows ranged from a minimum of 29 cfs in 1981 to a maximum of 362 cfs in 1970. A box and whisker plot of the daily flow from the Shell Creek near Punta Gorda gauge by calendar month is presented in Figure 2-34. The seasonal pattern of higher flows from July to October and lower flows from November to June is again documented. August is typically the month with the highest flows while May has the lowest flows. Finally, a flow duration curve of the daily flows from the Shell Creek near Punta Gorda gauge is shown in Figure 2-35. The daily flows ranged from 0 cfs to 7,590 cfs. The 25th percentile, median, and 75th percentile flows over the entire period of record were 61, 149, and 377 cfs, respectively.

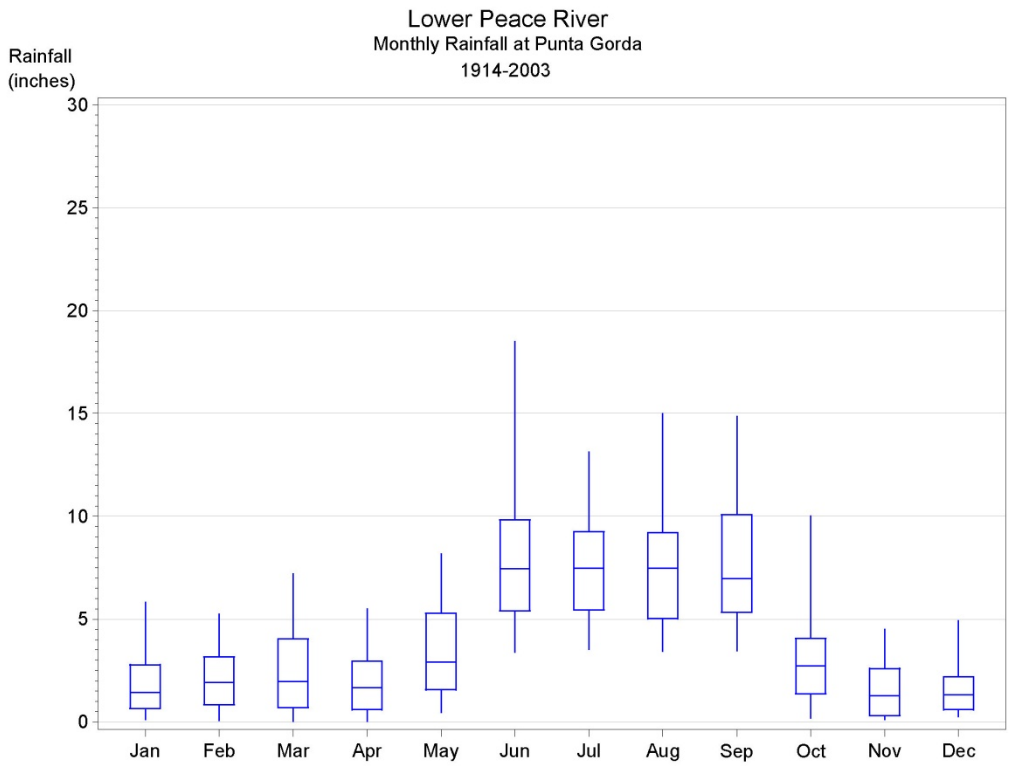


Figure 2-31. Box and Whisker of monthly rainfall (total inches) at Punta Gorda, 1914-2003. Whiskers represent the 5th and 95th percentile monthly rainfall.

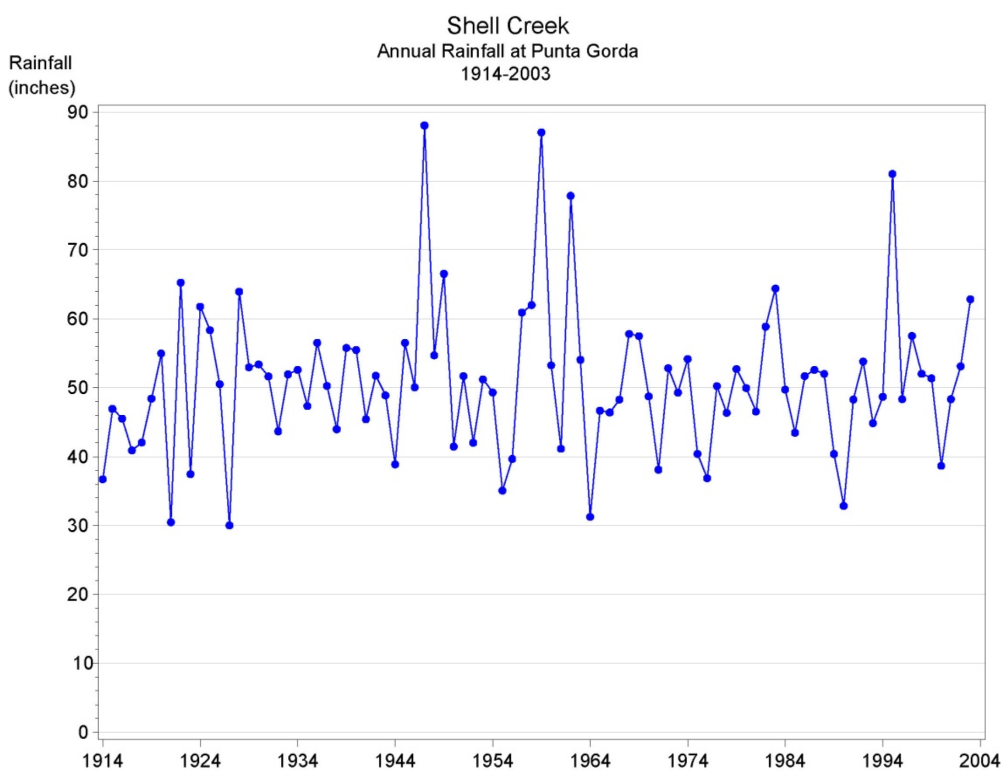


Figure 2-32. Annual rainfall (inches) at Punta Gorda, 1914-2003.

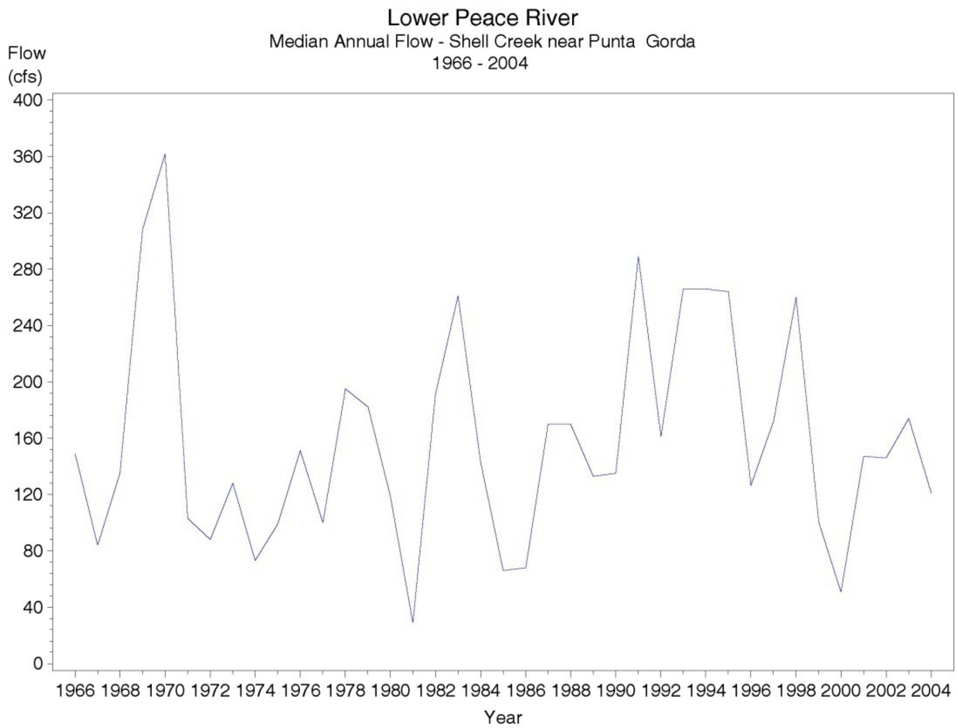


Figure 2-33. **Time series of annual median flows (cfs) from the Shell Creek near Punta Gorda gauge (USGS 02298202) for the period 1966 to 2004.**

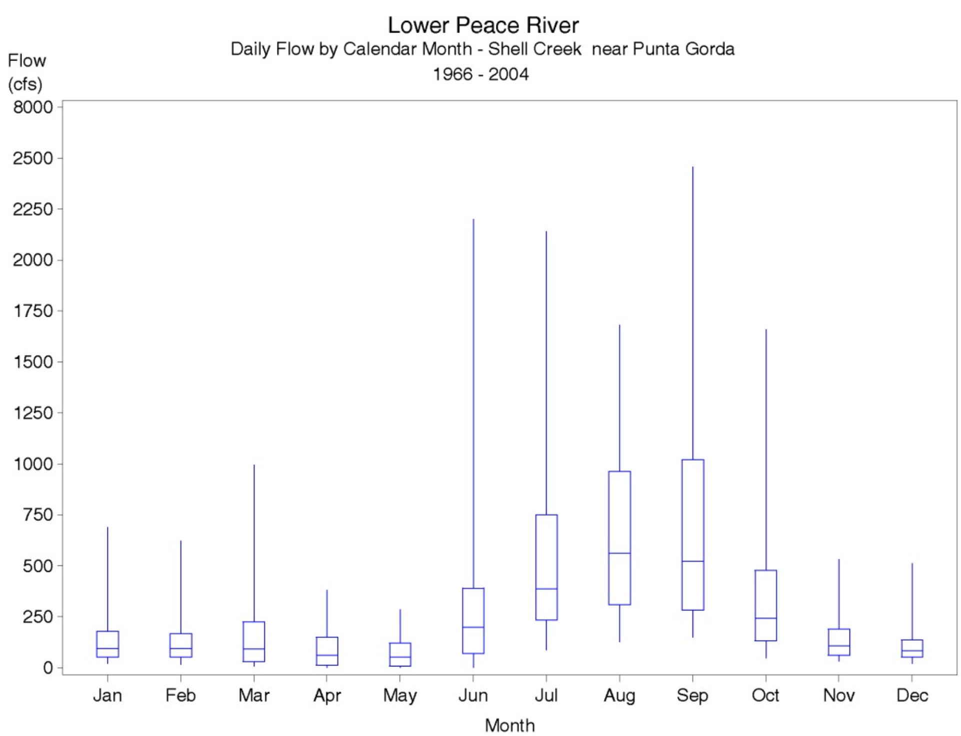


Figure 2-34. **Box and whisker plot of daily flows (cfs) by calendar month from the Shell Creek near Punta Gorda gauge (USGS 02298202) for the period 1966 to 2004. Boxes represent the inter-quartile range while the whiskers represent the 5th and 95th percentiles.**

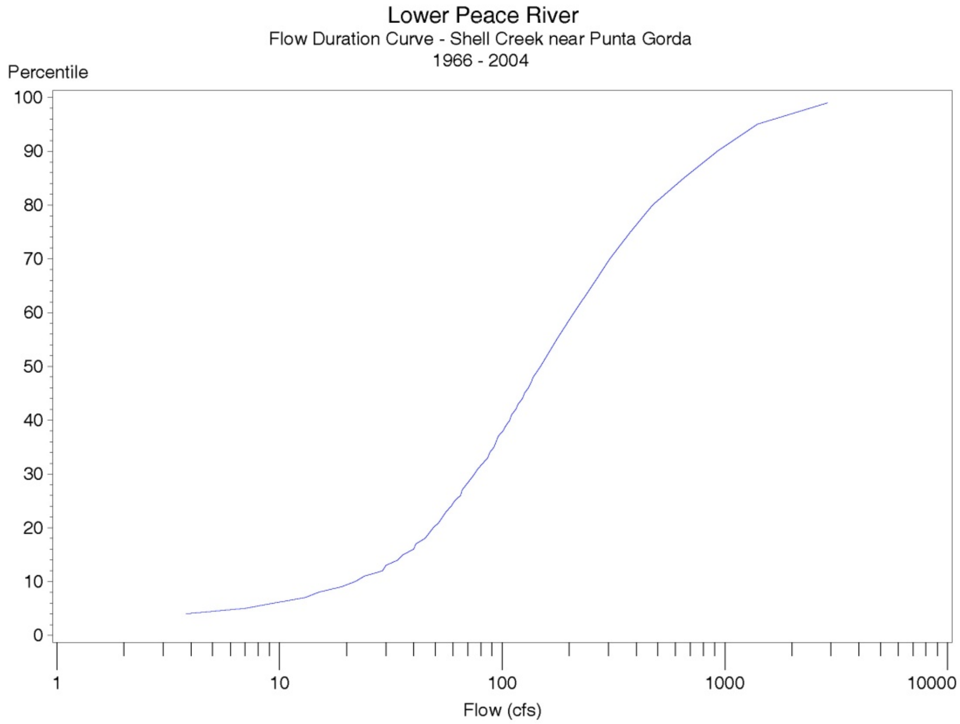


Figure 2-35. Flow duration curve of daily flows (cfs) from the Shell Creek near Punta Gorda gauge (USGS 02298202) for the period 1966 to 2004.

3 WATER QUALITY CHARACTERISTICS

In this chapter, the water quality characteristics of the LPR and SC are described. The purpose of this chapter is to review spatial and temporal variation in physical and water quality characteristics in order to place the minimum flow evaluation into the context of the dynamic LPR and SC.

3.1 Lower Peace River

In this subchapter, a historical review of previous studies that addressed water quality in the LPR is presented. In addition, data from ambient monitoring are presented and described.

3.1.1 Lower Peace River Historical Review

This section provides a brief overview of historical studies in the Peace River and the Charlotte Harbor Estuary. Specifically, this review will focus on those studies which include data and analysis on the Lower Peace River. The documents reviewed were by:

- the U.S. Geological Survey (USGS),
- Florida Department of Environmental Protection (FDEP),
- the District,
- Coastal Environmental, Inc.,
- Camp, Dresser & McKee,
- the Charlotte Harbor National Estuary Program (CHNEP) and,
- PBS&J(Peace River Cumulative Impact Study)
- PRMRWSA hydrobiological monitoring program (reports prepared by PBS&J)

The following section provides brief summaries of scientific reports prepared or sponsored by the U.S. Geological Survey, followed by summaries of studies prepared or sponsored by other agencies.

Stoker *et al.* (1989) investigated hydraulic and salinity characteristics of the tidal reach of the Peace River. The report provides an in-depth analysis of the relationship between freshwater inflow and salinity in the river. Long-term trends in streamflow at the Peace River at Arcadia gauging station indicated a significant decreasing trend in annual mean discharge. Stoker *et al.* (1989) concluded that salinity characteristics in the tidal river are influenced by freshwater inflows, tide, and harbor salinity. Vertical salinity stratification is common as expected in typical estuarine circulation. Freshwater replacement time in the tidal river ranged from 2 days during high flow to 40 days during low-flow periods (Stoker *et al.* 1989).

Fraser (1986) published long term water quality data summarized by major chemical and physical water quality constituents. Data were collected monthly over an eight year period, from 1976 through 1984 for Charlotte Harbor (Fraser 1986). Samples were taken from one station in Charlotte Harbor near the mouth of the Peace River. Data analysis included multilinear regression models and a seasonal Kendall test was used to determine trends. Increasing trends were shown for both temperature and orthophosphate. The Peace River was cited as the major source for phosphate in the basin. Concentrations of orthophosphate as P ranged from 0.07 mg/L to 0.66 mg/L with a surface water average of 0.59 mg/L. The three month moving average of orthophosphate concentration indicated an increasing trend. Fraser (1986) concluded that:

> "These changes were related to changes observed in the discharge of this constituent (orthophosphate) from the Peace River. The source of this material was from above Arcadia, and the trends were of such magnitude as to suggest that a relation exists with the economic conditions of the phosphate mining and fertilizer industry."

The range of concentrations for total phosphate were from 0.03 mg/L to 1.05 mg/L with a mean of 0.70 mg/L in surface waters and 0.99 mg/L in bottom waters (Fraser 1986). High and low values were consistent with low and high flows in the Peace River (Fraser 1986). Dissolved oxygen decreased in surface waters but showed no change in bottom water. Results showed that for all constituents, the 3-month moving averages appeared to have distinct seasonal variation as a result of freshwater flow from the Peace River (Fraser 1986). No changes were found for organic nitrogen, silica, and total phosphate. Ammonia and nitrate concentrations were to low for trend analysis.

Montgomery *et al.* (1991) conducted a study to evaluate the effects of inorganic nitrogen and phosphorus additions on phytoplankton productivity and chlorophyll *a* concentrations in the Peace River and Charlotte Harbor. Data were collected from two stations in the Peace River and two stations in Charlotte Harbor. *In situ* experiments were performed on two occasions, during one low flow and one high flow period. Experiments were conducted at 6 ppt salinity in the Lower Peace River and at approximately 20 ppt in upper Charlotte Harbor. Low flow experiments were performed during May 1985, and high flow experiments during September of the same year. Results from nutrient addition experiments showed that during low freshwater inflow, the availability of nitrogen may limit the production of phytoplankton throughout the system. During low flow, at 6 ppt salinity, chlorophyll a increased slightly by the additions of the nitrogen and phosphorus. At 20 ppt salinity there were significant increases of both forms of nitrogen. During high flow periods in the summer, the estuary was conceptually divided into a low-salinity zone where high color impacts light availability which mediates phytoplankton growth and a high-salinity zone where phytoplankton growth is nitrogen limited (Montgomery *et al.* 1991). Montgomery *et al.* (1991) concluded that: "exclusive of seasonal riverine influences that affect light penetration of the water column, nitrogen availability normally limits phytoplankton production within the Charlotte Harbor estuarine system."

Hammett (1990) described land use, water use, streamflow, and river water quality in the Charlotte Harbor estuarine system. The relationships between water quality changes and land use as well as changes related to increasing growth and development were also discussed. Hammett (1990) concluded that the main sources of water quality contaminants to the Lower Peace River were citrus processing and phosphate industry ore-processing plants. The concentrations of phosphorus are naturally high in the Peace River because of phosphate deposits in the area (McPherson *et al.* 1996). Hammett listed 114 facilities permitted to discharge domestic or industrial effluent to tributary waters of Charlotte Harbor, 88 of those were located in the Peace River Basin. Other potential sources of nutrient and pollutant loads impacting water quality included septic-tank drain fields, runoff from agricultural and pasture land, marinas and, nonpoint sources from residential areas (Hammett 1990). Hammett (1990) applied the Kendall tau trend test to the furthest downstream station, Peace River at Arcadia (1933-1989). Using a significance level of 0.10, statistically significant increases in specific conductance, pH, total organic nitrogen, dissolved chloride, dissolved sulfate, and dissolved solids were documented. A statistically significant decrease in total phosphorus was documented. Hammett (1990) suggested that "the increasing trend in total organic nitrogen may reflect inflow of effluent from wastewater treatment plants. Increases in chloride, sulfate, and dissolved solids probably represent an increased contribution of ground water from irrigation runoff and industrial processing. The increasing trend in specific conductance could result from either wastewater effluent or mineralized ground water. Although the decreasing trend in total phosphorus at the Peace River at Arcadia was reported previously by Smith *et al.* (1982), it is unexpected."

Using the Kendall Tau trend test with a significance level of 0.10, statistically significant declines in streamflow at the Peace River stations at Bartow (1939-1989), Zolfo Springs (1933-1989), and Arcadia (1931-1989) were documented. Decreases in flow may have been related to ground water withdrawals causing long-term declines in the potentiometric surface of the underlying Floridan aquifer. Hammett also provided population projections through 2020 for the ten counties within the Charlotte Harbor basin and calculated water supply needs, wastewater generation and projected increases in nutrient loads. Declining streamflow data showed reduced freshwater flow to Charlotte Harbor.

McPherson *et al.* (1996) conducted a geological survey of Charlotte Harbor which included water quality data. Water quality data were collected at one station in upper Charlotte Harbor just below the most southern portion of the Peace River. Mixing diagrams (property-salinity plots) were used to assess the uptake or release of various constituents in the estuary**.** Linear mixing relationships indicate net conservative mixing behavior whereas non-linear or highly scattered mixing relationships indicate non-conservative behavior. The construction of salinity plots is based upon an assumption of steady-state hydrodynamic conditions, which implies that the temporal evolution of the estuarine environment is dictated only by biogeochemical transformations occurring within the system. Results showed that distributions of phosphorus were nearly conservative and a function of river phosphorus concentration, flow, and physical mixing. Large discharges from the Peace River resulted in high concentrations throughout the northern part of the estuary, but the southern part was not greatly affected. Dissolved silica and ammonia concentrations were highly variable along the salinity gradient. At times dissolved silica concentrations were below the curve suggesting uptake by diatoms. Ammonia concentrations showed no clear trend. Nitrite plus nitrate concentrations were nonconservative and decreased sharply along the salinity gradient, which would signify substantial removal from the water column.

Other data collection programs and interpretive analyses of water quality data for the Lower Peace River and Charlotte Harbor have been conducted or sponsored by a number of agencies. One of the most extensive water quality data bases for the Lower Peace River has been collected as part of the Hydrobiological Monitoring Program (HBMP) conducted by the Peace River Manasota Regional Water Supply Authority. The HBMP is required as part of conditons of the Water User permit issued to the PRMRWSA by the Southwest Florida Water Management District. The purpose of the HBMP is to monitor ecological variables in the lower river that are related to the quanity of freshwater inflow in order to discern if the PRMRWSA's permitted withdrawals are having any adverse effects on the ecology of the estuary. Data collection for the HBMP began in the 1970s. Much of the water quality data presented in this report was collected for the HBMP.

A series of interpretive reports have been prepared for the HBMP and submitted to the District at regular multi-year intervals (Environmental Quality Laborotory 1995, PBS&J 1999, 2002, 2004, 2006, 2008). These reports analyze data collected to within one year of their preparation in oder to examine the status and trends of ecological variables in the lower river that are related to freshwater inflow. The most recent report (PBS&J) found significant decreasing trend in ortho and total phosphorus and an increasing trend in silica over the period of monitoring data (1976 - 2006).

In a separate effort conducted for the Charlotte Harbor Estuary Program, PBS&J (1999a) performed an interpretive synthesis of existing information for water quality conditons. Data from multiple sources were used to examine long-term water quality conditions in the Peace River Basin and Charlotte Harbor. The data sources were:

- Long-term monthly data collected from1975 to 1996 (including HBMP data)
- USGS data from gauged monitoring stations ; and
- SWFWMD monitoring data collected on a monthly basis.

No significant trends in conductivity were detected in either the Lower Peace River or the Peace River Estuary. The Peace River and its tributaries are all characterized as being black water freshwater streams. The narrow photic zone limits the growth of submerged aquatic vegetation and can also results in phytoplankton populations adapted to stay near the surface. Increases in turbidity were found in the Peace River at Arcadia, Horse Creek at SR 70, and the Lower Peace River from 1976 through 1990. Increases in turbidity most likely result from land uses shifts to agriculture and development in the region. Concentrations of inorganic nitrogen exhibit seasonal changes throughout the entire system. Periods of low flow and reduced color typically result in nitrogen concentrations at or near detection limits. In Horse Creek, nitrate and nitrite concentrations showed a significant increase along with chloride, which may have resulted from increased agriculture. A significant decline in nitrate and nitrite concentrations was documented in the lower Peace River. Decreases in TKN concentrations were documented at Arcadia and in the Lower Peace River. Increased concentrations were seen in Horse Creek and at the lowest reaches of the Peace River. High concentrations of dissolved and total phosphorus were observed from 1976 through 1982. Since 1982 concentrations and variability have decreased, although still remaining high relative to other Florida streams. Concentrations of chlorophyll *a* were typically below 20 μg/L, and values increased with distance upstream. Chlorophyll *a* concentrations in the Lower Peace River ranged from 0 to 240 μg/L.

The following section provides brief summaries of scientific reports prepared or sponsored by the SWFWMD.

SWFWMD (2005) investigated trends in water quality constituents in the Peace River as part of the development of minimum flows and levels for the Middle Peace River. The authors concluded: ”While elevated phosphorus concentrations in streams can potentially be ascribed to numerous sources (e.g., waste water treatment plant discharges, some industrial discharges, fertilizer applications in agriculture or residential areas), there is little doubt that the elevated concentrations seen in the Peace River from approximately 1960 (when routine water quality analysis began) to the early to mid 1980's are directly associated with phosphate mining activities in the watershed. Beginning in the early 1980's, there was a rather sudden decline in phosphorus and other chemical constituents found in association with phosphate ore (e.g., fluoride, silica). Concomitant declines in fluoride and phosphorus are evidence of a change in mining practices that led to dramatic reductions in phosphorus (and other constituent) loading to the Peace River system around 1980.” In addition to phosphorus and other constituents related to mining activities, statistical analysis of dissolved potassium revealed a significant increase that was not related to changes in flow (SWFWMD 2005).

Coastal Environmental (1996) identified and inventoried potential sources of pollution within the Charlotte Harbor watershed. The study estimated existing and future pollutant loadings by subbasin. Coastal Environmental (1996) also investigated historical, existing, and future freshwater conditions of estuarine inflows. Major sources of nutrient and solids loading, including nonpoint sources, domestic point sources, industrial point sources, atmospheric deposition, groundwater, and springs, were identified. The potential for loadings from septic tanks was also evaluated. Pollutant loadings were estimated for both current (1985-1991) and projected future (circa 2010) conditions.

Average annual TN loads to the LPR totaled almost 1,800 tons/year. Average TP loads were estimated to be about 640 tons/year, and TSS loads to the LPR were estimated at 14,400 tons/year. Of this load 80% of the TN load, 60% of the TP load, and 88% of the TSS load were of nonpoint source origin. Of the remaining sources of TN loading, point sources contributed about 15%, atmospheric deposition accounted for 3%, septic tank leakage accounted for 3% and groundwater and springs were negligible. The TP loads to the LPR harbor segment are similarly distributed among these sources and TSS is derived mainly from nonpoint sources, with some point source contribution.

TN, TP, and TSS loadings under projected future conditions were estimated to be slightly higher, but similar to existing conditions in most cases. Nonpoint sources and industrial point sources were estimated to contribute most of the LPR loads.

Coastal Environmental (1996) reviewed meteorological, flow, and water quality data from the Charlotte Harbor Estuarine System. Statistical tests were conducted for significant long-term trends in water quality characteristics at three of the U.S. Geological Survey gauging station in the Upper Peace River (Bartow, Zolfo Springs, and Arcadia) and Horse Creek. Analyses were conducted for USGS data collected from the early 1970’s to the early 1990’s for physical characteristics which included specific conductance and dissolved oxygen as well as concentrations and total loadings of inorganic nitrogen, total Kjeldahl nitrogen, nitrate+ nitrite nitrogen, nitrate nitrogen, total organic carbon, and total phosphorus.

A significant decline in conductivity was documented at the Peace River at Bartow station. Conductivity ranged from about 200 to 800 umhos/cm from 1970 to 1976, then dropped to a range of about 170 to 400 umhos/cm after 1982. The decline may be related to decreases in point source discharges due to improved regulations. Significant increases in conductivity were evident during the dry season at Arcadia and in Horse Creek. These increases may be attributed to heavy agricultural water uses of mineralized water from the Floridan aquifer draining into those gauging stations.

Trends in dissolved oxygen varied among the sites. Increasing trends were observed at Zolfo Springs for dry season months and at Horse Creek during wet season months. A decreasing long-term trend was observed at Arcadia for wet season months.

A significant decrease in dry season nitrate nitrogen concentration was documented at Zolfo Springs and Arcadia. This region contains several fertilizer processing plants which had undergone increased regulatory constraints resulting in reduction of nutrient loads. A significant increase in nitrate nitrogen concentration was documented at the Horse Creek station, which may be a result of higher loads from increased agricultural activities.

Total phosphorus concentrations showed significant declines during both dry and wet season conditions at all three gauging stations on the Peace River. Concentrations and loadings of total phosphorus exhibited the largest decline of any measured constituent. This decline was the result of improved regulations and production declines in the phosphate industry.

PBS&J (1997) investigated empirical and mechanistic approaches to establishing Pollutant Load Reduction Goals (PLRGs) in the Tidal Peace River. Water quality and loading data were used to develop empirical and mechanistic models to set PLRGs to support the development of trophic state goals and nitrogen management targets for the tidal reach of the Peace River.

For the empirical approach, water quality variables included TN, TP, TN:TP, chlorophyll *a*, and photosynthetic compensation depth. Trend tests of long term data showed an increasing trend in the median annual TN:TP which resulted from decreasing TP concentrations. Higher nutrient loads in the Peace River are associated with higher color and lower water clarity in the tidal river segment. Regression analysis showed no significant relationships in the LPR segments.

The mechanistic approach utilized a submodel of the U.S. EPA's WASP5 model system. A lack of fit between the modeled and observed data resulted from limitations of the existing data and the inability of the model to vary phytoplankton growth rates temporally and spatially, which may be necessary to accurately stimulate algal growth production and concentrations in this highly dynamic system.

Camp Dresser & McKee (1998) investigated seasonal and spatial patterns of hypoxia in Upper Charlotte Harbor by summarizing previous studies by Environmental Quality Laboratory, U.S. Geological Survey, Southwest Florida Water Management District, and Mote Marine Laboratory. Studies showed that hypoxic bottom water originate in the Lower Peace River during June and spread throughout the harbor during subsequent months (the months typically associated with the summer rainy season), peaking in September when a mean of 34 square miles of the upper harbor experiences hypoxic bottom waters (Camp Dresser & McKee 1998). During October, the areal extent decreased dramatically. By November, bottom waters across the harbor were equal to or greater than 4.0 mg/L (Camp Dresser & McKee 1998).

PBS&J (2007), as part of the Peace River Cumulative Impact Study, assessed the individual and cumulative impacts of certain anthropogenic and natural stressors in the Peace River watershed, including stream flow, water quality, and ecological indicators. Historical changes to water quality constituents were presented for the subbasins of LPR. At the Horse Creek near Arcadia monitoring site, changes in water quality were attributed to discharges of mineralized ground water from agricultural activities into Horse Creek, and in the southern portion of the Peace River watershed in general. The long-term data at the Horse Creek near Arcadia monitoring site indicated increases in inorganic nitrite+nitrate nitrogen concentrations during the mid-1980s (PBS&J 2007). The period-of-record for the Joshua Creek at Nocatee monitoring site extends back to the mid-1960s. Analysis of the data indicate comparatively large historical increases in conductivity, total dissolved solids, sodium, chloride, and sulfate levels (PBS&J 2007). Slightly smaller increases in calcium, magnesium, and silica concentrations were also observed. Observed changes in water quality were attributed to agricultural discharges of mineralized ground water to surface waters. PBS&J 2007 hypothesized that the recent large increases in observed inorganic nitrite+nitrate nitrogen in the Joshua Creek basin were also likely attributed to increases in intensive agriculture.

3.1.2 Variation in Water Quality Constituents

The physical and water quality data described in this section were complied from various data sources. The majority of the data were obtained from ongoing monitoring programs. Data sources included:

- PRMRWSA Hydro-Biological Monitoring Program (HBMP) (1996 - present) and
- U.S. Geological Survey continuous recorders (1997 - present).

In the following sections, spatial and temporal variations in water quality constituents in the LPR are described. Because there are numerous sampling stations in the LPR, a representative group of stations was selected for presentation in this section. The selected stations, which span the longitudinal distribution of HBMP sampling stations (Figure 2-3), include:

- Station 10 (rkm 6.6),
- Station 12 (rkm 15.5), and
- Station 14 (rkm 23.6).

Plots of spatial and temporal variation for all HBMP sampling locations in the LPR (Figure 2-3) are provided in Appendix 3-1.

3.1.2.1 Annual Variation in Water Quality Constituents

No long-term trends were detected in surface or bottom water salinity values from the HBMP stations in the LPR. However, fluctuations are evident over multi-year time scales that relate to large-scale meteorological events such as reduced salinity in 1998, associated with an El Niño event. Higher salinities were found during 2000 and 2001, associated with extended drought periods during these years. Typical yearly patterns showing higher salinities during the dry season and lower salinities during the wet season are evident. Annual variation in salinity at stations 10 (rkm 6.6), station 12 (rkm 15.5), and station 14 (rkm 23.6) are presented in Figures 3-1 through 3-3, respectively. Salinity plots of the 13 remaining stations can be found in Appendix 3-1. For the furthest downstream station, station 10, salinity ranged from 0 to 35 ppt (Figure 3-1). Characteristic of typical riverine flow, salinity was typically higher in the bottom water as compared to surface water. Salinity at station 12 (rkm 15.5) is presented in Figure 3-2. Salinities at station 12 were slightly lower, ranging from 0 to 27 ppt in both surface and bottom waters. The annual variation in salinity at station 14 (rkm 23.6) is presented in Figure 3-3. As expected, salinities at station 14 were lower compared to the downstream stations. While the observations ranged from 0 to 19 ppt, the majority of the salinity measurements at station 14 were less than 5 ppt.

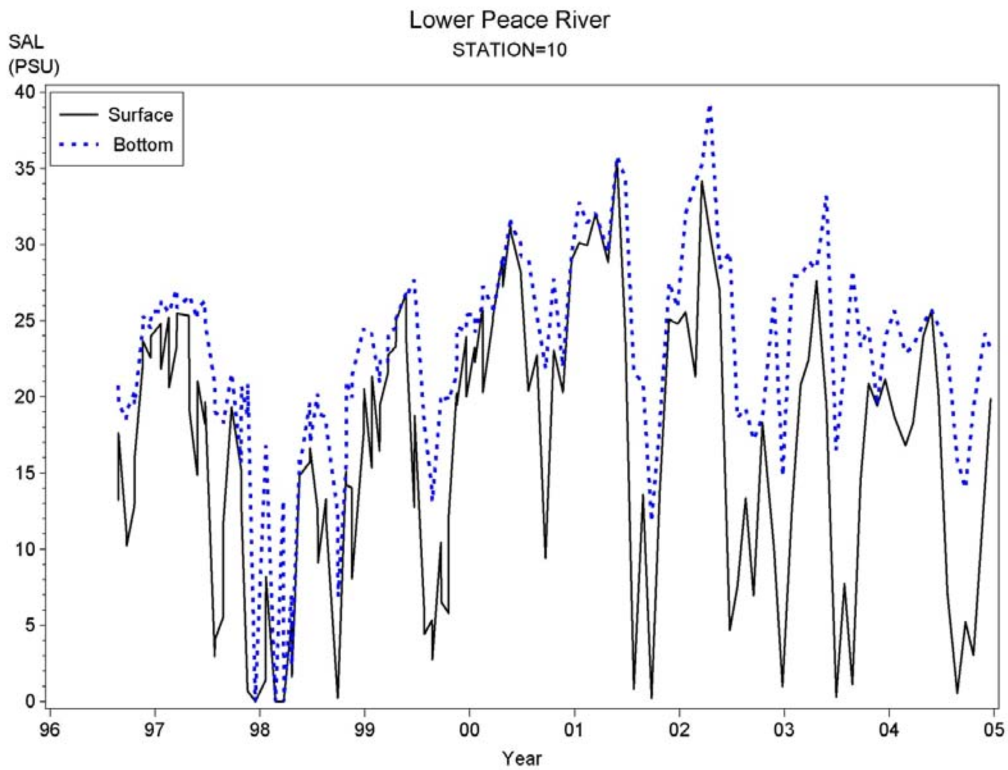


Figure 3-1. Time series of surface and bottom salinity at LPR station 10.

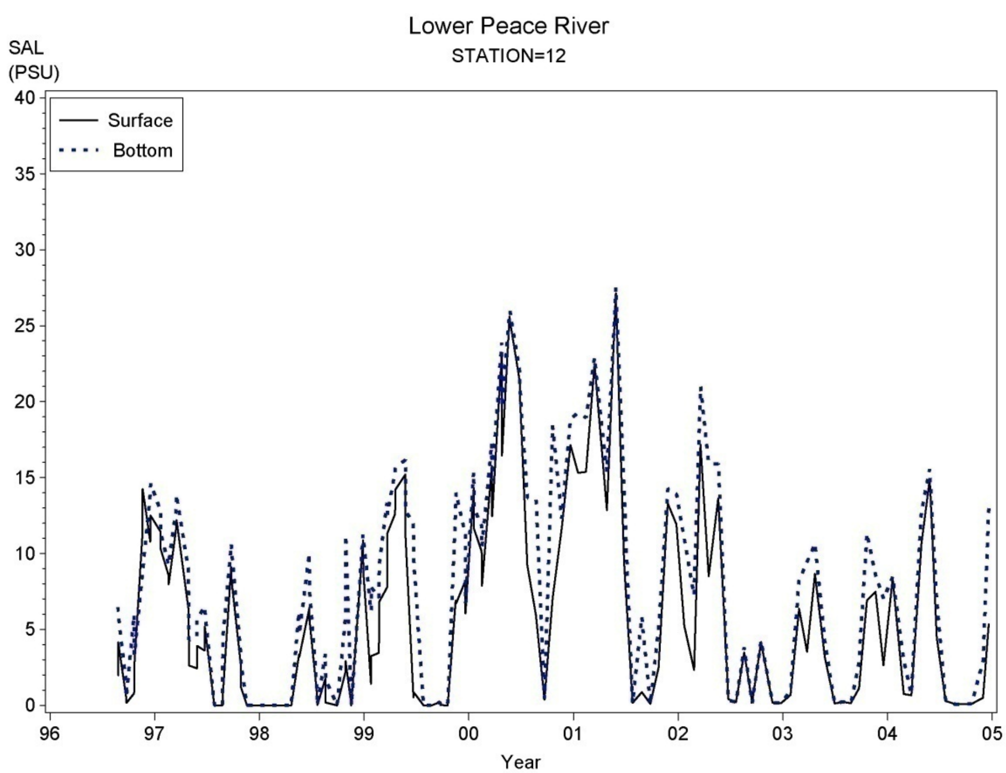


Figure 3-2. Time series of surface and bottom salinity at LPR station 12.

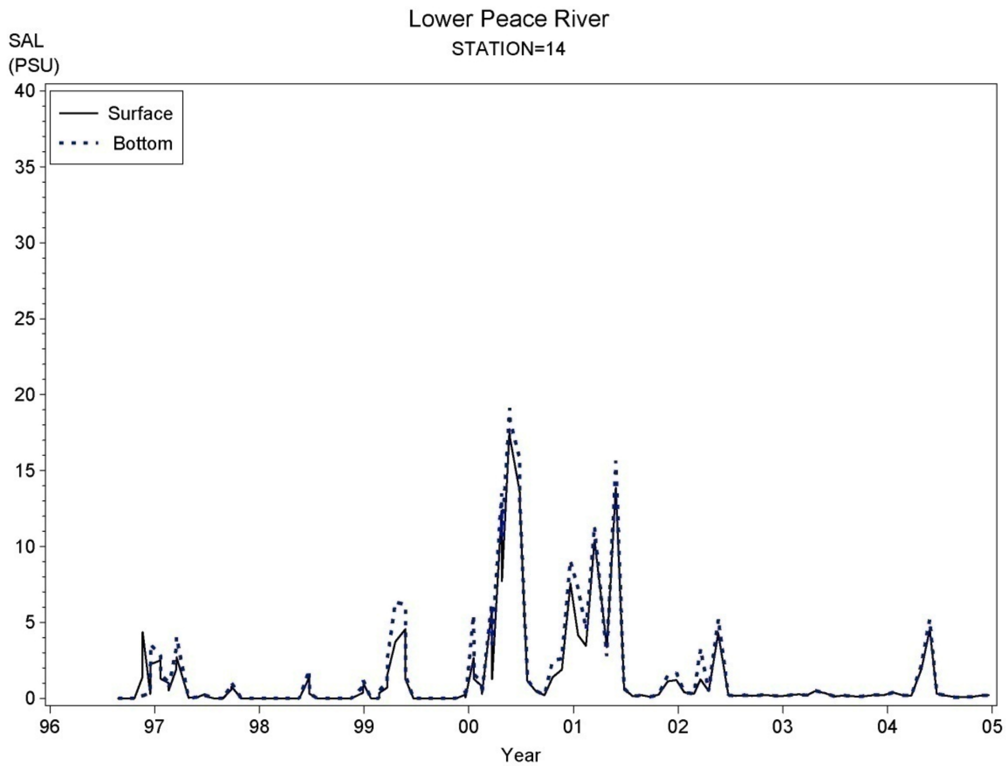


Figure 3-3. Time series of surface and bottom salinity at LPR station 14.

Water temperatures in the LPR showed typical seasonal cycles ranging from a summer peak of approximately 34 degrees C to a winter low of 13 degrees C (Figure 3-4 through 3-6). At all locations the range of surface and bottom water temperatures were very similar with slightly higher surface temperatures during the entire period-of-record.

The annual variation in dissolved oxygen (DO) was consistent over multi-year time scales, with typical summertime lows followed by higher concentrations in the cooler months. In the downstream portion of the LPR there were large differences in DO between the surface and bottom waters, with higher values in the surface water at the downstream stations. Values in the surface water for station 10 ranged from 0 to 14 mg/L and from 0 to 11 mg/L in bottom waters (Figure 3-7). Values in the surface water for station 12 ranged from 0 to 14 mg/L and from 0 to 10 mg/L in bottom water (Figure 3-8). Differences between surface and bottom water decreased with distance upstream as salinity decreased (Figure 3-9). Values in surface water for station 14 ranged from 0 mg/L to 12 mg/L for both surface and bottom waters. Lower values in bottom waters for the downstream portion are directly related to stratification inhibiting mixing of the water column, and therefore resulting in lower dissolved oxygen concentrations in bottom waters.

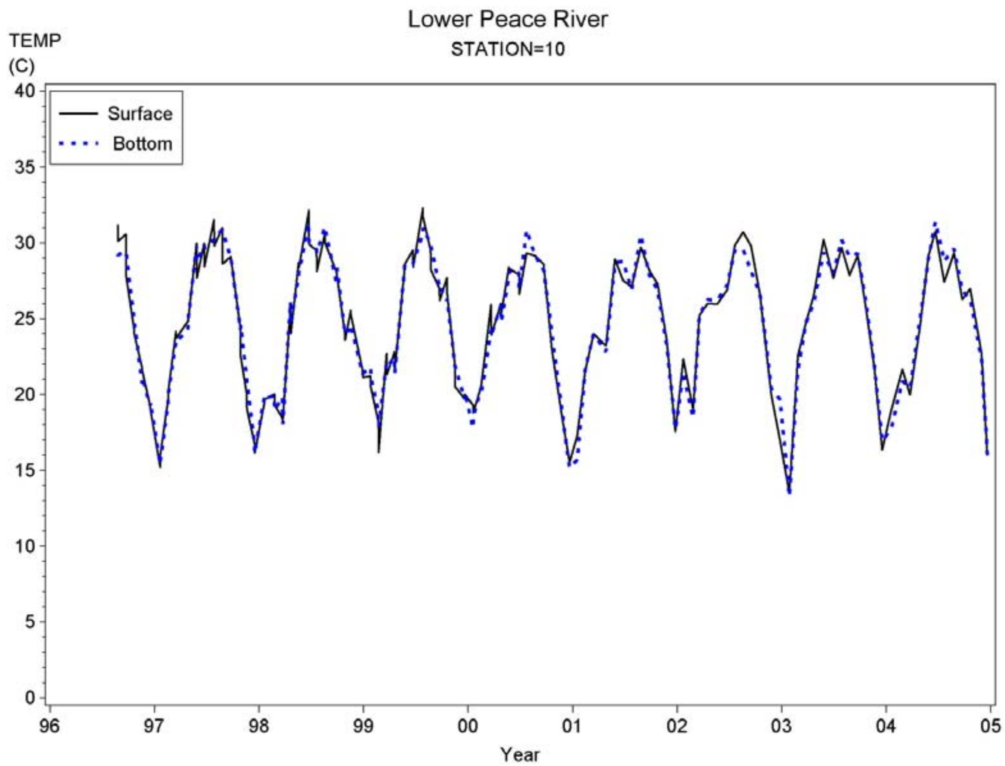


Figure 3-4. Time series of surface and bottom temperature at LPR station 10.

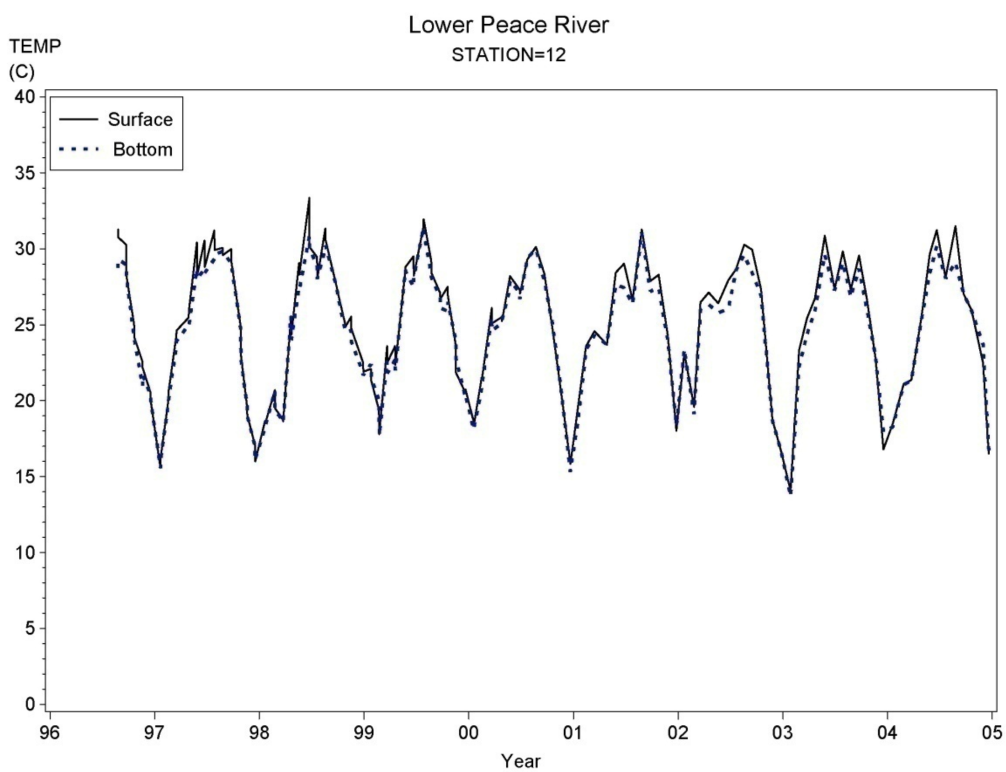


Figure 3-5. Time series of surface and bottom temperature at LPR station 12.

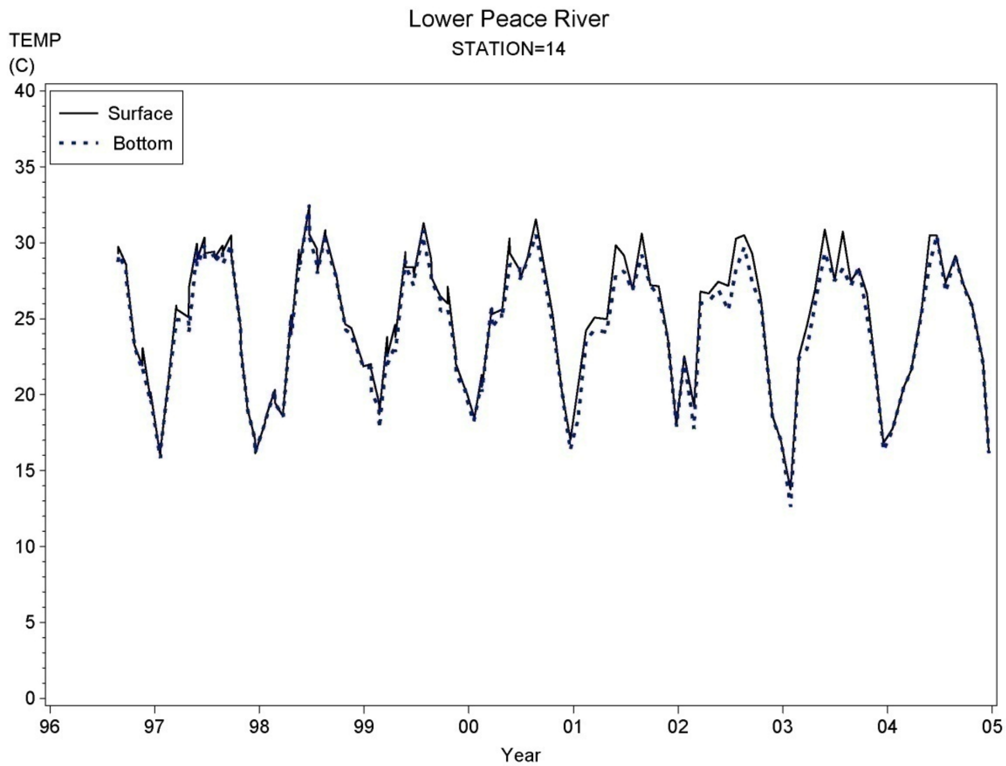


Figure 3-6. Time series of surface and bottom temperature at LPR station 14.

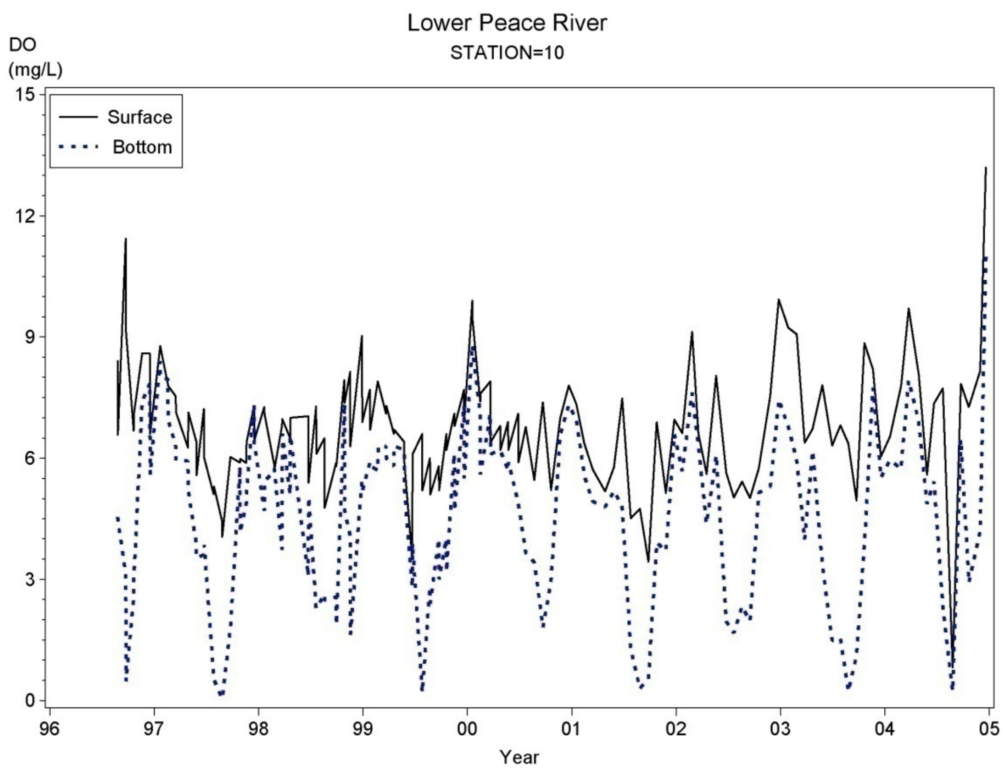


Figure 3-7. Time series of surface and bottom DO at LPR station 10.

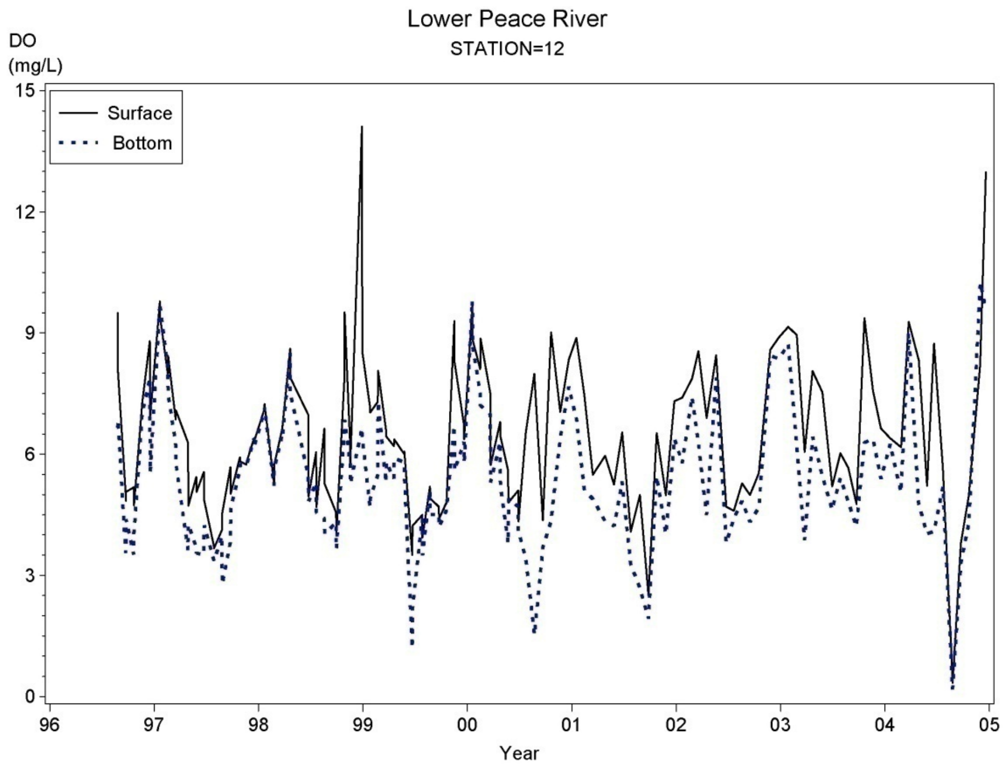


Figure 3-8. **Time series of surface and bottom DO at LPR station 12.**

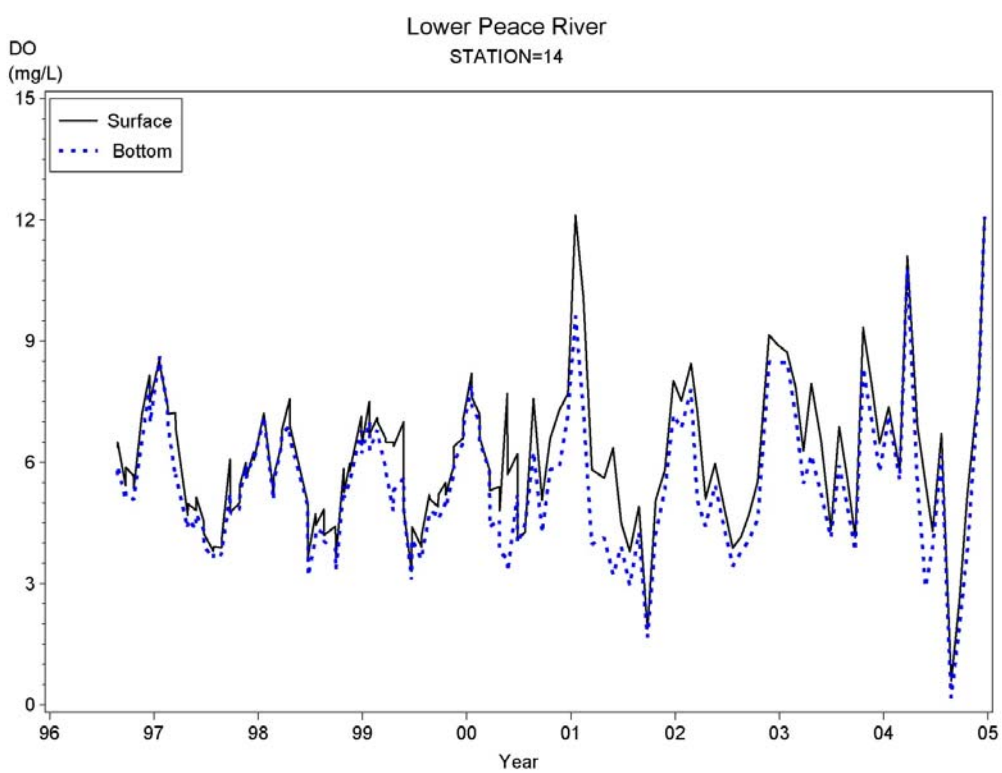


Figure 3-9. **Time series of surface and bottom DO at LPR station 14.**

The annual variation in chlorophyll *a* concentrations was highly variable between stations (Figures 3-10 to 3-12). Chlorophyll concentrations ranged from 5 to 150 µg/L. Concentrations were slightly lower in bottom water as compared to surface water.

The observed total nitrogen (TN) concentrations for the LPR are shown in Figures 3-13 through 3-15. These data indicated that TN ranged from 0 to 6 mg/L. TN concentrations increased slightly with distance upstream towards fresher water.

Total phosphorus (TP) showed annual variation across the period of record. Higher TP concentrations were evident during extremely wet years (the 1998 El Niño). Higher concentrations were also found during dry hot years (the later half of 2001) after a prolonged drought as shown in Figures 3-16 through 3-18. TP concentrations ranged from 0.3 to 1.4 mg/L and, increased slightly with distance upstream towards the fresher reaches of the river.

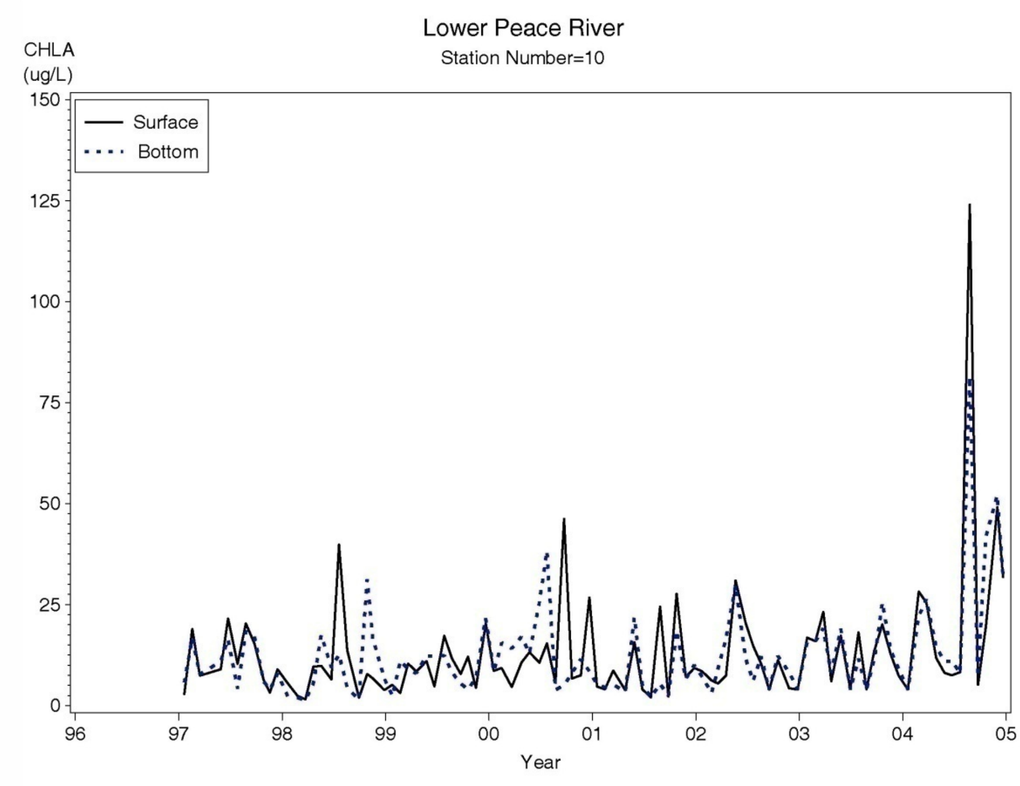


Figure 3-10. Time series of surface and bottom chlorophyll *a* at LPR station 10.

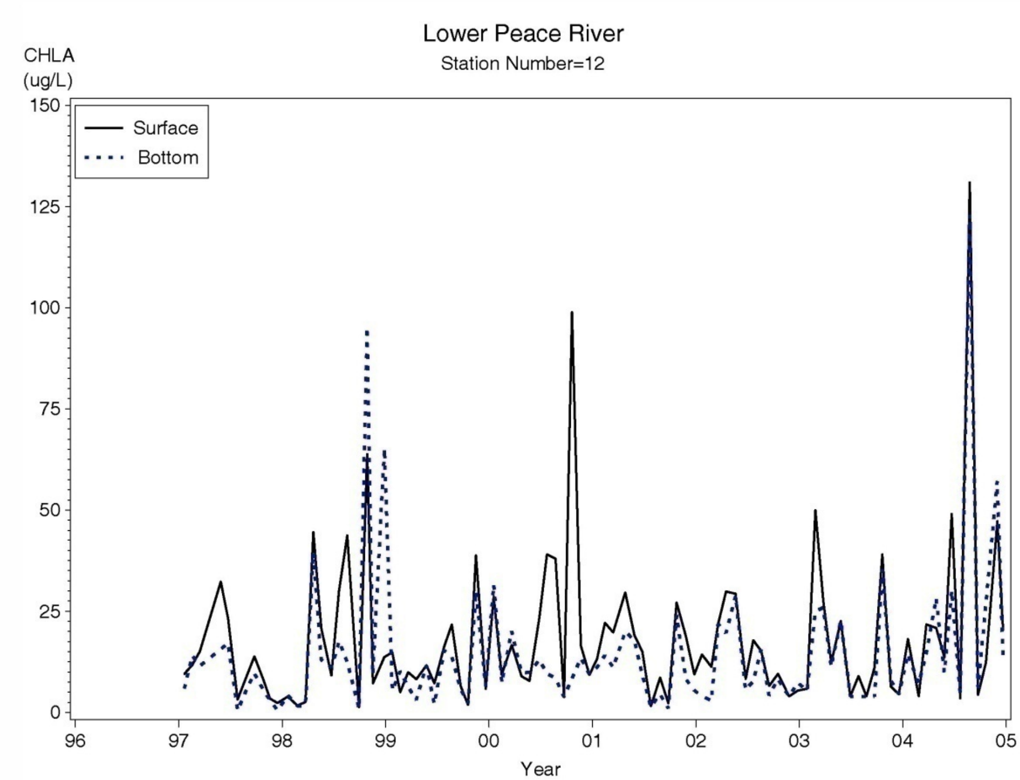


Figure 3-11. Time series of surface and bottom chlorophyll *a* at LPR station 12.

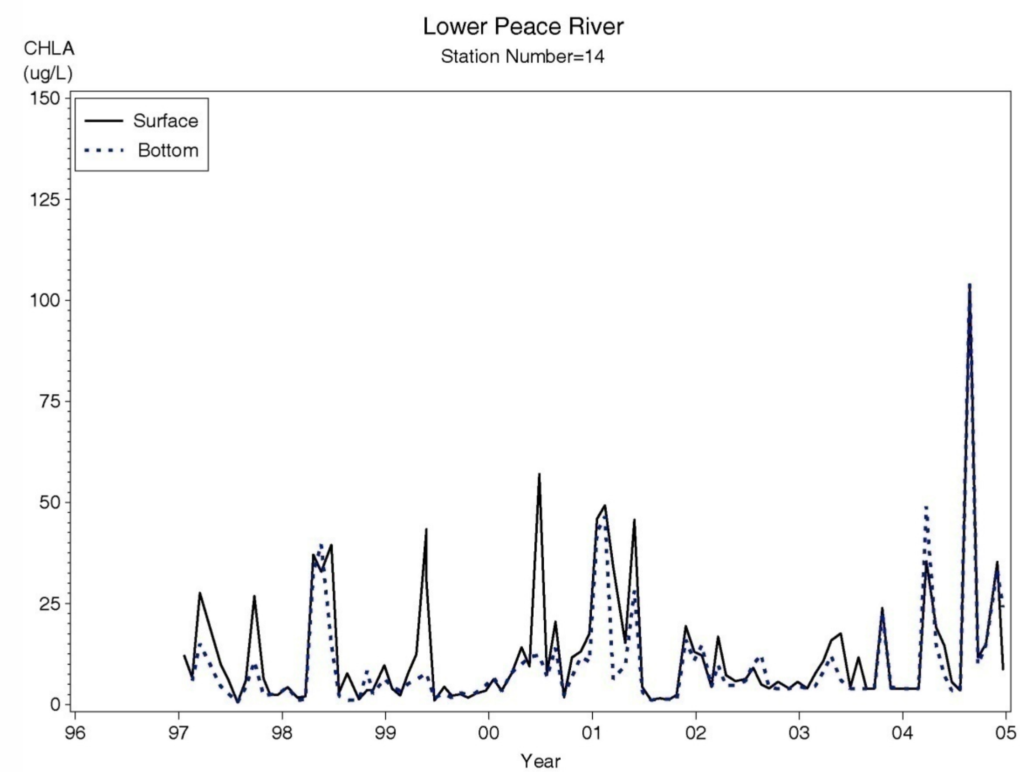


Figure 3-12. Time series of surface and bottom chlorophyll *a* at LPR station 14.

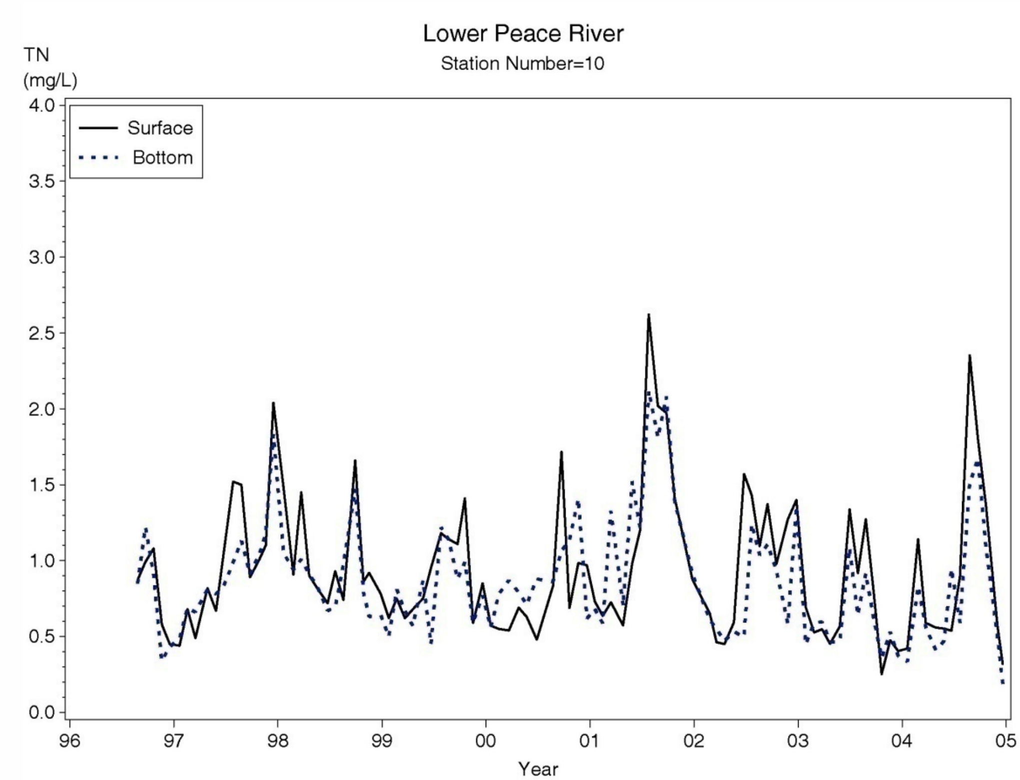


Figure 3-13. Time series of surface and bottom TN at LPR station 10.

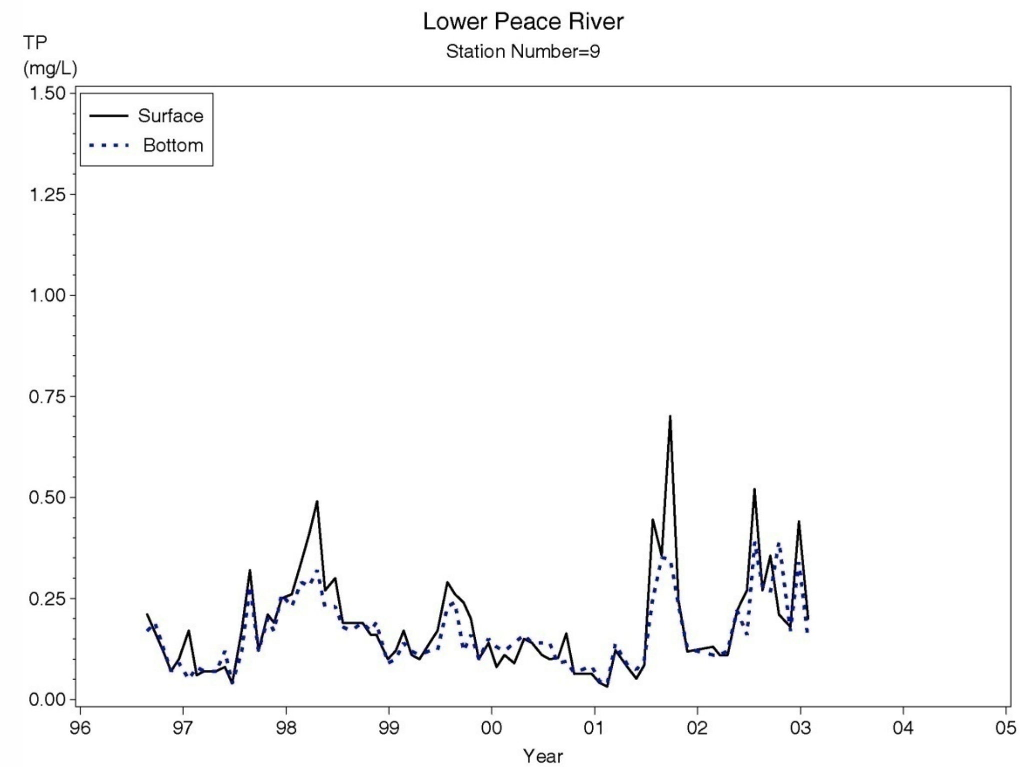


Figure 3-14. Time series of surface and bottom TN at LPR station 12.

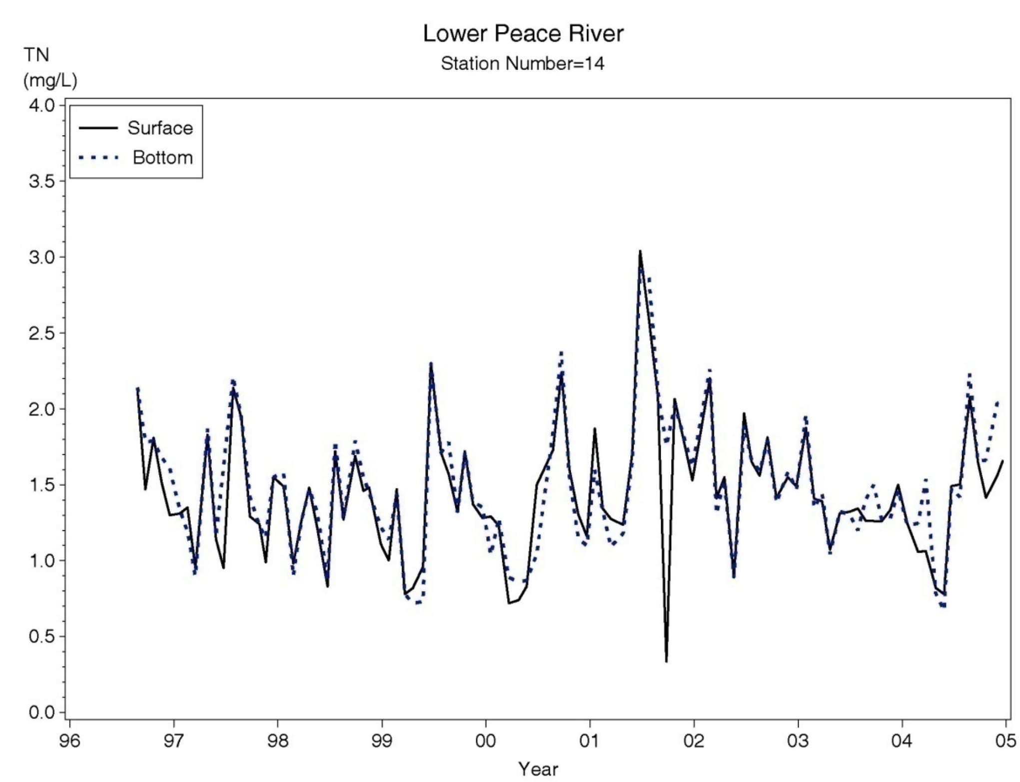


Figure 3-15. **Time series of surface and bottom TN at LPR station 14.**

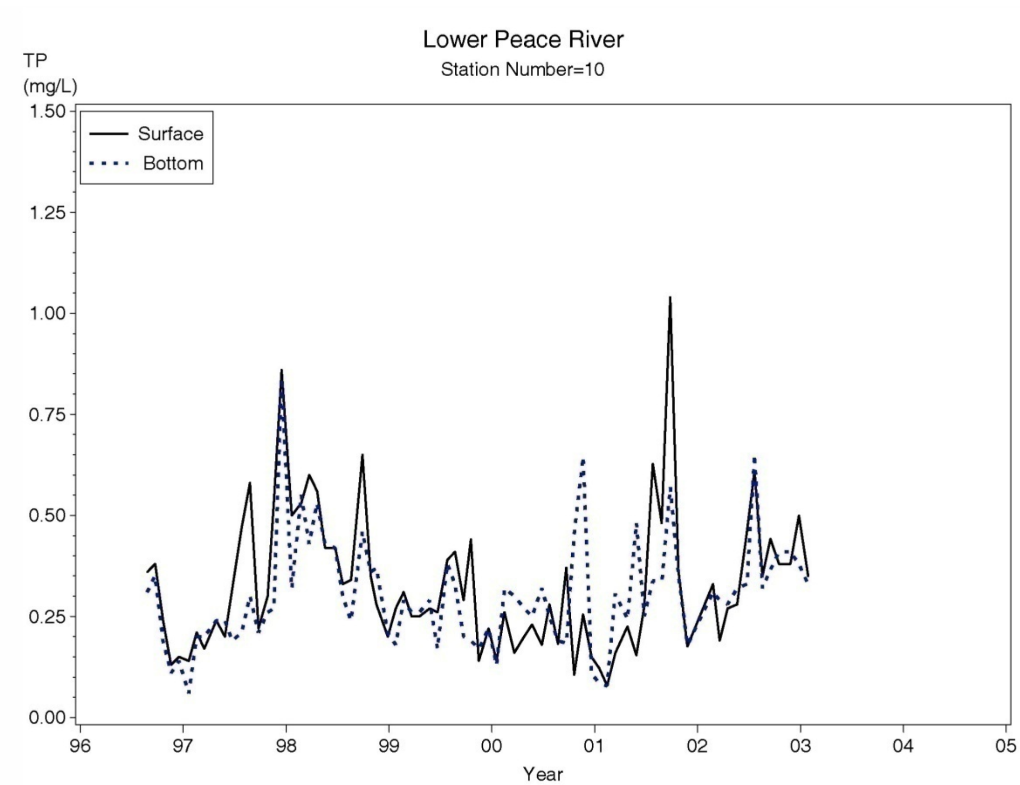


Figure 3-16. **Time series of surface and bottom TP at LPR station 10.**

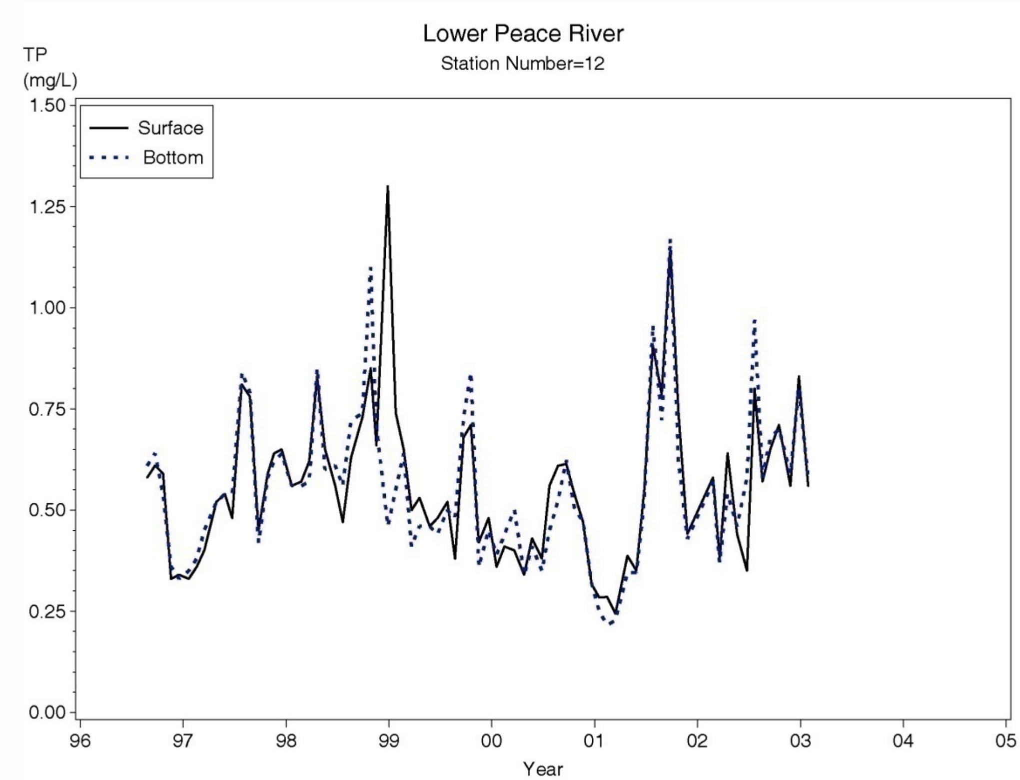


Figure 3-17. Time series of surface and bottom TP at LPR station 12.

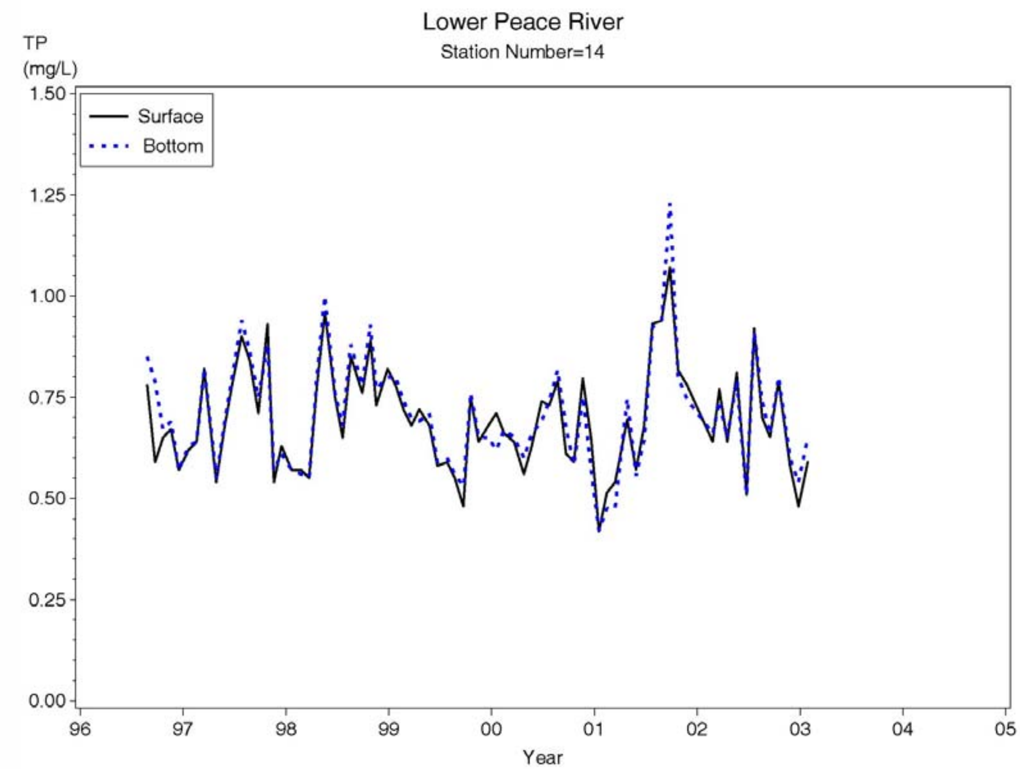


Figure 3-18. Time series of surface and bottom TP at LPR station 14.

3.1.2.2 Within-Year Variation in Water Quality Constituents

The physical and water quality characteristics of the LPR vary predictably based on the seasonal cycle of the local climate. Detailed plots for all locations and constituents are presented in Appendix 3-2.

Salinity concentrations were higher in the winter (dry season) months and lower in the summer (wet season) months. Within-year variation in salinity concentrations at the surface and bottom for station 10 in the LPR are presented in Figure 3-19. Less variation exists between bottom water salinities during the dry and wet season with evident fresh water flows resulting in low surface water salinities from July through October. With distance upstream, surface and bottom water salinities are more similar as shown for station 12 in Figure 3-20. High freshwater flow resulted in no differences between surface and bottom salinities from July through October at the most upstream stations as shown at station 14 (Figure 3-21).

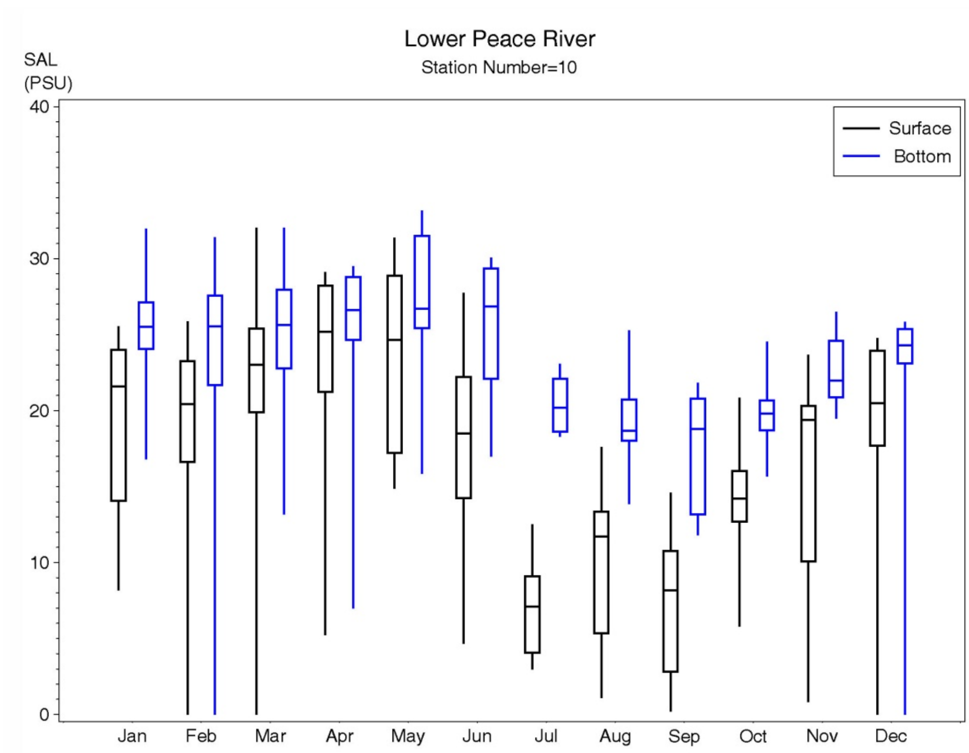


Figure 3-19. Monthly distribution of surface and bottom salinity (1997-2004) at LPR Station 10. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

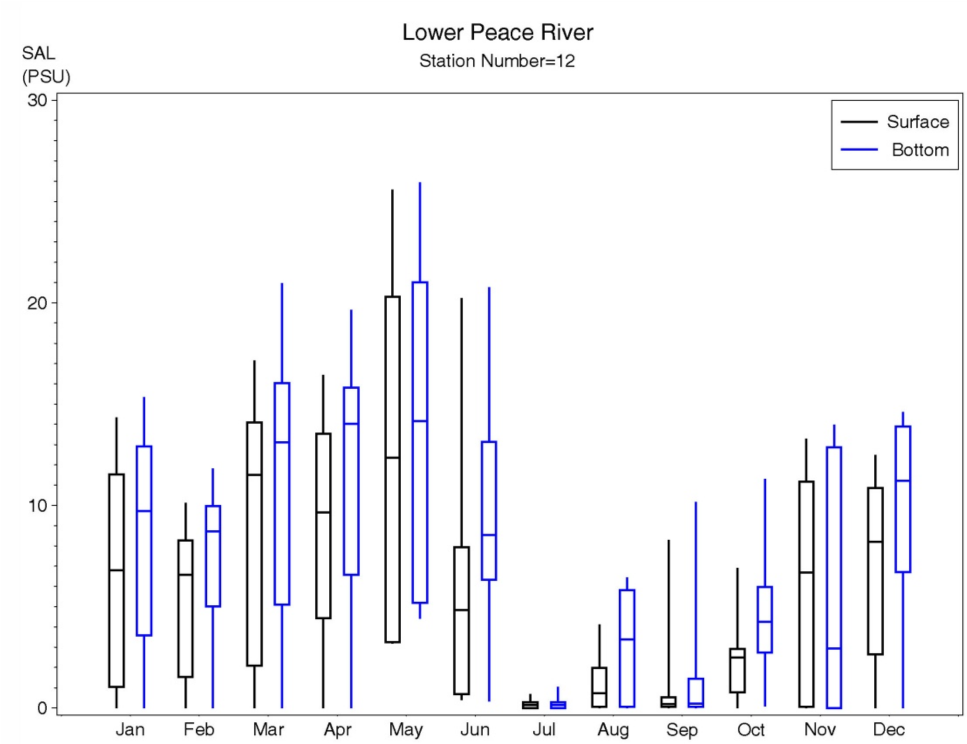


Figure 3-20. **Monthly distribution of surface and bottom salinity (1997-2004) at LPR Station 12. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.**

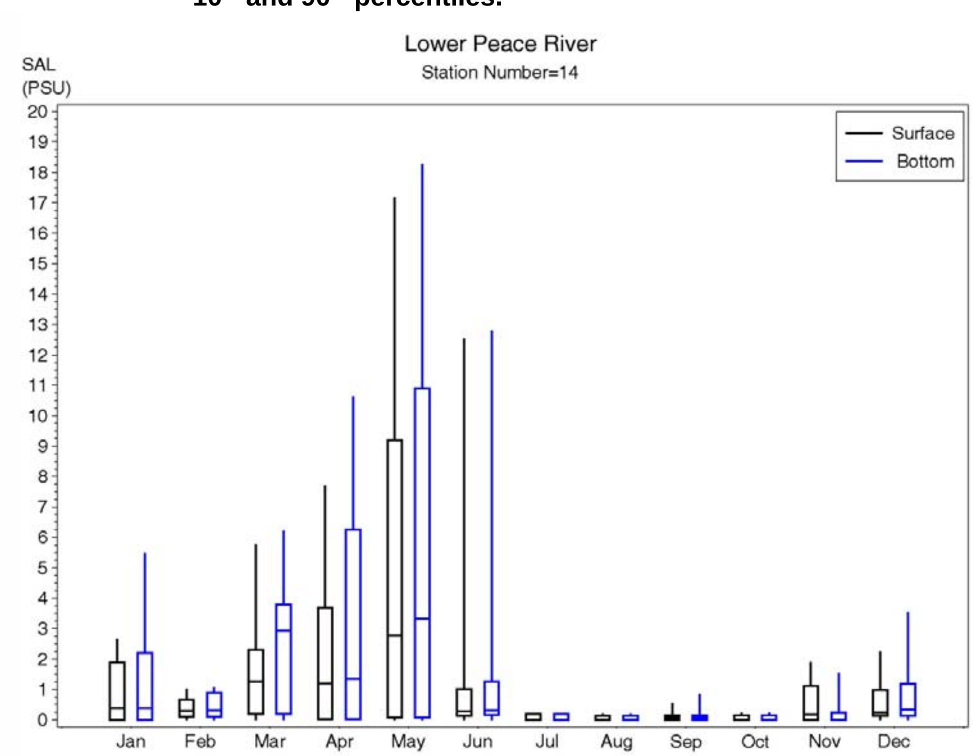


Figure 3-21. **Monthly distribution of surface and bottom salinity (1997-2004) at LPR Station 14. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.**

Similar to salinity, temperature was observed to follow a strong seasonal pattern over the period of record for all locations and depths. Lowest temperatures were observed during December and January. Highest temperatures were observed during July and August. The typical within-year temperature variation for Station 10 in the LPR is presented in Figure 3-22.

Dissolved oxygen (DO) exhibited typical seasonal trends with higher concentrations during cooler months and lower concentrations during warmer months. Lower DO concentrations occurred during July, August and September, resulting from higher water temperatures and thus lower saturation potential as well as higher productivity from primary producers using available nutrients. As shown in the yearly time series plots discussed previously, larger differences between surface and bottom water were evident downstream and decreased with distance upstream (Figures 3-23 to 3-25).

Monthly distributions of chlorophyll *a* concentrations were variable for all stations (Figures 3-26 through 3-28). Relatively high monthly median concentrations were observed in the spring in the mid and upper river regions (stations 12 and 14), due presumably to rising water termperatures and long residence times in the these regions of the river during low flows in the spring.

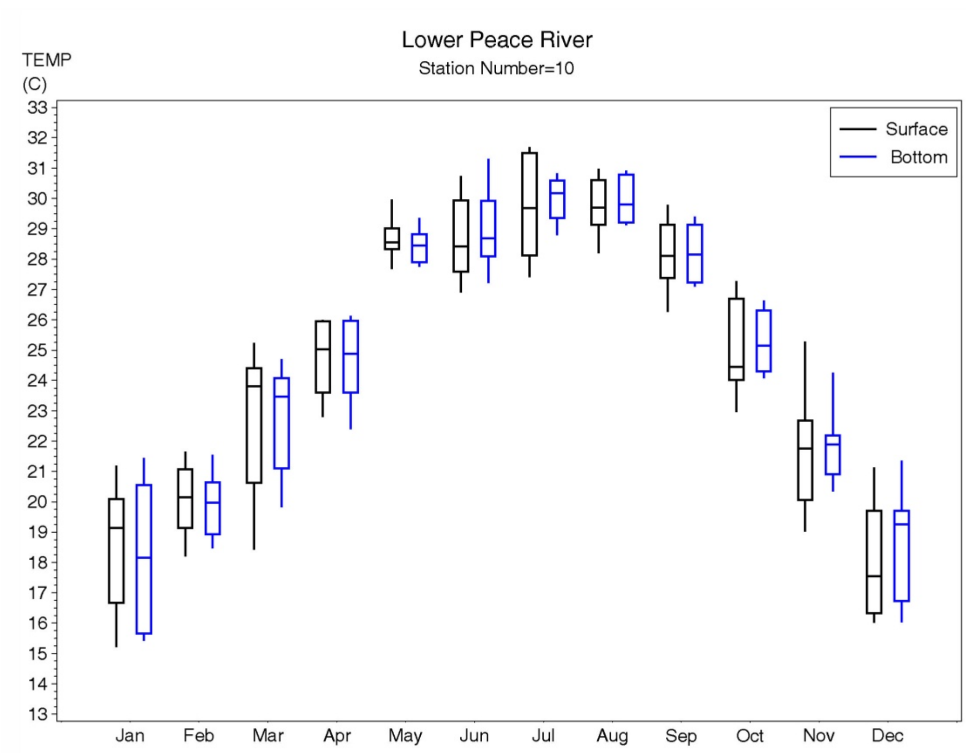


Figure 3-22. Monthly distribution of surface and bottom temperature (1997-2004) at LPR Station 10. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

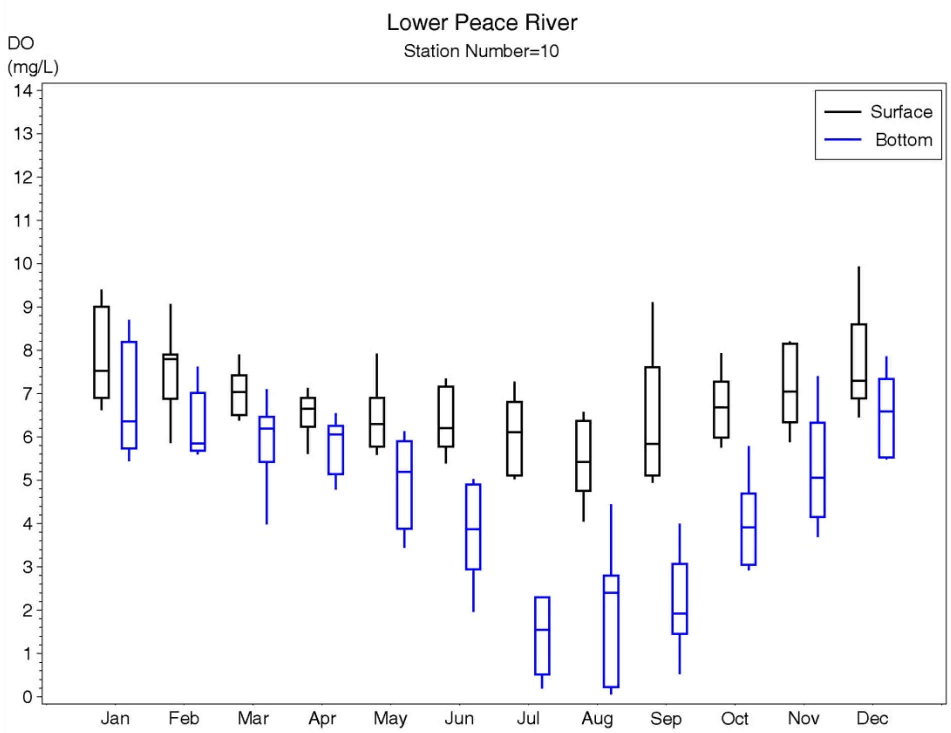


Figure 3-23. Monthly distribution of surface and bottom DO (1997-2004) at LPR Station 10. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

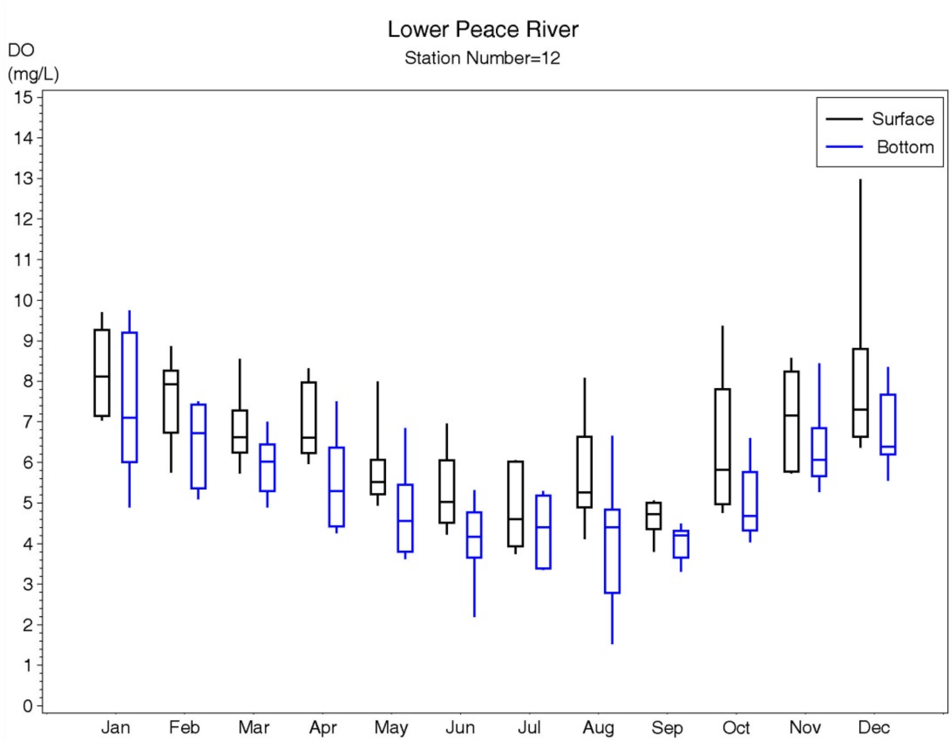


Figure 3-24. Monthly distribution of surface and bottom DO (1997-2004) at LPR Station 12. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

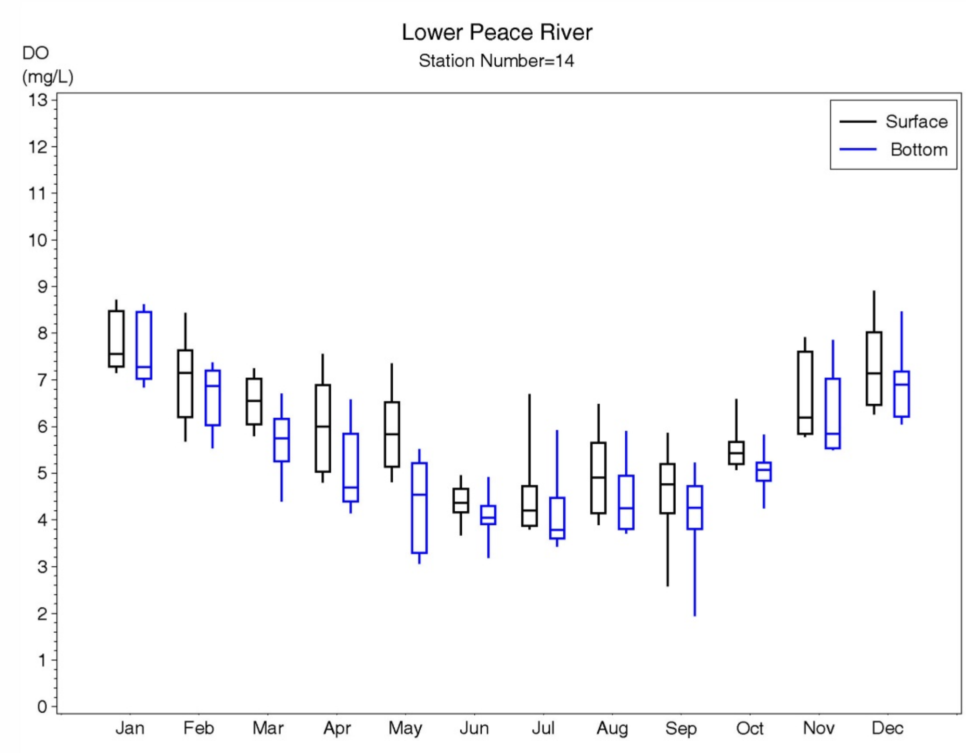


Figure 3-25. Monthly distribution of surface and bottom DO (1997-2004) at LPR Station 14. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

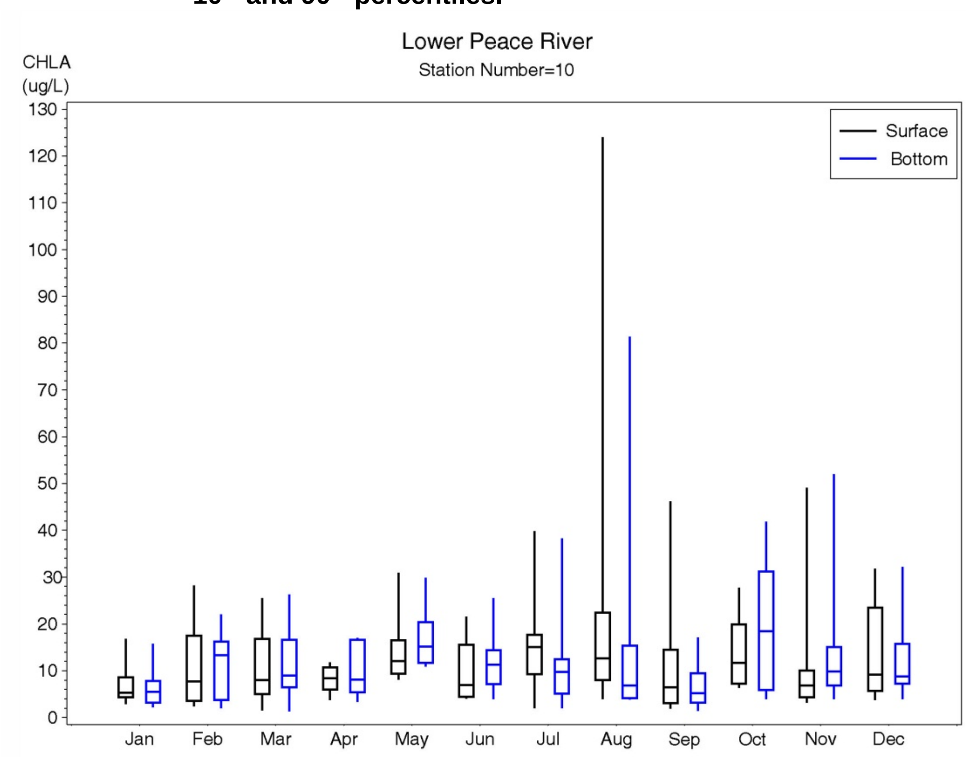


Figure 3-26. Monthly distribution of surface and bottom chlorophyll *a* (1997-2004) at LPR Station 10. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

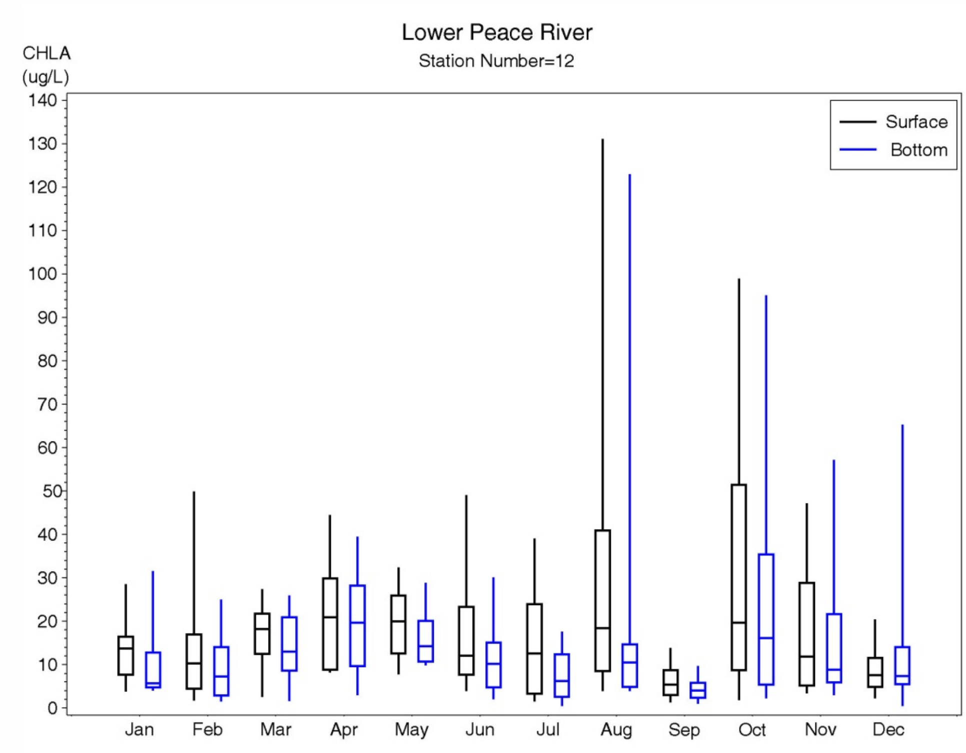


Figure 3-27. **Monthly distribution of surface and bottom chlorophyll *a* (1997-2004) at LPR Station 12. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.**

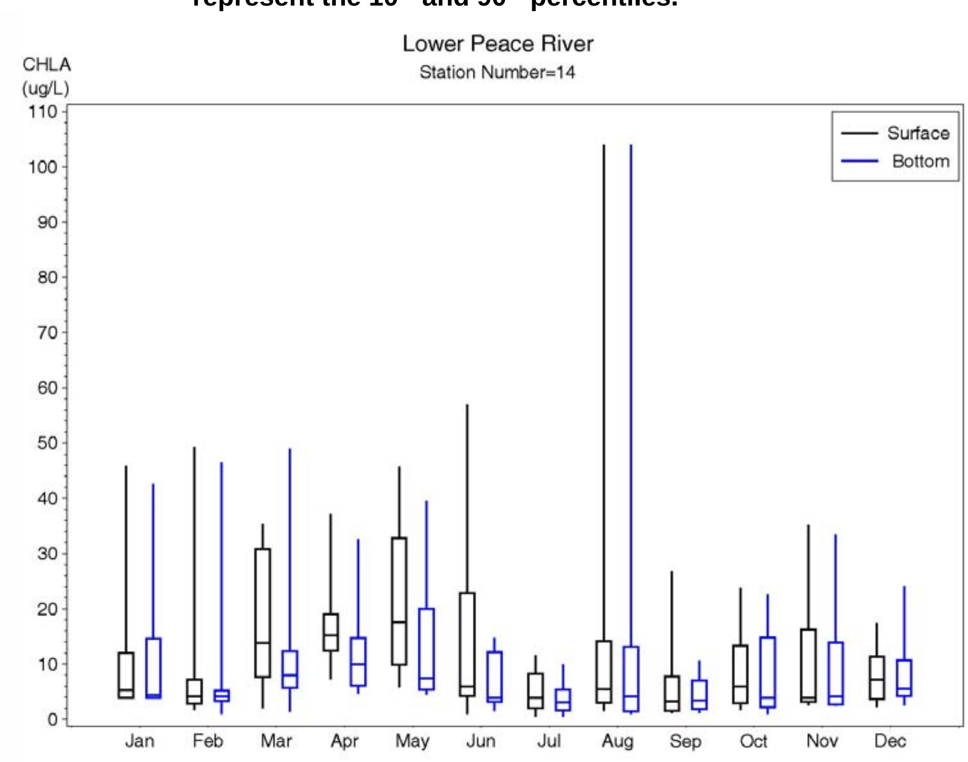


Figure 3-28. **Monthly distribution of surface and bottom chlorophyll *a* (1997-2004) at LPR Station 14. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.**

A within-year pattern of total nitrogen (TN) concentrations was evident in the monthly distributions across multiple years (Figures 3-29 through 3-31). Increased concentrations of TN during warmer high flow periods correspond with increased chlorophyll *a* values signaling the availability of inorganic nutrients in the LPR.

Within-year variation in total phosphorus (TP) concentrations for LPR stations are presented in Figures 3-32 through 3-34. Monthly concentrations of TP were higher during the late summer months of July, August and September. In typical estuarine/riverine systems TP lags behind TN and chlorophyll *a*, as is found in the LPR. This lag is often associated with the breakdown of primary producers and the flux of phosphorus from the sediments associated with low dissolved oxygen.

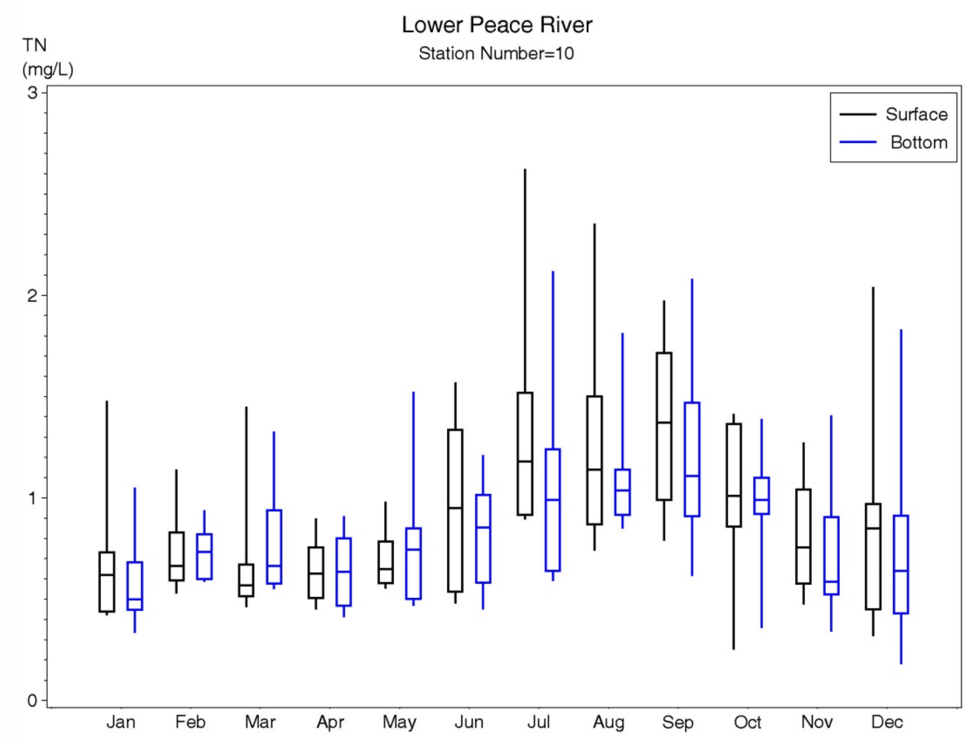


Figure 3-29. Monthly distribution of surface and bottom TN (1997-2004) at LPR Station 10. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

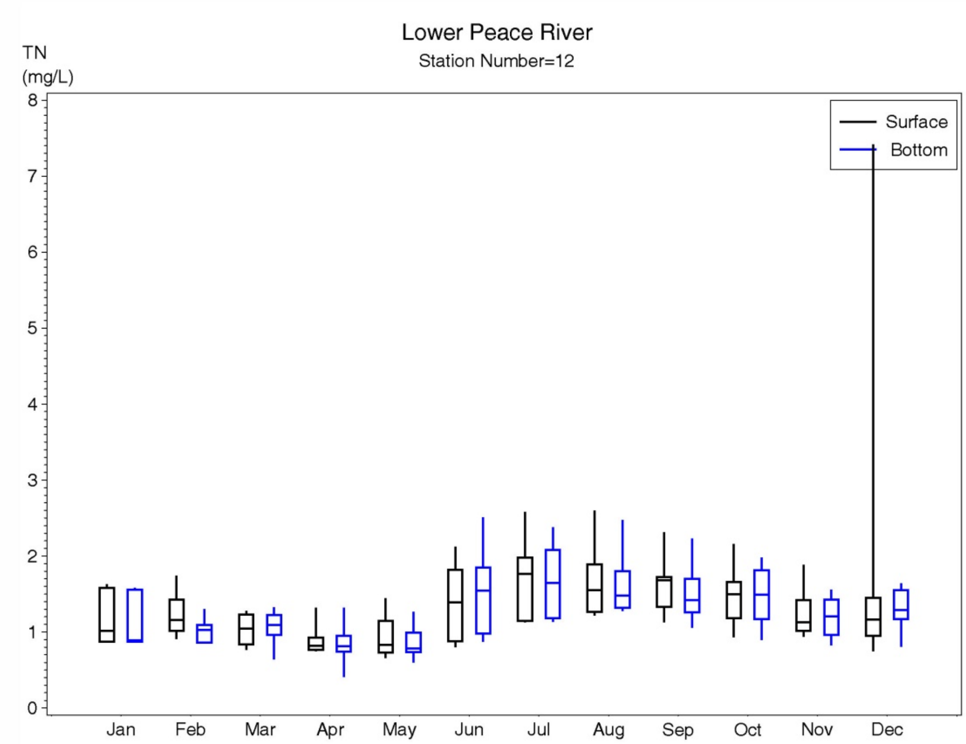


Figure 3-30. **Monthly distribution of surface and bottom TN (1997-2004) at LPR Station 12. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.**

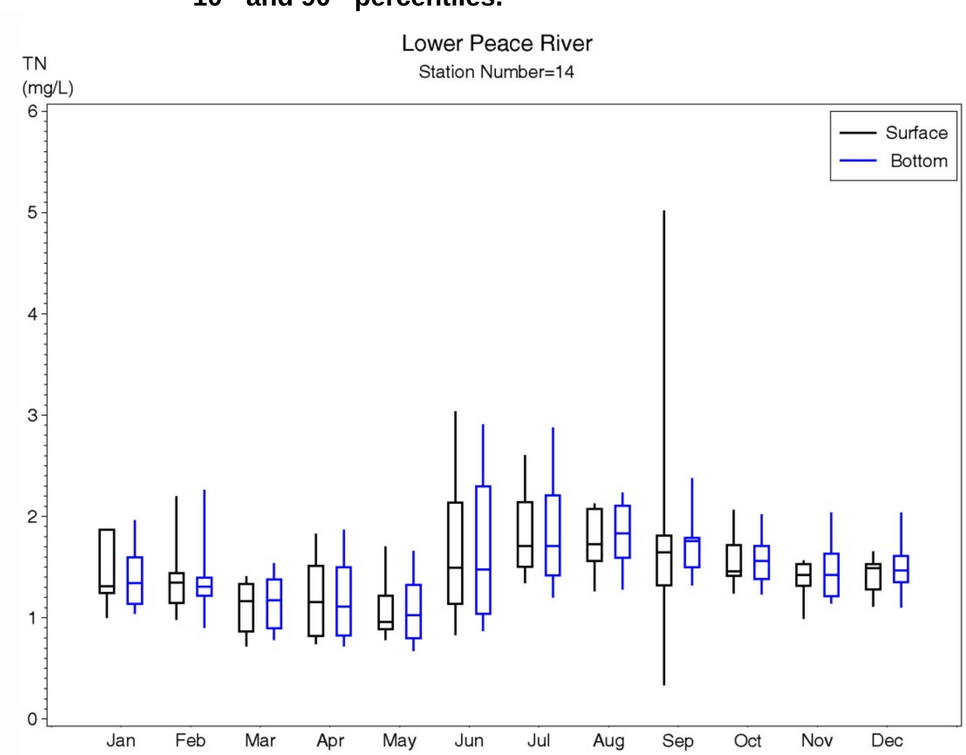


Figure 3-31. **Monthly distribution of surface and bottom TN (1997-2004) at LPR Station 14. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.**

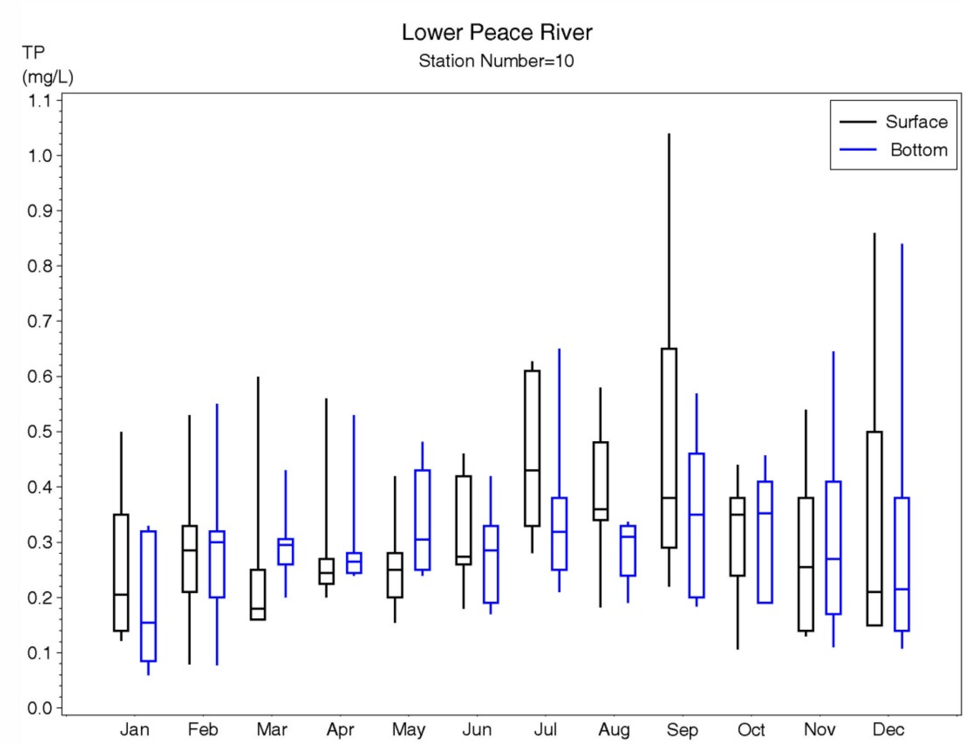


Figure 3-32. Monthly distribution of surface and bottom TP (1997-2004) at LPR Station 10. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

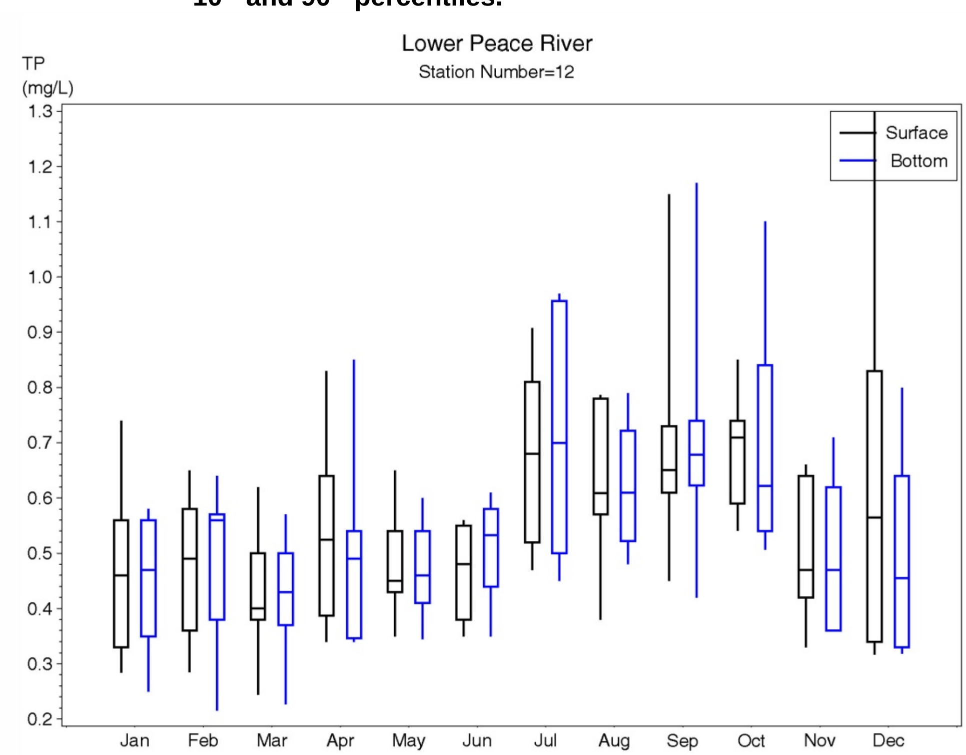


Figure 3-33. Monthly distribution of surface and bottom TP (1997-2004) at LPR Station 12. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

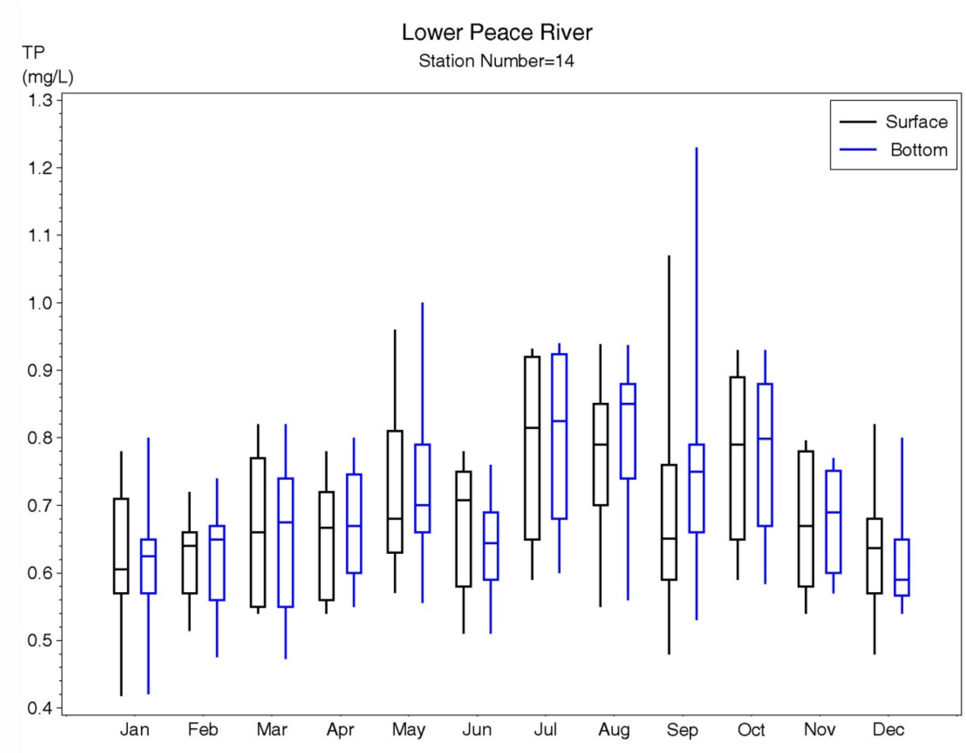


Figure 3-34. Monthly distribution of surface and bottom TP (1997-2004) at LPR Station 14. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

3.1.2.3 Spatial Variation in Water Quality Constituents

Spatial variation in physical constituents is shown by river kilometer for all stations for all years (1997-2004). Water quality constituents were observed longitudinally for Stations 9 (2.4 km), Station 10 (6.6 km), Station 12 (15.5 km), Station 14 (23.6 km), and Station 18 (30.4 km).

As expected, salinity values decreased with distance upstream. Typical estuarine circulation resulted in lower salinities in surface water and higher salinities in bottom water. Salinity differences between surface and bottom water decreased as tidal influence decreased (Figure 3-35)

The distribution of temperature values was observed to be relativity similar from the river mouth to Station 19. Figure 3-36 presents the longitudinal distribution of temperature observations over the geographic domain of the LPR. Temperature was slightly lower in bottom waters for the majority of stations.

Figure 3-37 presents the longitudinal distribution of DO over the geographic domain of the LPR. Bottom waters had slightly lower DO than surface water and DO did not show large variations among stations. Slightly higher DO was found downstream and decreased at the river's narrowest portion (km 21.9).

The distributions of chlorophyll *a* concentrations were observed to reach a peak at 15.5 km (station 9) and decreased again with distance upstream, as shown in Figure 3-38. As previously discussed, lower concentrations were found in bottom waters with greater light attenuation.

Total Nitrogen concentrations increased with distance upstream, as shown in Figure 3-39. Higher concentrations upstream result from freshwater sources and the potential greater availability due to reduced concentrations of primary producers.

Total Phosphorus showed similar behavior with increasing concentrations with distance upstream as shown in Figure 3-40.

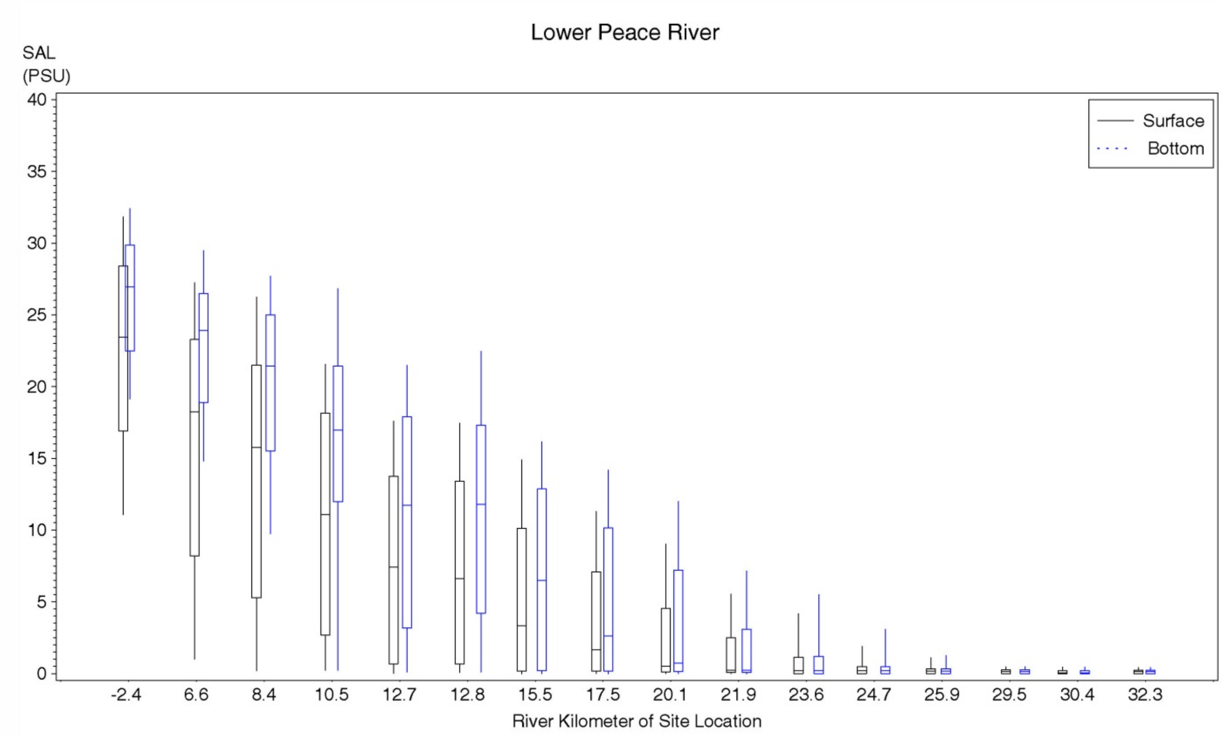


Figure 3-35. Observed longitudinal distributions of salinity for the LPR.

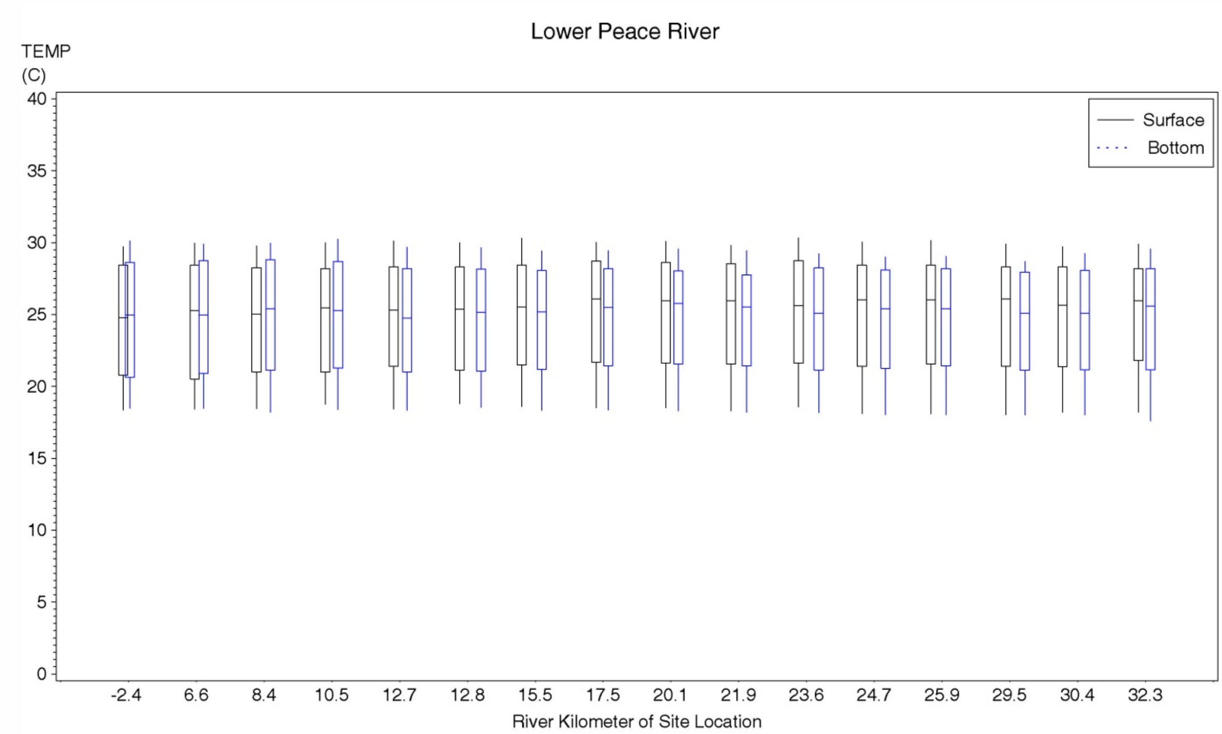


Figure 3-36. Observed longitudinal distributions of temperature for the LPR.

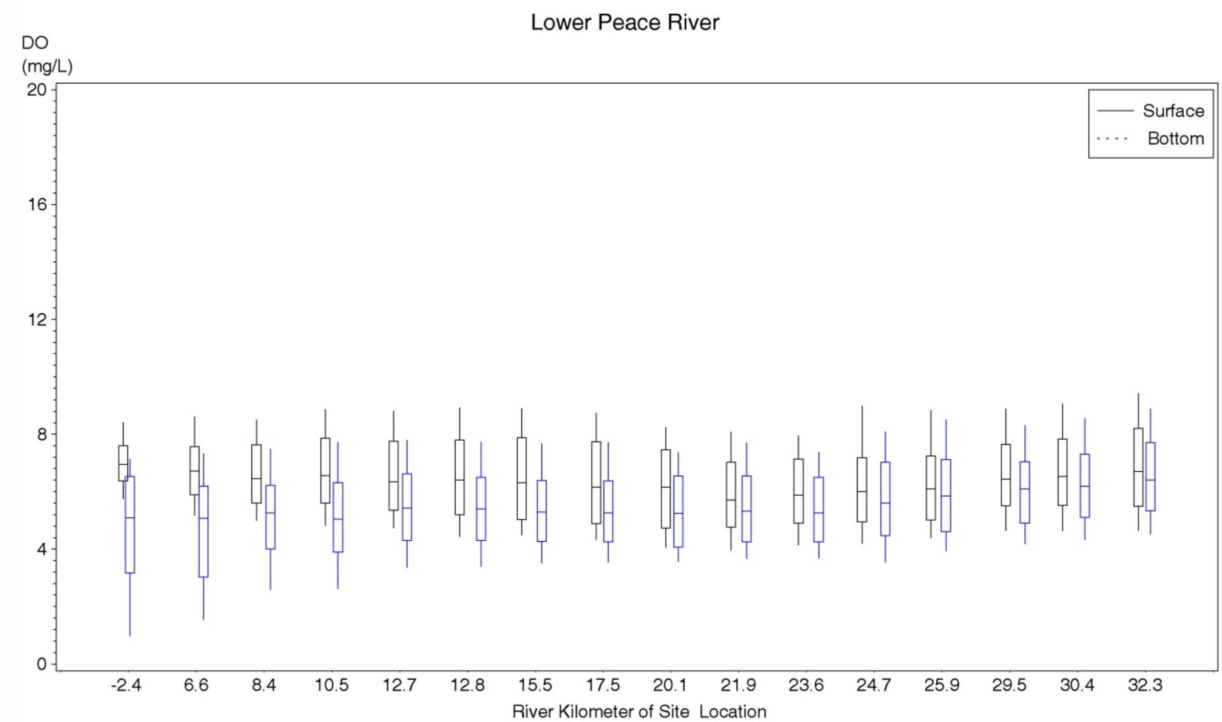


Figure 3-37. Observed longitudinal distributions of DO for the LPR.

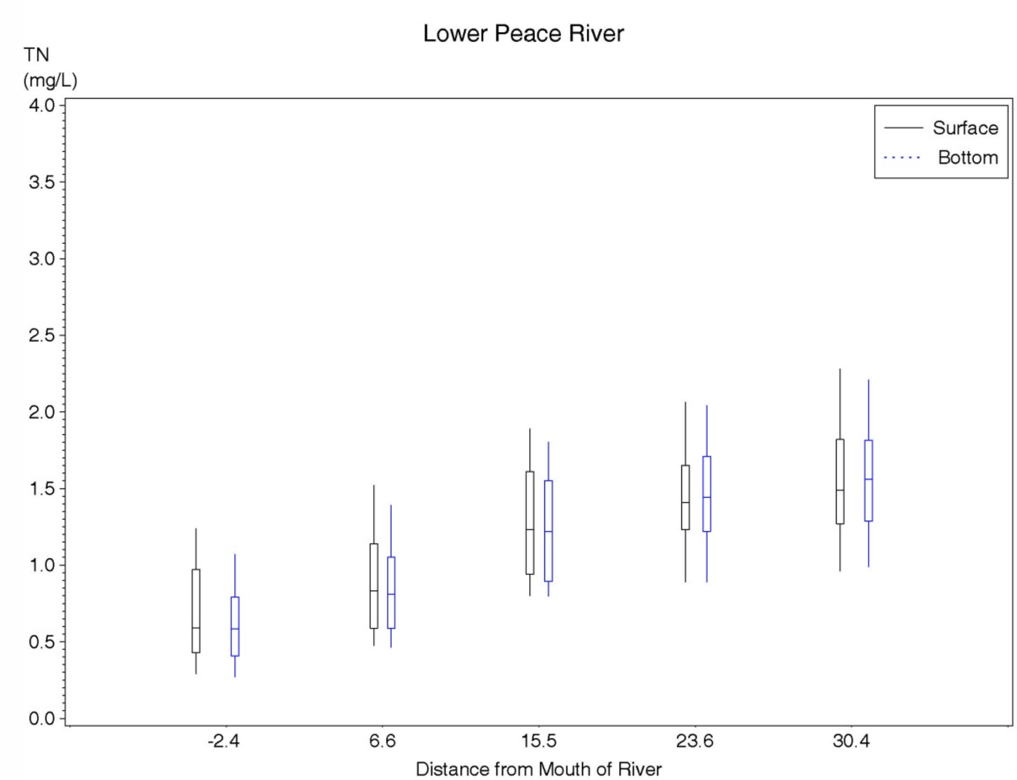


Figure 3-38. Observed longitudinal distributions of chlorophyll *a* for the LPR.

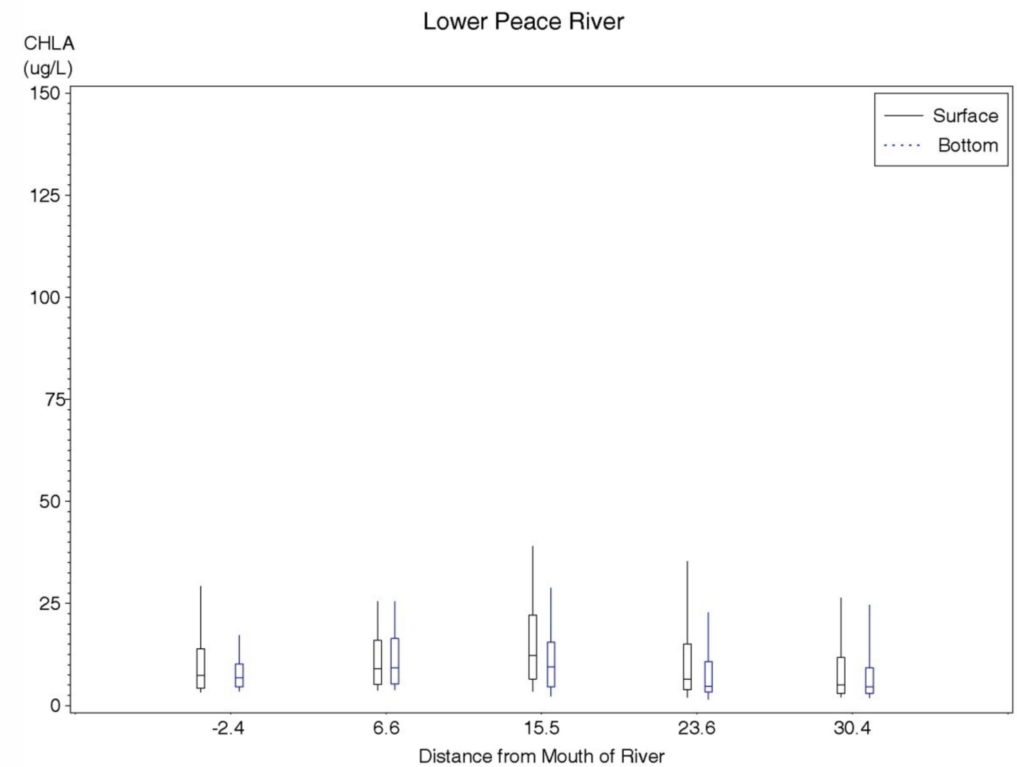


Figure 3-39. Observed longitudinal distributions of TN for the LPR.

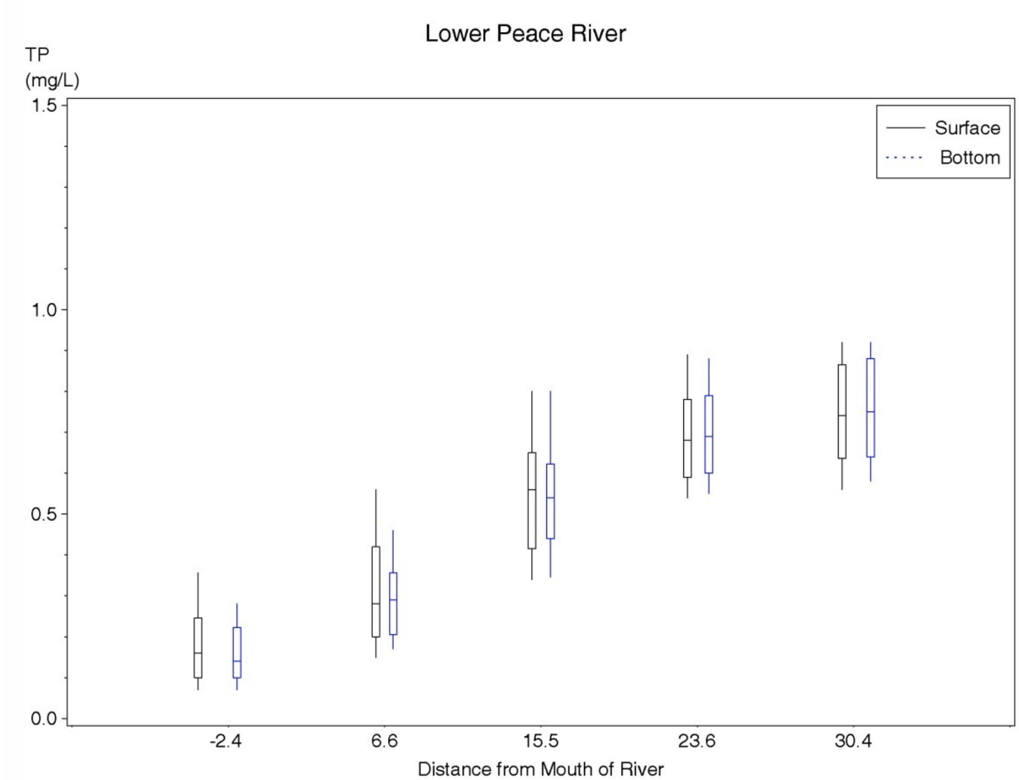


Figure 3-40. Observed longitudinal distributions of TP for the LPR.

3.2 Shell Creek

In this subchapter, a historical review of previous studies that addressed water quality in the SC is presented. In addition, data from ambient monitoring are presented and described.

3.2.1 Shell Creek Historical Review

The following section provides brief summaries of scientific reports which include data and analysis of SC. PBS&J (2001, 2006) assessed the potential SC impacts resulting from changes in City of Punta Gorda Facility withdrawals. The purpose of these documents was to assess if the biological communities of the SC/LPR estuarine system may be adversely impacted as a result of the proposed increase in permitted freshwater withdrawals. Data included use of the SC Hydrobiological Monitoring Program (HBMP) data which began in 1996 and provides comprehensive seasonal and long-term water quality data. Relationships between flow on salinity, dissolved oxygen and chlorophyll *a* were determined.

Under no flow conditions, surface salinities near the dam can reach nearly 15 ppt. As flow increases, salinities decrease to zero. Variability increases in the salinity flow relationship with movement downstream as a result of tidal influences. Bottom DO values were typically lower than surface DO values regardless of flow, although differences lessen during high flow. Analyses of chlorophyll *a* levels generally showed a pattern of declining concentrations with increasing flows. Increases in flow caused an increase in water color and decreases in residence time.

Janicki Environmental (2003) conducted a study for the Charlotte Harbor National Estuary Program to assess the status and trends of water quality conditions within the Charlotte Harbor National Estuary Program (CHNEP) study area. An extensive review was conducted that included the Peace River. Within the study area, a historical and current database of rainfall, flow, surface water quality, and groundwater quality were linked using a GIS system with respect to hydrology and geographic location to develop an integrated watershed database. Water quality was assessed by comparing recent period rainfall, stream flow, and various constituents across basins. Times series trends were assessed by applying seasonal Kendall tau analyses to rainfall, stream flow, and water quality data to each individual station in the study area. Statistical results were integrated at the drainage basin level by mapping trends across basins.

For the SC Basin, significant increasing salinity trends were identified for Station 1 at both surface and bottom. The salinity was observed to be increasing at 6.6% of the median value per year for the bottom measurements and at 5.5% of the median value per year for the surface measurements. The period of record for which the trends were detected was from 1991 to 2001. Matching surface and bottom conductivity trends were also detected for this station, but at a slightly lesser rate. A significant decreasing turbidity trend was also observed for SC for Station 2 for the same time period.

PBS&J (2007), as part of the Peace River Cumulative Impact Study, assessed the individual and cumulative impacts of certain anthropogenic and natural stressors in the Peace River watershed, including stream flow, water quality, and ecological indicators. Historical changes to water quality constituents were presented for the subbasins of LPR, including SC. Several water quality parameters exhibited long-term increasing patterns and were measured at or near historically high levels during the recent 1999-2001 drought. Available water quality data indicate comparatively large historical increases in levels of measured conductivity in Prairie Creek and the SC Reservoir. Similar patterns of increasing chloride and silica concentrations have also occurred (PBS&J 2007).

3.2.2 Variation in Water Quality Constituents

The physical and water quality data described in this section were compiled from various data sources. The majority of the data were obtained from City of Punta Gorda's Hydro-Biological Monitoring Program (HBMP) which began in 1996 and continues to present

In the following sections, spatial and temporal variations in water quality constituents in SC are described. Because there are numerous sampling stations in SC, a representative group of stations was selected for presentation in this section. The selected stations, which span the longitudinal distribution of HBMP sampling stations (Figure 2-3), include:

- Station 7 (rkm 2.3),
- Station 5 (rkm 6.7), and
- Station 4 (rkm 8.7).

Plots of spatial and temporal variation for all HBMP sampling locations in the SC (Figure 2-26) are provided in Appendix 3-3.

3.2.2.1 Annual Variation in Water Quality Constituents

Annual time series plots of salinity show typical estuarine conditions for SC. Salinity decreased with distance upstream and was slightly lower in surface waters as compared to bottom water. Downstream salinity ranged from 0 to 20 ppt and upstream salinity was usually 0 pptppt with occasional increases of greater than 5 ppt. Typical yearly patterns showed higher salinities during the dry season and lower salinity during the wet season. Over annual cycles, lower salinities were found during wet years with relation to large meteorological events such as the El Nino event of 1998. Higher salinities were found during 2000 and 2001 associated with the continuation of extended drought periods. Annual variation in salinity at stations 7, 5, and 4 at river kilometers 2.3 km, 6.7 km and 8.7 km, respectively, are presented in Figures 3-41 through 3-43. Salinity plots of the remaining stations can be found in Appendix 3-3.

Temperature in SC showed typical seasonal cycles with summer peaks ranging from 30 to 34 degrees C and winter lows ranging from 15 to 12 degrees C (Figure 3-44, 3-45, and 3-46). Little variation was observed from the basic seasonal pattern over annual scales. At all locations the surface and bottom ranges were very similar with slightly higher surface temperatures during the entire period at all locations.

Times series data of DO concentrations are shown in Figures 3-47 through 3-49. DO concentrations ranged from 1 to 13 mg/L. Surface concentrations were higher than bottom water concentrations for most stations with larger differences with distance upstream.

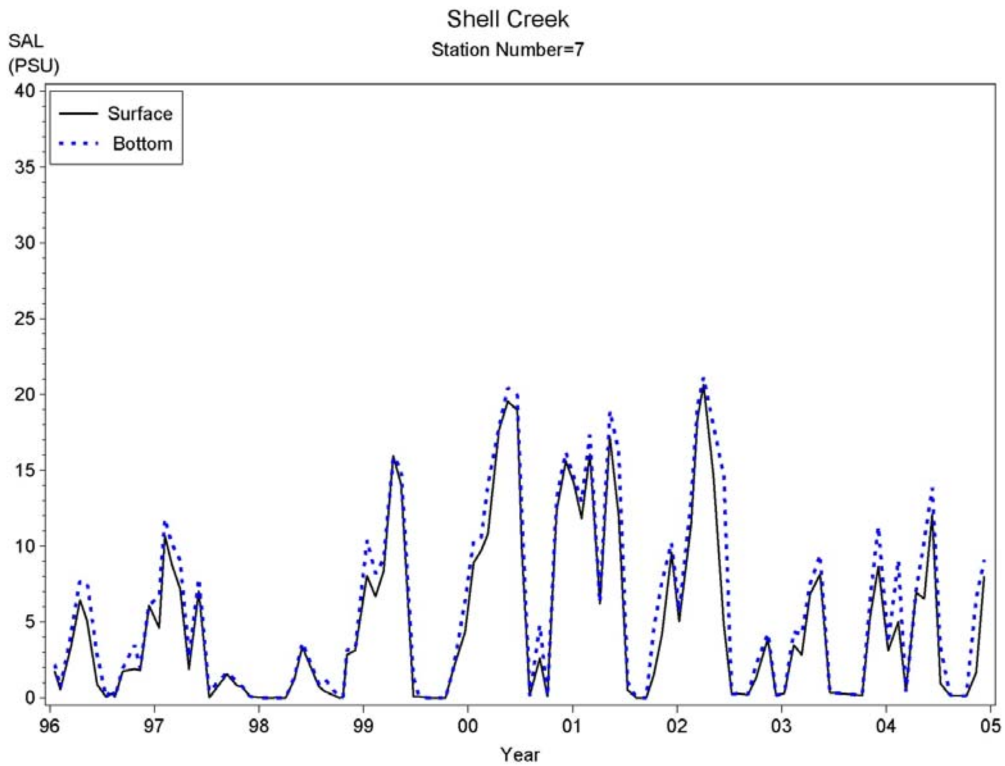


Figure 3-41. Time series of surface and bottom salinity at SC station 7.

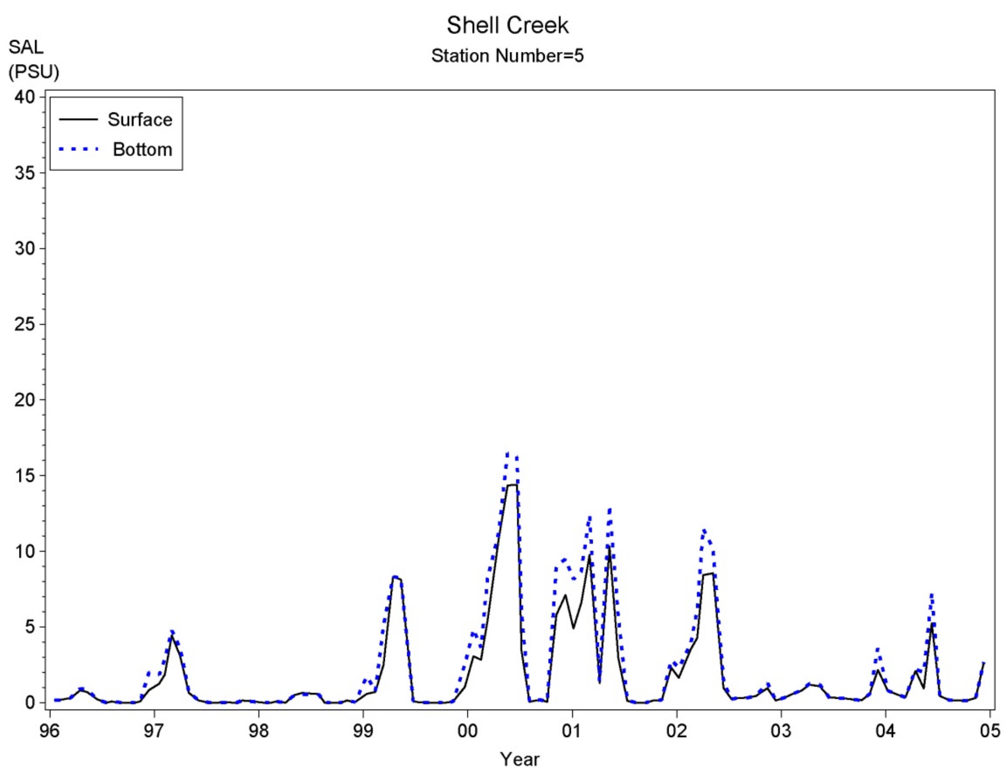


Figure 3-42. Time series of surface and bottom salinity at SC station 5.

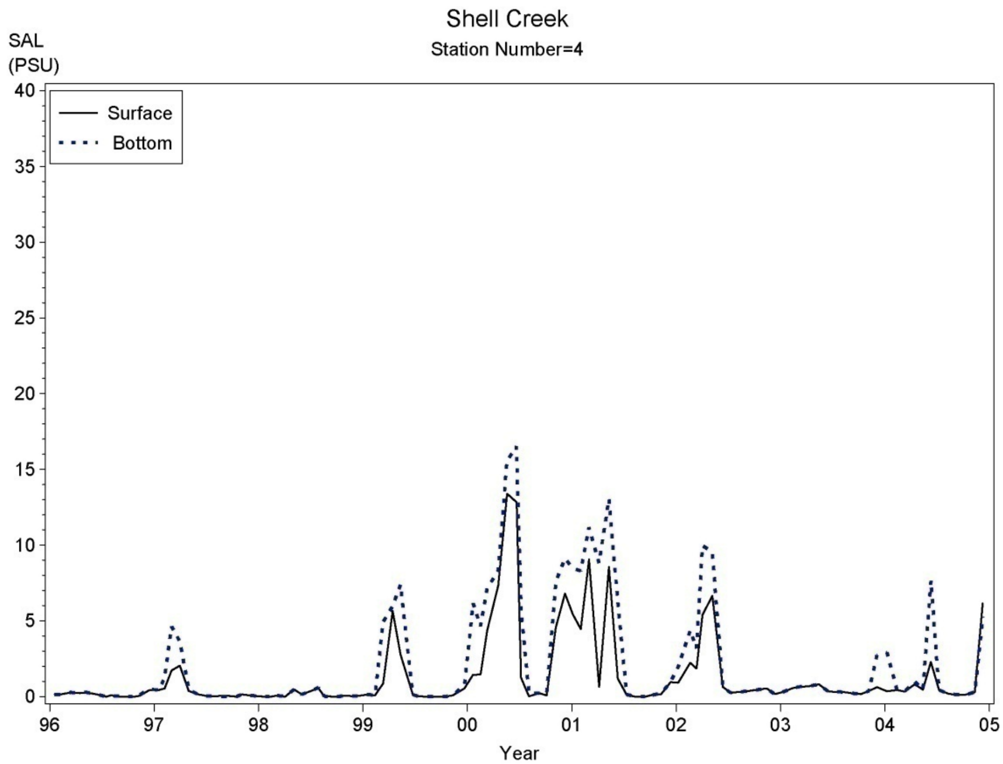


Figure 3-43. Time series of surface and bottom salinity at SC station 4.

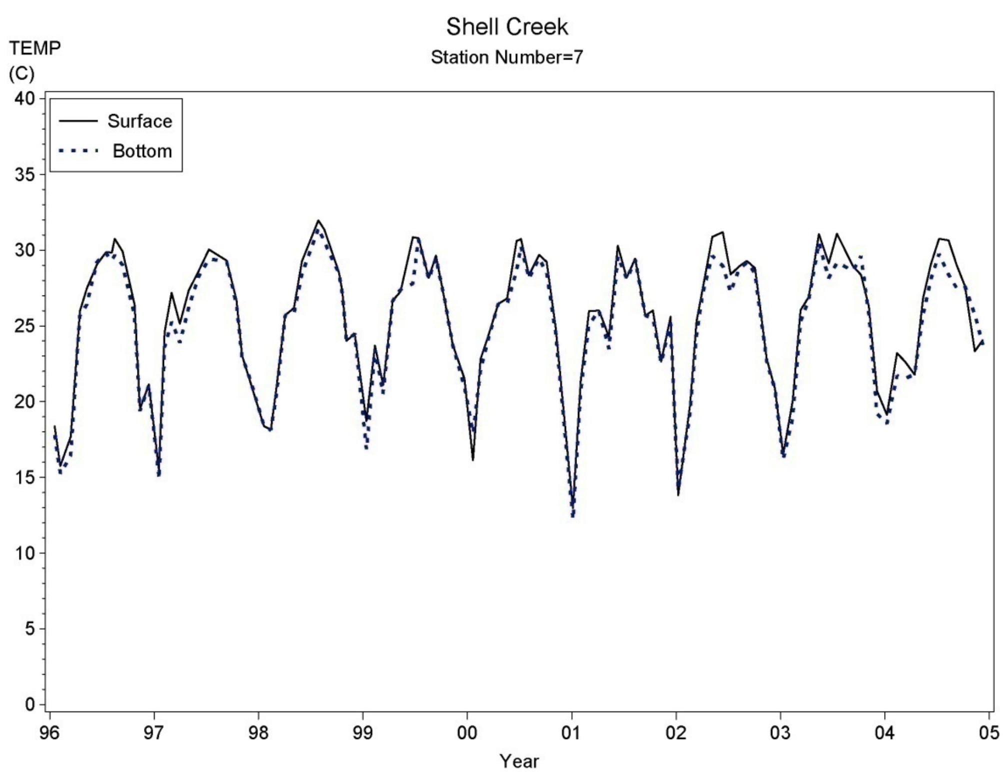


Figure 3-44. Time series of surface and bottom temperature at SC station 7.

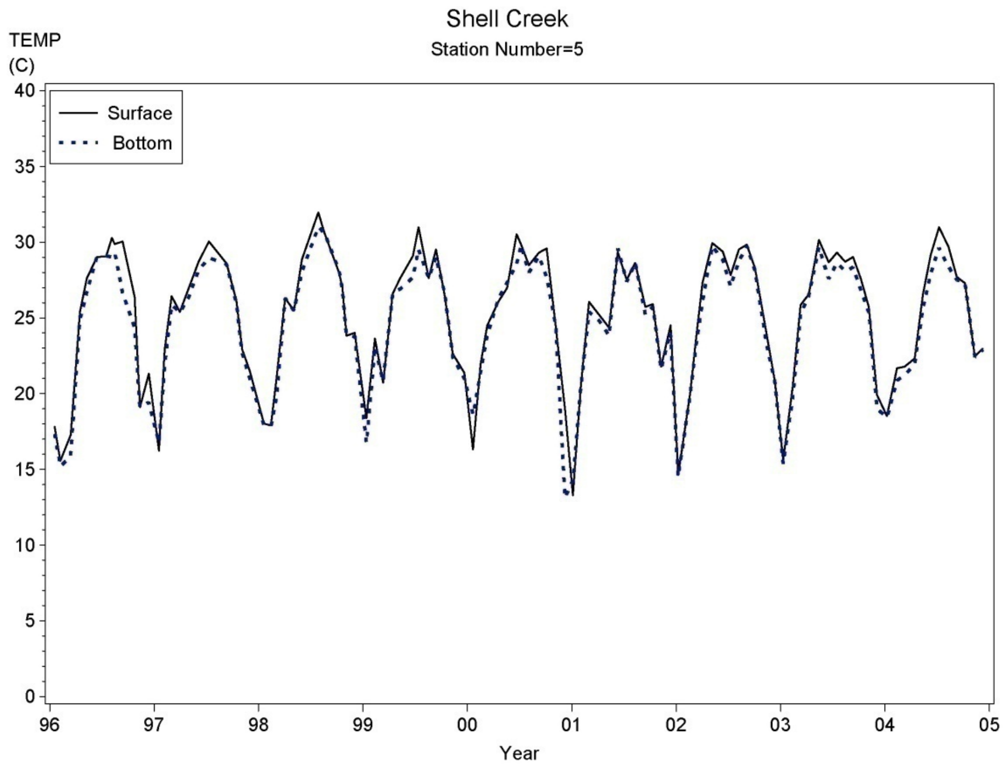


Figure 3-45. **Time series of surface and bottom temperature at SC station 5.**

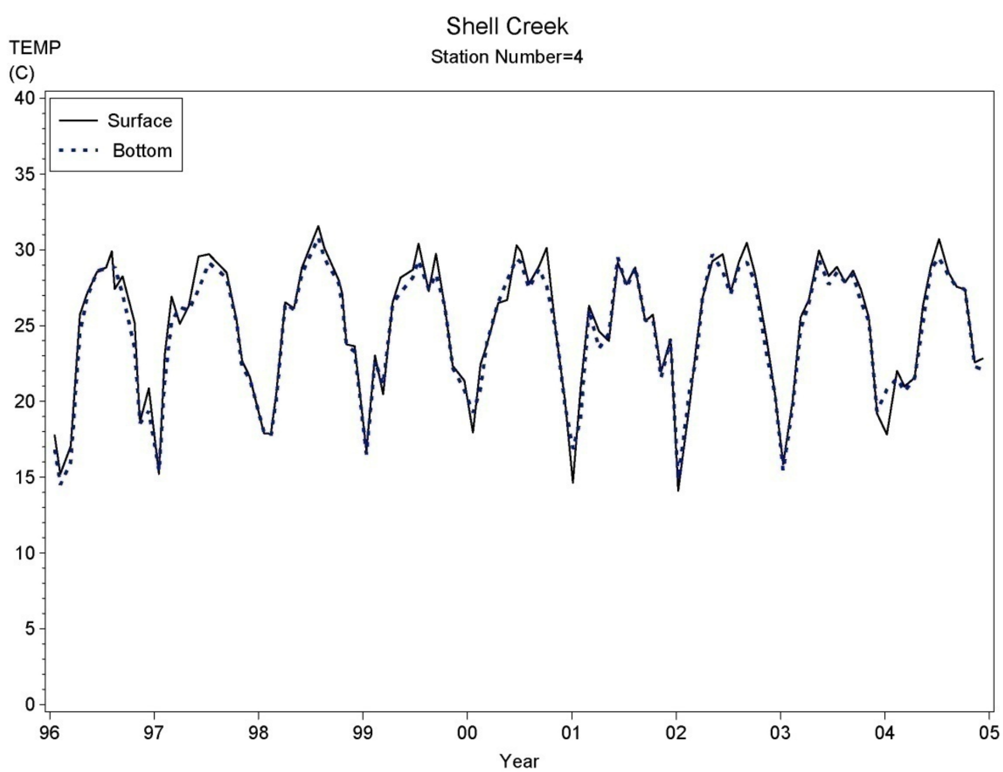


Figure 3-46. **Time series of surface and bottom temperature at SC station 4.**

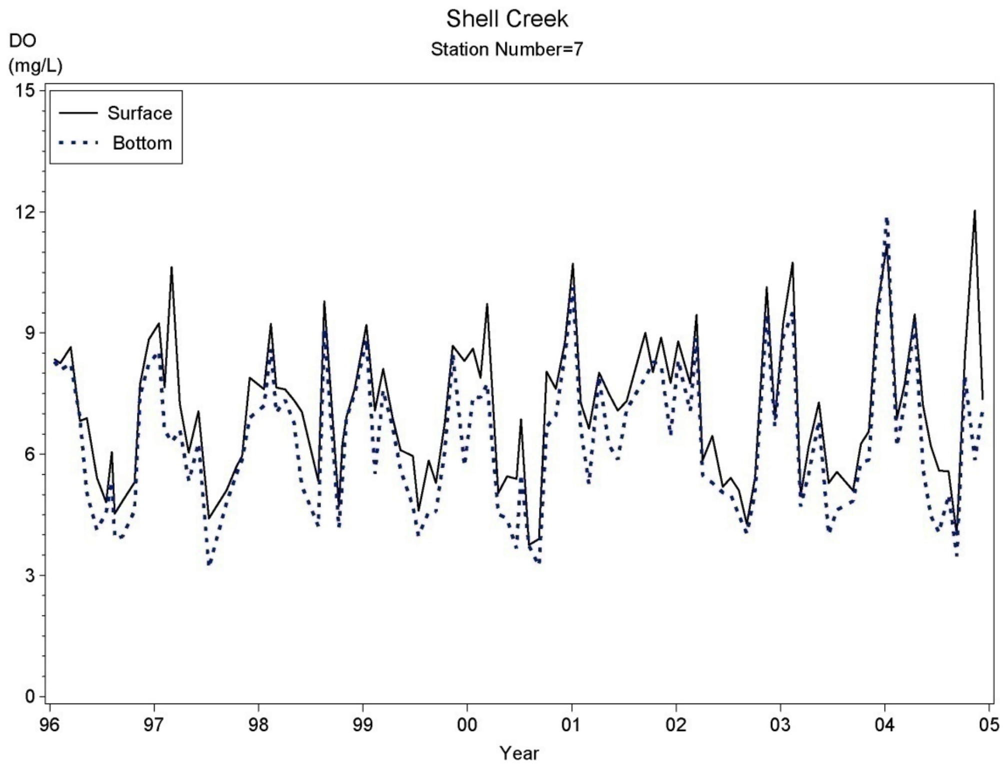


Figure 3-47. **Time series of surface and bottom DO at SC station 7.**

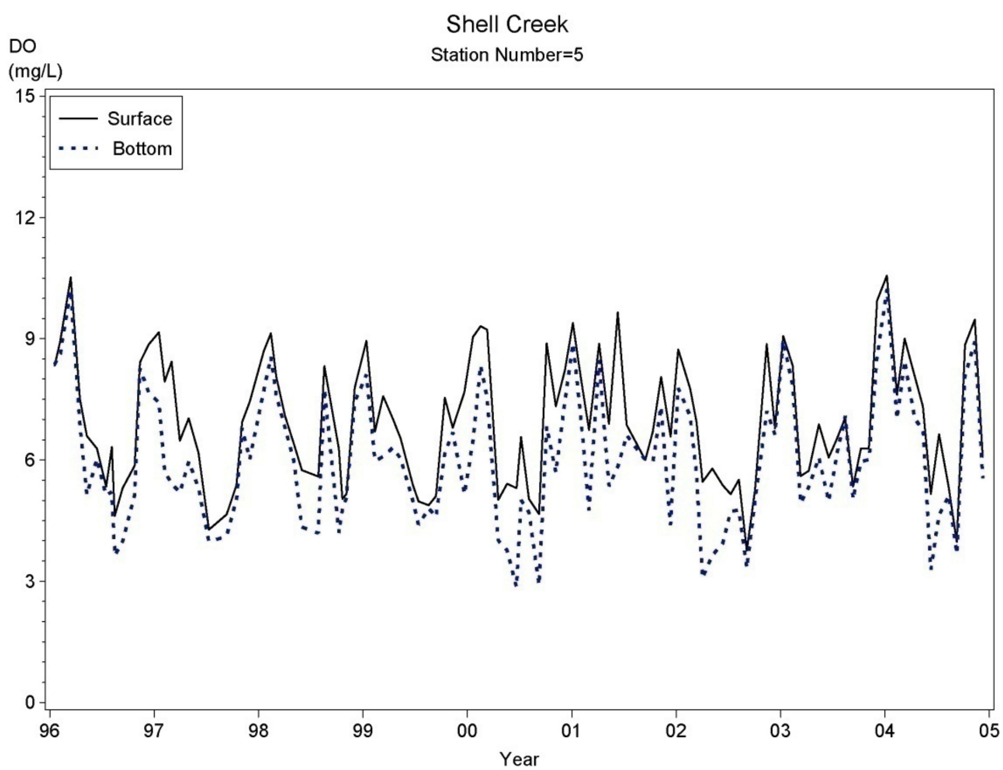


Figure 3-48. **Time series of surface and bottom DO at SC station 5.**

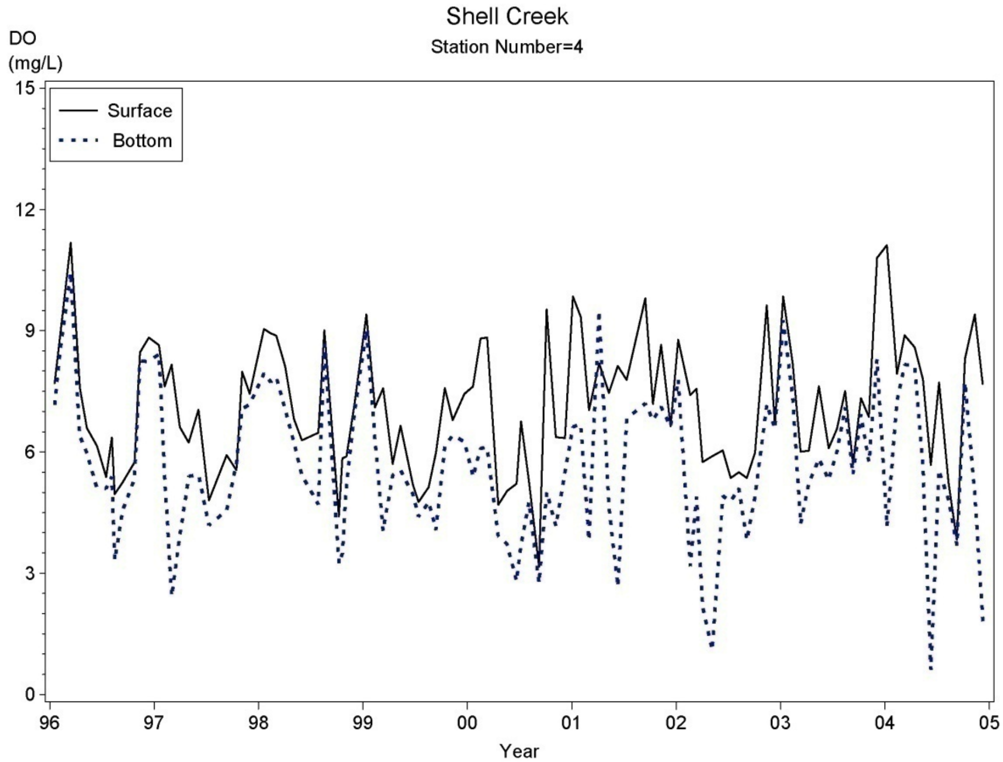


Figure 3-49. Time series of surface and bottom DO at SC station 4.

Annual time series of chlorophyll *a* are shown in Figures 3-50 through 3-52. There was considerable monthly variation in chlorophyll *a* concentrations at all stations. Chlorophyll *a* concentrations typically ranged from 5 to 20 µg/L, with periodic peak concentrations ranging from 50 to over 100 ug/l. The highest chlorophyll a concentrations typically occur during low flows (PBS&J 2006).

Concentrations of TN are shown in Figures 3-53 through 3-55. Concentrations of TN ranged from approximately 0.5 to 4 mg/L. On annual time scales, values were typically lower during the dry season and higher during the wet season, as expected with increased flow.

TP showed annual variation across the period of record. Concentrations of TP ranged from 0.2 to 1.3 mg/L. Higher TP concentrations were evident during wet years for example the 1998 El Nino. On an annual scale lower TP concentrations were found during the dry season and higher during the wet season (Figures 3-56 through 3-58).

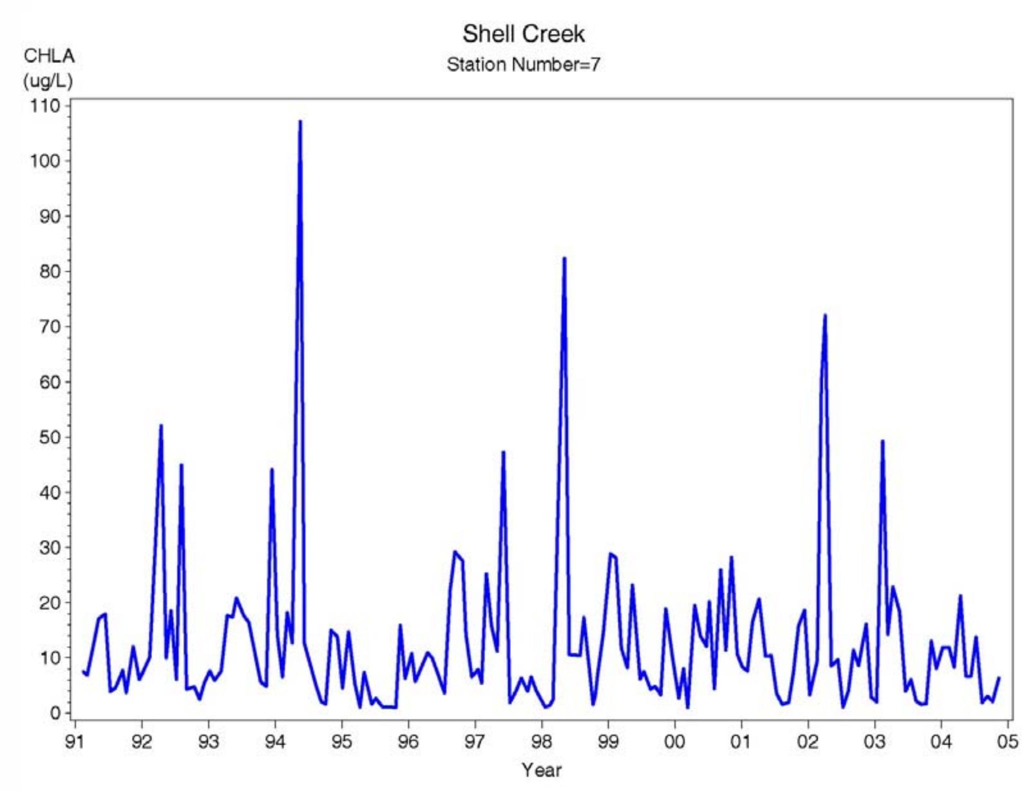


Figure 3-50. Time series of chlorophyll *a* at SC station 7.

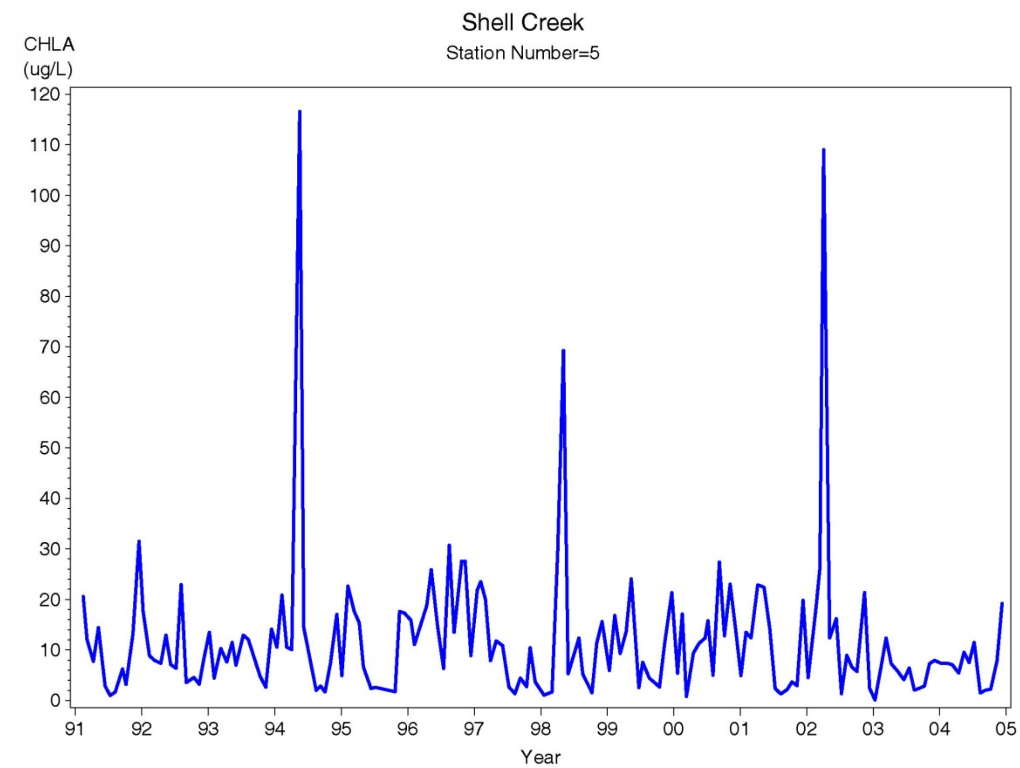


Figure 3-51. Time series of chlorophyll *a* at SC station 5.

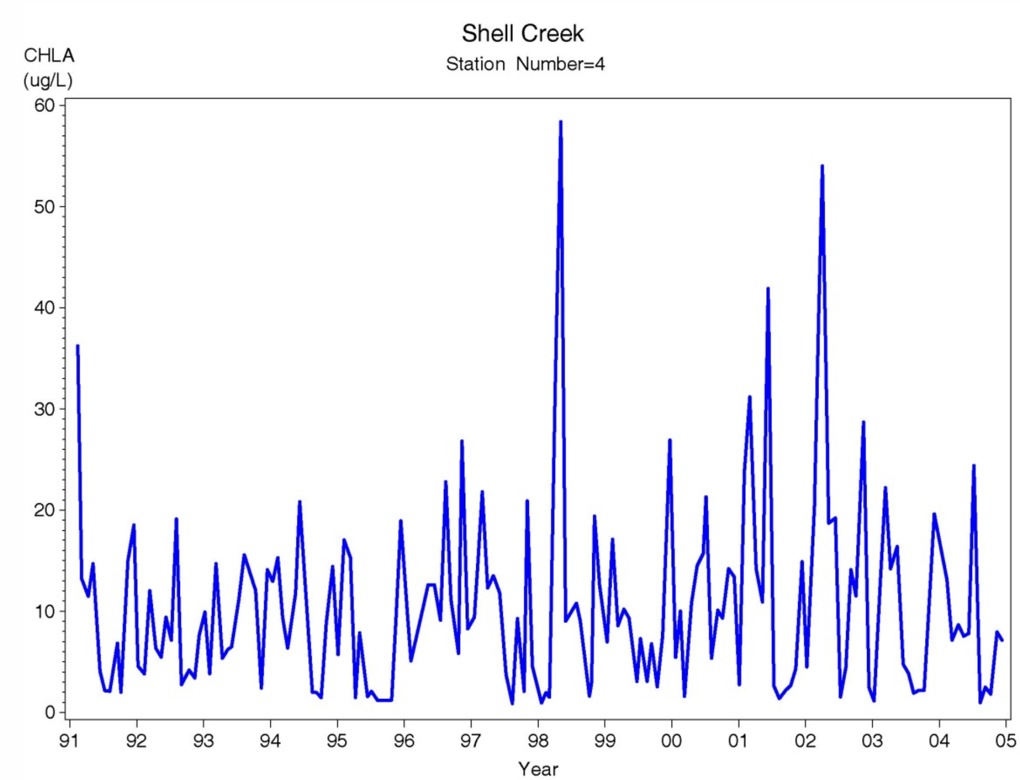


Figure 3-52. Time series of chlorophyll *a* at SC station 4.

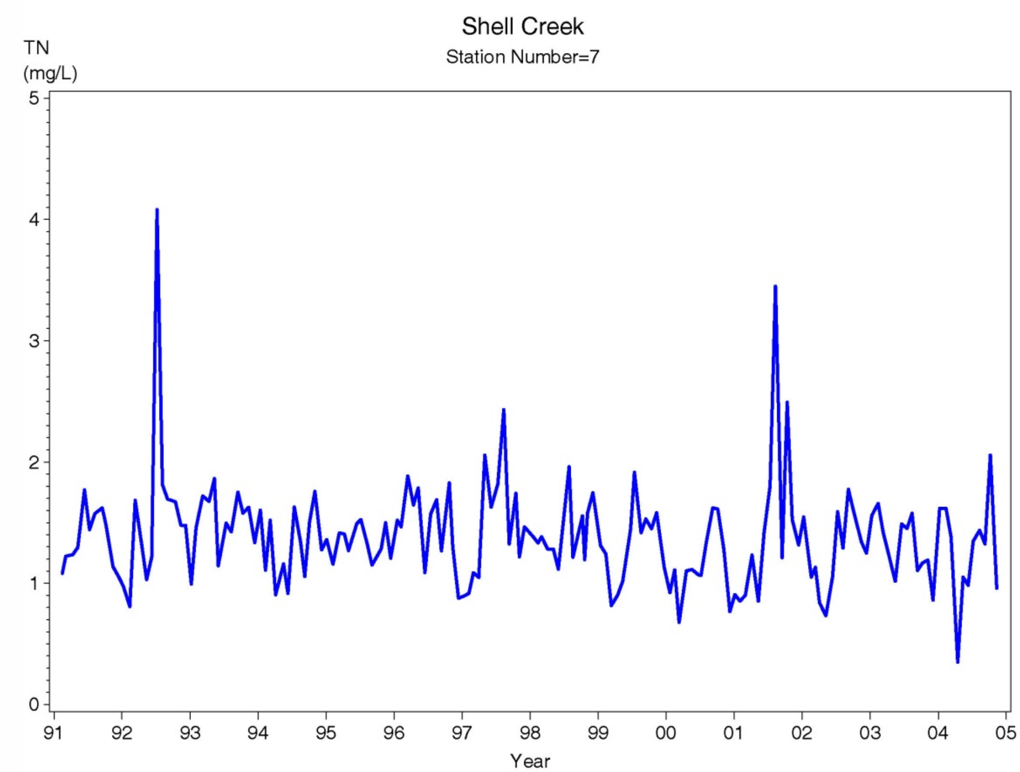


Figure 3-53. Time series of TN at SC station 7.

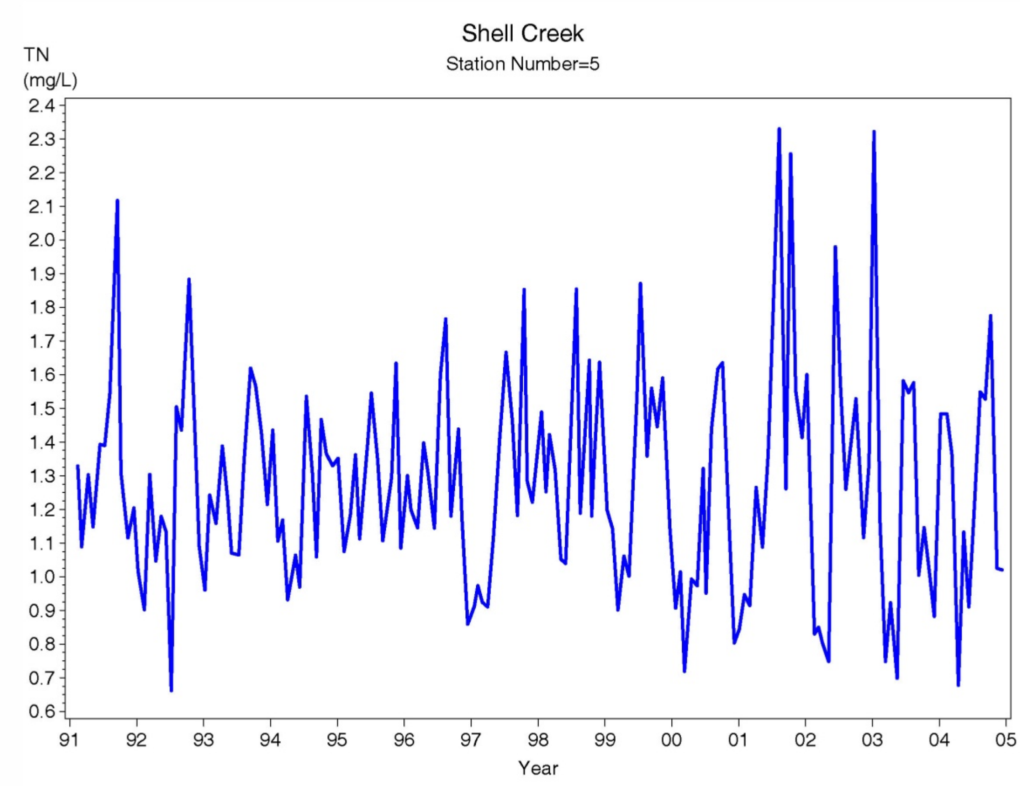


Figure 3-54. **Time series of TN at SC station 5.**

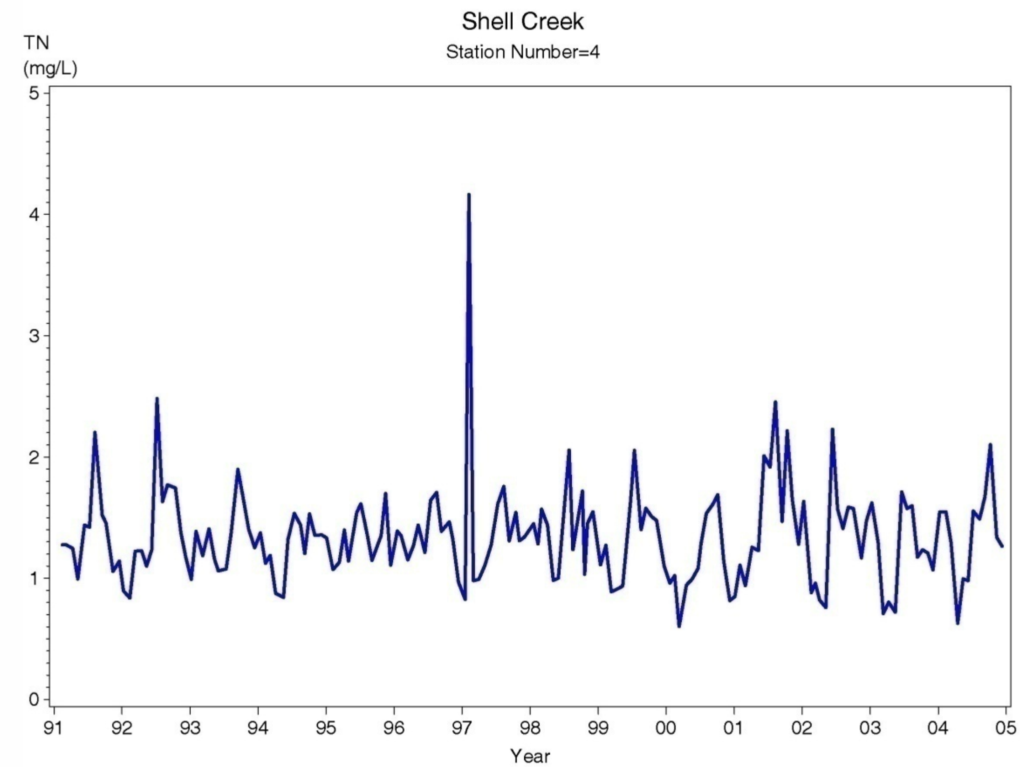


Figure 3-55. **Time series of TN at SC station 4.**

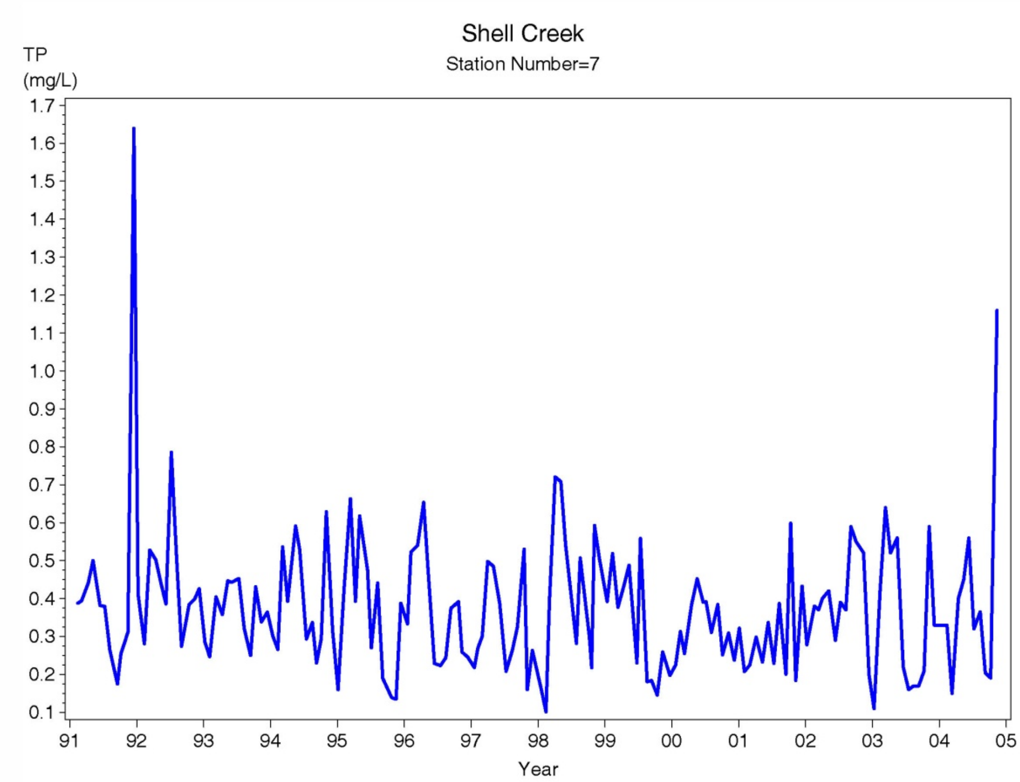


Figure 3-56. Time series of TP at SC station 7.

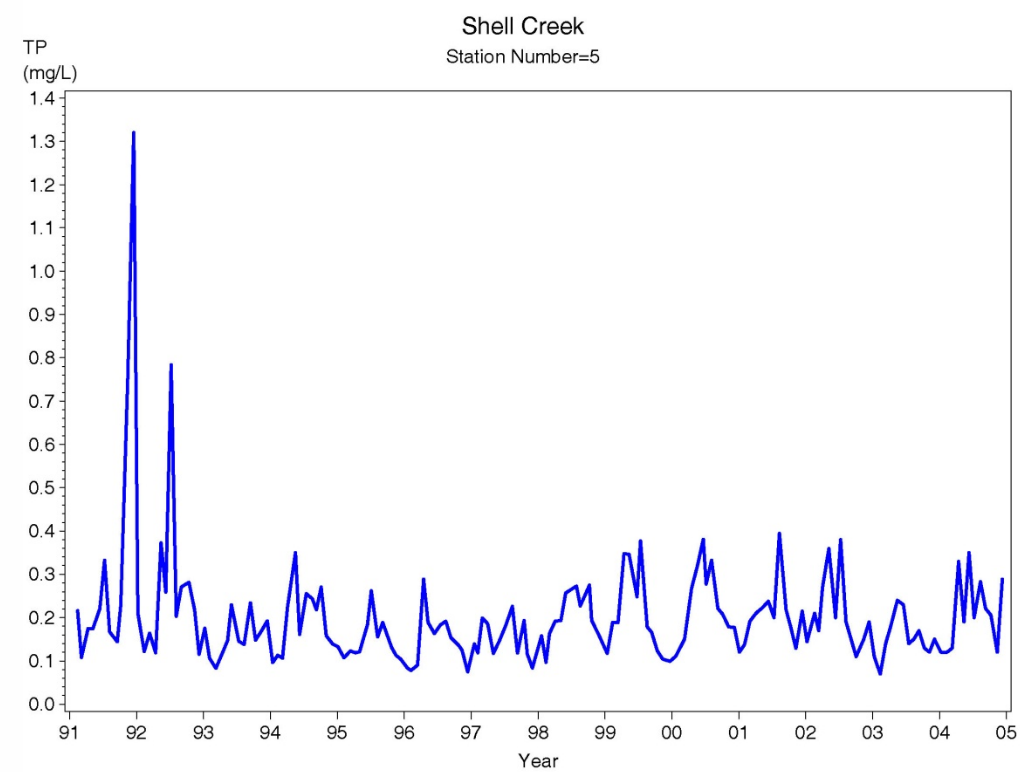


Figure 3-57. Time series of TP at SC station 5.

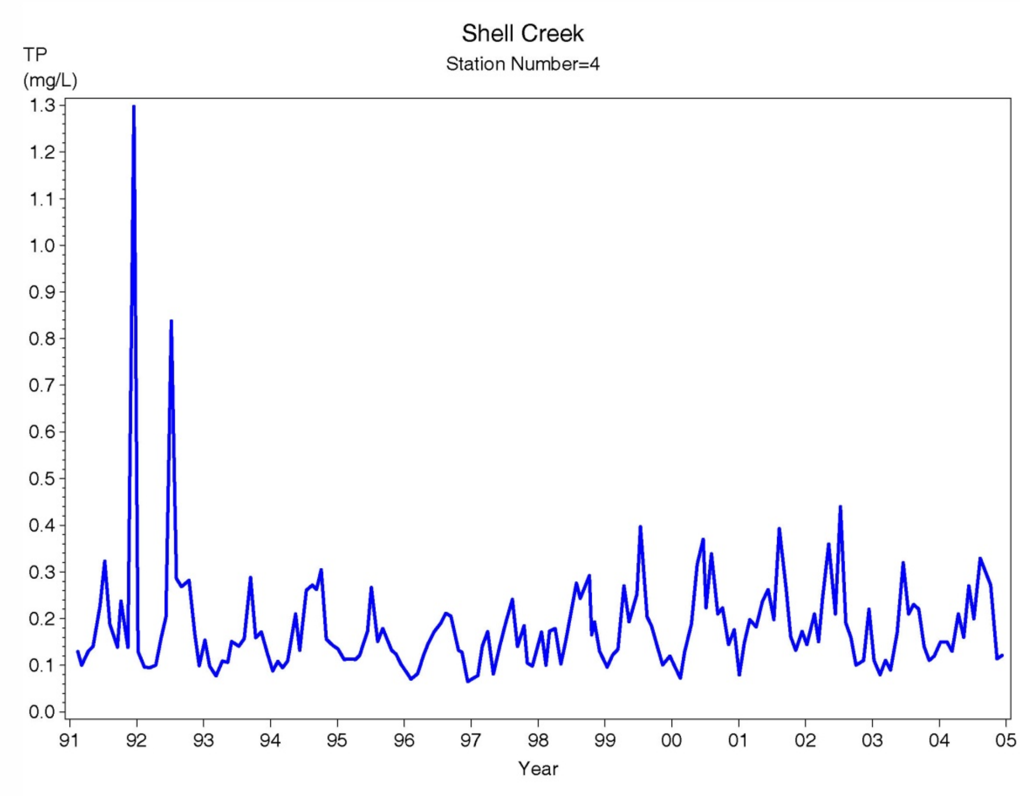


Figure 3-58. Time series of TP at SC station 4.

3.2.2.2 Within-Year Variation in Water Quality Constituents

The physical and water quality characteristics of the SC vary predictably based on the seasonal cycle of the local climate. Detailed plots for all locations and constituents are presented in Appendix 3-2.

Within each year the physical and water quality characteristics of SC vary on a predictable cycle driven by the summer warmer/wet and winter cooler/dry season cycle of the local climate.

Within-year variation in salinity at Stations 7, 5, and 4 are presented in Figures 3-59 through 3-61. Salinity was higher during the dry season months (November through May) and lower in the summer wet season (June through October). Salinity was typically lower in surface water and higher in bottom waters. High freshwater flow resulted in little or no differences between surface and bottom salinities from July through October for most stations.

Temperature also followed seasonal patterns (Figures 3-62 through 3-64) over the period of record for all locations and depths. Lowest temperatures were observed ruing December and January. Highest temperatures were observed during July and August.

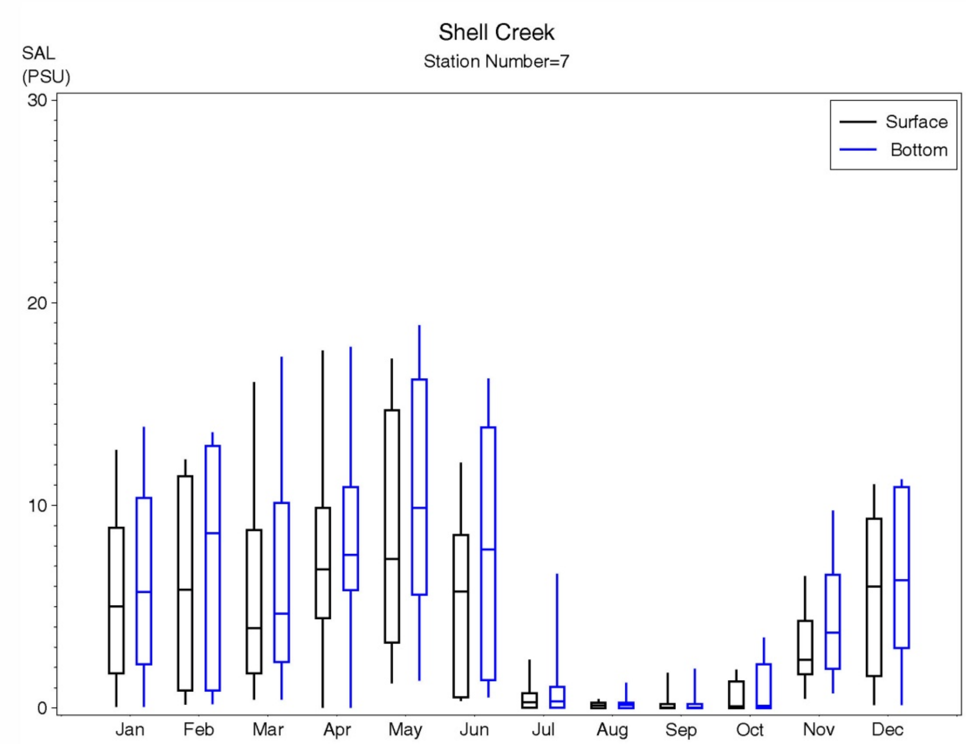


Figure 3-59. Monthly distribution of surface and bottom salinity (1997-2004) at SC Station 7. Boxes represent the 25^{th}, 50^{th}, and 75^{th} percentiles, while whiskers represent the 10^{th} and 90^{th} percentiles.

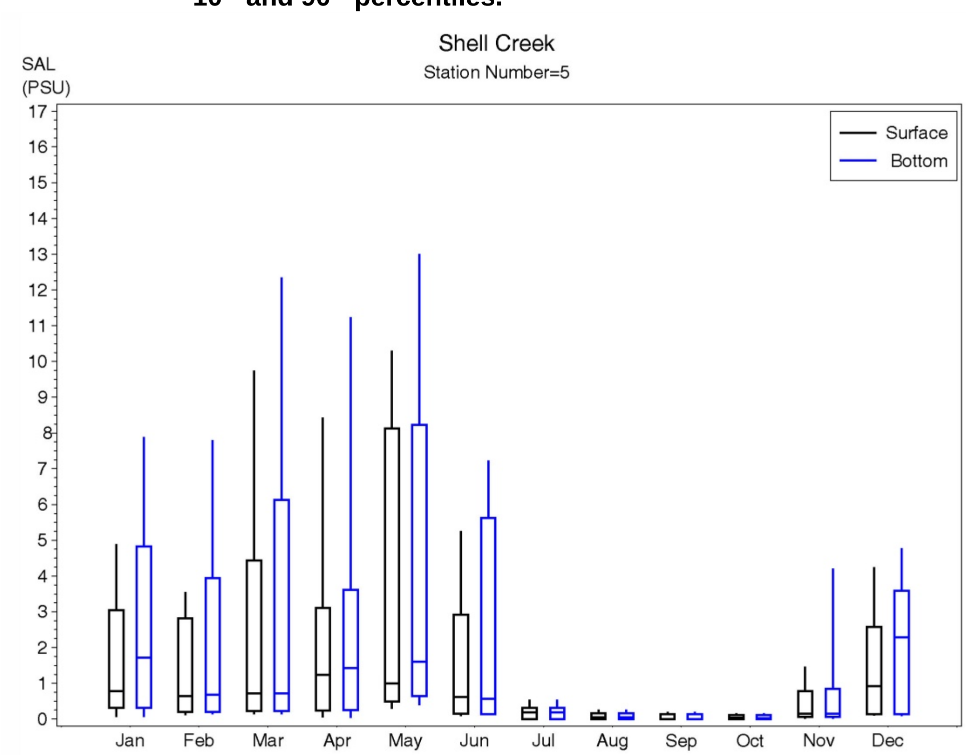


Figure 3-60. Monthly distribution of surface and bottom salinity (1997-2004) at SC Station 5. Boxes represent the 25^{th}, 50^{th}, and 75^{th} percentiles, while whiskers represent the 10^{th} and 90^{th} percentiles.

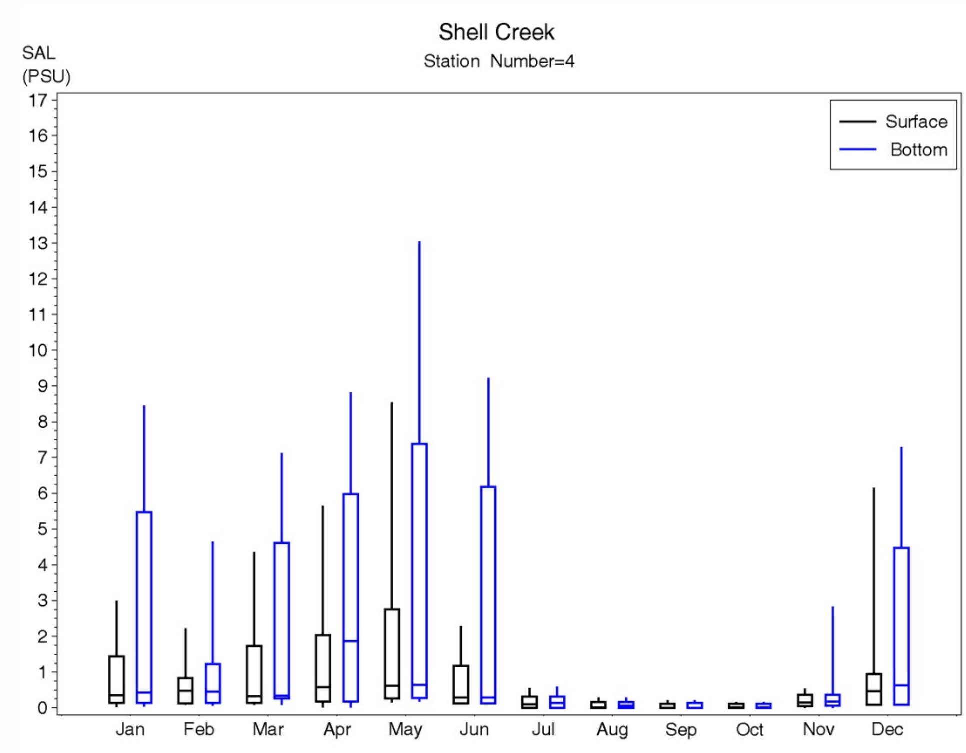


Figure 3-61. **Monthly distribution of surface and bottom salinity (1997-2004) at SC Station 4. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.**

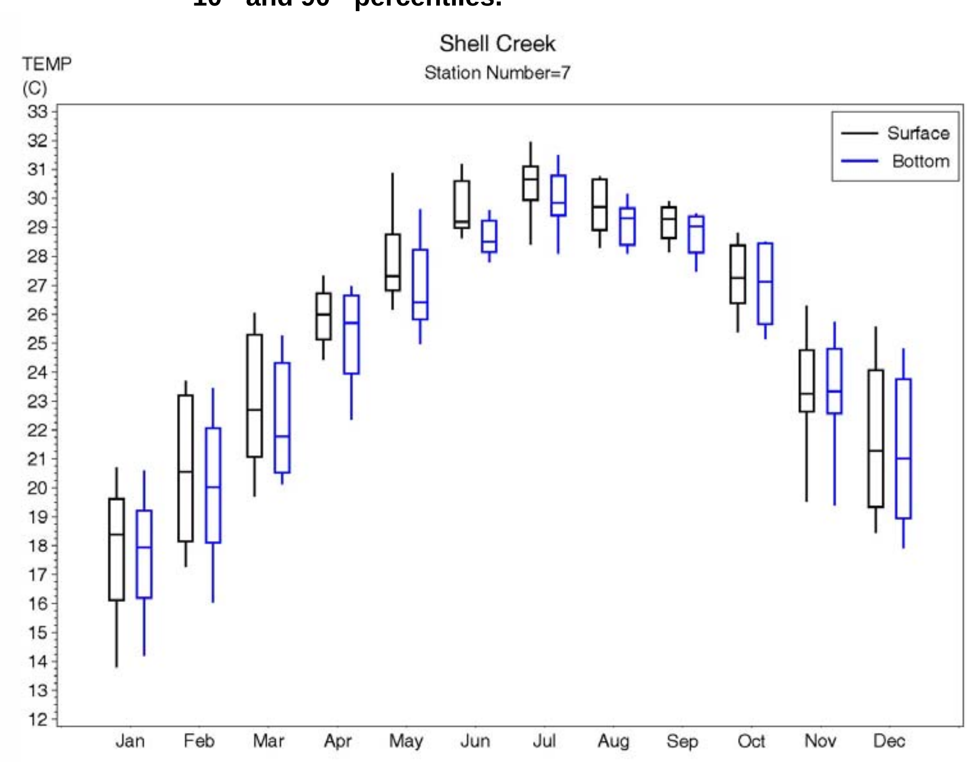


Figure 3-62. **Monthly distribution of surface and bottom temperature (1997-2004) at SC Station 7. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.**

DO showed typical seasonal trends (Figures 3-63 to 3-65), with higher concentrations during cooler months and lower concentrations during warmer months. DO was lower in bottom waters as compared to surface waters for all stations.

Overall, chlorophyll *a* showed spings peaks and summer minima (Figures 3-66 to 3-68). Ths pattern likely reflects a response to freshwater inflow, with higher concentrations occurring during periods of low inflow and low concentrations due to wash-out during periods of high inflow. The monthly median chlorophyll a concentrations ranged from five to 20 μg/L for all stations.

TN concentrations were higher during the wet season months and lower during the dry season (Figures 3-69 to 3-71). The monthly median TN concentrations ranged from one to two mg/L for all stations.

TP concentrations were higher during the wet season months and lower during the dry season (Figures 3-72 to 3-74).

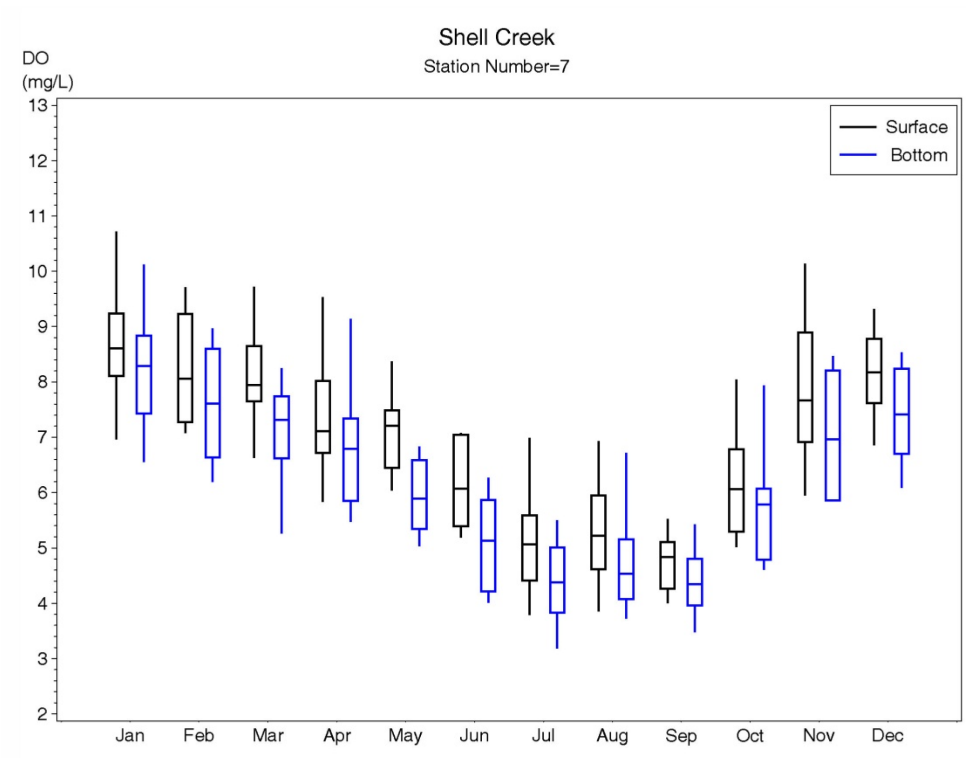


Figure 3-63. Monthly distribution of surface and bottom DO (1997-2004) at SC Station 7. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

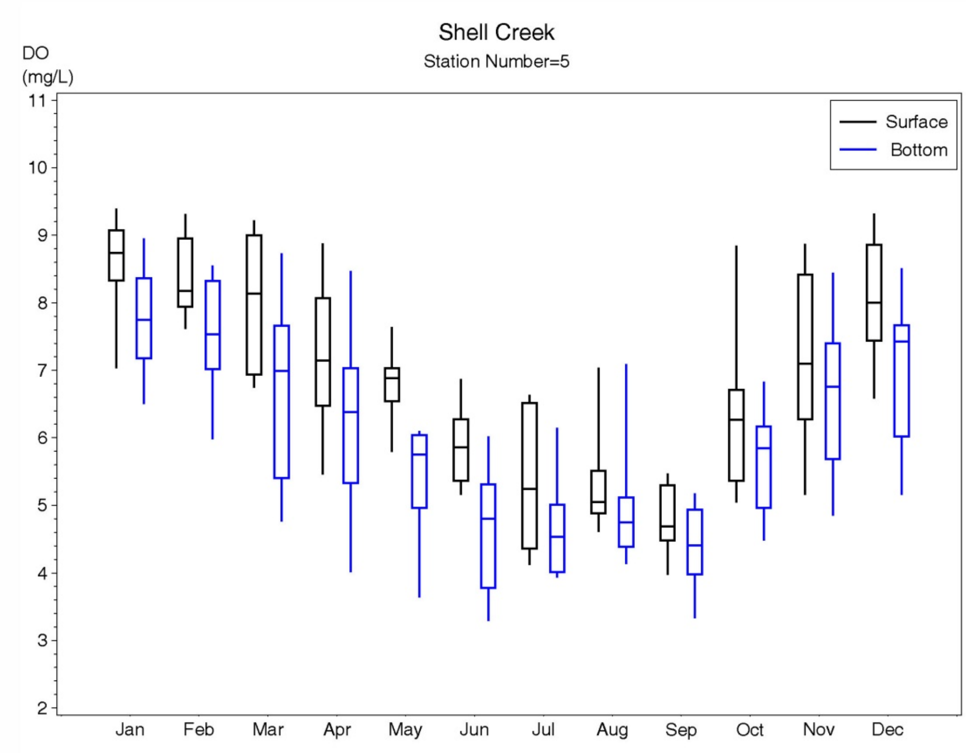


Figure 3-64. **Monthly distribution of surface and bottom DO (1997-2004) at SC Station 5. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.**

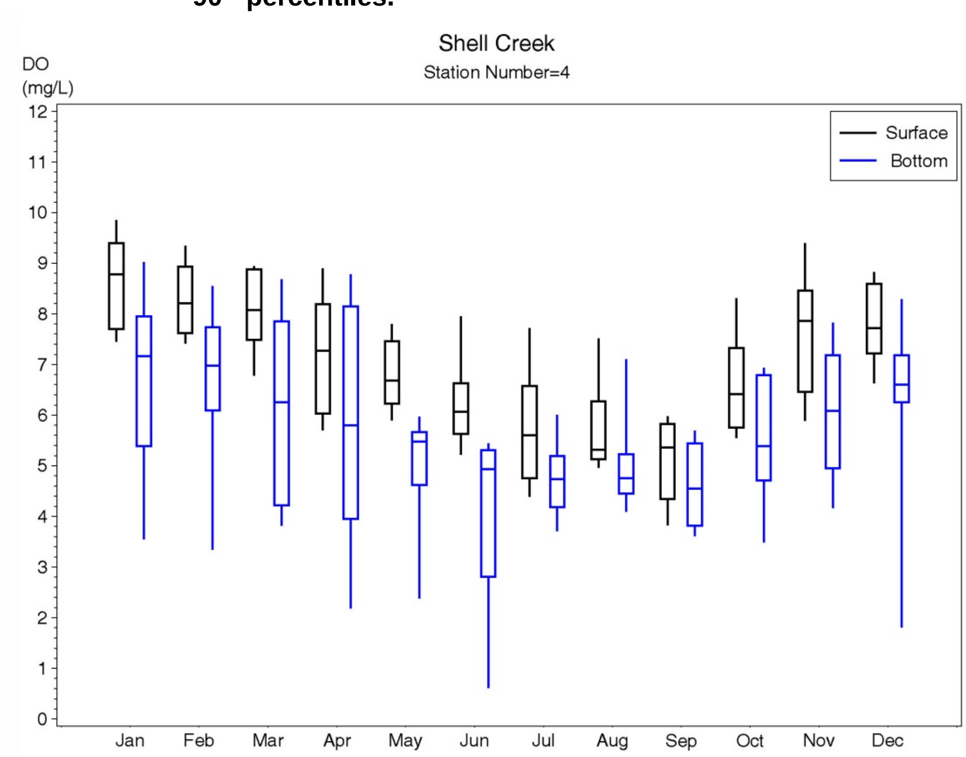


Figure 3-65. **Monthly distribution of surface and bottom DO (1997-2004) at SC Station 4. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.**

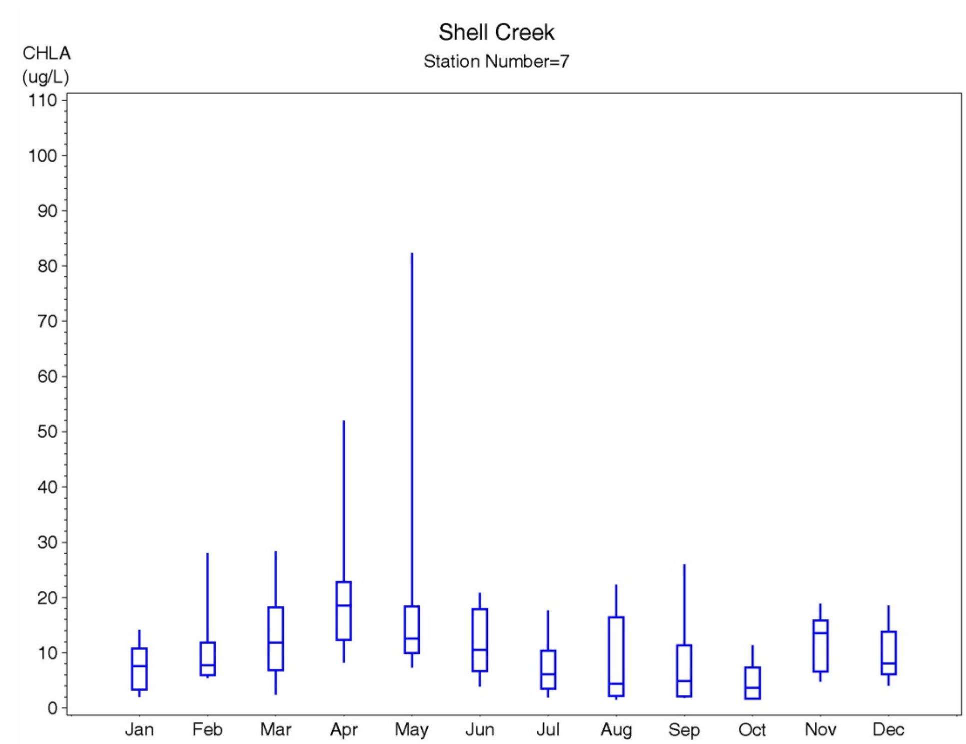


Figure 3-66. Monthly distribution of chlorophyll *a* (1997-2004) at SC Station 7. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

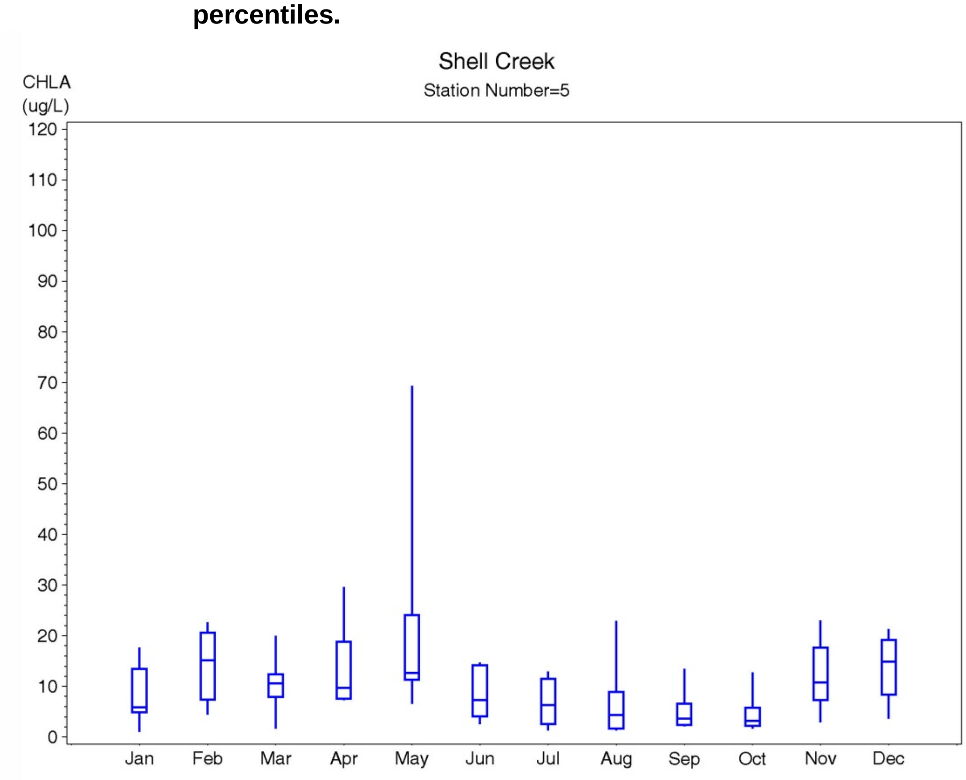


Figure 3-67. Monthly distribution of chlorophyll *a* (1997-2004) at SC Station 5. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

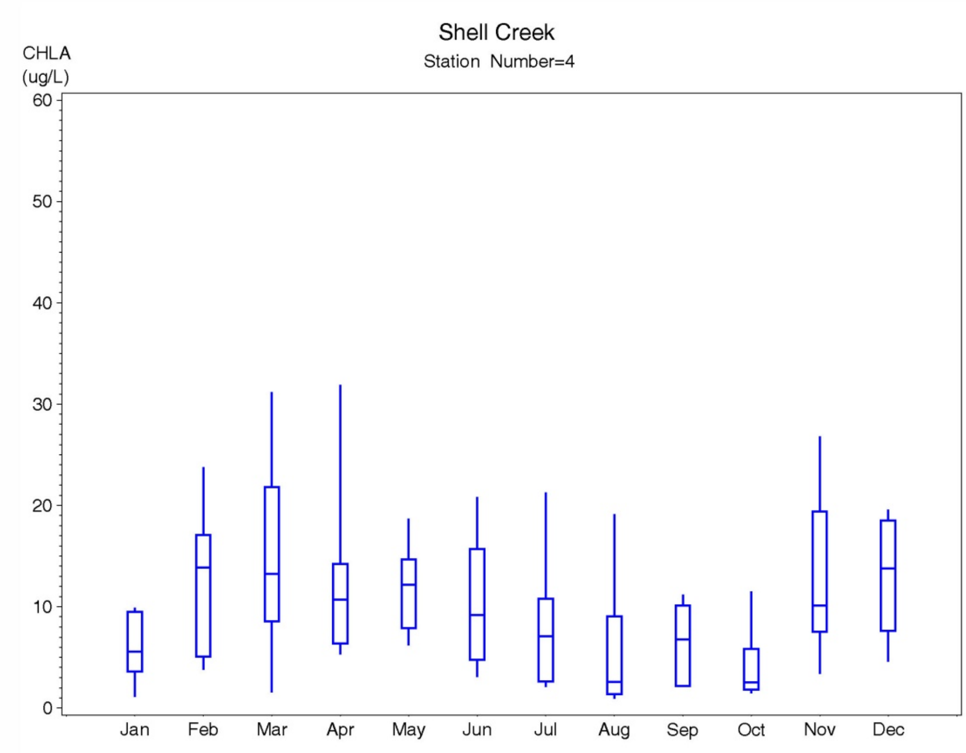


Figure 3-68. Monthly distribution of chlorophyll *a* (1997-2004) at SC Station 4. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

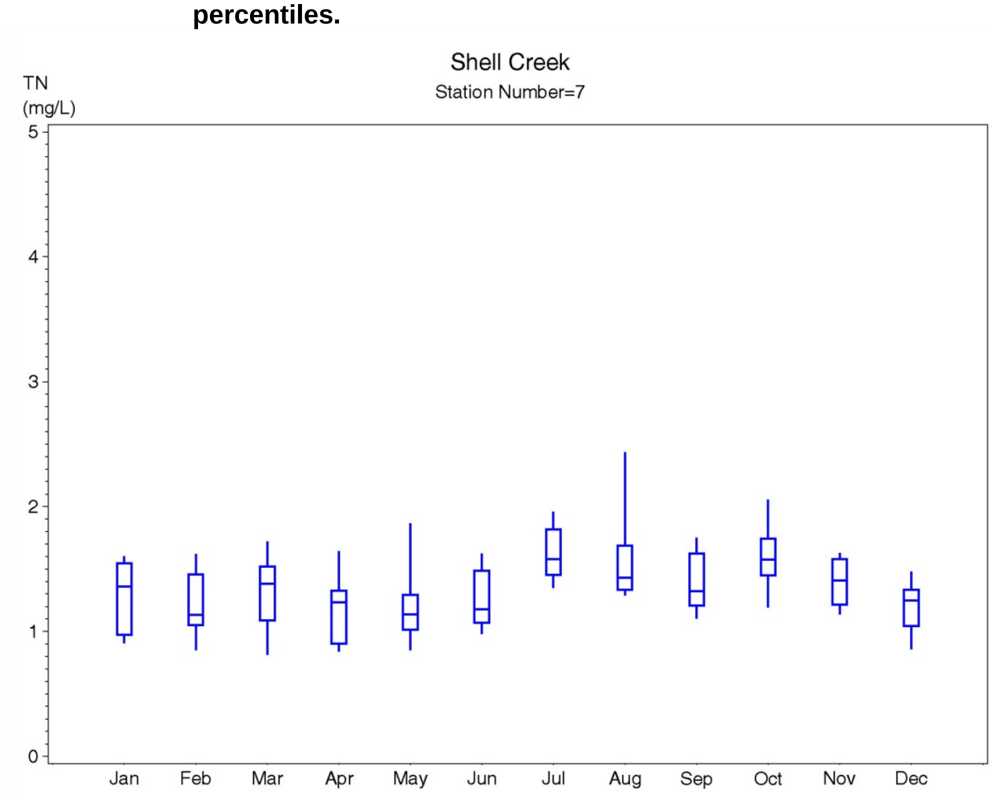


Figure 3-69. Monthly distribution of TN (1997-2004) at SC Station 7. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

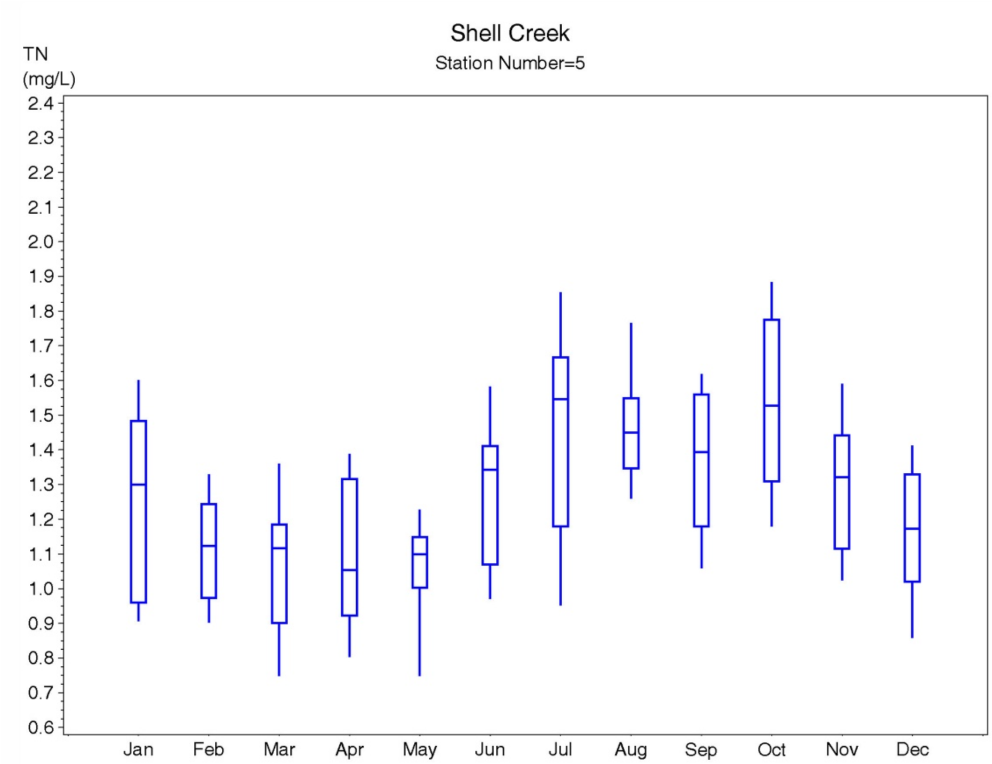


Figure 3-70. Monthly distribution of TN (1997-2004) at SC Station 5. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

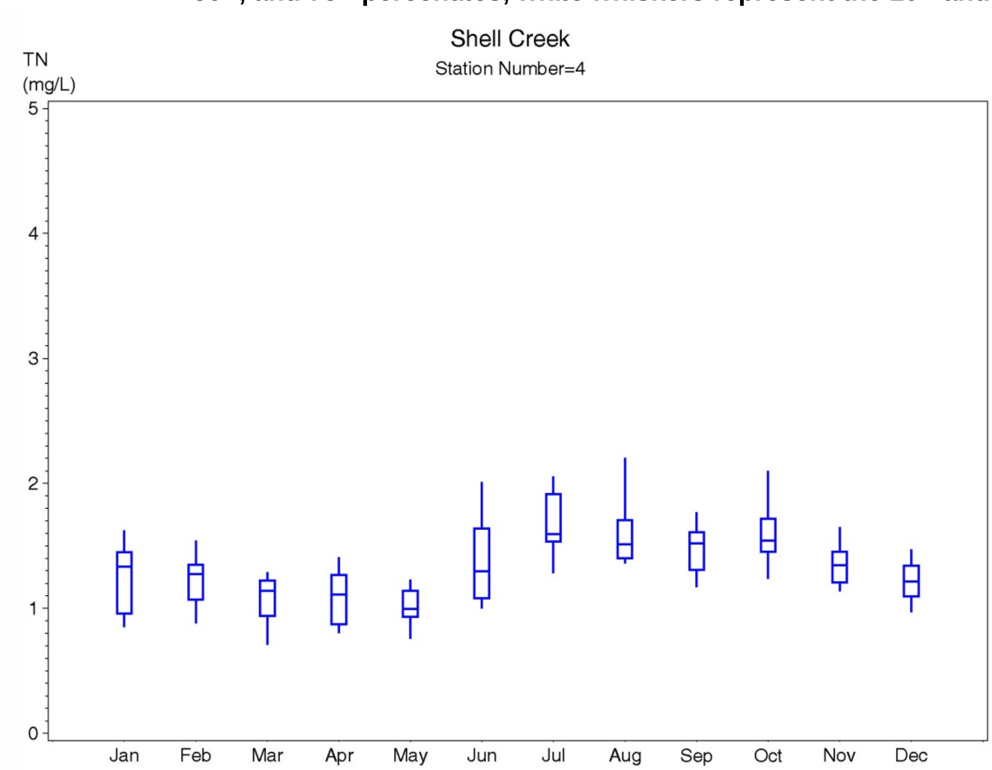


Figure 3-71. Monthly distribution of TN (1997-2004) at SC Station 4. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

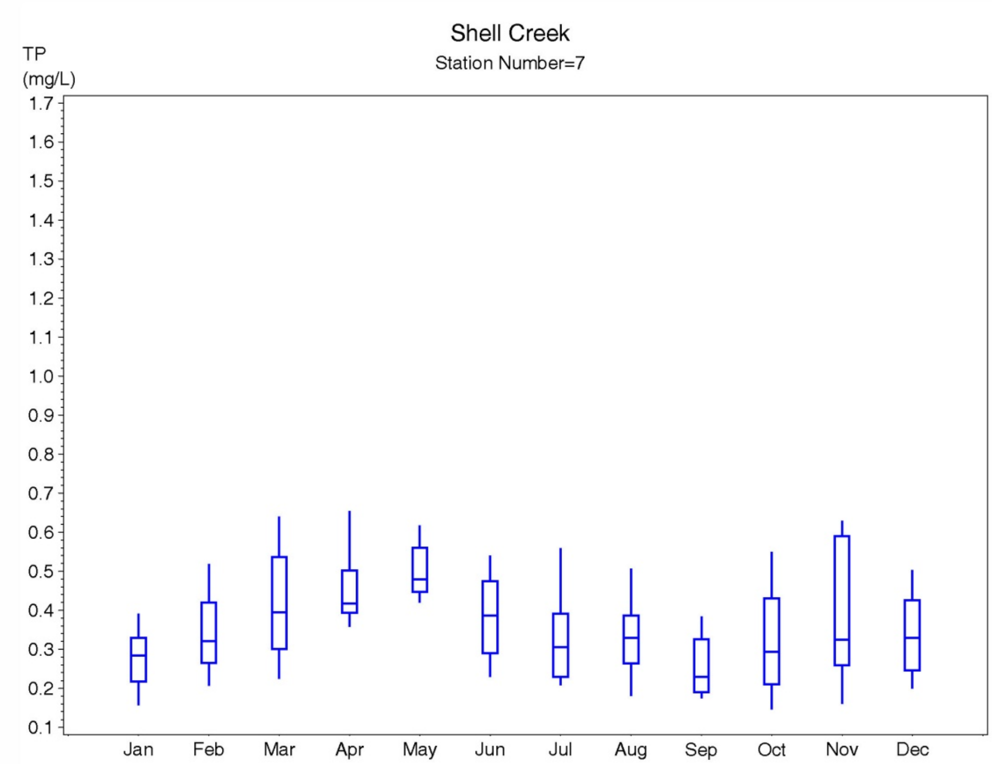


Figure 3-72. Monthly distribution of TP (1997-2004) at SC Station 7. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

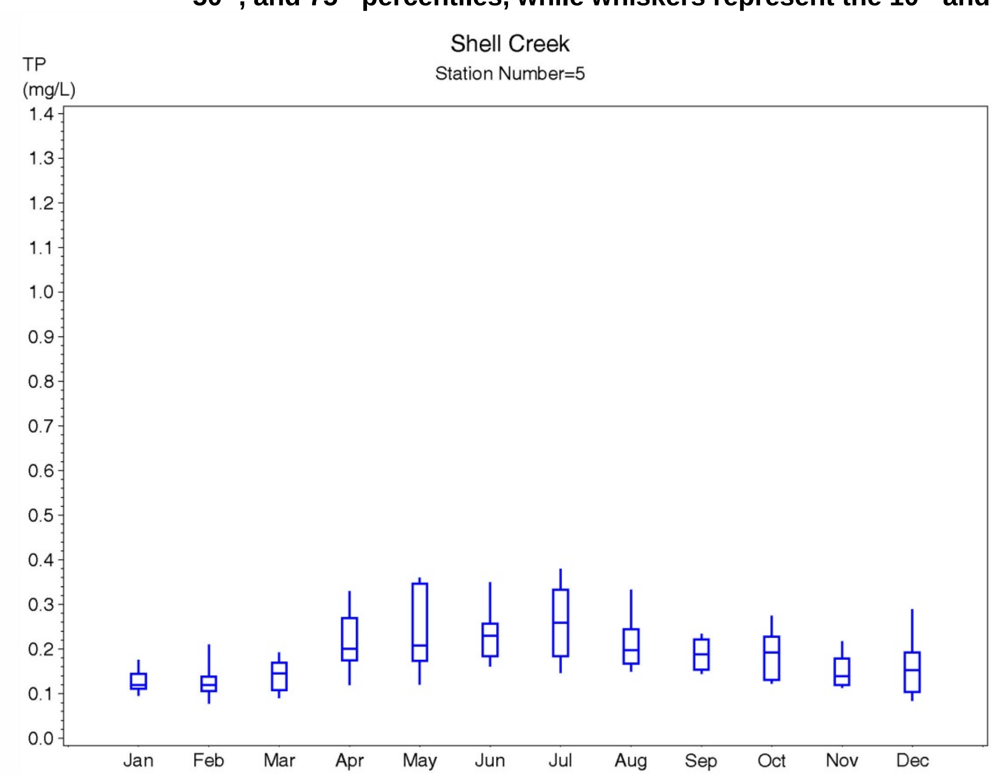


Figure 3-73. Monthly distribution of TP (1997-2004) at SC Station 5. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

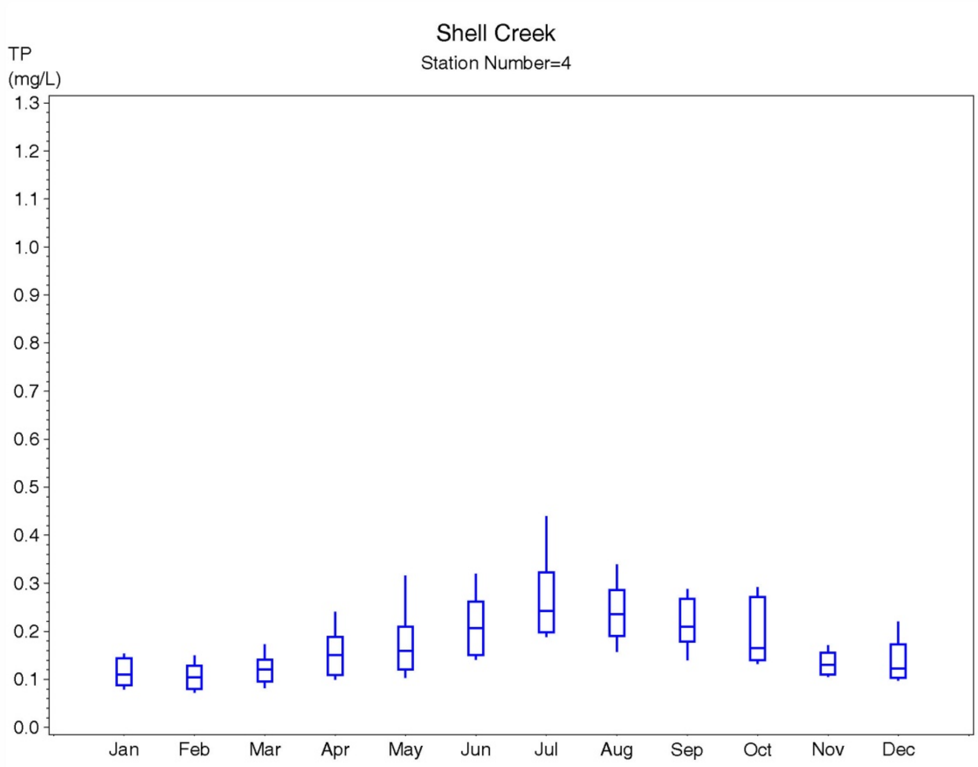


Figure 3-74. Monthly distribution of TP (1997-2004) at SC Station 4. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

3.2.2.3 Spatial Variation in Water Quality Constituents

To describe the spatial variation in water quality constituents, plots are presented by river kilometer for all stations for all years (1997-2004).

As expected, salinity values decreased with distance upstream. Typical estuarine circulation resulted in lower salinities in surface water and higher salinities in bottom water. Salinity differences between surface and bottom water decreased as tidal influence decreased (Figures 3-75). The distribution of temperature values was observed to be relativity similar throughout SC. The longitudinal distribution of temperature observations over the geographic domain of the LPR is presented in Figure 3-76. Temperature was slightly lower in bottom waters for the majority of stations. The longitudinal distribution of DO over the geographic domain of SC is shown in Figure 3-77. Bottom waters had slightly lower DO than surface water and DO did not show large variations among stations.

The distribution of chlorophyll *a* concentrations did not vary spatially (Figure 3-78). TN concentrations did not vary with distance upstream (Figure 3-79). TP concentrations decreased with distance upstream, as shown in Figure 3-80. Higher concentrations downstream result from higher ambient TP concentrations in LPR relative to SC.

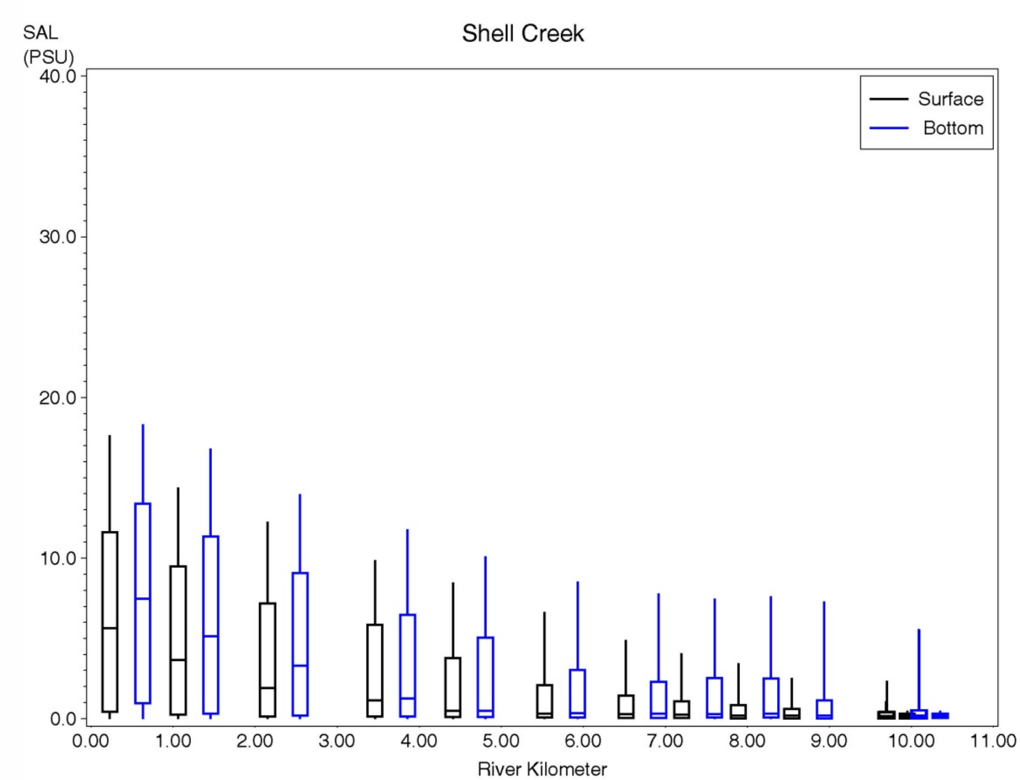


Figure 3-75. Observed longitudinal distributions of salinity for the SC.

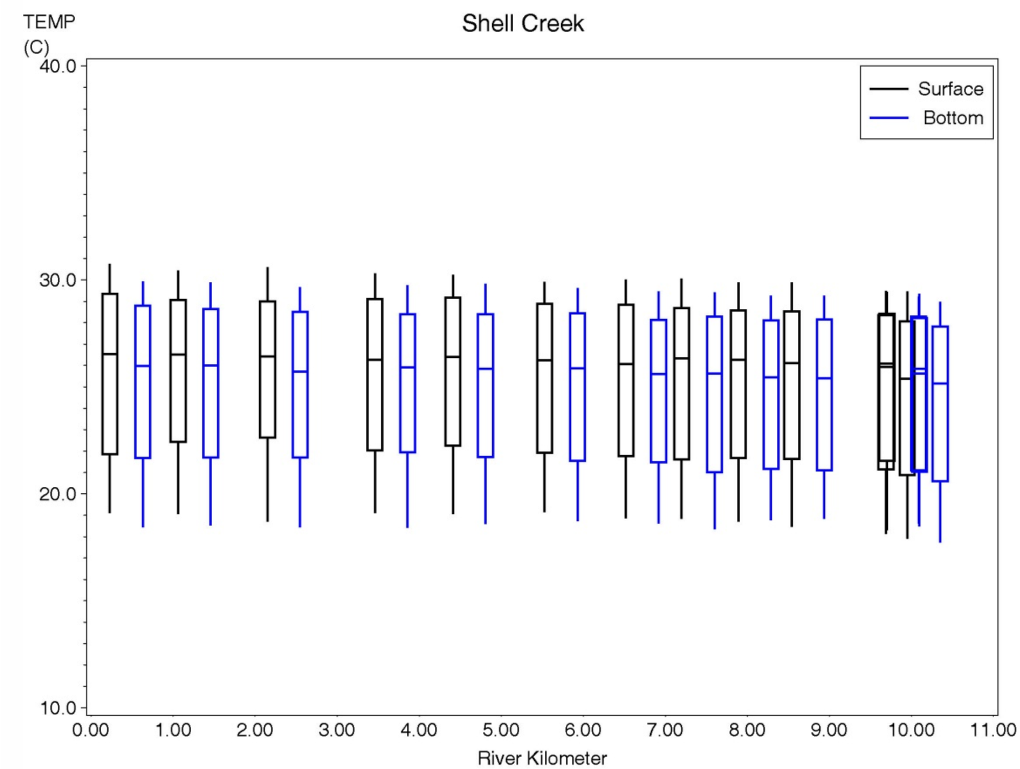


Figure 3-76. Observed longitudinal distributions of temperature for the SC.

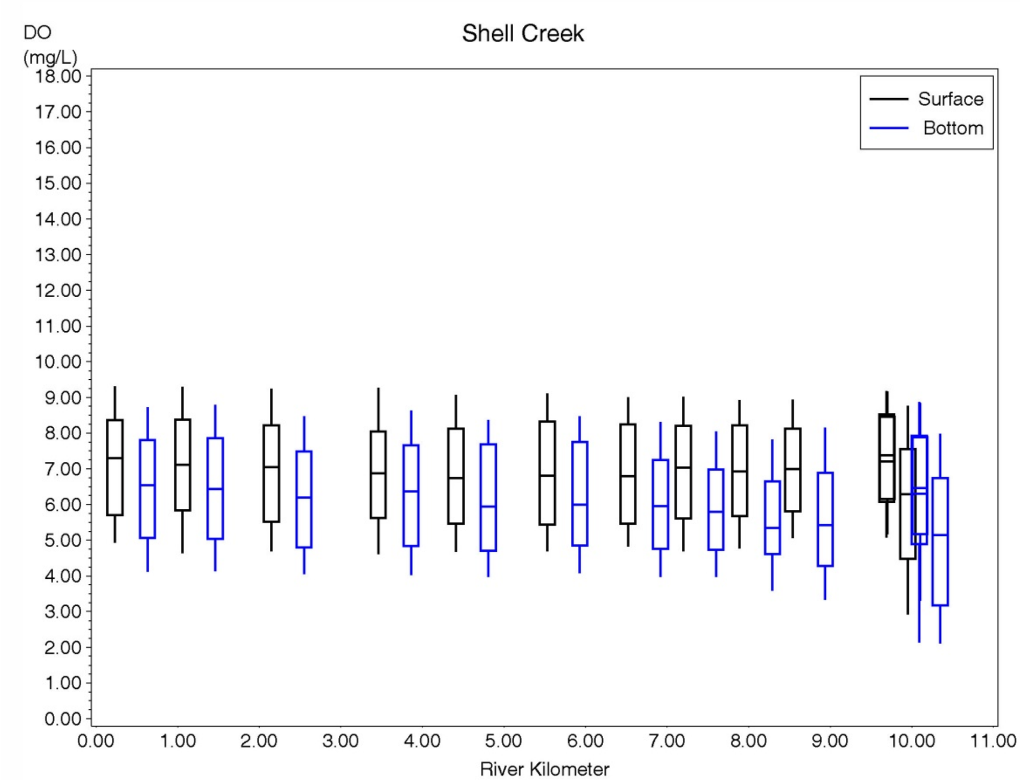


Figure 3-77. Observed longitudinal distributions of DO for the SC.

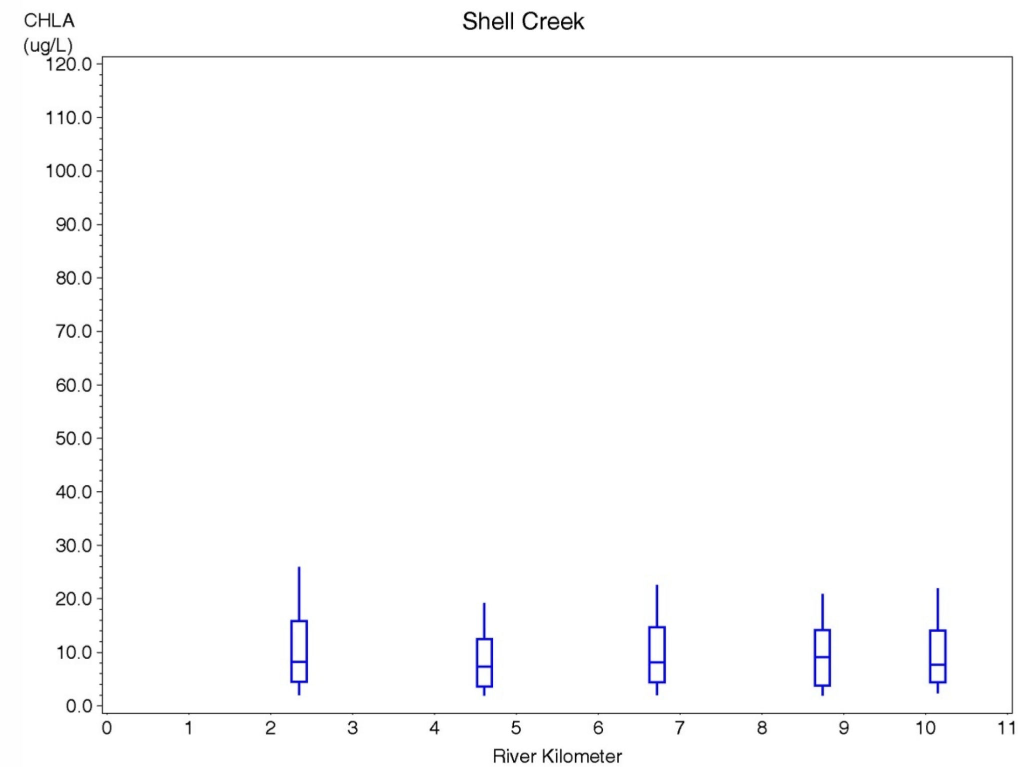


Figure 3-78. Observed longitudinal distributions of chlorophyll *a* for the SC.

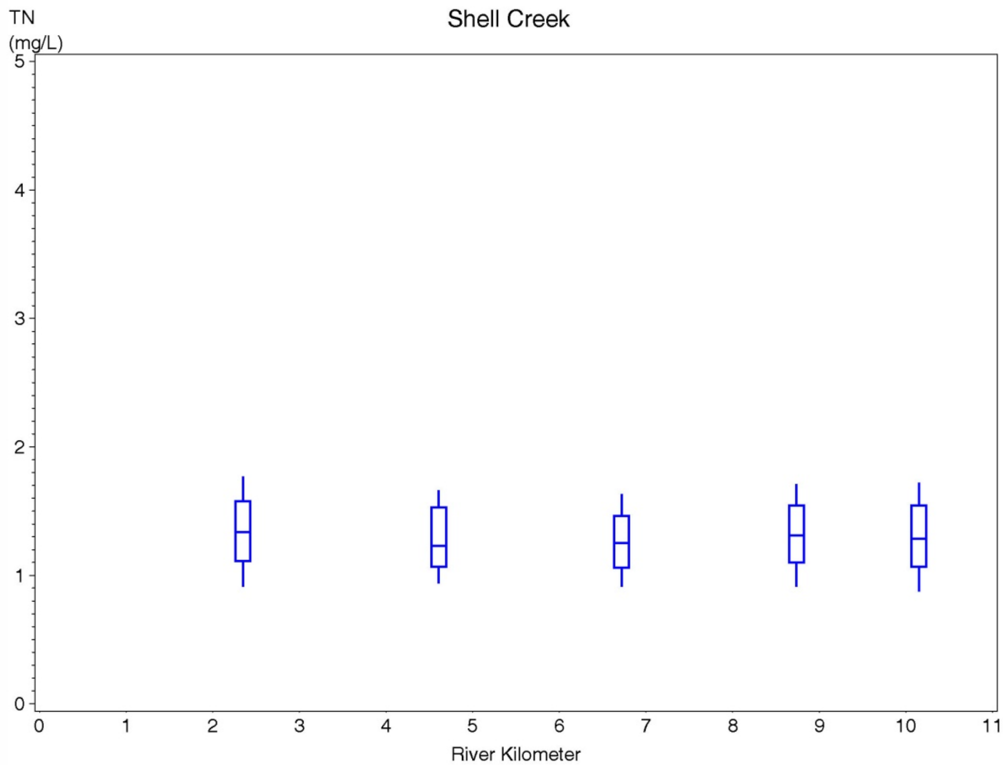


Figure 3-79. Observed longitudinal distributions of TN for the SC.

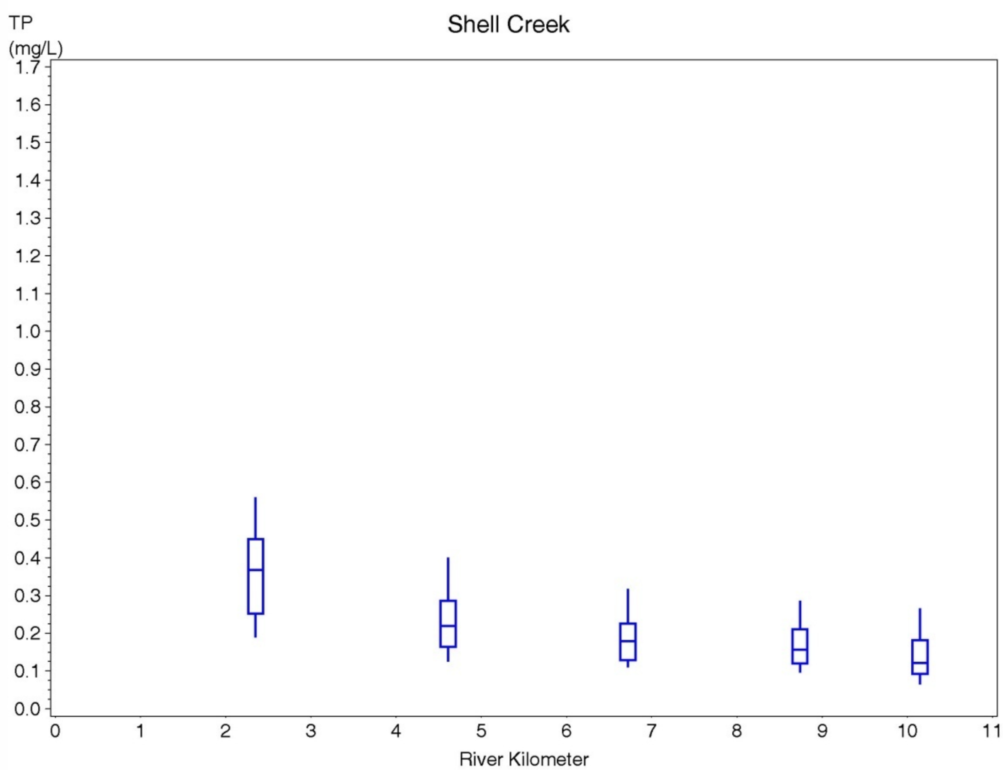


Figure 3-80. Observed longitudinal distributions of TP for the SC.

3.3 Summary of Water Quality Constituents

As expected, surface salinities are lower than bottom salinities and as one moves upstream surface and bottom salinities decrease. The channel of Shell Creek is a braided near it confluence with the Peace River (Figure 2-26). The mouth of the creek is located near rkm 13, but marshes and side channels associated with the creek intersect the river system upstream to near rkm 15. As a result, salinity in the ten kilometer reach of Shell Creek from its mouth to the Hendrickson dam are similar to salinity values in the Peace River from near rkm 14 to near rkm 25 As with salinity, DO in SC is similar to DO in LPR between rkm 14 and rkm 25. As anticipated, there is a general trend in both systems of higher DO concentrations in surface waters compared to bottom waters. The lowest DO concentrations were observed in the bottom water of LPR downstream of rkm ten.

Chlorophyll *a* concentrations were slightly lower in SC compared to LPR. The highest chlorophyll *a* concentrations were documented in the LPR at the confluence of SC. TN concentrations in LPR are more variable than those in SC and increase in the upstream direction. The lowest TN concentrations were documented in the downstream portion of LPR. TP concentrations in SC are generally lower than TP concentrations in LPR. For LPR, as with TN, TP concentrations increase in the upstream direction. In SC, TP concentrations decrease in the upstream direction.

4 BENTHIC MACROINVERTEBRATE COMMUNITY

Benthic macroinvertebrates are important living resources that can be sensitive to changes in flow regimes, and their relationship to flow is explored in this section. Flow is an influential component of estuarine and riverine systems, and changes to the flow regime can potentially affect many ecological and environmental variables (Figure 4-1). Flow affects the volume and velocity of the river, which directly affects benthos. During extremely high flows, benthic organisms may be physically washed out of the system. The transport of macroinvertebrates, known as "drift", is important as a mechanism for the establishment of new populations downstream (Benson and Pearson 1987, Matthaei *et al.* 1997). Aquatic drift can reduce overcrowding and facilitate feeding. Additionally, flow affects the following abiotic parameters, which influence the abundance and distribution of benthos: salinity, dissolved oxygen, sediments, and nutrients.

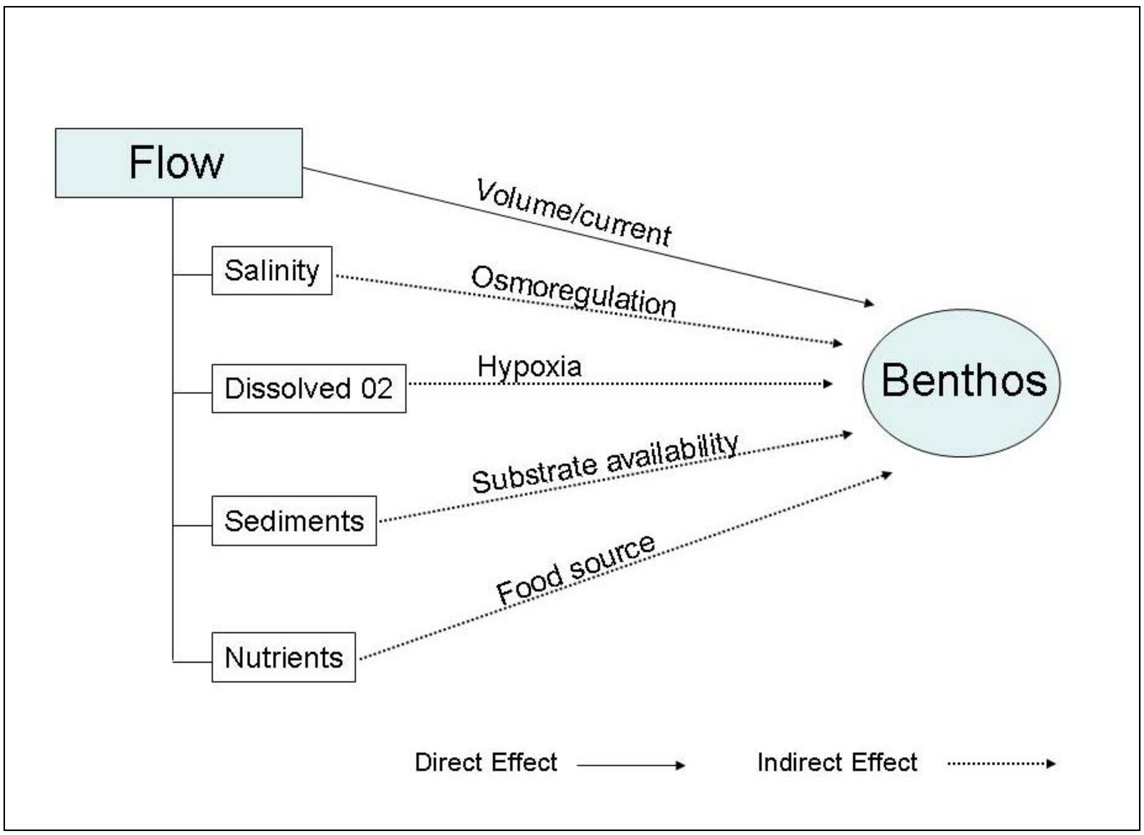


Figure 4-1. Conceptual diagram showing the direct (solid line) and indirect (dashed line) effects of flow on benthos.

Salinity is considered to be the primary physical factor that affects the biota of tidal rivers. In a tidal system, the salinity gradient will shift upstream or downstream due to natural variations in flow. Salinity is largely influenced by the amount of fresh-water inflow entering the system, and it is typically negatively correlated with flow in tidal rivers. A secondary contributor to fresh water in an estuarine system is precipitation.

During high flow periods, salinity at a particular location is expected to be lower than during an average or low flow year, expanding the habitat available for freshwater and oligohaline organisms. During low flow periods, saline water may extend further upstream, facilitating habitat expansion for estuarine species while contracting the habitat available for freshwater organisms (Alber 2002).

Many benthic species are limited in range by the physiological challenges and stresses associated with variable salinity environments. Osmotic limitations restrict the ability of many freshwater species from using habitats in downstream portions that are tidally influenced. Marine species also face osmotic problems, which restrict access to low salinity and fresh-water habitats. Estuarine species typically tolerate a wide range of salinities, although they may have discrete "preferences" for optimal reproduction and growth. Salinity is less of an acute stressor and more a chronic stressor for estuarine invertebrates. For example, a common estuarine isopod, *Cyathura polita*, can complete its life cycle over salinities ranging from 0 to 30 ppt, although northern populations are capable of osmoregulation in distilled water for up to 12 hours (Kelly and Burbanck 1976).

Changes in the timing and amount of fresh-water inflow may alter the salinity regime such that shifts in dominant species occur as the physical environment becomes less favorable for some species and more favorable for others. That is, the "preferred" salinity regime may now occur at a different time, in a different location, or occupy a smaller/larger area of the system. For example, the displacement could move a preferred salinity regime to a reach of the river where the sedimentary factors are unfavorable (*cf.* "stationary" *vs.* "dynamic" habitats of Browder and Moore 1981). Since sediment type is also a key abiotic factor affecting the structure of benthic communities, community structure and function could be altered.

Freshwater inflow can affect sediments in both the tidal river and the receiving waters. Current velocity, available source material, and organic input determine substrate composition. The important components of substrate composition are the size of the sediment grains, interstitial space between the grains, and the presence or absence of organic detritus. Typically, coarser grained sediments drop out from the current first, and are deposited furthest upstream. Finer grained sediments are carried further downstream, with the finest sediments being carried the furthest. The translocation of these finer grained sediments provide habitat for emergent vegetation lower in the estuary (Flemer and Champ 2006). Since contaminants such as metals and organic compounds preferentially bind to smaller particles (Seidemann 1991), they may be removed from the estuary at higher flows.

At lower flows, downstream sediment transport is diminished. This may adversely affect habitat availability for emergent vegetation and may contribute to the retention of contaminants in the estuary (Alber 2002). Additionally, if freshwater flows are diminished, tidal currents may displace coarser sediments upstream (Flemer and Champ 2006), altering the physical habitat of benthic organisms. Generally, biotic abundance and diversity increases with increasing substrate stability and the presence of organic detritus (Allan 1995).

The magnitude and timing of fresh-water inflows affect the amount of nutrients and organic matter that enters a waterway. Higher flows are associated with increased nutrient loading and lower nutrient concentrations. Low flows contribute to decreased turbidity, increased water clarity (Alber 2002, Flemer and Champ 2006). Under extreme low flows primary production could even shift from a phytoplankton-based system to one driven by benthic algae (Baird and Heymans 1996). Increased secondary production by benthic organisms is typically observed some time after a period of increased flow (Kalke and Montagna 1989, Bate *et al.* 2002).

Flow can affect dissolved oxygen concentrations in different ways. Decreased flows may increase hydraulic residence times in embayments and backwater regions of tidal rivers which, can interact with the effects of nutrient loading and lead to lowered levels of dissolved oxygen (Figure 4-2). This may also facilitate development of algal blooms, especially cyanobacteria. However, decreased flows may also contribute to increases in dissolved oxygen concentrations. By reducing the amount of density stratified water in the estuary, there is more opportunity for oxygenated surface waters to mix with bottom waters (Alber 2002, Flemer and Champ 2006). Any adverse effects of flow on dissolved oxygen could impact the benthos.

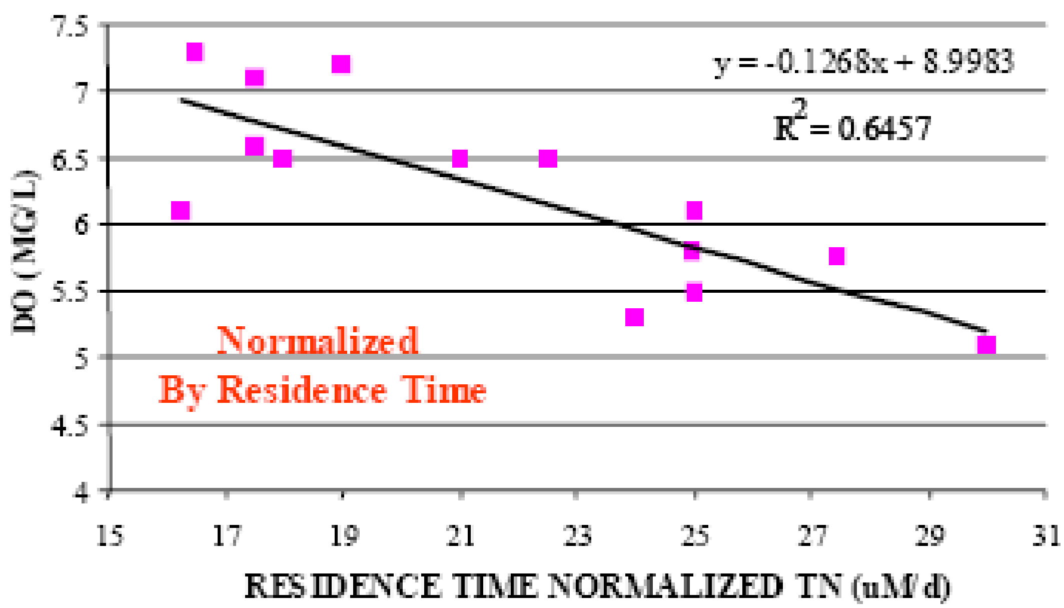


Figure 4-2. The relationship between dissolved oxygen and residence time in embayments of Maine estuaries From: Latimer and Kelly, 2003 (modified from Kelly *et al.* 1997).

The following describes a series of data analyses conducted to assess the benthic community structure of the LPR and SC, with an emphasis on exploring relationships to salinity and freshwater inflows.

4.1 Sources of Benthic Macroinvertebrate Data

Mote Marine Laboratory collected 581 “core” samples from the Lower Peace River during 1998-1999 (Mote Marine Laboratory 2002) and 39 core samples from SC during 2003 (Mote Marine Laboratory 2005) (Table 4-1; Figure 4-3). Estevez (1986) collected benthic samples at 25 stations in Charlotte Harbor in 1980. However, only two stations were located in the area we consider to be the Lower Peace River and a different sampling gear was used. Therefore these earlier data were not included in this report.

Mote Marine Laboratory (2002) divided the Lower Peace River into four longitudinal zones. These zones were based upon an analysis of long-term salinity data. Zone 1 had mean bottom salinities of <0.5 ppt. This Zone extended from river kilometer (RKM) 34 downstream to RKM 21.5. Zone 2 had mean bottom salinities ranging from 0.5 to 8.0 ppt. Zone 2 encompassed rkm 16.0 to 21. Zone 3 had mean bottom salinities ranging from 8.0 to 16.0 ppt. Zone 3 extended from rkm 6 to 15.5. Zone 4 had mean bottom salinities >16 ppt and extended downstream from rkm 6.

The sampling gear was a 7.62-cm (3”) diameter core sampler (area= 45.6 cm^2). Non-quantitative samples were collected with a sweep net and are not considered in this report.

Near-bottom salinity data were available for 540 of these samples. Other abiotic data collected in concert with many of these samples included temperature, pH, dissolved oxygen, and sample depth.

Additional samples were collected for particle size analysis. The sediment data were not incorporated into any quantitative analyses because the sample size was relatively small (n=121) and, for the 1998-1999 Lower Peace River sampling, only the November 1998 samples were analyzed (Mote Marine Laboratory 2002).

Studies of the benthic infauna of the LPR and SC were supplemented with data collection specific to mollusk communities in these systems (Mote Marine Laboratory 2002, 2004). Mollusk communities in both systems showed distinct shifts in species compostion along horizontal salinity gradients. The mollusk sampling involved a different sampling design and filed collection than the benthic infauna, these data were therefore not compiled with the benthic infauna data for further analysis. Many of these mollusk taxa, however, were collected by the infauna sampling cores and those data are included in the analyses presented on the following pages.

4.2 Sample Processing

Core samples for benthic infauna were sieved through a 0.5-mm mesh sieve and fixed with a 10% solution of buffered formalin. Samples were sorted in their entirety and the organisms identified to the lowest practical taxonomic level and counted.

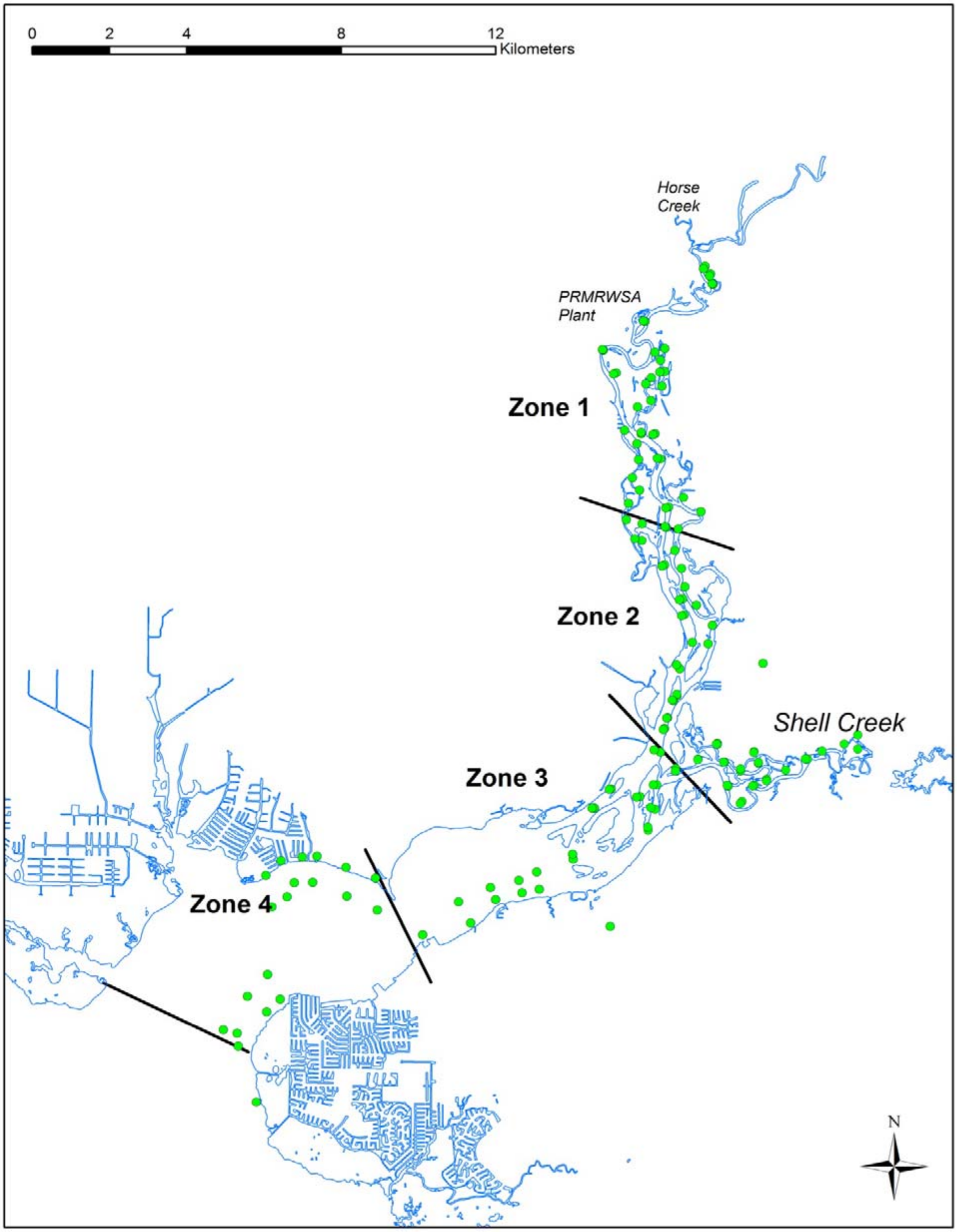


Figure 4-3. Location of benthic sampling stations in the LPR (1998 and 1999) and SC (2003).

Table 4-1. Number of benthic samples collected from the LPR, by river zone and subarea (Mote Marine Laboratory 2002, 2005).

Zone and Subarea	Number of Samples
Peace River Zone 1	95
Lettuce Lake	46
Deep Creek	46
Peace River Zone 2	95
Hunter Creek	49
Peace River Zone 3	100
Peace River Zone 4	100
SAV Sites RKM 0	50
Subtotal: Lower Peace River	581
Shell Creek	39
TOTAL	620

4.3 Data Analysis Objectives

Data were analyzed to satisfy the following objectives:

- Identify the “dominant” benthic taxa within the four previously defined zones (Mote Marine Laboratory 2002) of the LPR and SC;
- Define resource-based salinity classes, based upon the distribution of the benthos, for the LPR, including SC;
- Quantify the spatial characteristics of the structure of the benthos within and between zones of the LPR, including SC, Deep Creek, Hunter Creek, Lettuce Lake, and samples collected from SAV (submerged aquatic vegetation) beds at the mouth of the river;
- Quantify the association between a suite of abiotic variables, including salinity and cumulative flows for the LPR. and three biotic variables:
  - o The abiotic (independent) variables included:
    - Salinity;
    - Cumulative flow over 7, 15, 30, 60, 90, and 180 days preceding sample collection, as well as the flow on each sample date (Montagna and Kalke 1992). The contributions to these flows differed by zone within the river, reflecting contributions not only upstream at Arcadia, but also contributions from Horse Creek (Zones 1 to 4),
  - o The biotic (dependent) variables included:
    - Numbers of taxa;
    - Shannon-Wiener diversity;
    - Benthic standing crop (as total numbers of individuals)

- Determine which abiotic variables, including a large number of flow-related variables, were most highly correlated with multivariate benthic community structure;
- Evaluate the optimum salinity and tolerance ranges for selected taxa in the Lower Peace River.

These analyses should provide insight into the extent to which salinity and flow-related variables affect the composition and structure of the benthos within the Lower Peace River study area.

4.4 Results

4.4.1 Abiotic Characteristics of the Study Area

The 25th percentile salinities were generally similar within zones 1 and 2 of the LPR, including Lettuce Lake, Deep Creek, and Hunter Creek (Table 4-2a). The 75th percentile salinities increased moving downstream. Salinity in Zones 3 and 4 were typically in the mesohaline to polyhaline ranges of the Venice classification. Dissolved oxygen concentrations were typically >4 ppm throughout the study area (Table 4-2). pH values were generally circumneutral except in Zone 4 (slightly alkaline) (Table 4-2a). Sediments within Zone 1 had the lowest median percentage of fine-grained particles (silt+clay) and those in Zone 3 had the highest (Table 4-2a).

Salinities in SC were oligohaline and, therefore, more similar to those of Zones 1 and 2 (Table 4-2b). There was no evidence of hypoxia during the single sampling event in SC, and pH was slightly acidic.

4.4.2 Taxonomic Composition and Dominance

At least 176 distinct taxa have been identified from benthic collections in the LPR and SC combined (Appendix 4-1). Approximately 40 of these taxa (23%) are generally considered fresh water or tolerant of very low salinities (*e.g.*, chironomid larvae, some oligochaetes).

“Dominance” was calculated as the geometric mean of a taxon's Percent Occurrence and Percent Composition. This metric integrates a measure of how widespread an organism is in the study area (Percent Occurrence) with its contribution to the overall standing crop (Percent Composition). “Dominant taxa” (Table 4-3a) of the Lower Peace River varied between the previously defined zones.

Dominant taxa *within* Zone 1 were predominantly freshwater taxa that can tolerate low salinities. These include the invasive bivalve *Corbicula fluminensis*, hydrobiid gastropods and larvae of chironomids (Table 4-3a). Estuarine taxa such as some amphipods were more highly ranked in Deep Creek and the Peace River proper, than in Lettuce Lake.

Table 4-2. Median (interquartile ranges) of selected abiotic variable, by zone (Mote Marine Laboratory 2002) and subarea of the LPR and SC.

A. Lower Peace River

	Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (ppm)	pH	% Silt+Clay	Depth (m)
Peace River Zone 1	27.2 (22.0-28.1)	0.2 (0.1-0.4)	5.9 (5.2-6.6)	7.14 (6.86-7.25)	1.2 (0.0-17.5)	0.6 (0.3-1.4)
Lettuce Lake	26.6 (21.8-26.8)	0.2 (0.2-1.2)	5.5 (4.5-6.5)	7.08 (6.85-7.15)	No Data	0.5 (0.2-0.7)
Deep Creek	26.4 (22.0-27.8)	0.2 (0.2-6.2)	5.9 (4.5-6.6)	7.09 (6.66-7.18)	2.2 (0.8-14.6)	1.4 (0.3-1.6)
Peace River Zone 2	27.6 (22.3-28.4)	1.2 (0.2-15.2)	6.0 (4.6-6.4)	7.07 (6.86-7.51)	12.0 (5.4-21.2)	0.6 (0.2-1.7)
Hunter Creek	27.0 (22.9-28.2)	0.3 (0.2-7.9)	6.0 (5.3-6.3)	7.07 (6.79-7.23)	4.2 (3.3-23.6)	0.8 (0.2-1.4)
Peace River Zone 3	27.0 (22.9-28.2)	17.7 (7.0-22.2)	6.0 (4.7-6.7)	7.52 (7.24-7.70)	9.9 (7.4-16.2)	1.0 (0.2-1.8)
Peace River Zone 4	26.2 (22.7-28.6)	25.9 (21.5-27.9)	6.9 (5.4-7.8)	7.71 (7.60-7.84)	6.2 (4.6-16.6)	0.6 (0.1-1.7)
SAV Sites	No Data	No Data	No Data	No Data	5.4 (4.8-6.0)	No Data

B. Shell Creek

Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (ppm)	pH	% Silt+Clay	Depth (m)
29.8 (28.9-30.5)	1.3 (0.7-2.7)	5.3 (4.5-6.2)	6.82 (6.60-6.93)	6.4 (4.0-10.0)	2.9 (2.0-5.7)

Within Zone 2, including Hunter Creek, estuarine taxa were included among the more highly ranked dominants (Table 4-3a). Examples include the amphipods *Apocorophium lacustre* and *Grandidierella bonnieroides*. Some freshwater taxa (e.g., chironomid larvae) were also ranked.

Estuarine taxa predominated within Zone 3 in the Lower Peace River proper (Table 4-3a). Unlike Zone 2, bivalves (*Mulinia lateralis*, *Amygdalum papyrium*, and *Polymesoda caroliniana*) were more highly ranked. Amphipods were less important in Zone 3 than in Zone 2.

Freshwater taxa were not among the ranked dominants in Zone 4 (Table 4-3a). Bivalves and crustaceans remained highly ranked in Zone 4 and both polychaetes and amphipods were dominants in the SAV sites.

Dominants in SC (Table 4-3b) included *Polymesoda caroliniana, Grandidierella bonnieroides*, and hydrobiid gastropods.

Table 4-3. Median (interquartile ranges) of selected abiotic variable, by zone (Mote Marine Laboratory 2002) and subarea of the LPR and SC.

A. Lower Peace River

A-1 Peace River Zone 1, Lettuce Lake, and Deep Creek

Lower Peace River Zone 1	%Comp	%OCC	Dom		Lettuce Lake	%Comp	%OCC	Dom		Deep Creek	%Comp	%OCC	Dom
Corbicula fluminea	17.06	65.26	33.37		*Cladotanytarsus*	19.47	41.30	28.36		*Apocorophium lacustre*	22.57	56.52	35.72
Cladotanytarsus	15.69	43.16	26.02		*Hydrobiidae*	9.60	54.35	22.84		*Cladotanytarsus*	10.22	39.13	20
Gammarus cf tigrinus	11.46	47.37	23.29		*Apocorophium lacustre*	15.02	28.26	20.60		*Hydrobiidae*	8.77	41.3	19.04
Apocorophium lacustre	14.82	35.79	23.03		*Corbicula fluminea*	9.60	32.61	17.69		*Gammarus cf tigrinus*	5.88	50	17.14
Hydrobiidae	9.57	45.26	20.81		*Polypedilum scalaenum group*	7.09	32.61	15.21		*Corbicula fluminea*	8.26	32.61	16.41
Grandidierella bonnieroides	7.33	30.53	14.96		*Polypedilum halterale group*	3.89	43.48	13.01		*Grandidierella bonnieroides*	6.39	41.3	16.24
Polypedilum scalaenum group	3.37	30.53	10.14		*Gammarus cf tigrinus*	4.66	34.78	12.73		*Tanytarsus*	4.86	30.43	12.16
Tanytarsus	1.86	29.47	7.40		*Grandidierella bonnieroides*	5.22	23.91	11.17		*Polypedilum scalaenum group*	4.51	26.09	10.85
Polypedilum halterale group	2.13	21.05	6.70		*Tanytarsus*	2.78	32.61	9.52		*Polypedilum halterale group*	3.75	30.43	10.68
Chironomidae	1.24	25.26	5.60		*Chironomidae*	2.92	28.26	9.09		*Laeonereis culveri*	3.24	34.78	10.61
Laeonereis culveri	1.54	20.00	5.54		*Laeonereis culveri*	2.99	23.91	8.46		*Coelotanypus*	2.39	28.26	8.21
Apocorophium louisianum	1.70	12.63	4.63		*Tanytarsus sp*	2.29	21.74	7.06		*Apocorophium louisianum*	2.39	15.22	6.02
Chironomus	1.21	12.63	3.91		*Stictochironomus*	1.67	28.26	6.87		*Edotea montosa*	1.62	21.74	5.93
Taphromysis bowmani	0.78	16.84	3.63		*Coelotanypus*	1.25	28.26	5.95		*Chironomus*	1.79	19.57	5.92
Cryptochironomus	0.57	17.89	3.18		*Chironomus*	1.53	13.04	4.47		*Tanytarsus sp o*	1.79	17.39	5.58
Ceratopogonidae	0.51	15.79	2.84		*Fissimentum*	0.97	19.57	4.36		*Amakusanthura magnifica*	1.53	17.39	5.16
Edotea montosa	0.57	11.58	2.56		*Stempellina*	0.83	17.39	3.81		*Procladius*	1.36	19.57	5.16
Polymesoda caroliniana	0.51	12.63	2.54		*Dicrotendipes*	1.46	8.70	3.56		*Fissimentum sp*	1.19	17.39	4.55
Procladius	0.54	10.53	2.38		*Procladius*	0.56	17.39	3.11		*Cryptochironomus*	0.85	19.57	4.08
Coelotanypus	0.49	10.53	2.26		*Edotea montosa*	1.04	8.70	3.01		*Chironomidae*	0.85	17.39	3.85

A-2 Peace River Zone 2 and Hunter Creek

Lower Peace River Zone 2	%Comp	%OCC	Dom		Hunter Creek	%Comp	%OCC	Dom
Apocorophium lacustre	31.99	47.37	38.93		*Grandidierella bonnieroides*	19.00	59.18	33.53
Grandidierella bonnieroides	11.75	44.21	22.79		*Apocorophium lacustre*	19.64	40.82	28.31
Ampelisca abdita	8.17	29.47	15.52		*Hydrobiidae*	7.18	40.82	17.11
Hydrobiidae	5.07	42.11	14.61		*Laeonereis culveri*	5.15	53.06	16.53
Polypedilum scalaenum group	3.80	55.79	14.56		*Streblospio gynobranchiata*	7.22	28.57	14.36
Laeonereis culveri	3.60	57.89	14.43		*Apocorophium louisianum*	8.10	24.49	14.08
Apocorophium louisianum	5.57	29.47	12.81		*Hobsonia florida*	3.59	40.82	12.10
Streblospio gynobranchiata	3.14	38.95	11.05		*Edotea montosa*	2.58	38.78	9.99
Cyclaspis cf varians	3.03	26.32	8.92		*Polymesoda caroliniana*	3.63	26.53	9.82
Edotea montosa	2.47	30.53	8.69		*Polypedilum scalaenum group*	2.07	32.65	8.22
Corbicula fluminea	3.25	23.16	8.67		*Gammarus cf tigrinus*	1.98	24.49	6.96
Polymesoda caroliniana	2.36	27.37	8.04		*Coelotanypus*	1.56	28.57	6.68
Amakusanthura magnifica	1.59	31.58	7.08		*Amygdalum papyrium*	3.08	10.20	5.61
Hobsonia florida	1.38	32.63	6.72		*Polydora ligni*	2.99	8.16	4.94
Amygdalum papyrium	2.36	18.95	6.69		*Corbicula fluminea*	1.29	16.33	4.59
Gammarus cf tigrinus	1.83	17.89	5.72		*Amakusanthura magnifica*	0.78	24.49	4.38
Polydora ligni	1.51	17.89	5.20		*Chironomus*	0.78	20.41	3.99
Cryptochironomus	0.81	26.32	4.62		*Rangia cuneata*	1.15	12.24	3.75
Tagelus plebeius	0.70	17.89	3.54		*Ampelisca abdita*	0.92	10.20	3.06
Almyracuma proximoculi	0.85	14.74	3.54		*Ceratopogonidae*	0.41	14.29	2.43

A-3 Peace River Zone 3

Lower Peace River Zone 3	%Comp	%OCC	Dom
Mulinia lateralis	25.71	52.00	36.56
Cyclaspis cf varians	19.63	58.00	33.75
Amygdalum papyrium	10.96	61.00	25.85
Ampelisca abdita	10.74	47.00	22.47
Streblospio gynobranchiata	5.11	48.00	15.67
Polymesoda caroliniana	2.95	30.00	9.41
Assiminea succinea	3.65	24.00	9.36
Laeonereis culveri	1.80	36.00	8.06
Nereis succinea	1.27	36.00	6.77
Amakusanthura magnifica	1.26	28.00	5.94
Polypedilum scalaenum group	1.20	27.00	5.70
Apocorophium lacustre	2.19	13.00	5.34
Tagelus plebeius	1.05	27.00	5.31
Hobsonia florida	1.37	17.00	4.83
Grandidierella bonnieroides	0.95	24.00	4.76
Edotea montosa	0.83	24.00	4.46
Almyracuma proximoculi	0.63	15.00	3.07
Pectinaria gouldii	0.43	19.00	2.86
Cryptochironomus	0.36	18.00	2.54
Capitella capitata complex	0.57	11.00	2.51

A-4 Peace River Zone 4 and SAV Sites

Lower Peace River Zone 4	%Comp	%OCC	Dom		Lower Peace River SAV Sites	%Comp	%OCC	Dom
Cyclaspis cf varians	16.68	60.00	31.64		*Capitella capitata complex*	53.91	40.00	46.44
Ampelisca abdita	13.05	65.00	29.13		*Nereis succinea*	6.60	50.00	18.17
Mulinia lateralis	6.76	53.00	18.93		*Ampelisca abdita*	5.15	58.00	17.28
Capitella capitata complex	9.65	36.00	18.63		*Cymadusa compta*	4.31	40.00	13.13
Mysella planulata	9.87	34.00	18.32		*Erichthonius brasiliensis*	4.25	36.00	12.36
Amygdalum papyrium	5.27	54.00	16.87		*Mulinia lateralis*	2.82	30.00	9.20
Nereis succinea	4.98	39.00	13.93		*Streblospio gynobranchiata*	2.73	22.00	7.75
Oxyurostylis smithi	3.70	52.00	13.87		*Polydora ligni*	2.48	22.00	7.39
Streblospio gynobranchiata	6.45	19.00	11.07		*Laeonereis culveri*	2.42	22.00	7.29
Pectinaria gouldii	1.57	32.00	7.09		*Amygdalum papyrium*	1.39	34.00	6.89
Laeonereis culveri	3.66	13.00	6.90		*Glycinde solitaria*	0.99	32.00	5.63
Glottidia pyramidata	3.22	13.00	6.47		*Mysella planulata*	2.32	12.00	5.28
Paramphinome sp b	1.07	21.00	4.74		*Erichsonella attenuata*	1.05	24.00	5.03
Polydora ligni	1.21	17.00	4.54		*Bemlos sp*	0.96	22.00	4.60
Glycinde solitaria	0.69	28.00	4.40		*Dipolydora socialis*	0.81	22.00	4.21
Nemertea sp	0.73	21.00	3.90		*Apocorophium lacustre*	0.68	16.00	3.30
Paraprionospio pinnata	0.66	20.00	3.62		*Nudibranchia*	0.65	12.00	2.79
Bemlos sp	0.74	16.00	3.45		*Astyris lunata*	0.34	20.00	2.61
Tagelus plebeius	0.90	11.00	3.14		*Nemertea sp f*	0.37	16.00	2.44
Acteocina canaliculata	0.50	17.00	2.92		*Diopatra cuprea*	0.34	16.00	2.34

B. Shell Creek

Shell Creek	%Comp	%OCC	Dom
Polymesoda caroliniana	34.54	66.67	47.98
Grandidierella bonnieroides	20.90	71.79	38.74
Hydrobiidae	25.96	43.59	33.64
Mesanthura pulchra	3.07	48.72	12.23
Laeonereis culveri	2.30	38.46	9.41
Polypedilum scalaenum group	1.76	48.72	9.26
Edotea montosa	1.44	25.64	6.09
Rangia cuneata	0.90	28.21	5.05
Cryptochironomus	0.54	23.08	3.54
Boccardiella	1.26	7.69	3.12
Procladius	0.63	15.38	3.12
Chironomus	0.45	17.95	2.85
Hobsonia florida	0.45	15.38	2.64
Rhithropanopeus harrisii	0.45	15.38	2.64
Tanytarsus sp g	0.59	10.26	2.45
Dicrotendipes lobus	0.59	7.69	2.12
Djalmabatista pulchra	0.32	12.82	2.01
Heteromysis formosa	0.32	10.26	1.80
Cyclaspis cf varians	0.23	12.82	1.70
Sphaeroma terebrans	0.23	10.26	1.52

4.4.3 Relationship Between Salinity and Benthic Community Structure

Janicki Environmental (2007) showed that the benthos within 12 southwest Florida tidal rivers, including the Peace River and SC, was distributed across four salinity ranges that were generally similar to the traditional Venice classification scheme (Anonymous 1959, Weisberg *et al*. 1997):

- Oligohaline <7 ppt
- Mesohaline 7 to 18 ppt
- Polyhaline 18 to 29 ppt
- Euhaline >29 ppt

Since the database for matched benthos and salinity data for the Lower Peace River included 540 samples, rather than use the regional salinity classification scheme developed previously (Janicki Environmental 2007), a classification scheme specific to the study area was developed using the methods outlined in Bulger *et al*. (1993) and Janicki Environmental (2007).

For this principal components analysis the database was trimmed to exclude taxa that were only identified to Class or Order. Similarly, Family and Genus level identifications were excluded if there were representatives identified to genus or species, respectively. For example: two species of amphipods in the genus *Apocorophium* (*Apocorophium lacustre* and *Apocorophium louisianum*) were identified and included. These species may distribute themselves somewhat differently along salinity gradients. For example, in the Anclote River, *Apocorophium lacustre* was more abundant in salinities <8 ppt whereas *Apocorophium louisianum* was more abundant at salinities of 8 to 15 ppt (Janicki Environmental, Inc., 2006b). Therefore, animals identified as *Apocorophium* sp. were excluded. The result was that the PCA was run for 31 salinity increments (<1 to 31 ppt in 1 ppt increments) and 119 taxa.

Four principal components (PC), representing four salinity classes, explained >85% of the variation distribution of the benthos (Figure 4-4). These salinity classes are:

Tidal Freshwater:	<1 ppt	(5.5% of variance)
Oligohaline-Mesohaline:	≥ 1<18 ppt	(42.6% of variance)
Mesohaline-Polyhaline:	≥ 16<28 ppt	(29.2% of variance)
Euhaline:	≥ 28.0 ppt	(8.0% of variance)

PRIMER's (PRIMER-E Ltd. 2001) SIMPER (similarity percentage) program was used to rank the contribution different taxa made to community structure within each of the four salinity classes (Clarke and Warwick 2001).

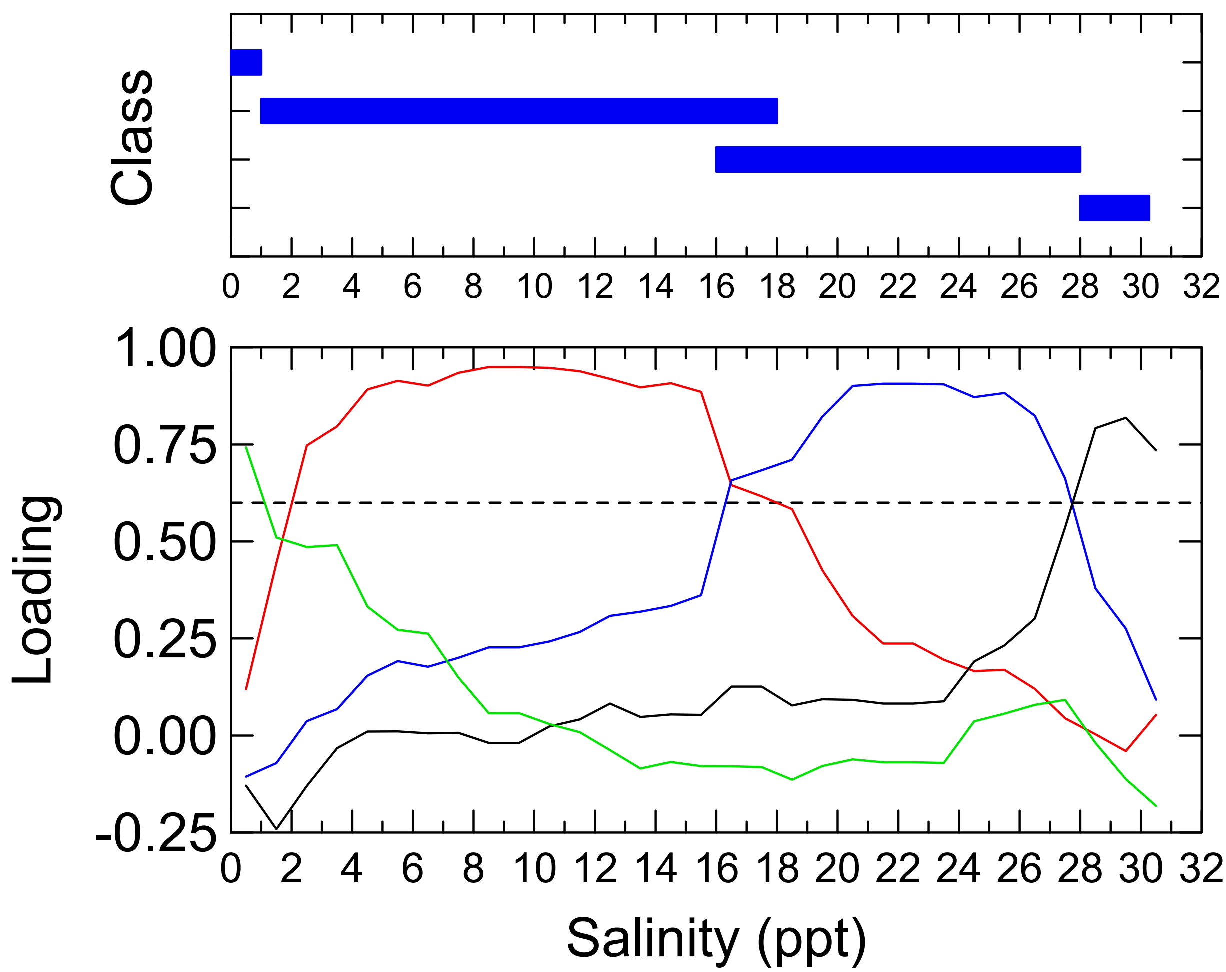


Figure 4-4. **Salinity classes identified by Principal Components Analysis for the LPR (1998-1999) and SC (2003), based upon the distribution of 119 benthic taxa.**

Community structure was defined as Bray-Curtis similarity (Boesch, 1973) using 4^{th} root transformed numbers of individuals. Organism counts were 4^{th} root transformed for all multivariate community analyses. The 4^{th} root transformation in multivariate analyses permits a greater number of taxa to influence the results (Clarke and Warwick, 2001). The use of untransformed data yields results strongly influenced by the most abundant taxa. Cao *et al.* (1998) argue that "rare" taxa may be more sensitive to environmental perturbation than common species. Therefore, an analytical approach that is more responsive to the "community" rather than to only a few, numerically abundant taxa was desirable. Thorne *et al.* (1999) have also demonstrated that the 4^{th} root transformation is preferred in multivariate community analyses because it represents a "good compromise between untransformed and binary data". Therefore the 4^{th} root transformation was employed where possible in the multivariate analyses.

The Tidal Freshwater salinity class was characterized by the presence of *Corbicula fluminea* whereas the Oligohaline-Mesohaline class was dominated by *Grandidierella bonnieroides*, *Laeonereis culveri*, and *Streblospio gynobranchiata* (Table 4-4). *Apocorophium lacustre* was abundant in both salinity classes. As salinity increased to the Mesohaline-Polyhaline class, freshwater taxa were no longer ranked. The cumacean *Cyclaspis cf. varians*, the amphipod *Ampelisca abdita*, and the bivalves *Amygdalum papyrium* and *Mulinia lateralis* were abundant in both the Mesohaline-Polyhaline and Euhaline salinity classes (Table 4-4).

A comparison of the regional salinity classification scheme and that specific to the Lower Peace River showed that:

- The Lower Peace River supports a distinct Tidal Freshwater assemblage, whereas in the regional analysis there was a Tidal Freshwater-Oligohaline fauna.

- Within the Lower Peace River, there were two salinity classes overlapping the upper end of the Mesohaline range.

- The regional classification scheme produced classes that essentially represented Polyhaline and Euhaline zones. The Lower Peace River included a salinity class that embraced the upper Mesohaline and Polyhaline salinity zones.

- A Euhaline salinity class was evident in both analyses.

Table 4-4. SIMPER analysis showing the taxa that explained ≥25% of the within PCA-salinity class similarity (4^{th} root n+0.1 transformed counts; Bray-Curtis similarity) for the LPR and SC.

A. Tidal Freshwater Salinity Class (< 1 ppt)

Taxa	Mean Number of Individuals (4^{th} Root n+1)	% Contribution to Within Class Similarity
Corbicula fluminea	0.97	0.09
Apocorophium lacustre	0.91	0.08
Polypedilum scalaenum group	0.85	0.08
Cladotsanytarsus	0.90	0.08
Hydrobiidae	0.84	0.08
Grandidierella bonnieroides	0.90	0.08
Gammarus cf tigrinus	0.83	0.08
Laeonereis culveri	0.77	0.08
Polypedilum halterale group	0.70	0.08
Tanytarsus	0.69	0.08
334 taxa:	≤0.69	0.07

B. Oligohaline-Mesohaline Salinity Class (1 – 18 ppt)

Taxa	Mean Number of Individuals (4^{th} Root n+1)	% Contribution to Within Class Similarity
Grandidierella bonnieroides	1.05	0.09
Laeonereis culveri	0.95	0.09
Streblospio gynobranchiata	0.93	0.09
Apocorophium lacustre	0.99	0.09
Polypedilum scalaenum group	0.85	0.08
Hydrobiidae	0.93	0.08
Polymesoda caroliniana	0.92	0.08
Cyclaspis cf varians	0.87	0.08
Edotea montosa	0.79	0.08
Amygdalum papyrium	0.86	0.08
Ampelisca abdita	0.79	0.08
Hobsonia florida	0.73	0.08
Gammarus cf tigrinus	0.74	0.08
Cryptochironomus	0.69	0.08
Amakusanthura magnifica	0.69	0.08
677 taxa:	≤0.74	0.07

C. Mesohaline-Polyhaline Salinity Class (16 - 28 ppt)

Taxa	Mean Number of Individuals (4^{th} Root n+1)	% Contribution to Within Class Similarity
Cyclaspis cf varians	1.30	0.11
Ampelisca abdita	1.23	0.11
Amygdalum papyrium	1.03	0.10
Mulinia lateralis	1.10	0.09
Nereis succinea	0.83	0.08
Oxyurostylis smithi	0.82	0.08
Streblospio gynobranchiata	0.82	0.08
Pectinaria gouldii	0.72	0.08
Capitella capitata complex	0.78	0.08
Laeonereis culveri	0.74	0.08
Amakusanthura magnifica	0.71	0.08
333 taxa:	≤0.77	0.07

Table 4-4. Continued
D. Euhaline Salinity Class (> 28 ppt)

Taxa	**Mean Number of Individuals (4th Root n+1)**	**% Contribution to Within Class Similarity**
Cyclaspis cf varians	1.60	0.15
Mysella planulata	1.45	0.14
Ampelisca abdita	1.30	0.11
Mulinia lateralis	1.21	0.11
Glottidia pyramidata	1.26	0.11
Amygdalum papyrium	0.98	0.10
Pectinaria gouldii	0.97	0.09
Oxyurostylis smithi	0.92	0.09
Macoma tenta	0.93	0.09
Nereis succinea	0.86	0.09
Bemlos	0.83	0.08
Acteocina canaliculata	0.78	0.08
Spiochaetopterus costarum oculata	0.79	0.08
Nemertea sp f	0.77	0.08
Paramphinome sp b	0.74	0.08
Paraprionospio pinnata	0.71	0.08
Uromunna	0.74	0.08
Asychis elongate	0.69	0.08
324 taxa :	≤0.72	0.07

4.4.4 Spatial Characteristics of Lower Peace River Benthos

ANOSIM and SIMPER analyses (Clarke and Warwick, 2001) were applied to determine whether community structure differed between Zones of the Lower Peace River (Mote Marine Laboratory 2002) proper as well as between subareas (e.g., Deep Creek, Lettuce Lake) within each of the zones.

Test results, then, were only included if they represented comparisons between Zones and subareas that were contiguous. That is, Peace River Zone 1 was compared to Peace River Zone 2, Lettuce Lake, and Deep Creek, but not to SC (discharging mainly to Zone 3). If the ANOSIM test was not significant ($p>0.05$), than the data from the two zones/subareas were combined for a “within group” SIMPER analysis

The ANOSIM test showed that community structure differed:

- between each of the four zones of the Lower Peace River proper, as defined by Mote Marine Laboratory (2002);
- between Deep Creek and Lettuce Lake within Zone 1;
- between the SAV sites in the vicinity of RKM 0 and Zone 4 of the Lower Peace River; and
- between SC and Zone 3 of the LPR.

Freshwater taxa, such as hydrobiid gastropods and Chironomidae larvae were characteristic of the fauna in Zone 1 of the river proper, Deep Creek, and Lettuce Lake

(Table 4-5). ANOSIM showed that the assemblage in Zone 1 of the river was similar to that of both Deep Creek and Lettuce Lake.

The assemblages of Lettuce Lake and Deep Creek, however, were different (Table 4-5). SIMPER analysis showed that the assemblage of Lettuce Lake had higher mean densities of hydrobiids and chironomids and lower densities of estuarine amphipods than did Deep Creek

The fauna in Zone 2 differed from that of Zone 1 in that freshwater organisms declined in numbers and estuarine taxa increased. Notably, mean numbers of larvae of the chironomid *Polypedilum scalaneum* increased from Zone 1 to Zone 2. The benthos of Hunter Creek and Zone 2 of the river proper were not significantly different.

Zones 2 and 3 also differed in the composition of the benthos. Mean numbers of *Cyclaspis varians*, *Mulinia lateralis*, and *Amygdalum papyrium* were much higher in Zone 3 whereas *Apocorophium lacustre, Grandidierella bonnieroides*, and *Polypedilum scalaneum* numbers declined moving downstream. The benthos of Zone 4 also differed from that of Zone 3. Taxa whose mean numbers declined downstream included *Cyclaspis, Mulinia, Amygdalum*, and *Streblospio gynobranchiata* (Table 4-5). Organisms whose numbers increased downstream included *Ampelisca abdita* and *Mysella planulata*. The benthos associated with the SAV beds near RKM 0 also differed from that of Zone 4 as a whole. The polychaetes *Capitella capitata* and *Nereis succinea* were more abundant in the SAV samples.

SC, a low salinity habitat, joins the LPR primarily within Zone 3 (Figure 4-3), where salinities typically range between 7 and 22 ppt (Table 4-2). The benthos of SC was different from that of Zone 3 (Table 4-5). *Grandidierella bonnieroides, Polymesoda caroliniana*, and hydrobiids were much more abundant in SC than in Zone 3. ANOSIM showed that SC was similar (p=0.32) in structure to Zone 2.

Table 4-5. ANOSIM and SIMPER analyses comparing benthic community structure between Zones and subareas of the Lower Peace River (4^{th} root n+0.1 transformed counts; Bray-Curtis similarity). ANOSIM table shows the R statistic for comparison of community structure between zones and the *p* value for the test (Clarke and Warwick, 2001).

A. ANOSIM Test

Groups	R Statistic	*p*
Zone 1 vs. Deep Creek	0.009	0.401
Zone 1 vs. Lettuce Lake	0.012	0.377
Deep Creek vs. Lettuce Lake	0.025	0.019
Zone 1 vs. Zone 2	0.121	0.001
Zone 2 vs. Hunter Creek	-0.012	0.609
Zone 2 vs. Zone 3	0.125	0.001
Zone 3 vs. Shell Creek	0.144	0.006
Zone 3 vs. Zone 4	0.091	0.001
Zone 4 vs. SAV Sites	0.084	0.015

Table 4-4. Continued

B. SIMPER Analyses

B-1 Peace River Zone 1 and Lettuce Lake (Combined)

Taxa	**Mean Number of Individuals (4th Root n+1)**	**% Contribution to Within Class Similarity**
Corbicula fluminea	1.13	0.10
Hydrobiidae	0.98	0.09
Cladotanytarsus	1.03	0.09
Gammarus cf tigrinus	0.95	0.09
Apocorohium lacustre	0.91	0.08
Polypedilum scalaenum group	0.81	0.08
Grandidierella bonnieroides	0.83	0.08
Tanytarsus	0.76	0.08
Polypedilum halterale group	0.76	0.08
Chironomidae	0.73	0.08
Laeonereis culveri	0.72	0.08
334 Taxa	≤0.65	0.07

B-2 Peace River Zone 1 and Deep Creek (Combined)

Taxa	**Mean Number of Individuals (4th Root n+1)**	**% Contribution to Within Class Similarity**
Corbicula fluminea	1.11	0.10
Gammarus cf tigrinus	0.97	0.09
Apocorophium lacustre	1.01	0.09
Cladotanytarsus	0.99	0.09
Hydrobiidae	0.93	0.09
Grandidierella bonnieroides	0.86	0.08
Polypedilum scalaenum group	0.78	0.08
Tanytarsus	0.76	0.08
Laeonereis culveri	0.72	0.08
Polypedilum halterale group	0.73	0.08
Chironomidae	0.69	0.08
334 taxa	<0.69	0.07

B-3 Deep Creek vs. Lettuce Lake

Taxa	**Deep Creek (Mean Number of Individuals (4th Root n+1)**	**Lettuce Lake (Mean Number of Individuals (4th Root n+1)**	**% Contribution to Between Group Dissimilarity**
Apocorophium lacustre	1.14	0.84	8.34
Cladotanytarsus	0.89	1.03	7.53
Hydrobiidae	0.89	1.02	6.69
Corbicula fluminea	0.84	0.90	6.15
Gammarus cf tigrinus	0.91	0.85	5.55
Grandidierella bonnieroides	0.88	0.78	5.34
Polypedilum scalaenum group	0.75	0.85	4.99
Polypedilum halterale group	0.77	0.85	4.65
Tanytarsus	0.78	0.76	4.16

Table 4-4. Continued

B-4 Peace River Zone 1 vs. Peace River Zone 2

Taxa	Zone 1 (Mean Number of Individuals (4^{th} Root n+1)	Zone 2 (Mean Number of Individuals (4^{th} Root n+1)	% Contribution to Between Group Dissimilarity
Apocorophium lacustre	0.94	1.20	7.73
Corbicula fluminea	1.24	0.79	7.05
Grandidierella bonnieroides	0.86	1.06	6.22
Hydrobiidae	0.96	0.91	5.28
Cladotanytarsus	1.03	0.60	5.02
Gammarus cf tigrinus	0.99	0.70	4.89
Polypedilum scalaenum group	0.80	0.99	4.75
Laeonereis culveri	0.70	0.98	4.42
Apocorophium louisianum	0.67	0.87	3.78
Ampelisca abdita	0.57	0.88	3.36

B-5 Peace River Zone 2 and Hunter Creek (Combined)

Taxa	Mean Number of Individuals (4^{th} Root n+1)	% Contribution to Within Class Similarity
Grandidierella bonnieroides	1.12	0.10
Laeonereis culveri	0.97	0.10
Apocorophium lacustre	1.16	0.09
Polypedilum scalaenum group	0.92	0.09
Hydrobiidae	0.92	0.09
Streblospio gynobranchiata	0.86	0.08
Hobsonia florida	0.80	0.08
Edotea montosa	0.81	0.08
Apocorophium louisianum	0.86	0.08
Polymesoda caroliniana	0.79	0.08
Amakusanthura magnifica	0.75	0.08
Ampelisca abdita	0.80	0.08
Corbicula fluminea	0.75	0.08
Cyclaspis cf varians	0.74	0.08
330 taxa	<0.74	0.07

B-6 Peace River Zone 2 vs. Peace River Zone 3

Taxa	Zone 2 (Mean Number of Individuals (4^{th} Root n+1)	Zone 3 (Mean Number of Individuals (4^{th} Root n+1)	% Contribution to Between Group Dissimilarity
Cyclaspis cf varians	0.80	1.33	7.10
Mulinia lateralis	0.60	1.26	6.43
Amygdalum papyrium	0.73	1.24	6.24
Apocorophium lacustre	1.20	0.68	6.14
Ampelisca abdita	0.88	1.06	5.63
Grandidierella bonnieroides	1.06	0.72	4.91
Streblospio gynobranchiata	0.87	1.00	4.65
Polypedilum scalaenum group	0.99	0.75	4.06
Laeonereis culveri	0.98	0.82	4.03
Polymesoda caroliniana	0.80	0.84	3.64

Table 4-4. Continued

B-7 Peace River Zone 3 vs. Peace River Zone 4

Taxa	**Zone 3 (Mean Number of Individuals (4^{th} Root n+1)**	**Zone 4 (Mean Number of Individuals (4^{th} Root n+1)**	**% Contribution to Between Group Dissimilarity**
Cyclaspis cf varians	1.33	1.26	7.88
Mulinia lateralis	1.26	1.04	7.06
Ampelisca abdita	1.06	1.15	6.21
Amygdalum papyrium	1.24	1.00	6.14
Streblospio gynobranchiata	1.00	0.80	4.97
Mysella planulata	0.61	0.98	4.08
Nereis succinea	0.79	0.90	3.77
Oxyurostylis smithi	0.63	0.95	3.67
Capitella capitata complex	0.65	0.90	3.50
Laeonereis culveri	0.82	0.71	3.18

B-8 Peace River Zone 4 vs. SAV sites

Taxa	**Zone 4 (Mean Number of Individuals (4^{th} Root n+1)**	**SAV Sites (Mean Number of Individuals (4^{th} Root n+1)**	**% Contribution to Between Group Dissimilarity**
Capitella capitata complex	0.90	1.31	8.07
Cyclaspis cf varians	1.26	0.58	6.50
Ampelisca abdita	1.15	1.05	5.64
Nereis succinea	0.90	1.04	5.14
Mulinia lateralis	1.04	0.82	4.96
Mysella planulata	0.98	0.71	4.54
Amygdalum papyrium	1.00	0.80	4.26
Streblospio gynobranchiata	0.80	0.80	3.73
Oxyurostylis smithi	0.95	0.64	3.58
Cymadusa compta	0.57	0.91	3.27
Erichthonius brasiliensis	0.59	0.90	3.23

B-9 Shell Creek vs. Peace River Zone 3

Taxa	**Shell Creek (Mean Number of Individuals (4^{th} Root n+1)**	**Zone 3 (Mean Number of Individuals (4^{th} Root n+1)**	**% Contribution to Between Group Dissimilarity**
Grandidierella bonnieroides	1.41	0.72	7.49
Polymesoda caroliniana	1.36	0.84	7.39
Cyclaspis cf varians	0.62	1.33	7.08
Mulinia lateralis	0.56	1.26	6.52
Amygdalum papyrium	0.56	1.24	6.32
Hydrobiidae	1.09	0.56	4.99
Ampelisca abdita	0.56	1.06	4.62
Streblospio gynobranchiata	0.61	1.00	4.11
Laeonereis culveri	0.85	0.82	3.60

4.4.5 Relationships Between the Benthos and Abiotic Variables

4.4.5.1 Multiple Regression Analyses and Univariate Community Metrics

Forward stepwise multiple linear regression was applied to quantify relationships between taxa richness, diversity, and abundance and a suite of environmental variables. The environmental variables considered included:

- Water temperature, salinity, pH, and dissolved oxygen measured at the time of collection;
- Flow variables (flow on the day of collection and the cumulative flows over the 7, 15, 30, 60, 90, and 180 days preceding the collection of the benthic samples). Montagna and Kalke (1992) used this approach to examine the effects of flow on the benthos of Texas estuaries.

The resultant relationships and equations may be used to predict expected responses of the benthos within each of the four zones of the Lower Peace River to the “best fit” combination of abiotic variables.

Statistically significant ($p<0.05$) relationships were found between numbers of taxa, diversity, or total abundance and the abiotic variables within each of the four river zones. However, each of the r^2 values were ≤ 0.41 (Table 4-6). The best fitting equation ($r^2=0.41$) was for the relationship between numbers of individuals, temperature, salinity, the 7-day cumulative flow, and the flow on the date of collection within Zone 2. The second best fitting relationship ($r^2=0.39$) was between numbers of taxa, the 7-day cumulative flow, and the flow on the date of collection within Zone 2 as well.

Based upon the low r^2 values, none of the three univariate community metrics are considered to demonstrate any ecologically meaningful relationships with salinity, dissolved oxygen, sample depth or flow, based upon forward stepwise multiple regression.

Table 4-6. Summary of forward stepwise multiple regression estimating numbers of taxa (S), Shannon-Wiener diversity (H'), and total numbers of individuals per sample, by zone, in the LPR, including SC. Dependent variables: Log_{10} n+1 transformed temperature, salinity, dissolved oxygen, and Log_{10} flow on the date of collection and 7, 15, 30, 60, 90, and 180-day cumulative flows. *p* values: NS=$\geq$0.05 *<0.05 ** <0.01 *<0.001**

A. ZONE 1 (INCLUDING LETTUCE LAKE AND DEEP CREEK) (n=186)

	Log_{10} n+1 Numbers of Taxa (S)	Shannon Diversity (H')	Log_{10} n+1 Total Numbers of Individuals
p	***	***	***
Adjusted Multiple R^2	0.32	0.25	0.19
Constant	8.05	24.87	12.30
Temperature			
Salinity			
Dissolved Oxygen			
pH			
Daily Flow	-0.96	-3.11	-1.45
7-Day Cumulative Flow	0.64	2.04	1.01
15-Day Cumulative Flow			
30-Day Cumulative Flow			
60-Day Cumulative Flow			
90-Day Cumulative Flow			
180-Day Cumulative Flow	-1.45	-4.58	-2.23

B. ZONE 2 (INCLUDING HUNTER CREEK) (n=139)

	Log_{10} n+1 Numbers of Taxa (S)	Shannon Diversity (H')	Log_{10} n+1 Total Numbers of Individuals
p	***	***	***
Adjusted Multiple R^2	0.39	0.29	0.41
Constant	8.52	-2.30	-5.10
Temperature		5.99	5.67
Salinity			-0.62
Dissolved Oxygen			
pH			
Daily Flow	-1.02	-3.10	-2.96
7-Day Cumulative Flow	0.73	3.13	1.41
15-Day Cumulative Flow			
30-Day Cumulative Flow		-2.00	
60-Day Cumulative Flow			
90-Day Cumulative Flow			
180-Day Cumulative Flow	-1.57		

Table 4-6. Continued

C. ZONE 3 (INCLUDING SHELL CREEK) (n=133)

	Log_{10} n+1 Numbers of Taxa (S)	Shannon Diversity (H')	Log_{10} n+1 Total Numbers of Individuals
p	***	***	***
Adjusted Multiple R^2	0.23	0.18	0.23
Constant	1.75	-29.72	9.03
Temperature	-0.62		-4.02
Salinity	0.14	-0.57	0.74
Dissolved Oxygen	0.61	1.69	1.29
pH			
Daily Flow	-0.28		-0.43
7-Day Cumulative Flow			
15-Day Cumulative Flow			
30-Day Cumulative Flow		4.93	
60-Day Cumulative Flow			
90-Day Cumulative Flow		-21.19	
180-Day Cumulative Flow		21.67	-0.52

D. ZONE 4 (EXCLUDES SAV SITES) (n=97)

	Log_{10} n+1 Numbers of Taxa (S)	Shannon Diversity (H')	Log_{10} n+1 Total Numbers of Individuals
p	***	**	***
Adjusted Multiple R^2	0.17	0.06	0.25
Constant	-3.28	-2.07	-6.67
Temperature	2.22	3.00	4.90
Salinity			
Dissolved Oxygen			-0.73
pH			
Daily Flow			
7-Day Cumulative Flow			-0.71
15-Day Cumulative Flow			1.08
30-Day Cumulative Flow			
60-Day Cumulative Flow	0.23		
90-Day Cumulative Flow			
180-Day Cumulative Flow			

4.4.5.2 Relationship with Dissolved Oxygen

Dissolved oxygen was included in the variable subsets predicting numbers of taxa, diversity, as well as abundance within Zone 3. Dissolved oxygen also was related to

the numbers of taxa in Zone 2. However as noted above, the overall relationships developed by multiple regression analyses explained little of the variance.
Notwithstanding these analyses, the relationship between benthic community metrics and dissolved oxygen is an important consideration in a region where hypoxia is a concern-- even though there was little evidence of hypoxia in this database.

The relationship between numbers of taxa, diversity, and abundance with dissolved oxygen was slightly U-shaped, although all of the interquartile ranges overlapped (Figure 4-5).

4.4.5.3 Relationship Between Multivariate Community Structure and Abiotic Variables

PRIMER's BIO-ENV procedure (Clarke and Warwick 2001) was used as an exploratory tool to ascertain whether benthic community structure within each zone of the Lower Peace River was associated with one or more abiotic variables. These variables included salinity, temperature, pH, dissolved oxygen, and cumulative flow statistics.

The objective was to find a matrix of some combination of standardized abiotic variables that provided a "best fit" with the structure of the benthic community in the study areas. The abiotic matrix is formed by calculating Euclidean distances between all station combinations for each subset of abiotic variables tested. In Euclidean distance, stations are more similar if they are closer together in n-dimensional space then if they are further apart. If there are three abiotic variables under consideration, than it is the distance in three-dimensional space; if it is five variables, then it is five-dimensional space, etc. The statistic used to describe the degree of association is the Spearman rank correlation coefficient ($\rho_{s,}$ Clarke and Ainsworth 1993). It is not appropriate to assign significance values to ρ_s values (Clarke and Warwick 2001), and thus this approach can only be used in an exploratory manner.

Salinity measured at the time of collection exerted the primary influence on benthic community structure within the Lower Peace River in this analysis as it was either the best fitting single variable or was included with the "best fit" combinations of variables (Table 4-6). Cumulative flows were only included among the "best fit" variables in the two most downstream zones. The interquartile salinities in Zones 2 and 3 were the most wide-ranging (>13 ppt; Table 4-2). Mean salinities underwent the greatest changes from Zone 2 to Zone 3 (15.5 ppt) and from Zone 3 to Zone 4 (8.2 ppt) (Table 4-2, Figure 4-4). Median salinities were so low in both Zones 1 and 2 that only extremely low flows should affect salinity.

Mote Marine Laboratory (2002) also observed in their analysis of these same data that salinity was more highly correlated with biotic changes in zones 3 and 4 than more upstream. Montagna (2006), using the same analytic approach, showed that salinity was the single abiotic variable that was most highly correlated with the structure of the mollusk community in six southwest Florida tidal rivers; secondary variables included temperature, pH, and some sediment variables.

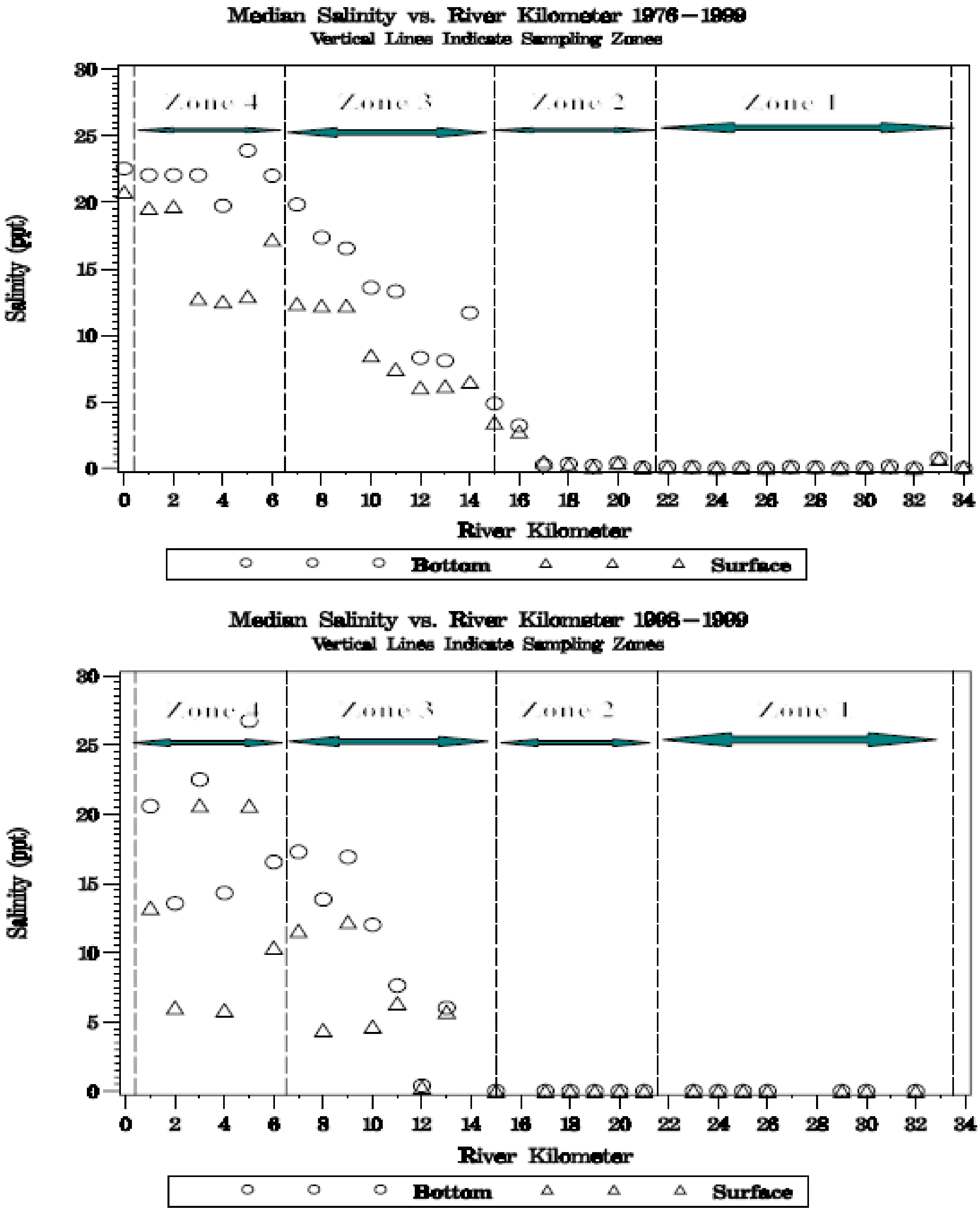


Figure 4-5. **Median salinity, by Zone, in the Lower Peace River, 1976-1999 and 1998-1999 (From: Mote Marine Laboratory, 2002).**

4.4.5.4 Relationships Between Salinity and the Distribution of Selected Taxa (Logistic Regression Analyses

Univariate logistic regression analyses developed for the District from three tidal rivers in the Charlotte Harbor area (LPR, SC, and Myakka River) (Janicki Environmental, Inc. 2006a) were used to identify salinity optima and tolerance ranges for taxa characteristic of the LPR.

Twenty-four taxa, including eight crustaceans, six bivalves, and five polychaetes, exhibited statistically significant relationships between salinity and their probability of occurrence within the Charlotte Harbor area (Janicki Environmental, Inc., 2006a). The probability of occurrence of three of the species (*Chironomus sp., Corbicula fluminea,* and *Polypedilum halterale*) generally declined as salinity increased (Figure 4-6). The distributions of *Chironomus* and *Corbicula* extended from Zone 1 into Zone 2; *Polypedilum halterale* was confined to Zone 1. Montagna (2006) reported a similar distribution for *Corbicula*.

Nine taxa had salinity optima in the Oligohaline-Mesohaline salinity class (Figures 4-7 to 4-9). Four taxa (*Edotea montosa, Grandidierella bonnieroides, Laeonereis culveri*, and *Streblospio gynobranchiata*) were found in each of the four Zones of the river. *Polypedilum scalaneum* was most abundant in Zone 1, the two *Apocorophium* species, *Edotea*, and *Grandidierella* attained maximum abundance in Zone 2, *Polymesoda caroliniana* in Zone 3, and *Laeonereis, Streblospio*, and *Tagelus plebeius* in Zone 4. Montagna (2006) reported *Polymesoda* to be common at salinities up to 20 pp.

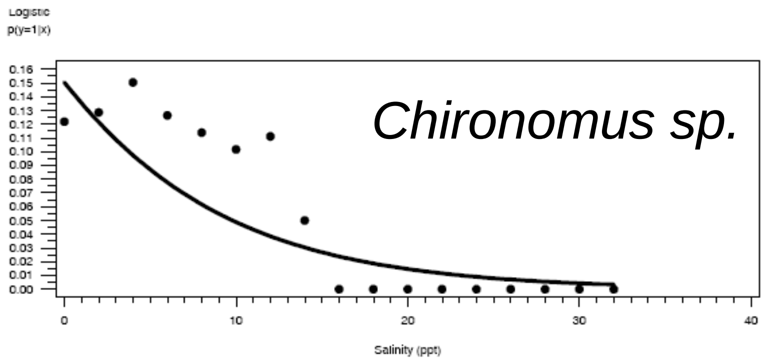
Five taxa (Figures 4-10 to 4-11) were most often encountered in salinities within the Mesohaline-Polyhaline salinity class. These species were not found in Zone 1 and were most abundant in zones 3 and 4.

Six taxa preferred salinities within the Euhaline class (Figures 4-12 through 4-13). The most widely distributed species in this group, *Mulinia lateralis*, was found as far upstream as Zone 1 and *Paraprionospio pinnata* was found at the demarcation point between zones 1 and 2. *Gammarus mucronatus* was found in both zones 3 and 4 and *Acteocina canaliculata, Glottidia pyramidata*, and *Xenanthura brevitelson* were only found in Zone 4.

The salinity "tolerance range" is the range of salinities ±25% of the optimum (Peeters and Gardeniers, 1998). Eight species had a narrow (≤5 ppt range) tolerance range within the Charlotte Harbor estuarine system (Appendix 4-2). Three species (*Corbicula, Chironomus*, and *Polypedilum halterale*) were found in tidal freshwaters, whereas the other five were found at the highest salinities in this system. Reductions in freshwater inflows could expand the penetration of the river by *Glottidia, Xenanthura, Gammarus mucronatus, Acteocina*, and *Paraprionospio* and diminish the available habitat of the three freshwater species. The distributions of the taxa with the wider tolerance ranges (>10 ppt) (Appendix 4-2) could be modified but they would be more difficult to detect. Salinities vary widely seasonally, annually, and may vary by 4 to 5 ppt over a tidal cycle in parts of the river (Mote Marine Laboratory, 2002).

In SC, where the measured salinities averaged 1.3 ppt, dominants included *Polymesoda, Grandidierella*, unidentifiable hydrobiid gastropods (Figure 4-14), and the anthurid isopod *Mesanthura pulchra.* The joint salinity tolerance ranges for *Polymesoda* and *Grandidierella* encompassed 5 and 17 ppt (Figure 4-8). Since the hydrobiids can include both freshwater and estuarine genera (Thompson, 2004) interpreting the salinity tolerances and preferences at the Family level is not particularly meaningful. The dominance of *Mesanthura pulchra* in this low salinity habitat is unexpected. This is more typically a coastal species. Marilyn Schotte (Personal communication), wrote “My impression is that it (*M. pulchra*) needs salinities above 18-20 ppt but can't verify it.”

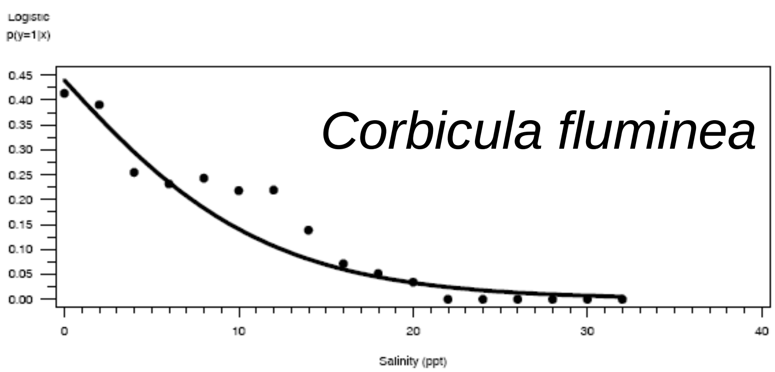
Were salinities in SC to depart markedly (e.g., >5 ppt) from the range observed during this single sampling event, it is possible that purely freshwater taxa relinquish habitat to the more typically estuarine species that are typical of Zone 2 (ANOSIM tests showed SC was similar to Zone 2 fauna but not to Zone 1 fauna).



Probability Statistics: Prob > Chi-Square: Intercept=<.001 x=<.001

Association Statistics: 64.4% Concordant 26.3% Discordant 9.3% Ties Sample Size: Present in 51 of 602 samples

Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)



Probability Statistics: Prob > Chi-Square: Intercept=0.056 x=<.001

Association Statistics: 73.3% Concordant 22.2% Discordant 4.5% Ties Sample Size: Present in 134 of 530 samples

Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)

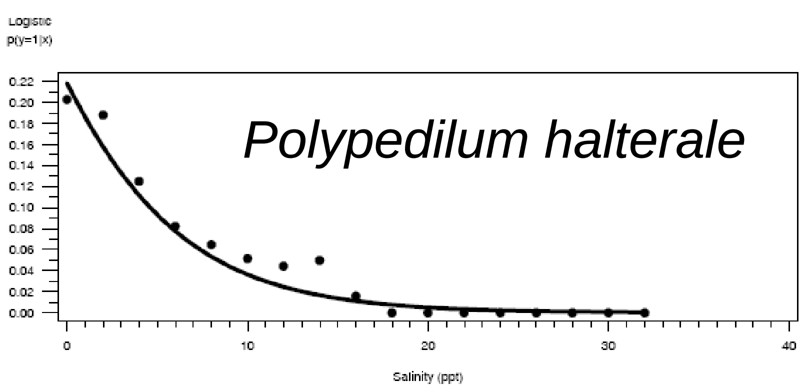
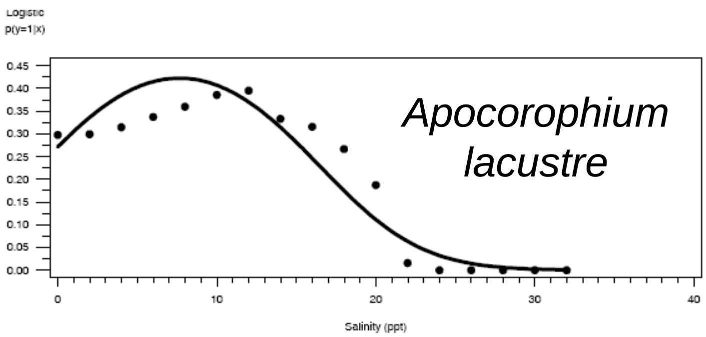


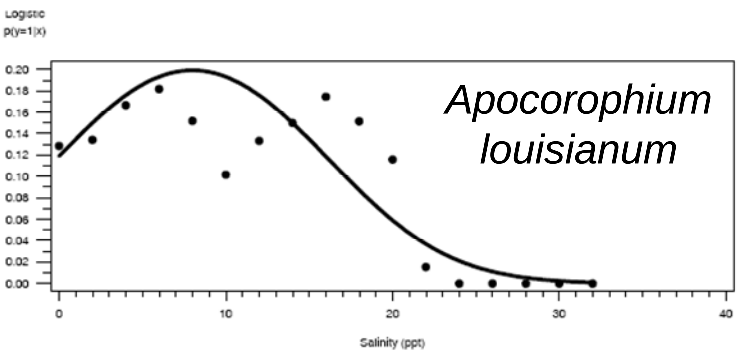
Figure 4-6. Estimated probability of occurrence, as a function of salinity, for taxa with optimal salinities in the Tidal Freshwater salinity class (cf. Figure 4-4): *Chironomus* sp., *Corbicula fluminea*, and *Polypedilum halterale* in Charlotte Harbor tidal rivers, all months.



Probability Statistics: Prob > Chi-Square: Intercept=<.001 x=<.001 x2=<.001

Association Statistics: 64.4% Concordant 30.3% Discordant 5.3% Ties Sample Size: Present in 142 of 573 samples

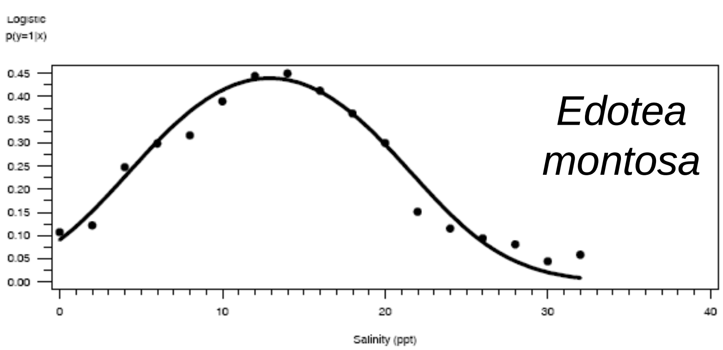
Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)



Probability Statistics: Prob > Chi-Square: Intercept=<.001 x=0.010 x2=0.001

Association Statistics: 58.3% Concordant 31.7% Discordant 10% Ties Sample Size: Present in 68 of 603 samples

Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)

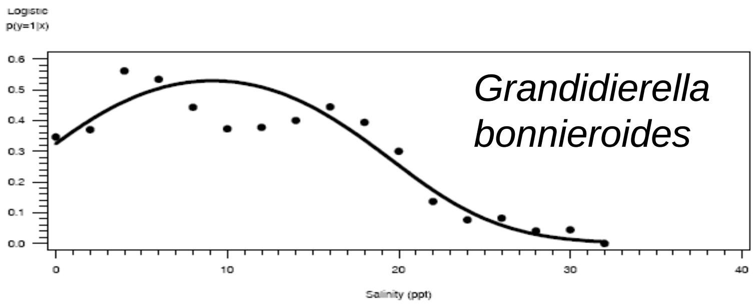


Probability Statistics: Prob > Chi-Square: Intercept=<.001 x=<.001 x2=<.001

Association Statistics: 72.6% Concordant 25.8% Discordant 1.6% Ties Sample Size: Present in 111 of 602 samples

Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)

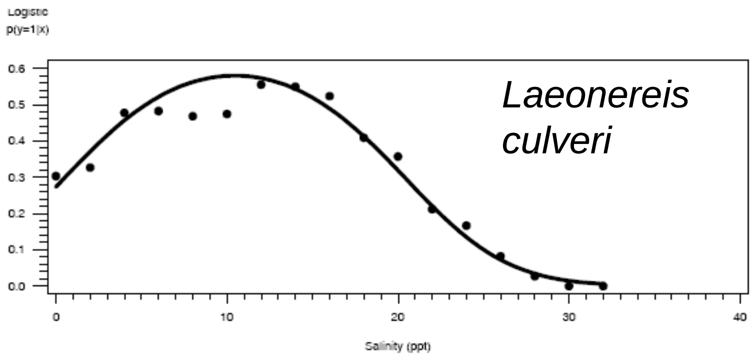
Figure 4-7. Estimated probability of occurrence, as a function of salinity, for taxa with optimal salinities in the Oligohaline-Mesohaline salinity class (cf. Figure 4-4): *Apocorophium lacustre, Apocorophium louisianum,* and *Edotea montosa* in Charlotte Harbor tidal rivers, all months.



Probability Statistics: Prob > Chi-Square: Intercept=<.001 x=<.001 x2=<.001

Association Statistics: 67.3% Concordant 29.1% Discordant 3.6% Ties Sample Size: Present in 196 of 607 samples

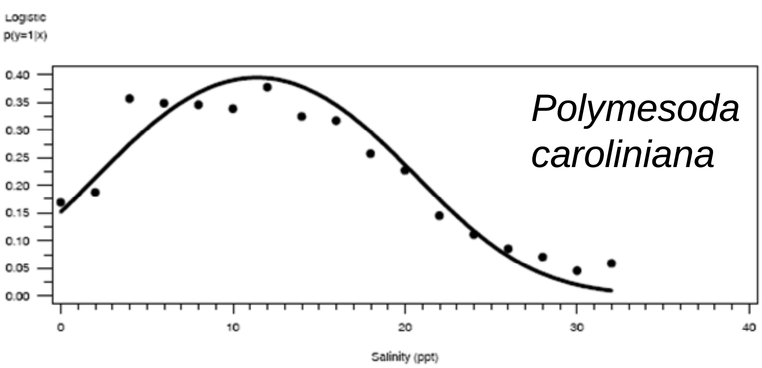
Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)



Probability Statistics: Prob > Chi-Square: Intercept=<.001 x=<.001 x2=<.001

Association Statistics: 67.7% Concordant 29% Discordant 3.3% Ties Sample Size: Present in 192 of 600 samples

Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)

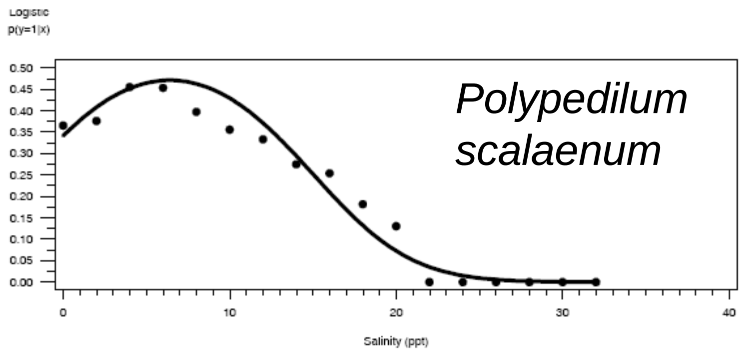


Probability Statistics: Prob > Chi-Square: Intercept=<.001 x=<.001 x2=<.001

Association Statistics: 68.3% Concordant 29.8% Discordant 1.9% Ties Sample Size: Present in 120 of 587 samples

Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)

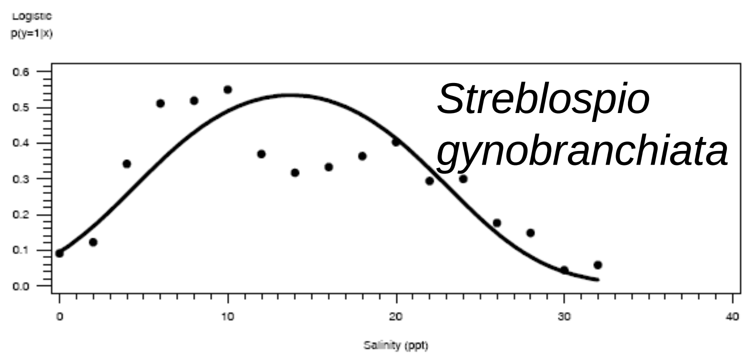
Figure 4-8. Estimated probability of occurrence, as a function of salinity, for taxa with optimal salinities in the Oligohaline-Mesohaline salinity class (cf. Figure 4-4): *Grandidierella bonnieroides, Laeonereis culveri,* and *Polymesoda caroliniana* in Charlotte Harbor tidal rivers, all months.



Probability Statistics: Prob > Chi-Square: Intercept=<.001 x=<.001 x2=<.001

Association Statistics: 69.1% Concordant 26.3% Discordant 4.6% Ties Sample Size: Present in 168 of 600 samples

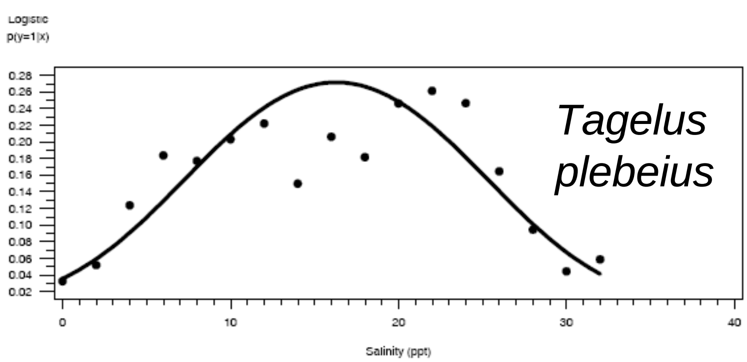
Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)



Probability Statistics: Prob > Chi-Square: Intercept=<.001 x=<.001 x2=<.001

Association Statistics: 74.8% Concordant 24% Discordant 1.1% Ties Sample Size: Present in 138 of 612 samples

Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)

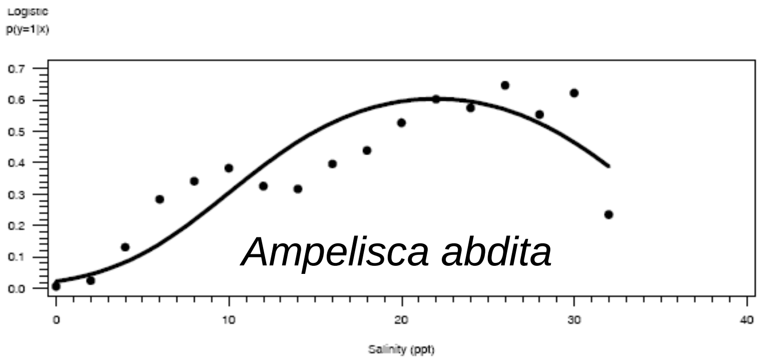


Probability Statistics: Prob > Chi-Square: Intercept=<.001 x=<.001 x2=<.001

Association Statistics: 71.9% Concordant 26.6% Discordant 1.5% Ties Sample Size: Present in 68 of 598 samples

Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)

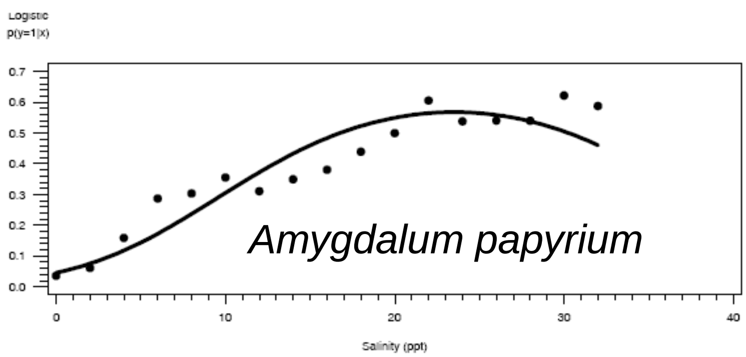
Figure 4-9. Estimated probability of occurrence, as a function of salinity, for taxa with optimal salinities in the Oligohaline-Mesohaline salinity class (cf. Figure 4-4): *Polypedilum scalaenum, Streblospio gynobranchiata,* and *Tagelus plebeius* in Charlotte Harbor tidal rivers, all months.



Probability Statistics: Prob > Chi-Square: Intercept=<.001 x=<.001 x2=<.001

Association Statistics: 85.7% Concordant 13.9% Discordant 0.4% Ties Sample Size: Present in 145 of 613 samples

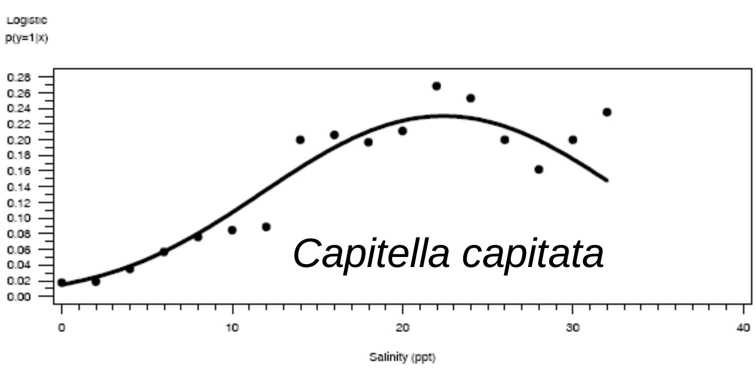
Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)



Probability Statistics: Prob > Chi-Square: Intercept=<.001 x=<.001 x2=<.001

Association Statistics: 82.5% Concordant 16.7% Discordant 0.8% Ties Sample Size: Present in 148 of 601 samples

Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)

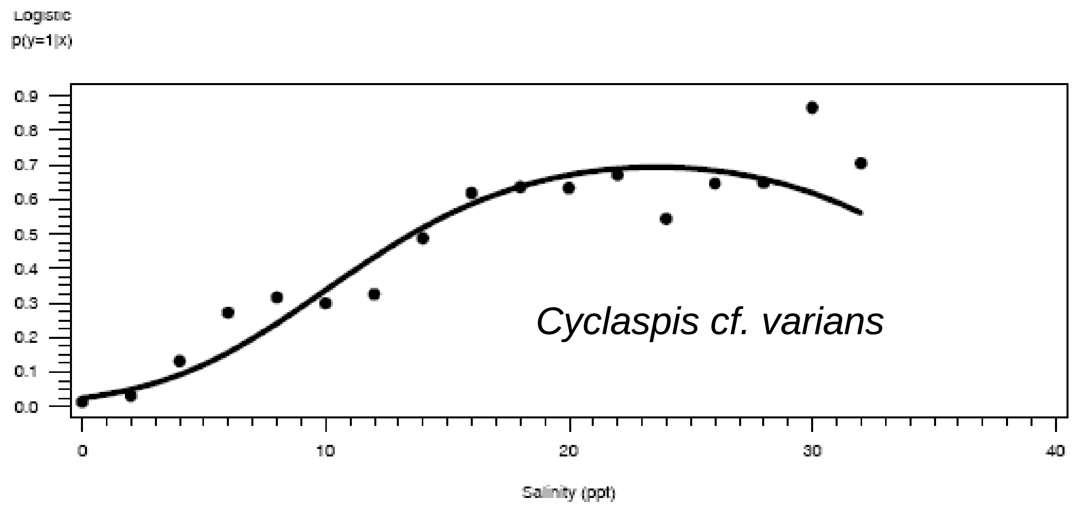


Probability Statistics: Prob > Chi-Square: Intercept=<.001 x=<.001 x2=0.003

Association Statistics: 75.9% Concordant 21.1% Discordant 2.9% Ties Sample Size: Present in 56 of 608 samples

Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)

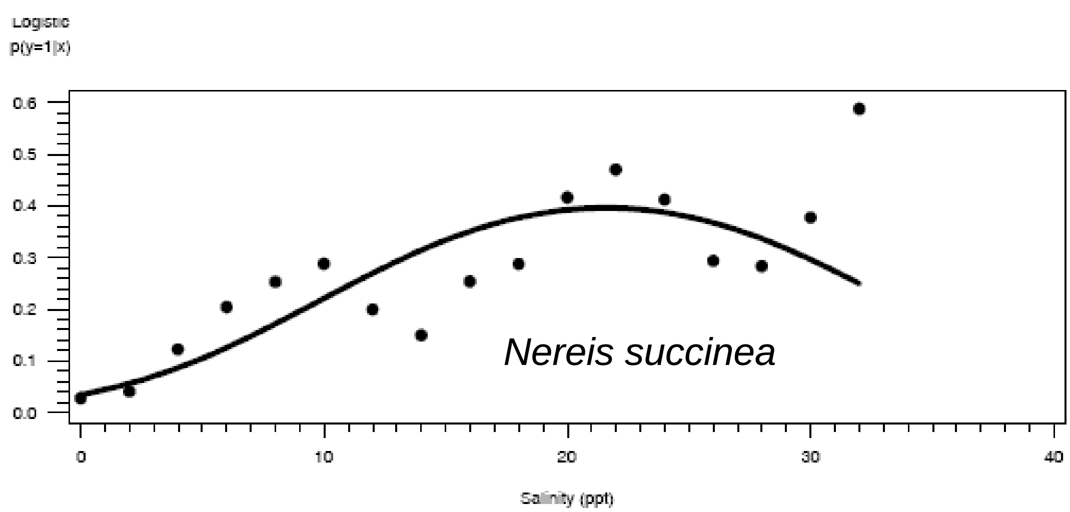
Figure 4-10. Estimated probability of occurrence, as a function of salinity, for taxa with optimal salinities in the Mesohaline-Polyhaline salinity class (cf. Figure 4-4): *Ampelisca abdita, Amygdalum papyrium,* and *Capitella capitata* in Charlotte Harbor tidal rivers, all months.



Probability Statistics: Prob > Chi-Square: Intercept=<.001 x=<.001 x2=<.001

Association Statistics: 87.2% Concordant 12.3% Discordant 0.5% Ties Sample Size: Present in 167 of 612 samples

Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)



Probability Statistics: Prob > Chi-Square: Intercept=<.001 x=<.001 x2=<.001

Association Statistics: 78.4% Concordant 19.8% Discordant 1.8% Ties Sample Size: Present in 104 of 610 samples

Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)

Figure 4-11. Estimated probability of occurrence, as a function of salinity, for taxa with optimal salinities in the Mesohaline-Polyhaline salinity class (cf. Figure 4-4): *Cyclaspis cf. varians* and *Nereis succinea* in Charlotte Harbor tidal rivers, all months.

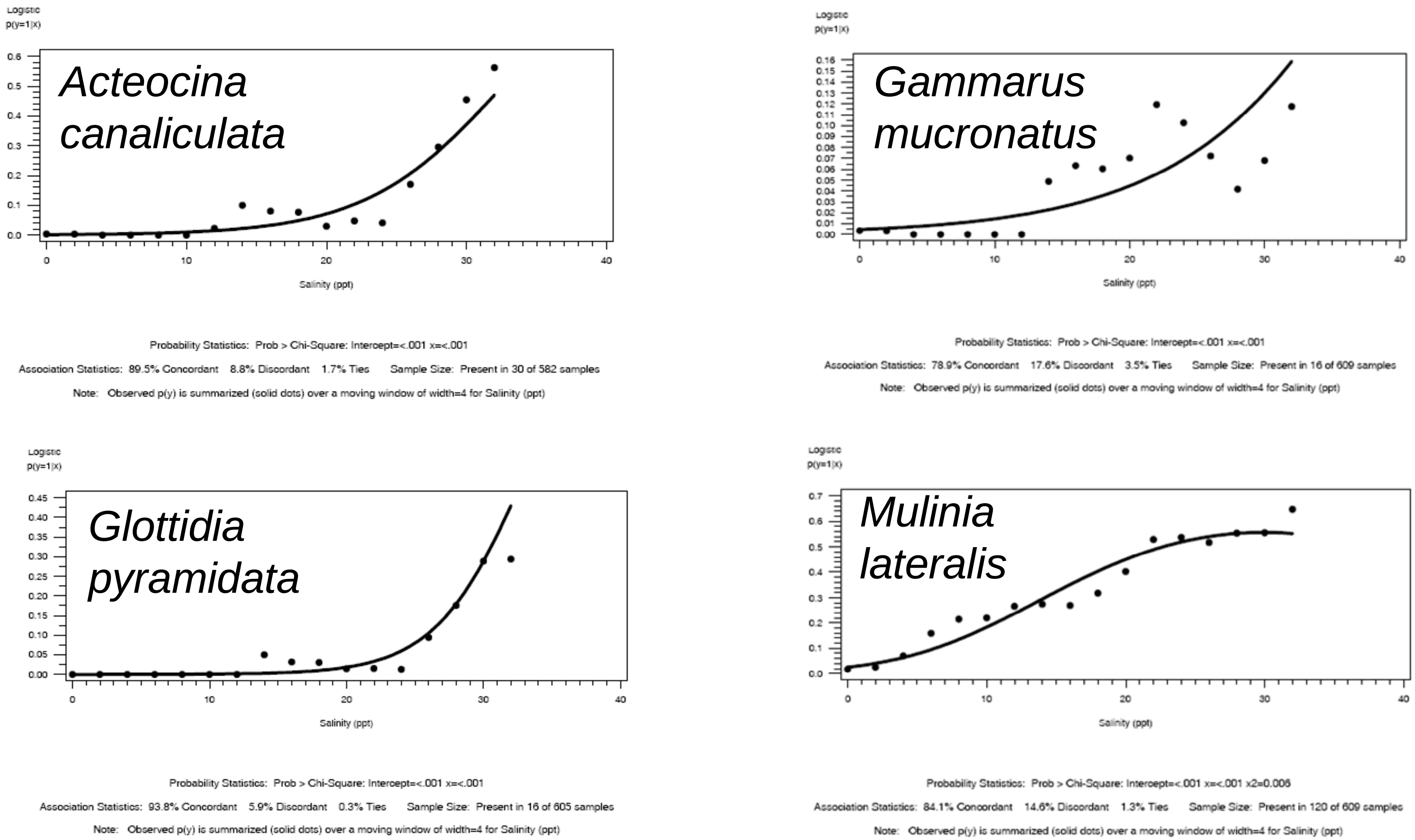
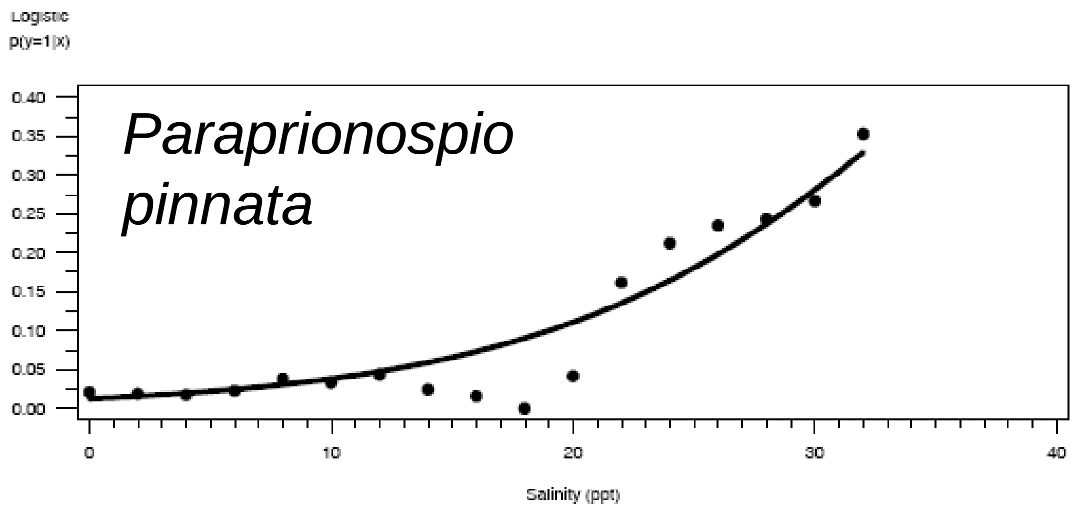


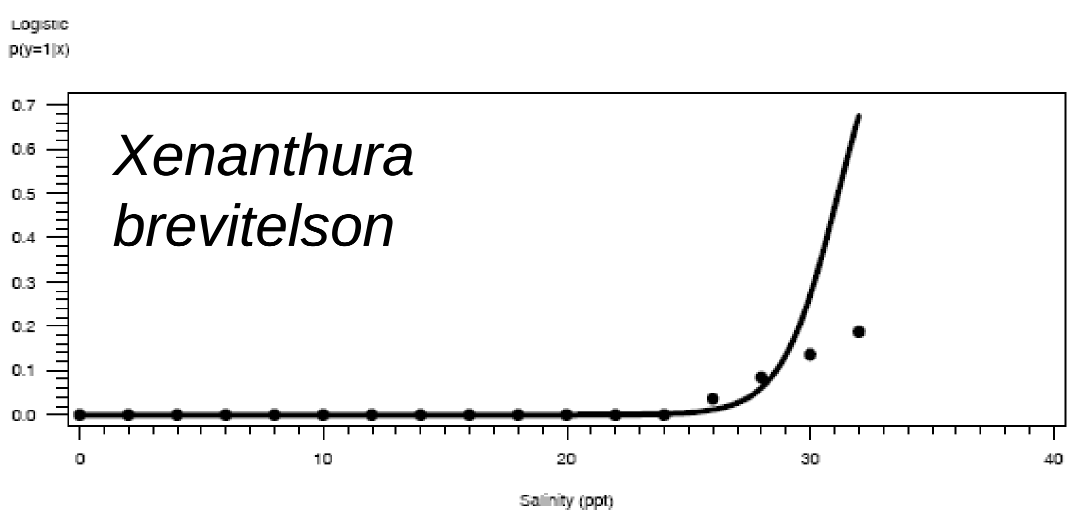
Figure 4-12. Estimated probability of occurrence, as a function of salinity, for taxa with optimal salinities in the Euhaline salinity class (cf. Figure 4-4): *Acteocina canaliculata, Gammarus mucronatus, Glottidia pyramidata* and *Mulinia lateralis* in Charlotte Harbor tidal rivers, all months.



Probability Statistics: Prob > Chi-Square: Intercept=<.001 x=<.001

Association Statistics: 76.7% Concordant 17.7% Discordant 5.5% Ties Sample Size: Present in 39 of 613 samples

Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)



Probability Statistics: Prob > Chi-Square: Intercept=0.005 x=0.008

Association Statistics: 97.7% Concordant 2.2% Discordant 0% Ties Sample Size: Present in 6 of 581 samples

Note: Observed p(y) is summarized (solid dots) over a moving window of width=4 for Salinity (ppt)

Figure 4-13. Estimated probability of occurrence, as a function of salinity, for taxa with optimal salinities in the Euhaline salinity class (cf. Figure 4-4): *Paraprionospio pinnata* and *Xenanthura brevitelson* in Charlotte Harbor tidal rivers, all months.

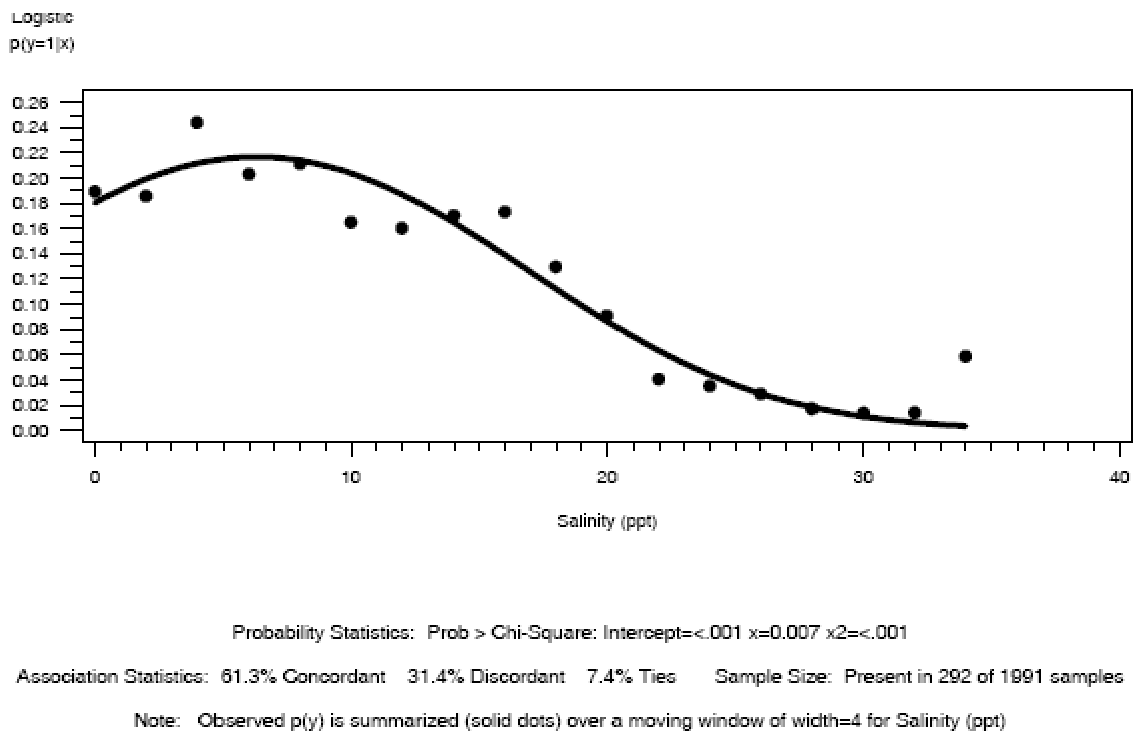


Figure 4-14. Estimated probability of occurrence, as a function of salinity, of hydrobiid gastropods, a dominant taxon in SC, in Charlotte Harbor tidal rivers, all months.

4.5 Results

The “best available data” to examine relationships between benthic community structure and salinity were limited to one year of sampling in the Lower Peace River and a single sampling event in SC.

Mote Marine Laboratory (2002) divided the LPR into four zones *a priori* based upon historical salinity data. Reanalysis of their data showed that multivariate community structure of the benthos differed between contiguous zones:

- within Zone 1, both Lettuce Lake and Deep Creek were similar to Zone 1 but differed from each other; the benthos within Zone 1 was mainly a freshwater fauna (chironomid larvae and hydrobiid gastropods);

- the fauna in Zone 2 differed from that of Zone 1 as freshwater organisms were replaced by estuarine fauna;

- Zones 2 and 3 also differed as the numbers of *Cyclaspis varians*, *Mulinia lateralis*, and *Amygdalum papyrium* increased in Zone 3 and *Apocorophium lacustre, Grandidierella bonnieroides*, and *Polypedilum scalaneum* decreased;

- Zone 4 differed from Zone 3 as the abundance of *Cyclaspis, Mulinia, Amygdalum*, and *Streblospio gynobranchiata* decreased downstream; *Ampelisca abdita* and *Mysella planulata* abundance increased;

- the benthos associated with the SAV beds near RKM 0 also differed from that of Zone 4; the polychaetes *Capitella capitata* and *Nereis succinea* were more abundant in SAV;

- SC benthos were more similar to that of Zone 2 in the LPR.

These data also showed that the benthos within the LPR was primarily influenced by salinity:

PCA showed that the benthos (based upon presence-absence) could be apportioned among four salinity classes:

- Tidal Freshwater: < 1 ppt
- Oligohaline-Mesohaline: 1 - 18 ppt
- Mesohaline-Polyhaline: 16 - 28 ppt
- Euhaline: $\geq$ 28.0 ppt

Multivariate analysis of community structure, based upon numbers of organisms rather than merely presence absence, showed that there were shifts in the taxa characteristic of each of the salinity classes:

- the Tidal Freshwater salinity class was characterized by the presence of *Corbicula fluminea;*
- the Oligohaline-Mesohaline class was dominated by *Grandidierella bonnieroides*, *Laeonereis culveri*, and *Streblospio gynobranchiata;*
- as salinity increased to the Mesohaline-Polyhaline class, freshwater taxa were no longer ranked.
- the cumacean *Cyclaspis cf. varians*, the amphipod *Ampelisca abdita*, and the bivalves *Amygdalum papyrium* and *Mulinia lateralis* were abundant in both the Mesohaline-Polyhaline and Euhaline salinity classes.

Statistically significant (p<0.05) relationships were found between numbers of taxa, diversity, or total abundance and the abiotic variables within each of the four river zones. However, each of the r^2 values was $\leq$ 0.41:

- the best fitting equation (r^2=0.41) was for the relationship between numbers of individuals, temperature, salinity, the 7-day cumulative flow, and the flow on the date of collection within Zone 2;

- the second best fitting relationship (r^2=0.39) was between numbers of taxa, the 7-day cumulative flow, and the flow on the date of collection within Zone 2 as well.

Exploratory analysis did show that, consistent with the above analyses, that salinity was the single variable that was most correlated with benthic community structure within each of the four zones of the Lower Peace River.

Twenty-four taxa showed statistically significant relationships between salinity and their probability of occurrence within the Charlotte Harbor area.

Reductions in freshwater inflows could facilitate habitat expansion by *Glottidia, Xenanthura, Gammarus mucronatus, Acteocina*, and *Paraprionospio* and diminish available habitat for freshwater species. The distributions of taxa with the wider tolerance ranges (>10 ppt) could be modified, but would be more difficult to detect.

In SC, where the measured salinities averaged 1.3 ppt during the 2003 benthos sampling effort, dominants included *Polymesoda and Grandidierella*, both are species with relatively wide salinity tolerance ranges. These species are not likely to be affected by increased salinities. Hydrobiid gastropods are also abundant in SC. Since salinity tolerances may differ by genera and several genera may be represented, responses to altered salinities by this family is an unknown.

5 Fish Communities of the Lower Peace River and Shell Creek

Flow is an influential component of riverine and estuarine systems, and changes to the flow regime can potentially affect many ecological and environmental variables. Freshwater inflow influences the salinity of a tidal system and this interaction largely determines the distribution of fish in the river. Freshwater flow also influences water quality, namely dissolved oxygen, nutrient loading, and chlorophyll-a.

Salinity is an important factor for fish in tidal rivers, and is influenced by the amount of freshwater inflow entering the system, combined with the effects of the tides. Salinity may affect the distribution and abundance of individual species, and the overall composition of the fish community. Flow is typically negatively correlated with salinity in tidal rivers and generally the salinity gradient is expected to shift upstream and downstream based on flow conditions.

The physiological challenges and stresses associated with variable salinity environments affect the presence, absence and range of fish species. Osmotic limitations restrict the ability of many freshwater species from using habitat in downstream portions that are tidally influenced. Marine species also face osmotic problems, which restrict access to upstream freshwater habitats that are low in salinity. However, numerous euryhaline species exist that have adaptations that allow them to live within a wide range of salinity conditions (Banks *et al.* 1991). Many species, including estuarine-dependent fish, rely on different habitats/salinity zones, during different life stages (Wang and Raney 1971, Peebles 2002, Greenwood *et al.* 2004).

Salinity can impact the overall abundance of certain species and these composite effects influence the fish community as a whole. The success of an individual fish within a species may be affected by the physiological stresses caused by salinity, consequently impacting the overall abundance of that species. While the distribution of a given species is determined by salinity, species able to tolerate saline conditions may still be affected by salinity-related stressors. Species typically have an optimal salinity that is somewhere within the range of salinity that they may be able to inhabit. The salinity in which the eggs, larval, or juvenile forms of certain species develop, may impact their growth and survival rates. It will also affect the availability of prey and where adults of the species congregate and forage (Peterson-Curtis 1997; Baltz *et al.* 1998). The composition of the fish community in a tidal system is likely to change based on the salinity regime. Responses in the fish community are expected to be the composite result of the affects of salinity on all the individual species within the community, as described previously.

Additionally, many fish use the tidal river as nursery habitat. Transport to desirable nursery grounds can be influenced by freshwater flow, in terms of currents that carry larval and juvenile fish (Barbin 1998), and in terms of water quality constituents which serve as olfactory cues for larval fish movement (Benfield and Aldrich 1991).

Freshwater flow also affects dissolved oxygen concentrations by modifying residence times and by physically altering stratification conditions. Increased residence times and stratification may be associated with decreased dissolved oxygen. Alterations in dissolved oxygen conditions may affect the fauna as well (Browder and Moore 1981).

Other physical factors influenced by flow include depth, velocity, substratum, and residence time. Water depth influences two physical factors relevant to fish, habitat availability and structure, and dissolved oxygen. Available habitat expands as water levels increase and additional areas adjacent to the edge of the river become inundated. Accessibility to these habitats also changes with water depth, as increasing depth allows larger sized fish to enter into areas typically restricted only to the smallest fish. As water depth increases, the volume of certain habitats increases as well. Dissolved oxygen also changes with depth. Typically dissolved oxygen is lower in bottom waters than in surface waters due to influx from the atmosphere and possible lack of mixing and stratification in the bottom waters.

Water velocity is a physical force exerted on organisms inhabiting flowing water systems. Velocity affects the size of particles that make up the substrate, as well as nutrient and food delivery to the system. Velocity also affects dissolved oxygen concentrations. During higher flows, dissolved oxygen levels are expected to be higher than during low flow periods. However, under very high flow conditions the river can become stratified with very low dissolved oxygen levels at the bottom.

The magnitude and timing of freshwater inflows affects the amount of nutrients and organic matter that enters a waterway, such that increased productivity may occur some time after a period of increased flows (Kalke and Montagna 1989; Bate *et al*. 2002). Sediment loads to a water body are also increased during high flows. Loadings of contaminants, including metals and organic compounds that bind to smaller particles are often associated with increased sediment loads (Browder and Moore 1981).

Residence time affects the ability of phytoplankton to uptake nutrients, as well as the ability for secondary producers to consume phytoplankton. This extends to other consumers as well. Higher flows are associated with increased nutrient loading. Low flow also allows a longer residence time for chlorophyll and nutrients. During high flow conditions, flushing is more rapid and residence time in the river is reduced (Jassby *et al*. 1995, Sheldon and Alber 2002).

5.1 Lower Peace River

A number of studies have been conducted since 1975 in the Lower Peace River. The following presents summaries of the earliest studies, as gathered from PBS&J (1999b) and more recent studies (1996-present), Peebles (2002) and Greenwood *et al.* (2004).

5.1.1 Earlier Studies, 1975-1996

The first comprehensive study of fish from the Charlotte Harbor area was by Wang and Raney (1971). They used a random trawl sampling program which reported a total of 107 species. Wang and Raney (1971), along with an earlier report by Finucane and Sykes (1966), observed the bay anchovy to be the most abundant species with other common fish including the pinfish, silver perch, sand seatrout, spot, and silver jenny. General fish abundance in the harbor was reported to decrease with decreasing salinity in the wet season (June-September) and decreased with decreasing temperature in the winter (January-February) (Wang and Raney 1971). This study did not comprehensively describe fish distribution and abundance in the lower salinity tributaries (i.e. the LPR and SC).

In 1996 the PRMRWSA initiated the preparation of a document summarizing all data available to date on the Lower Peace River and Upper Charlotte Harbor Estuarine System (PBS&J, 1999b). This document included summaries of fish communities, based on a long-term monitoring program by Environmental Quality Laboratory, Inc. (EQL) from 1975-1989 and sampling conducted by the Fish and Wildlife Research Institute (FWRI) (formerly the Florida Marine Research Institute) from 1989-1995.

5.1.1.1 Environmental Quality Laboratory (EQL)

Objectives

The EQL sampling was initiated through the Hydrobiological Monitoring Program (HBMP) set forth in the original Consumptive Use Permit for the Peace River Regional Water Treatment Plant. The HBMP was designed to describe and assess the responses of various physical, chemical and biological characteristics of the Charlotte Harbor system in response to change in flow in the Peace River (PBS&J 1999a). Fish sampling was a component of the HBMP, with the main goal of determining the relationship between freshwater inflow and trawl susceptible fish. Fraser (1997) published the findings and conclusions of this 13 year study.

Sampling Methods

Results from Wang and Raney (1971) were used to help locate a sampling area considered to be representative of the Upper Charlotte Harbor estuary (e.g., Marker #1 on Figure 5-1). Reciprocal trawl tows (4.9 m otter trawls) were made at the four cardinal points of the compass with Marker #1 at the center of the sampling effort, each tow lasting 5-7 minutes. Trawling began the first hour after twilight and yielded eight samples per date (June 1975-May 1988). *In-situ* physical data profiles were collected with a Hydrolab prior to each evening trawl.

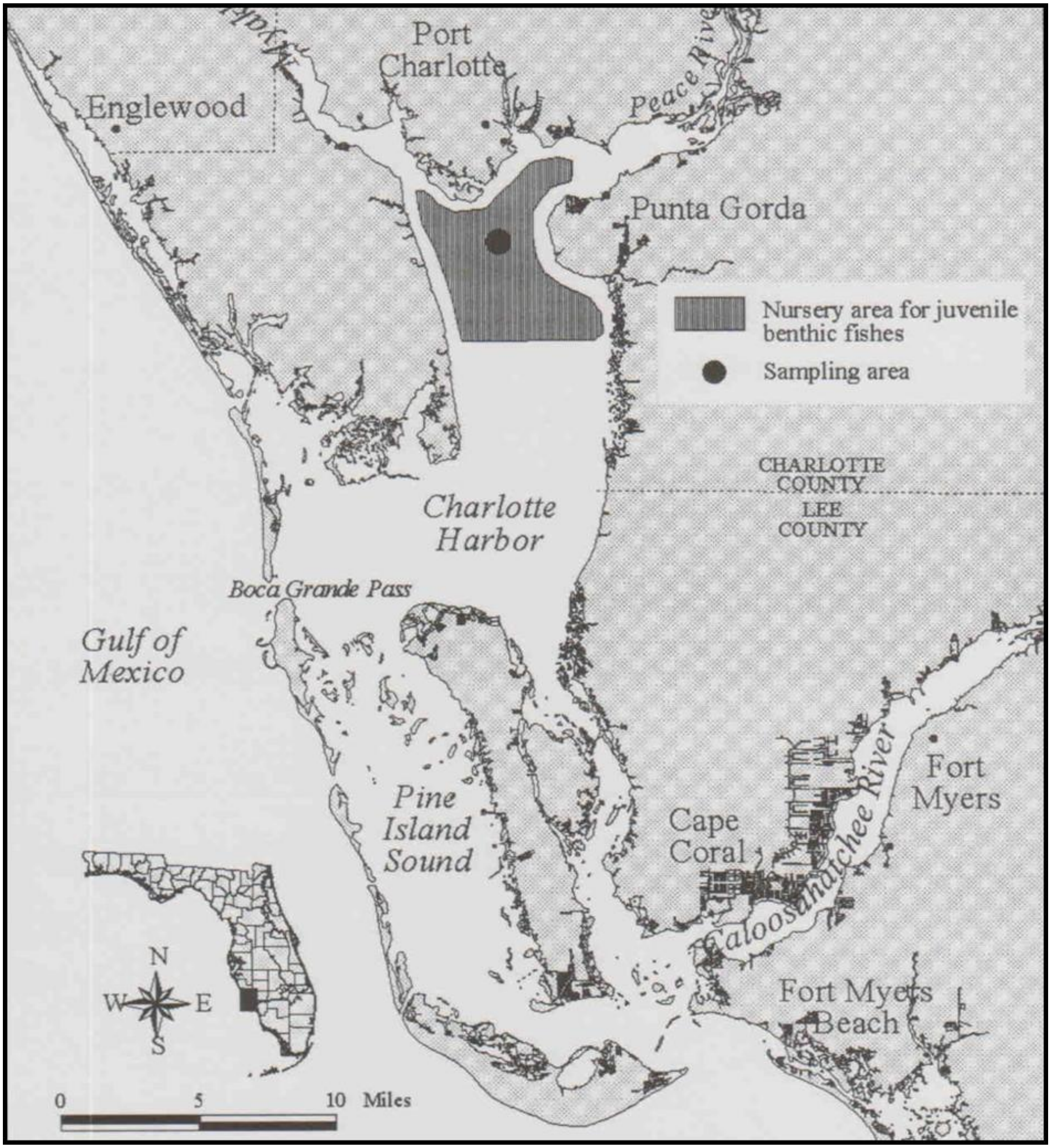


Figure 5-1. **Map from P BS&J (1999) showing the location of EQL Marker #1 (after Fraser,, 1997)**

Analysis Methods

The occurrence and abundance of each species was examined, both with respect to other fish species and community structure indices. The effects of freshwater inflow, temperature, salinity, dissolved oxygen, and other variables were examined. Rainfall data from six gauges throughout the study area were obtained from the District. Rainfall totals for the same day and the previous 29 days were added and used to estimate direct rainfall and runoff from ungauged areas. Freshwater inflow from the following gauged stations was used: SC, Horse Creek, Joshua Creek, Peace River at Arcadia, Big Slough, Deer Prairie Creek and the Myakka River. In order to determine which flows were most highly with the physical-chemical data and with fish abundance and distribution, a series of flow lags were investigated (from 1 to 28 days). Calculating flow lags consisted of taking the average over a certain number of days. For example, the 7 day lag flow consisted of taking the average of the flow on and given day and the preceding six days. Cluster, principal components, and regression analyses were used.

Results and Conclusions

Sixty-two species of fish were collected over the course of the study. Size frequency analysis suggested that the habitat around Marker #1 was used primarily by juveniles less than one year old. The 13 most abundant species and the total numbers caught are shown in Table 5-1. Of these 13 species, consistent seasonal groupings (wet vs. dry season) were observed. The wet season group, as evidenced from cluster and principal components analysis, included: sand seatrout *(Cynoscion arenarius)*, gafftopsail catfish *(Bagre marinus),* hardhead catfish *(Arius felis)*, and southern kingfish *(Menticirrhus americanus)*. The wet season group was more abundant in periods of higher flows and temperature and lower salinity and dissolved oxygen. The dry season group regularly consisted of silver perch *(Bairdiella chrysoura)*, blackcheek tonguefish *(Symphurus plagiusa)*, southern kingfish, silver jenny *(Eucinostomus gula)*, bighead searobin *(Prionotus tribulus)*, and pinfish *(Lagodon rhomboides)*. The dry season group was more abundant in periods of lower flow and temperature and higher salinity and dissolved oxygen.

Significant changes in species abundance were correlated with trends in seasonal freshwater flow and water quality. These changes were consistent with the wet season and dry season groupings. Low dissolved oxygen values were observed in September, causing the relative abundance of all species to decline noticeably. This pattern occurred to some degree every wet season. The more abundant species seemed to have higher tolerances for low dissolved oxygen conditions. Generally, it was concluded that the trawl susceptible fish community was slowly changing in response to wet and dry periods and that these responses to variation in freshwater inflow could be on the order of several years in duration. Because of the long duration, combined with natural variation and interactions between species, critical flow levels and thresholds were not identified based on month or season.

Table 5-1. The 13 most abundant fish species sampled by EQL during the 13 year monitoring period and the total number collected.

Species	**Total Number Collected**
Anchoa mitchilli (bay anchovy)	14, 110
Cynoscion arenarius (sand seatrout)	9,795
Leiostomus xanthurus (spot)	4,982
Arius felis (hardhead catfish)	4,335
Menticirrhus americanus (southern kingfish)	2,689
Symphurus plagiusa (blackcheek tonguefish)	1,964
Prionotus scitulus (leopard searobin)	1,908
Trinectes maculatus (hogchoker)	1,548
Eucinostomus gula (silver jenny)	1,465
Lagodon rhomboides (pinfish)	1,427
Bagre marinus (gafftopsail catfish)	897
Prionotus tribulus (bighead searobin)	525
Bairdiella chrysoura (silver perch)	523
Grand Total	46,168

5.1.1.2 FWRI

Objectives

FWRI has conducted fish monitoring in Charlotte Harbor, as a spatial component of the Fisheries Independent Monitoring (FIM) program, since 1989. The objectives are to describe and quantify the annual status and trends of fish communities, independent of recreational and commercial fishing effort, in estuaries throughout Florida.

Sampling Methods

Two methods, fixed stations and variable stations based on a stratified-random design, were used to sample fish in Charlotte Harbor. The stratified random sampling included three bay zones (a fourth was added in 1994 to encompass Pine Island Sound) and two river zones (Figure 5-2). The bay zones were sampled using seines, trawls, gillnets (night only) and drop nets (day only), while the river zones were only sampled with seines and trawls. Stratified random sampling occurred in the spring (March-May) and fall (September-November). The fixed sampling consisted of 15 stations and occurred monthly. Temperature, salinity, dissolved oxygen and other physical-chemical data were typically collected with a Hydrolab.

Analysis Methods

Data summaries are provided periodically by FWRI, but analyses are not carried out in respect to freshwater inflow or water quality parameters for Charlotte Harbor. An assessment of the data from 1990-1994 was presented by PBS&J (1999a) which reported the most abundant species, across all years, and the dominant species, by gear type and year. A more recent study by FWRI biologists that is focused on the Peace River and incorporates data from the FIM program is discussed in a following section of this report.

Results and Conclusions

The seven most abundant species, as derived from the fixed station data, were: sand seatrout, kingfish (*Menticirrhus* spp.), hogchoker, anchovies (*Anchoa* spp.), hardhead catfish, silver perch, and blackcheek tonguefish. Comparisons between the previously described EQL data and the FWRI data showed the bay anchovy being far more abundant in the EQL data, while the relative dominance of sand seatrout and kingfish were similar in both data sources. Station locations differed in the two studies, and reduced dominance of bay anchovy in the FWRI dataset was attributed to the upstream location of one of their stations.

Additionally, while some inter-annual variability in catches is attributable to changes in gear and sampling regime, FWRI reported an increase in fish numbers for 1990-1994. However, specific analyses in relation to freshwater inflow or water quality variables were not provided. Summaries of the top five dominant species from the stratified random sampling regime are provided by gear type and year in Table 5-2 and 5-3.

5.1.2 Recent Studies, 1996-Present

Surveys of fish and zooplankton in the Lower Peace River have been conducted by the University of South Florida, Department of Marine Science (Peebles 2002) for the District and by the Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute (Greenwood *et al.* 2004).

5.1.2.1 USF/DMS

Objectives

Peebles (2002) conducted a 26 month study, beginning in April 1997, of freshwater inflow effects on habitat use by estuarine taxa in the tidal portion of the Peace River and SC. This study was funded by the District and the PRMRWSA in efforts to develop ecological relationships and develop criteria that could be used in establishing MFLs and to improve the overall management of these systems. The main objectives of the project were to establish a descriptive database to serve as a baseline against future ecological change and to develop regressions to model the response of estuarine organisms to variations in freshwater inflows and salinity (Peebles 2002).

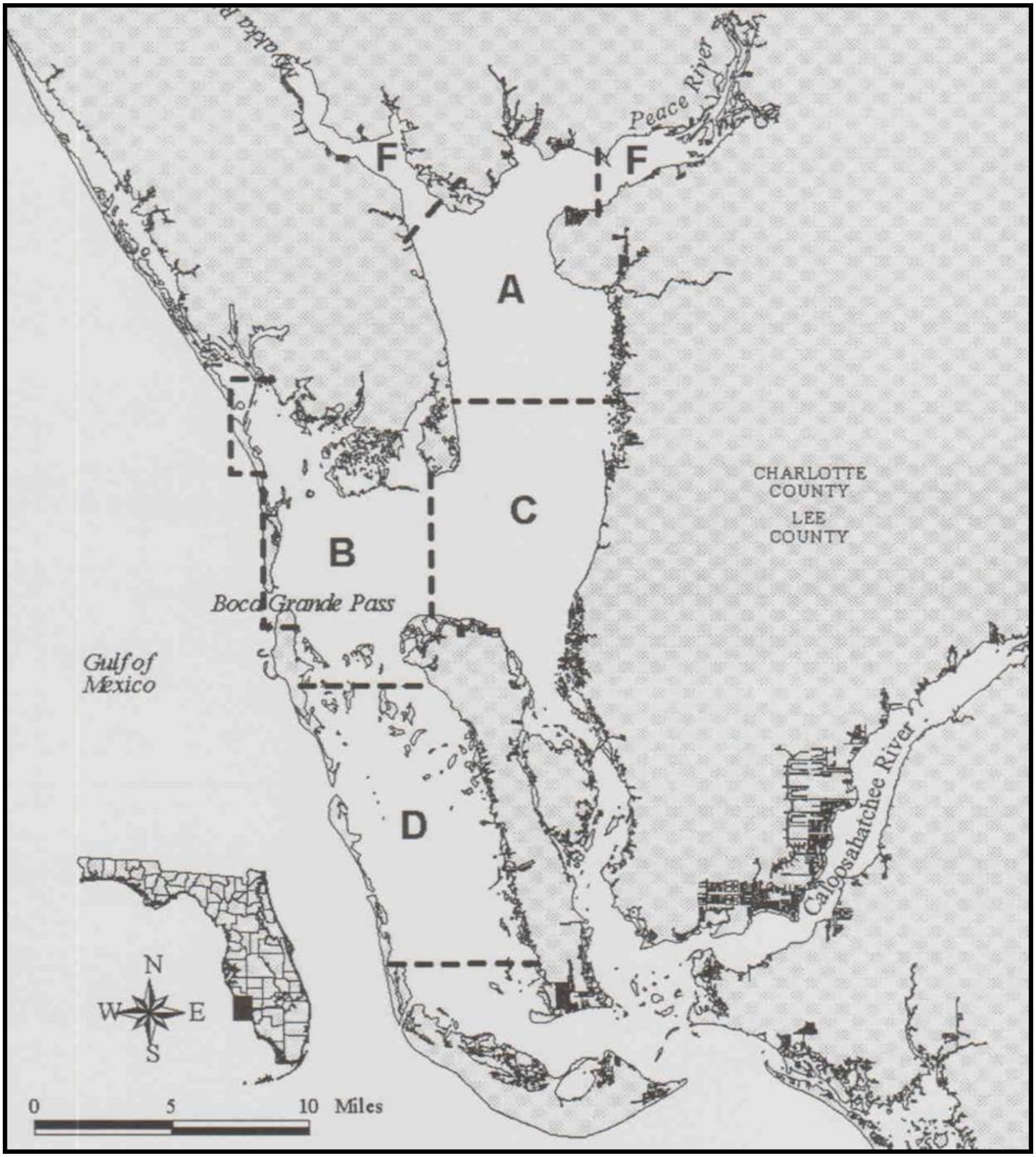


Figure 5-2. **Location of FWRI sampling zones in Charlotte Harbor (PBS&J, 1999b).**

Table 5-2. Summary table from PBS&J (1999b) showing the top five numerically dominant catch data from the FWRI stratified-random sampling during spring in Charlotte Harbor (1990-1994).

GEAR	1990		1991		1992		1993		1994	
Offshore Seines	1. *L. rhomboides* 2. *L. parva* 3. *Anchos* spp. 4. *B. chrysoura* 5. *O. chrysoptera*	6122 3411 686 471 431 14032	1. *Anchoa* spp. 2. *L. rhomboides* 3. *O. chrysoptera* 4. *B. chrysoura* 5. *Eucinostomus* spp.	9126 3609 1645 897 816 18376	1. *L. rhomboides* 2. *O. chrysoptera* 3. *L. parva* 4. *Anchoa* spp. 5. *D. holbrooki*	46171 10436 3628 1714 1412 66722	1. *L. rhomboides* 2. *O. chrysoptera* 3. *L. parva* 4. *S. scovelli* 5. *M. gulosus*	11079 1293 492 401 363 14728	1. *L. rhomboides* 2. *O. chrysoptera* 3. *Anchoa* spp. 4. *Eucinostomus* spp. 5. *B. chrysoura*	48764 6626 3995 2668 1637 68644
Boat Seines	1. *Anchoa* spp. 2. *Menidia* spp. 3. *L. rhomboides* 4. *T. maculatus* 5. *B. chrysoura*	9337 864 791 221 136 12068	1. *Anchoa* spp. 2. *Menidia* spp. 3. *Eucinostomus* spp. 4. *L. rhomboides* 5. *M. martinica*	8913 1231 881 568 626 13396	1. *Anchoa* spp. 2. *F. majalis* 3. *L. rhomboides* 4. *Menidia* spp. 5. *B. chrysoura*	87664 2216 1744 1691 1341 97467	1. *Anchoa* spp. 2. *Menidia* spp. 3. *T. maculaatus* 4. *B. chrysoura* 5. *Eucinostomus* spp.	830 818 223 86 83 2480	1. *Anchos* spp. 2. *Menidia* spp. 3. *Brevoortia* spp. 4. *Eucinostomus* spp. 5. *T. maculatus*	26743 1436 814 380 368 30086
Beach Seines	1. *Menidia* spp. 2. *L. rhomboides* 3. *F. similis* 4. *Anchoa* spp. 5. *Mugil* spp.	4812 863 712 610 447 8473	1. *Anchoa* spp. 2. *Menidia* spp. 3. *L. rhomboides* 4. *Eucinostomus* spp. 5. *L. parva*	34763 11944 8601 4108 2872 71312	1. *L. rhomboides* 2. *F. carpio* 3. *C. variegatus* 4. *Mugil* spp. 5. *Eucinostomus* spp.	16621 4590 4630 3688 2614 43641	1. *L. rhomboides* 2. *Anchoa* spp. 3. *Menidia* spp. 4. *Eucinostomus* spp. 5. *L. parva*	14928 9700 2618 1896 1327 34481	1. *L. rhomboides* 2. *L. parva* 3. *Menidia* spp. 4. *Eucinostomus* spp. 5. *Anchoa* spp.	32820 12271 11763 7671 6649 81736
Trawls	1. *O. chrysoptera* 2. *L. rhomboides* 3. *P. scitulus* 4. *Penaeus* spp. 5. *C. sapidus*	1678 1212 634 666 400 6731	1. *Penaeus* spp. 2. *T. maculatus* 3. *P. scitulus* 4. *L. rhomboides* 5. *C. sapidus*	2844 668 466 463 374 7281	1. *Anchoa* spp. 2. *P. scitulus* 3. *T. maculatus* 4. *C. sapidus* 5. *C. arenarius*	2429 2206 869 582 247 8269	1. *Anchoa* spp. 2. *O. chrysoptera* 3. *P. scitulus* 4. *L. rhomboides* 5. *C. arenarius*	4694 1829 1224 777 748 12040	1. *Anchoa* spp. 2. *L. rhomboides* 3. *T. maculatus* 4. *P. scitulus* 5. *O. chrysoptera*	8737 1910 1893 1064 1013 19897
Gillnets	1. *A. felis* 2. *B. marinus* 3. *E. saurus* 4. *S. tiburo* 5. *Brevoortia* spp.	469 83 39 29 24 774	1. *A. felis* 2. *Brevoortia* spp. 3. *B. marinus* 4. *C. hippos* 5. *C. arenarius*	176 93 81 66 38 642	1. *Brevoortia* spp. 2. *A. felis* 3. *B. marinus* 4. *C .faber* 5. *E. saurus*	362 93 79 56 41 870	1. *A. felis* 2. *Brevoortia* spp. 3. *B. marinus* 4. *E. saurus* 5. *C. sapidus*	169 91 63 36 14 509	1. *H. jaguana* 2. *A. felis* 3. *O. oglinum* 4. *B. marinus* 5. *E. saurus*	349 191 131 71 63 1076
Dropnets	1. *L. parva* 2. *S. scovelli* 3. *L. rhomboides* 4. *G. robustum* 5. *Penaeus* spp.	148 123 99 69 24 633	1. *L. rhomboides* 2. *S. scovelli* 3. *O. chrysoptera* 4. *Penaeus* spp. 5. *G. robustum*	281 121 88 67 56 807	1. *L. rhomboides* 2. *S. scovelli* 3. *M. gulosus* 4. *G. robustum* 5. *O. chrysoptera*	417 71 62 36 32 732	1. *L. rhomboides* 2. *S. scovelli* 3. *O. chrysoptera* 4. *G. robustum* 5. *M. gulosus*	95 70 70 47 46 355	1. *L. rhomboides* 2. *Anchoa* spp. 3. *G. robustum* 4. *L. parva* 5. *S. scovelli*	841 171 128 107 99 1650

Table 5-3. Summary table from PBS&J (1999b) showing the top five numerically dominant catch data from the FWRI stratified-random sampling during fall in Charlotte Harbor (1990-1994).

GEAR/	1990		1991		1992		1993		1994	
Offshore Seines	1. *Anchoa* spp. 2. *Eucinostomus* spp. 3. *Penaeus* spp. 4. *O. oglinum* 5. *M. martinica* Total catch	32123 3974 974 660 427 40251	1. Anchoa *spp.* *2. Eucinostomus* spp. 3. *Penaeus* spp. 4. *B. Chrysoura* 5. *C. nebulosus* Total catch	8314 4217 2035 1153 587 18807	1. *Eucinostomus* spp. 2. *Penaeus* spp. 3. *Anchoa* spp. 4. *B. chrysoura* 5. *C. nebulosus* Total catch	3761 2224 2211 704 428 12015	1. *Eucinostomus* spp. 2. *Penaeus* spp. 3. *Anchoa* spp. 4. *L. parva* 5. *M. gulosus* Total catch	9980 6536 2255 990 689 22903	1. *L. parva* 2. *Anchoa* spp. 3. *Eucinostomus* spp. 4. *Penaeus* spp. 5. *L. rhomboides* Total catch	16984 8277 4609 1768 503 34696
Boat Seines	1. *Anchoa* spp. 2. *Menidia* spp. 3. *Eucinostomus* spp. 4. *L. parva* 5. *G. holbrooki* Total catch	28643 2023 1669 1559 884 29640	1. *Anchoa* spp. 2. *G. holbrooki* 3. *Menidia* spp. 4. *L. parva* 5. *Eucinostomus* spp. Total catch	18483 1769 1060 964 860 25236	1. *Anchoa* spp. 2. *Menidia* spp. 3. *Eucinostomus* spp. 4. *F. majalis* 5. *Penaeus* spp. Total catch	7603 2176 468 153 114 11193	1. *Menidia* spp. 2. *Eucinostomus* spp. 3. *Anchoa* spp. 4. *Penaeusi* spp. 5. *D. plumieri* Total catch	2662 2030 904 218 115 6654	1. *Anchoa* spp. 2. *Eucinostomus* spp. 3. *Menidia* spp. 4. *S. ocellatus* 5. *M. gulosus* Total catch	10268 2062 973 220 96 13924
Beach Seines	1. *Anchoa* spp. 2. *Eucinostomus* spp. 3. *Mugil* spp. 4. *Menidia* spp. 5. *Penaeus*spp. Total catch	86643 43611 28331 15216 4891 190541	1. *Anchoa* spp. 2. *Eucinostomus* spp. 3. *F. carpio* 4. *Menidia* spp. 5. *L. parva* Total catch	6549 6435 6953 4791 2816 35035	1. *Eucinostomus* spp. 2. *Anchoa* spp. 3. *Penaeus* spp. 4. *L. parva* 5. *Menidia* spp. Total catch	16399 6630 3448 2581 1938 38888	1. *Eucinostomus* spp. 2. *L. parva* 3. *Penaeus* spp. 4. *Menidia* spp. 5. *F. carpio* Total catch	10586 9948 4032 3229 2301 36742	1. *L. parva* 2. *Eucinostomus* spp. 3. *Anchoa* spp. 4. *Penaeus* spp. 5. *F. carpio* Total catch	19990 19076 8439 4369 3616 63676
Trawls	1. *Anchoa* spp. 2. *C. arenarius* 3. *T. maculatus* 4. *Penaeus* spp. 5. *L. rhomboides* Total catch	8761 3759 3396 2569 2637 28174	1. *P. scitulus* 2. *T. maculatus* 3. *Penaeus* spp. 4. *L. rhomboides* 5. *O. chrysoptera* Total catch	1214 899 804 699 690 7669	1. *Anchoa* spp. 2. *L. rhomboides* 3. *P. scitulua* 4. *T. maculatus* 5. *Penaeus* spp. Total catch	3409 2561 1297 1155 943 13009	1. *T. maculatus* 2. *P. scitulus* 3. *C. arenarius* 4. *Penaeus* spp. 5. *Anchoa* spp. Total catch	2449 881 760 598 547 7420	1. *L. rhomboides* 2. *Menticirrhus* spp. 3. *Eucinostomus* spp. 4. *Anchoa* spp. 5. *Penaeus* spp. Total catch	2833 1709 1634 1626 1300 14715
Gillnets	1. *A. felis* 2. *T. falcatus* 3. *B. marinus* 4. *Mugil* spp. 5. *C. sapidus* Total catch	168 98 70 47 39 608	1. *Brevoortia* spp. 2. *A. felis* 3. *Mugil* spp. 4. *B. marinus* 5. *C. sapidus* Total catch	163 143 79 44 32 658	1. *Brevoortia* spp. 2. *A. felis* 3. *B. marinus* 4. *E. saurus* 5. *C. sapidus* Total catch	327 129 62 30 24 730	1. *Brevoortia* spp. 2. *A. felis* 3. *C. sapidus* 4. *B. marinus* 5. *E. saurus* Total catch	240 121 48 48 32 657	1. *Brevoortia* spp. 2. *B. marinus* 3. *A. felis* 4. *E. saurus* 5. *L. xanthurus* Total catch	465 204 146 129 62 1399
Dropnets	1. *Penaeus* spp. 2. *G. robustum* 3. *M. gulosus* 4. *S. scsovelli* 5. *Eucinostomus* spp. Total catch	361 190 126 94 74 982	1. *Penaeus* spp. 2. *G. robustum* 3. *C. sapidus* 4. *M. gulosus* 5. *Anchoa* spp. Total catch	394 289 265 123 120 1500	1. *Penaeus* spp. 2. *G. robustum* 3. *M. gulosus* 4. *S. scovelli* 5. *C. sapidus* Total catch	459 189 138 113 104 1168	1. *Penaeus* spp. 2. *Eucinostomus* spp. 3. *C. sapidus* 4. *S. scovelli* 5. *G. robustum* Total catch	487 283 184 64 59 1220	1. *Anchoa* spp. 2. *Penaeus* spp. 3. *M. gulosus* 4. *G. robustum* 5. *S. scovelli* Total catch	469 441 182 99 66 1483

Sampling Methods
Sampling consisted of plankton, seine and trawl nets, deployed within seven zones on the mainstem of the Peace River and four zones in SC (Figure 5-3). Two plankton nets were deployed monthly in each zone in the channel during nighttime flood tides. Two seine nets were deployed monthly in each zone along the shoreline during the day under variable tide conditions. One trawl net was deployed monthly in the channel during the day under variable tide conditions. Salinity, water temperature, DO and pH measurements were recorded with each gear deployment. Daily freshwater flows were derived by summing flows at the following gauges: Peace at Arcadia, Joshua Creek at Nocotee, Horse Creek near Nocotee, and Shell Creek near Punta Gorda.

Analysis Methods
Isohaline location was used, along with same day inflow, to investigate organism response to flow. Isohaline location was not measured directly, but was determined based on salinity measurements associated with various gear deployments. Organism weighted salinity (i.e., the central tendency for catch-per-unit-effort) and center of CPUE (i.e., the central geographic tendency for CPUE) was calculated. Organism total number was calculated for plankton net catches only, as it was related to water volume within each zone. Inflow response regressions were developed between organism total number and flow and isohaline location and between center of CPUE and flow and isohaline location.

Results and Conclusions
Habitat use patterns were documented and found to be consistent with those observed in other tidal rivers. The habitat use of egg, larval, juvenile and adult stages of estuarine-dependent, estuarine-resident, and freshwater fish were described. Estuarine-dependent fish are spawned at seaward locations and move into tidal rivers as late larval or early juvenile life stages. Estuarine resident fish are present in tidal rivers throughout their entire life cycle. The ingress of estuarine-dependent fish into the Peace River was observed based on salinities associated with certain life stages. The mean salinity at capture for the bay anchovy decreased during development, beginning at 22 pptppt during the egg stage and decreasing from 21 to 14 pptppt during the various larval stages, ending at 6 pptppt as juveniles occupied their estuarine nursery habitat. Similar patterns of were observed for other estuarine-dependent species.

The plankton net fish assemblage was dominated by bay anchovy *(Anchoa mitchilli)*, gobies (primarily *Gobiosoma* spp. and *Microgobius* spp.), menhaden *(Brevoortia* spp.*)*, sand seatrout, rainwater killifish *(Lucania parva)*, silversides (*Menidia* spp.) and the hogchoker *(Trinectes maculatus)*. The plankton net invertebrate assemblage was dominated by larval crabs, arrow worms, copepods, mysids, amphipods, isopods, cumaceans, the larvacean *Oikepleura dioica*, larval and juvenile bivalves, and ctenophores. Shoreline seines were dominated by bay anchovy, menhaden, silversides, mojarras *(Eucinostomus* spp.*),* eastern mosquitofish *(Gambusia holbrooki)*, killifish *(Fundulus* spp.*),* striped mullet *(Mugil cephalus)* and hogchoker. The trawl catch was dominated by bay anchovy, sand seatrout, southern kingfish, hogchoker and blue crab *(Callinectes sapidus)*.

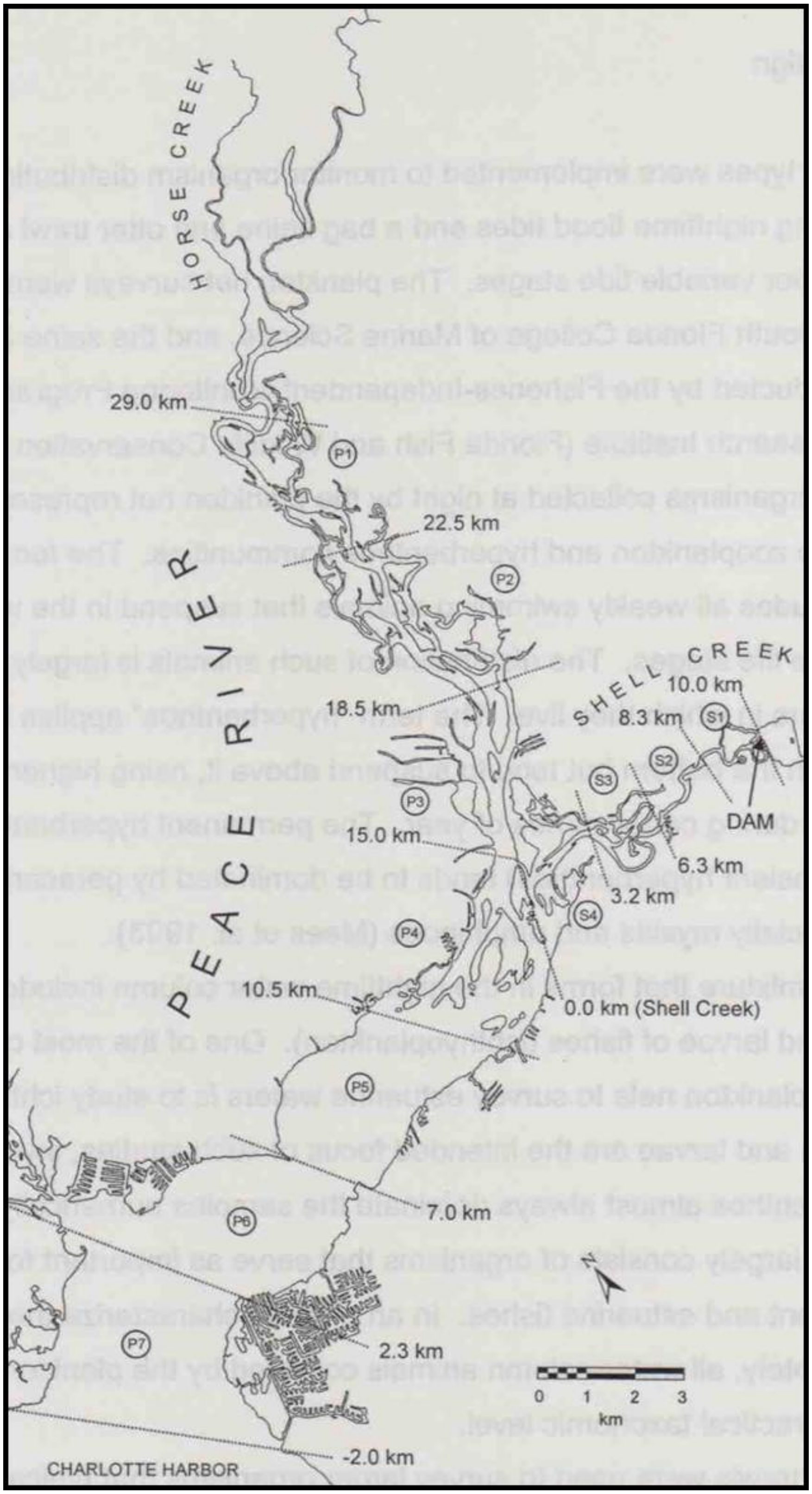


Figure 5-3. Map from Peebles (2002) showing study area with sampling zones numbered based on labels used for plankton samples.

Species determined to be spawning in or very near the tidal Peace River, based on the presence of eggs or early larval stages, were the bay anchovy, silversides, rough silverside *(Membras martinica)*, blennies (primarily *Chasmodes saburrae)*, several species of goby *(Gobiosoma* spp*., Microgobius* spp*., Bathygobius soporator),* sand seatrout, southern kingfish, and skilletfish *(Gobiesox strumosus)*. Live-bearing species, such as the eastern mosquitofish, lined seahorse *(Hippocampus erectus)*, chain pipefish *(Syngnathus louisianae)*, gulf pipefish *(Syngnathus scovelli)* and dusky pipefish *(Syngnathus floridae)*, released young into the tidal Peace River. Seine data indicated that juvenile snook, red drum, and striped mullet occurred commonly in the tidal river although no eggs or larvae were captured.

Estuarine-dependent species documented as congregating in the tidal Peace River as juveniles are the bay anchovy, yellowfin menhaden *(Brevoortia smithi)*, gulf menhaden *(Brevoortia patronus)*, ladyfish *(Elops saurus)*, snook *(Centropomis undecimalis)*, red drum *(Sciaenops ocellatus)*, spotted seatrout *(Cynoscion nebulosus)*, sand seatrout, striped mullet, hogchoker, blue crab and pink shrimp *(Penaeus duorarum)*. Of these species, all were also detected as larvae except for snook, striped mullet, and blue crab.

Seasonality was evident among the fish catches. In the plankton catch, the number of taxa increased during spring, decreased during fall, and was generally highest from April-October. A spring increase was also seen in the seine data, but the fall decrease was not observed, because the older juveniles caught in the seines remained in the river long after the larval recruitment observed in the plankton nets had ended. April to June was considered to be the time period with the most potential for impact due the combined effect of naturally low inflows and increased use of the estuary as nursery habitat. However, because other species (i.e., red drum and menhaden) spawn in the fall, the potential for ecological or economic impacts exists year round.

Over 20 taxa of fish and invertebrates displayed distributional responses to freshwater inflow based on the plankton catch data. Almost all, 94%, of these taxa moved downstream in response to increasing inflow and example regression plots are shown in Figure 5-4. Good indicators of organism position within the tidal river were determined to be same day inflow and the reference isohaline (7 ppt isohaline). While most organisms displayed the same directional response, the distribution of different organisms within the river was staggered and some were located farther upstream than others.

Eighteen taxa in the LPR and ten taxa in SC displayed either positive or negative abundance responses to flow. Positive responses were generally observed for freshwater species that shifted downstream with increasing flow, increasing their total numbers on the river (Figure 5-5). High salinity organisms accounted for the negative responses as these organisms generally left the tidal river during periods of high inflow. Positive responses were also found for sand seatrout juveniles and mysids (opossum shrimp). The majority of estuarine and estuarine dependent taxa had positive responses to high inflow that were delayed 3-6 months. The very high flows of the 1997-1998 El Nino event was followed by very large peaks of these taxa several months after the event.

Additionally, mysids are an important prey source for many juvenile estuarine-dependent organisms; reducing mysid abundance during low flow periods is expected to reduce the carrying capacity of the LPR and SC for snook, red drum, sand seatrout, spotted seatrout and other species. Inflow-induced movement of important prey groups (i.e., mysids) relative to the fixed structural habitats preferred by certain fish could cause prey distributions to be offset (upstream or downstream) of their fish predators, acting to reduce the carrying capacity of the river for these fish. In the LPR, mysid populations were frequently located upstream from the principal habitat of juvenile red drum. It was suggested that the mysids in SC were favored as an alternative food supply and this contributed to the red drum remaining downstream of the mysid peak in the Lower Peace River. Other species, such as juvenile spotted seatrout and sand seatrout were more spatially in step with their prey in the Lower Peace River, often congregating above the confluence with SC.

5.1.2.2 FWC/FWRI

Objectives

Greenwood *et al.* (2004) conducted a multi-year study from January 1996 to December 2003 to establish relationships between freshwater inflow and biotic populations and communities within Peace River and SC by staff from the Fisheries-Independent Monitoring Program (FIM) of the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FCW/FWR). This is the same sampling program that was described earlier by PBS&J (1999b) but with more recent efforts the FIM program has expanded to include sampling areas in the LPR and SC.

The specific objectives of this project were to: 1) assess the composition of the nekton community (finfish and selected macroinvertebrates) over the period of record, 2) to examine habitat use for selected economically or ecologically important species, 3) to analyze movement and relative abundance of the nekton populations in relation to magnitude of freshwater inflow, and 4) to examine nekton community composition in relation to magnitude of freshwater inflow. Data collected for the SWFWMD by Peebles (2002) was also included in the analysis and provided additional data for 1997-1999.

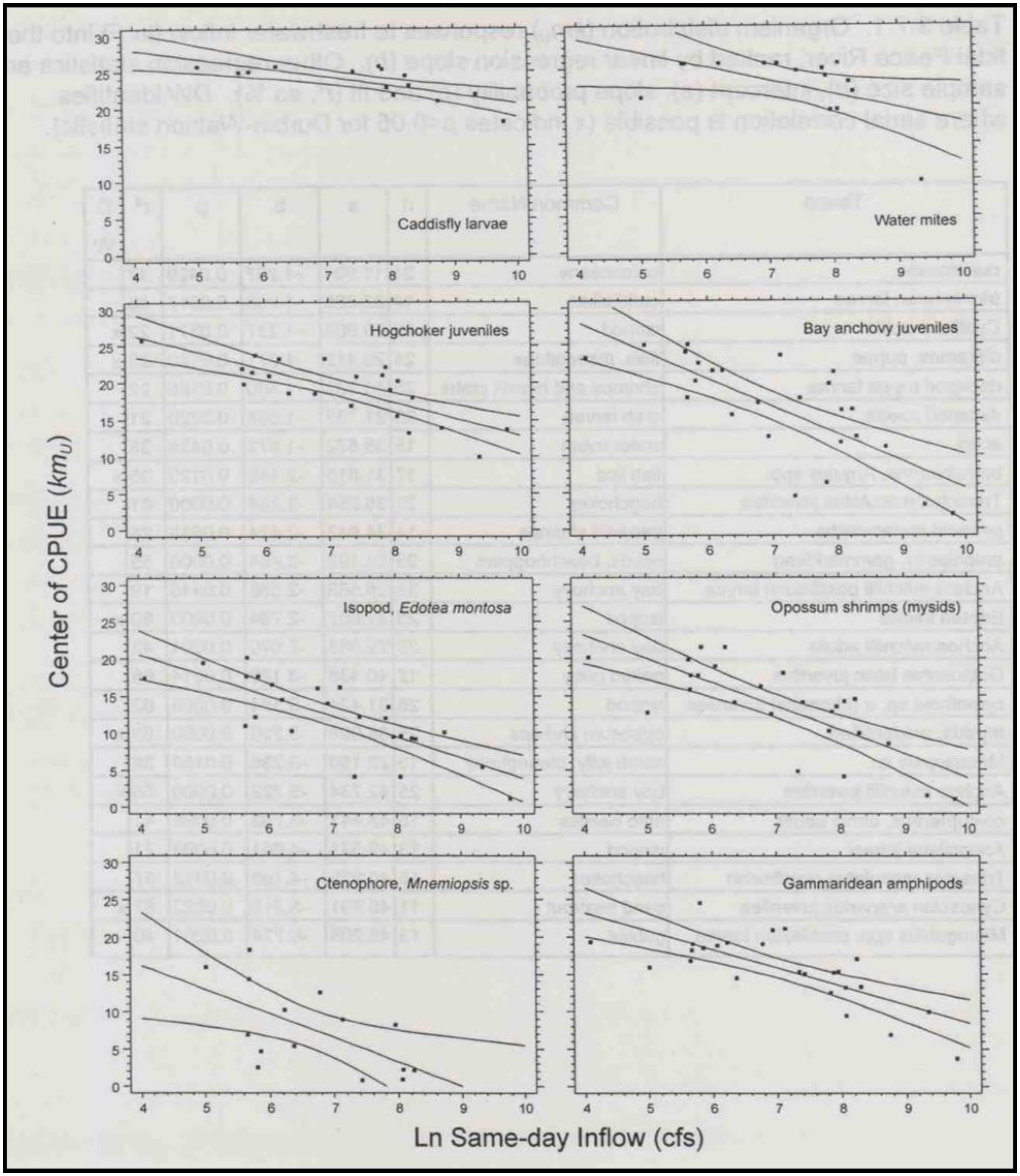


Figure 5-4. **Example regressions of organism location vs. inflow with 95% confidence limits for estimated means, showing general trend of movement downstream with increasing flows (Peebles 2002).**

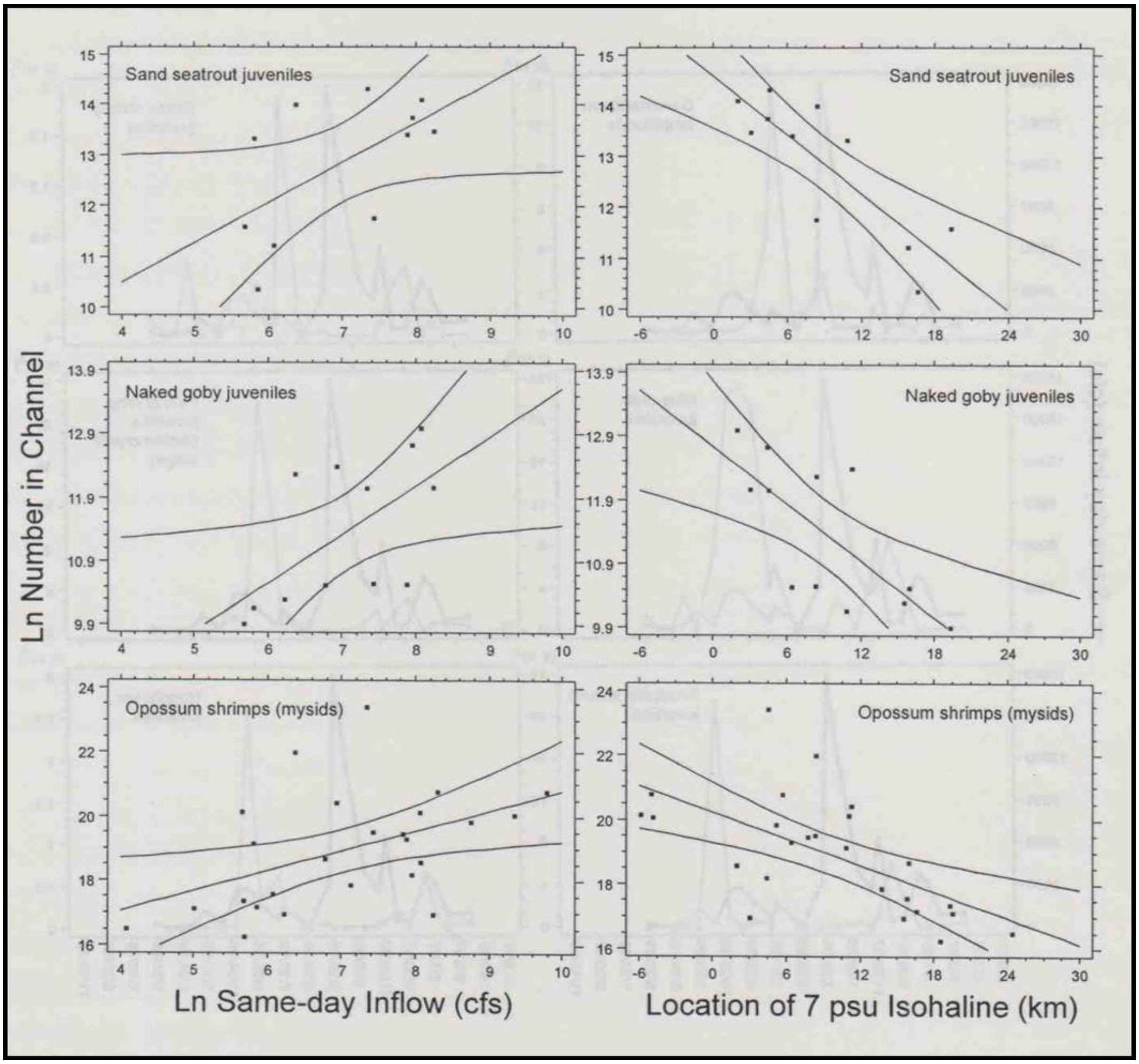


Figure 5-5. **Example regressions of organism number vs. inflow and 7 ppt isohaline location, with 95% confidence limits for estimated means (Peebles 2002).**

Sampling Methods

Sampling consisted of seine and trawl sampling in the main stem of the LPR and SC (Figure 5-6). Nearshore habitats were sampled with a 21.3 m seine set from a boat and channel habitats were sampled with a 6.1 m otter trawl. Stratified random sampling was used to collect the FIM data; the data in the Peebles (2002) study where based on the establishment of seven zones in the LPR and four in SC and consisted of two seines samples and one trawl sample per month (Figure 5-6). A Hydrolab multi-probe was used to record water temperature, salinity, pH and dissolved oxygen with each sample, at the surface and at 1.0-m intervals down to the bottom. Secchi disk readings were taken at the end of each sample.

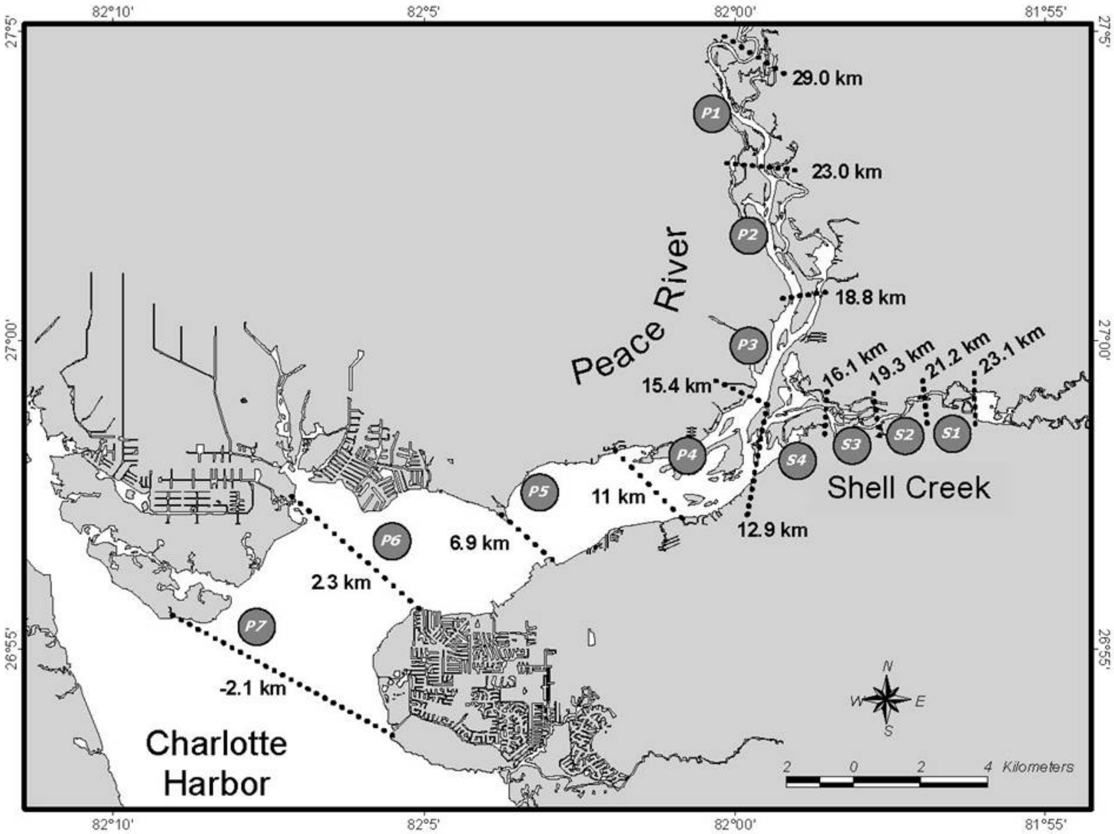


Figure 5-6. **Study area of the tidal Peace River and Shell Creek showing the sampling locations of the SWFWMD study data (Peebles 2002) that were incorporated with the FWRI stratified-random sampling program (occurred between river km 6.8 and 15.4) (Greenwood *et al.* 2004).**

Analysis Methods

The analysis goal was to regress organism abundance/distribution from a sampling trip, comprised of several individual seine or trawl samples, against the mean daily inflow that corresponded to the sampling trip. Abundance information was summarized separately for seine and trawl data for all species that were either 1) commercially or recreationally important, and/or 2) had an Index of Relative Important (Gilmore, 1988) of greater than 0.3. Plots of monthly length frequency were used to determine the appropriate size classes and time periods within each species (i.e., termed pseudo-species).

Samples were divided into three geographic zones prior to analysis based on different river flow. These groups included data from the following locations: 1) Peace River above the confluence of SC which corresponded to the summed inflow from the USGS gauges at Joshua Creek at Nocatee, Horse Creek at Nocatee, and Peace River at Arcadia; 2) SC and the corresponding inflow from Shell Creek near Punta Gorda; and 3) Peace River below the confluence with SC and the corresponding flow was summed from the gauges used for the previous two categories. Additionally data were separated into six different salinity classes: limnetic, oligohaline, low mesohaline, high mesohaline, polyhaline and euhaline. Data was presented for the distribution of size classes of major taxa and abundance on a monthly basis.

Linear regressions of center of CPUE (kmu) and freshwater inflow were computed for pseudo-species with IRI values >0.3 to examine the response to variations in river flow (km=the distance from the river mouth; u=the number of animals per 100 m^2). The kmu for each pseudo-species was regressed against mean daily flow for the sampling day and various lags. Lags included flow for the same day plus the previous 6, 13, 29, 44, 59, 89, 179, or 364 days. Linear and non-linear regressions were also developed for CPUE and same day flow, within the period of highest pseudo-species abundance.

Nekton community structure was analyzed using the Bray-Curtis similarity measure.

Results and Conclusions

In the Peace River above the confluence with SC, bay anchovies were the most abundant species and accounted for over 61% of the total catch. Hogchoker was the most frequently occurring species, being found in over 80% of all samples. In the Peace River below the confluence with SC, bay anchovies were still the most abundant species, accounting for 67% of the seine catch and nearly 47% of the trawl catch. Silversides were the most frequently occurring seine species, being found in nearly 73% of all samples and blue crab was the most frequently occurring trawl species, being found in nearly 70% of the samples.

The following ten species were most abundant in the nearshore habitat (based on total numbers caught) and comprised between 90.4%-97% of the total catch in the three segments: bay anchovy, silversides, rainwater killifish, eastern mosquitofish, mojarras, hogchoker, seminole killifish *(Fundulus seminolis)*, sailfin molly *(Poecilia latipinna)*, tidewater mojarra *(Eucinostomus harangulus)*, and striped mullet. Bay anchovies dominated the catch in each segment, with the percentage of the catch comprised of bay anchovies ranging from 59.4%-67%.

The following ten species were most abundant in the channel habitat (based on total numbers caught) and comprised between 96.3-97.7% of the total catch in the three segments: bay anchovy, hogchoker, sand seatrout, pink shrimp, blue crab, southern kingfish, mojarras, silver perch, bighead searobin, and hardhead catfish. The bay anchovy dominated the total catch in both the Peace River below the confluence of SC (46.7%) and in SC (41.8%), while the hogchoker was most abundant in the Peace River above the confluence (39.8%).

Thirty-four taxa were selected for detailed regression analysis on the basis of overall abundance. Regression results were complex and numerous, preventing the summary of individual species results. However, overall the comparisons of freshwater inflow to population center-of-abundance and overall relative abundance showed that many species are likely to move upstream during periods of low flow and reach their maximum abundance at intermediate flows. Longer term inflow lag periods (90-365 days) generated the best fitting regressions indicating the longer lags have a stronger relationship with nekton abundance and distribution than short term inflow patterns. Complex relationships were seen between relative importance of freshwater inflow and the life history stages of species found within the river. Although less common, there were some differences between the relationships observed depending on which of the three segments of the system, or which of the two habitats (shoreline or channel), is being considered.

Community structure in the Peace River and SC were generally separated into assemblages above and below the confluence between the two systems. Relatively little difference was observed between the Peace River above the confluence and SC. However, these two segments differed from the Peace River below the confluence with SC.

Annual cycles were most evident in the Peace River below the confluence and were poorly defined in the other areas. This was thought to relate to the Lower Peace River being used as a nursery area for a number of transient species with fairly well-defined seasonal patterns of recruitment. Patterns observed in community structure in the Peace River above the confluence and SC were more strongly correlated with changes in salinity (as opposed to flow), while changes in community structure below the confluence were equally correlated with both salinity and flow.

5.2 Shell Creek

A number of studies have been conducted since 1975 in the LPR. The following presents summaries of the earliest studies, as gathered from PBS&J (1999b) and more recent studies (1996-present) as gathered from Peebles (2002) and Greenwood *et al.* (2004).

5.2.1 Earlier Studies, 1975-1996

The first comprehensive study of fish from the Charlotte Harbor area was by Wang and Raney (1971), but did not include SC or other lower salinity tributaries. In 1999 a summary document was prepared by PBS&J (1999b) for the PRMRWSA. This document included summaries of fish communities, based on a long-term monitoring program by EQL from 1975-1989 and sampling conducted by the FWRI from 1989-1995. However, sampling from these programs focused solely on the LPRr and Charlotte Harbor and did not extend sampling into SC.

5.2.2 Recent Studies, 1999-Present

Surveys of fish and zooplankton in the LPR and SC have been conducted by the University of South Florida, Department of Marine Science (Peebles 2002) for the District and by the Florida Fish and Wildlife Conservation Commission, FWRI (Greenwood *et al.* 2004).

5.2.2.1 USF/DMS

Objectives

Peebles (2002) conducted a 26 month study, beginning in April 1997, of freshwater inflow effects on habitat use by estuarine taxa in the tidal portion of the Peace River and SC. This study was funded by the District and the PRMRWSA in efforts to develop ecological relationships and develop criteria that could be used in establishing MFLs and to improve the overall management of these systems. The main objectives of the project were to establish a descriptive database to serve as a baseline against future ecological change and to develop regressions to model the response of estuarine organisms to variations in freshwater inflows and salinity (Peebles 2002).

Sampling Methods

Sampling consisted of plankton, seine and trawl nets, deployed within seven zones on the mainstem of the Peace River and four zones in SC (Figure 5-3). Two plankton nets were deployed monthly in each zone in the channel during nighttime flood tides. Two seine nets were deployed monthly in each zone along the shoreline during the day under variable tide conditions. One trawl net was deployed monthly in the channel during the day under variable tide conditions. Salinity, water temperature, DO and pH measurements were recorded with each gear deployment. Daily freshwater flows were derived by summing flows at the following gauges: Peace at Arcadia, Joshua Creek at Nocatee, Horse Creek near Nocatee, and Shell Creek near Punta Gorda.

Analysis Methods

Isohaline location was used, along with same day inflow, to investigate organism response to flow. Isohaline location was not measured directly, but was determined based on salinity measurements associated with various gear deployments. Organism weighted salinity (i.e., the central tendency for catch-per-unit-effort) and center of CPUE (i.e., the central geographic tendency for CPUE) was calculated. Organism total number was calculated for plankton net catches only, as it was related to water volume within each zone. Inflow response regressions were developed between organism total number and flow and isohaline location and between center of CPUE and flow and isohaline location.

Results and Conclusions

SC had high inflows during most of the Peebles (2002) study, which caused the numbers of freshwater organisms to increase and numbers of estuarine organisms to decrease. There were no apparent inflow-related trends in the numbers of estuarine and estuarine-dependent organisms within SC, but this may have been due to the lack of low flow conditions during the study period. SC exhibited freshwater conditions during 13 of 25 surveys and the mean salinity during the study period was only 3.0

pptppt. Salinities greater than 17 pptppt were never observed during this study, although earlier work by PBS&J (1999b) reported salinities of greater than 25 pptppt.

The lifestage specific ingress demonstrated in the Peace River was not observed in SC for two possible reasons. First, larvae of fish such as anchovies, seatrout and other species that broadcast their eggs spawned primarily in the bay-like reaches of the Peace River as opposed to the more river-like areas of SC. Additionally, salinities in SC were generally low during the sampling period which prevented much gradient for ingress to be identified.

The plankton net fish assemblage was dominated by bay anchovy, gobies (primarily *Gobiosoma spp*. and *Microgobius spp.*), menhaden, sand seatrout, rainwater killifish, silversides and the hogchoker. The plankton net invertebrate assemblage was dominated by larval crabs, arrow worms, copepods, mysids, amphipods, isopods, cumaceans, the larvacean *Oikepleura dioica*, larval and juvenile bivalves, and ctenophores. Shoreline seines were dominated by bay anchovy, menhaden, silversides, mojarras, eastern mosquitofish, killifish, striped mullet and hogchoker. The trawl catch was dominated by bay anchovy, sand seatrout, southern kingfish, hogchoker and blue crab.

Species determined to be spawning in or very near the tidal Peace River, based on the presence of eggs or early larval stages, were the bay anchovy, silversides, rough silverside, blennies (primarily *Chasmodes saburrae*), several species of goby *(Gobiosoma* spp*., Microgobius* spp*., Bathygobius soporator)*, sand seatrout, southern kingfish, and skilletfish. Live-bearing species, such as the eastern mosquitofish, lined seahorse, chain pipefish, gulf pipefish and dusky pipefish, released young into the tidal Peace River.

Estuarine dependent species documented as congregating in the tidal Peace River as juveniles are the bay anchovy, yellowfin menhaden, gulf menhaden, ladyfish, snook, red drum, spotted seatrout, sand seatrout, striped mullet, hogchoker, blue crab and pink shrimp. Of these species, all were also detected as larvae except for snook, striped mullet, and blue crab. Seasonality was evident among the fish catches. In the plankton catch, the number of taxa increased during spring, decreased during fall, and was generally highest from April-October. A spring increase was also seen in the seine data, but the fall decrease was not observed because the older juveniles caught in the seines remained in the river long after the larval recruitment observed in the plankton nets had ended. April to June was considered to be the time period with the most potential for impact due the combined effect of naturally low inflows and increased use of the estuary as nursery habitat. However, because other species (i.e., red drum and menhaden) spawn in the fall, the potential for ecological or economic impacts exists year round.

Over 20 taxa of fish and invertebrates displayed distributional responses to freshwater inflow based on the plankton catch data. Almost all, 94%, of these taxa moved downstream in response to increasing inflow and example regression plots are shown in

Figure 5-4. Good indicators of organism position within the tidal river were determined to be same day inflow and the reference isohaline (7 ppt isohaline). While most organisms displayed the same directional response, the distribution of different organisms within the river was staggered and some were located farther upstream than others.

Eighteen taxa in the Lower Peace River and ten taxa in SC displayed either positive or negative abundance responses to flow. Positive responses were generally observed for freshwater species that shifted downstream with increasing flow, increasing their total numbers on the river (Figure 5-5). High salinity organisms accounted for the negative responses as these organisms generally left the tidal river during periods of high inflow. The majority of estuarine and estuarine dependent taxa had positive responses to high inflow that were delayed 3-6 months. The very high flows of the 1997-1998 El Nino event was followed by very large peaks of these taxa several months after the event.

Additionally, mysids are an important prey source for many juvenile estuarine-dependent organisms; reducing mysid abundance during low flow periods is expected to reduce the carrying capacity of the LPR and SC for snook, red drum, sand seatrout, spotted seatrout and other species. Inflow-induced movement of important prey groups (i.e., mysids) relative to the fixed structural habitats preferred by certain fish could cause prey distributions to be offset (upstream or downstream) of their fish predators, acting to reduce the carrying capacity of the river for these fish. In the Lower Peace River, mysid populations were frequently located upstream from the principal habitat of juvenile red drum. It was suggested that the mysids in SC were favored as an alternative food supply and this contributed to the red drum remaining downstream of the mysid peak in the LPR. Other species, such as juvenile spotted seatrout and sand seatrout were more spatially in step with their prey in the LPR, often congregating above the confluence with SC.

5.2.2.2 FWC/FWRI

Objectives

Greenwood *et al.* (2004) conducted a multi-year study from January 1996 to December 2003 to establish relationships between freshwater inflow and biotic populations and communities within Peace River and SC by staff from the FIM of the Florida Fish and Wildlife Conservation Commission's FWRI. The specific objectives of this project were to: 1) assess the composition of the nekton community (finfish and selected macroinvertebrates) over the period of record, 2) to examine habitat use for selected economically or ecologically important species, 3) to analyze movement and relative abundance of the nekton populations in relation to magnitude of freshwater inflow, and 4) to examine nekton community composition in relation to magnitude of freshwater inflow. Data collected for the SWFWMD by Peebles (2002) was also included in the analysis and provided additional data for 1997-1999.

Sampling Methods

Sampling consisted of seine and trawl sampling in the main stem of the LPR and SC (Figure 5-6). Nearshore habitats were sampled with a 21.3 m seine set from a boat and channel habitats were sampled with a 6.1 m otter trawl. Stratified random sampling was used to collect the FIM data; the data in the Peebles (2002) study where based on the establishment of seven zones in the LPR and four in SC and consisted of two seines samples and one trawl sample per month (Figure 5-6). A Hydrolab multi-probe was used to record water temperature, salinity, pH and dissolved oxygen with each sample, at the surface and at 1.0-m intervals down to the bottom. Secchi disk readings were taken at the end of each sample.

Analysis Methods

The analysis goal was to regress organism abundance/distribution from a sampling trip, comprised of several individual seine or trawl samples, against the mean daily inflow that corresponded to the sampling trip. Abundance information was summarized separately for seine and trawl data for all species that were either 1) commercially or recreationally important, and/or 2) had an Index of Relative Important (Gilmore 1988) of greater than 0.3. Plots of monthly length frequency were used to determine the appropriate size classes and time periods within each species (i.e., pseudo-species).

Samples were divided into three geographic regions prior to analysis based on different river flow. These groups included data from the following locations: 1) Peace River above the confluence of SC which corresponded to the summed inflow from the USGS gauges at Joshua Creek at Nocatee, Horse Creek at Nocatee, and Peace River at Arcadia; 2) SC and the corresponding inflow from Shell Creek near Punta Gorda; and 3) Peace River below the confluence with SC and the corresponding flow was summed from the gauges used for the previous two categories.

Linear regressions of center of CPUE (kmu) and freshwater inflow were computed for pseudo-species with IRI values >0.3 to examine the response to variations in river flow (km=the distance from the river mouth; u=the number of animals per 100 m^2). The kmu for each pseudo-species was regressed against mean daily flow for the sampling day and various lags. Lags included flow for the same day plus the previous 6, 13, 29, 44, 59, 89, 179, or 364 days. Linear and non-linear regressions were also developed for CPUE and same day flow, within the period of highest pseudo-species abundance.

Nekton community structure was analyzed using the Bray-Curtis similarity measure.

Results and Conclusions

In SC, as in the Peace River, bay anchovies were the most abundant taxa, comprising nearly 60% of the total catch. Silversides and the rainwater killifish were the most frequently occurring taxa, being present in over 83% of all samples.

The following ten species were most abundant in the channel habitat (based on total numbers caught) and comprised between 96.3-97.7% of the total catch in the three segments: bay anchovy, hogchoker, sand seatrout, pink shrimp, blue crab, southern kingfish, mojarras, silver perch, bighead searobin, and hardhead catfish. The bay anchovy dominated the total catch in both the Peace River below the confluence of SC (46.7%) and in SC (41.8%), while the hogchoker was most abundant in the Peace River above the confluence (39.8%).

Regression results were complex and numerous, preventing the summary of individual species results. However, overall the comparisons of freshwater inflow to population center-of-abundance and overall relative abundance showed that many species are likely to move upstream during periods of low flow and reach their maximum abundance at intermediate flows. Longer term inflow lag periods (90-365 days) generated the best fitting regressions indicating the longer lags have a stronger relationship with nekton abundance and distribution than short term inflow patterns. Complex relationships were seen between relative importance of freshwater inflow and the life history stages of species found within the river. Although less common, there were some differences between the relationships observed depending on which of the three segments of the system, or which of the two habitats (shoreline or channel), is being considered.

Community structure in the Peace River and SC were generally separated into assemblages above and below the confluence between the two systems. Relatively little difference was observed between the Peace River above the confluence and SC. However, these two segments differed from the Peace River below the confluence with SC. Annual cycles were most evident in the Peace River below the confluence and were poorly defined in the other areas. This was thought to relate to the Lower Peace River being used as a nursery area for a number of transient species with fairly well-defined seasonal patterns of recruitment. Patterns observed in community structure in the Peace River above the confluence were more strongly correlated with changes in salinity (as opposed to flow), while changes in community structure below the confluence were equally correlated with both salinity and flow.

5.3 Fish Community Structure and Distribution in the Lower Peace River

To expand on the existing information, additional analyses were completed for this report using the same dataset used by Greenwood *et al.* (2004). While the same data were used, they were spatially segregated into the four zones used by Mote Marine Laboratory (2002), plus SC. Zones 1 and 2 of the new segregation are above the confluence of SC, while Zones 3 and 4 correspond to the below SC zone used by FWRI.

The spatial variation in the total abundance and number of taxa has been examined and summarized in Figures 5-7 through 5-10. The taxa richness varied spatially as expected; seine data showed the lowest number of species in the higher salinity zones (Zones 3 and 4) and slightly higher numbers of species in the lower salinity zones

(Zones 1, 2 and SC) (Figure 5-7). Trawl data exhibited an opposite pattern, with fewer species in the lower salinity zones (Zones 1, 2, and SC) and the highest number of species in the highest salinity zone (Zone 4) (Figure 5-8).

Since seines samples shoreline habitat and trawls sample deeper channel habitat, these opposing patterns may reflect differing extents of each habitat type present in the various zones. Additionally, shoreline habitat is increasingly important as nursery area in lower salinity zones, it may follow that the greatest number of seine species would occur in the lower salinity zones for this reason. Trawls sample deeper channel habitat which is typically occupied by marine and euryhaline species which tolerate higher salinities and this may account for the greatest number of trawl species being reported in the higher salinity zones.

The total number of taxa caught per seine sample was highest in Zone 2 and SC, where the median number of taxa per sample was 9. Similar numbers of taxa were found in Zone 1 (median number of taxa=8) and Zone 3 (median number of taxa=7). The fewest number of taxa was found in Zone 4 (median number of taxa=6).

The total number of species caught per trawl sample was generally lower than numbers reported for seines, and displayed a similar pattern of higher numbers of taxa in the more saline environments (Figure 5-8). The total number of taxa caught per trawl was lowest in Zone 1 (median=4). Slightly higher numbers of taxa were found in Zone 2 (median=5) and SC (median=4). The median number of taxa per trawl was 6 in Zone 3 and greatest in Zone 4 (median=7).

The total number of fish caught per seine sample varied across zones much more than number of taxa (Figure 5-9). The lowest number of fish per seine occurred in Zone 1 (median=114 individuals/sample) and Zone 4 (median=65 individuals/sample). Slightly higher abundances were found in Zone 2 (median=121 individuals/sample) and Zone 3 (median=90 individuals/sample). The highest number of organisms per seine samples was found in SC (median=311 individuals/sample).

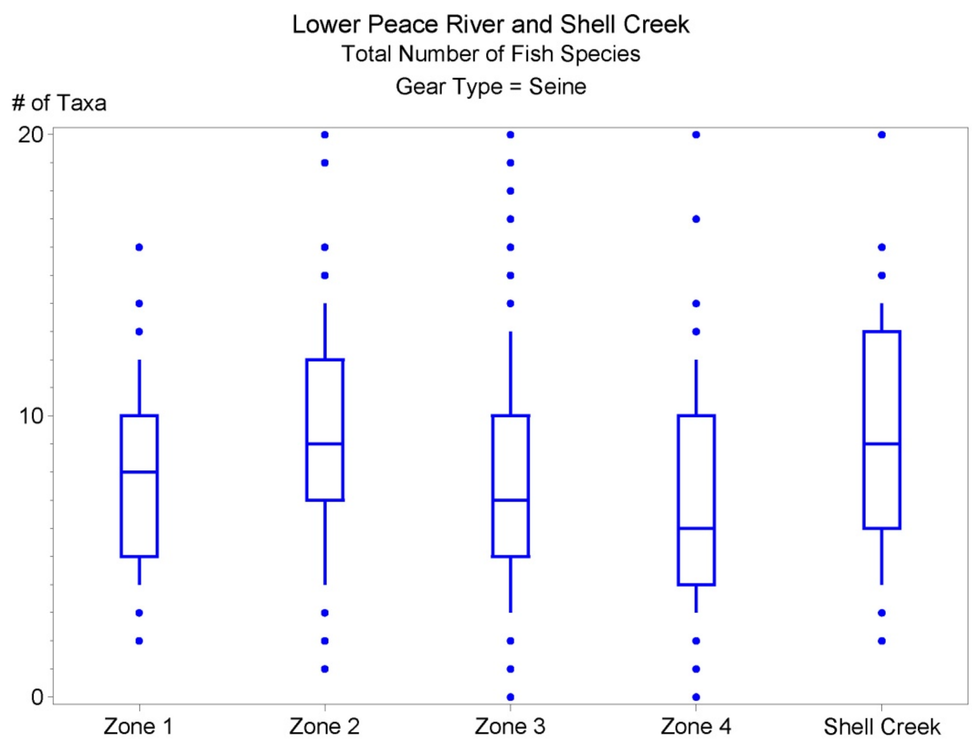


Figure 5-7. **Box-and-whisker plots of the taxa richness in seine samples collected in the four LPR zones and SC (Data source: Greenwood *et al.* 2004).**

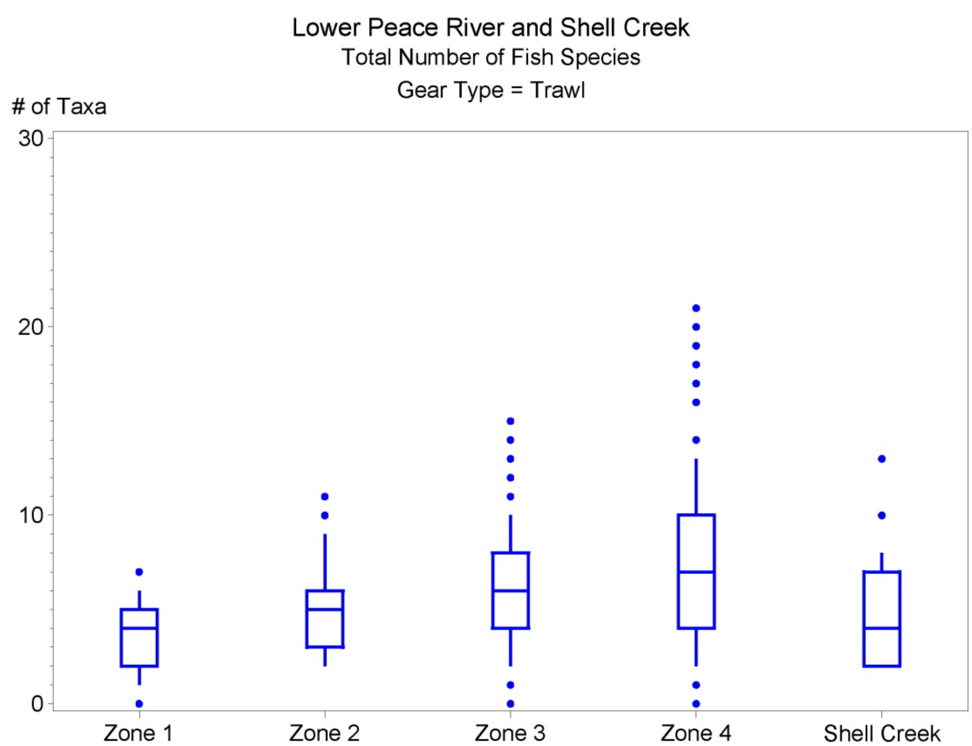


Figure 5-8. **Box-and-whisker plots of the taxa richness in trawl samples collected in the four LPR zones and SC (Data source: Greenwood *et al*. 2004).**

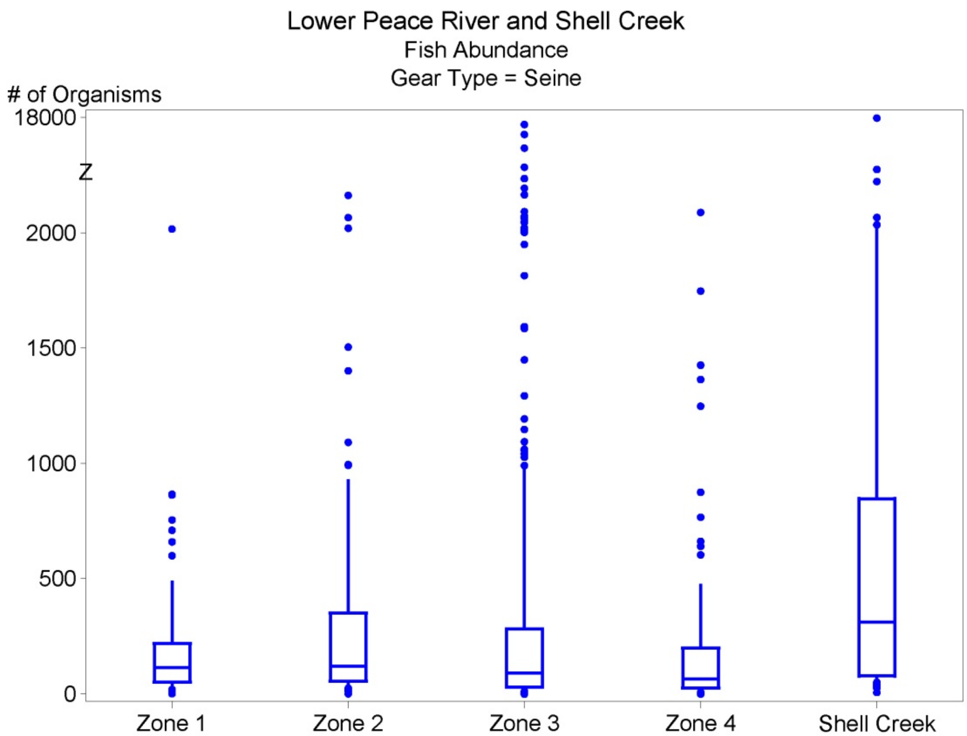


Figure 5-9. Box-and-whisker plots of the total abundance (individuals/sample) in seine samples collected in the four LPR zones and SC k (Data source: Greenwood *et al.* 2004).

The total number of organisms caught per trawl sample was more consistent than in the seine data (Figure 5-10). The median number of individuals/sample in Zones 1 through 4 was 30, 33, 39, and 29, respectively. The lowest number of fish per trawl was found in SC where the median was 27.

It should be noted that opposing patterns were seen between the two gear types, indicating differences in the type of habitat available to fish in the different zones. The seine data, which samples shoreline habitat, reported the lowest number of species per sample in Zone 4. The trawl data, which samples deeper water channel habitat, indicated the highest number of species per sample in Zone 4. This would suggest that of all the zones, Zone 4 may exhibit the least amount of shoreline habitat and the most amount of channel habitat. As for total number of organisms, number per seine sample was highest in SC, where as the number per trawl sample was lowest in SC. Additionally, in terms of number of species per sample, Zone 2 and SC were very similar for both gear types.

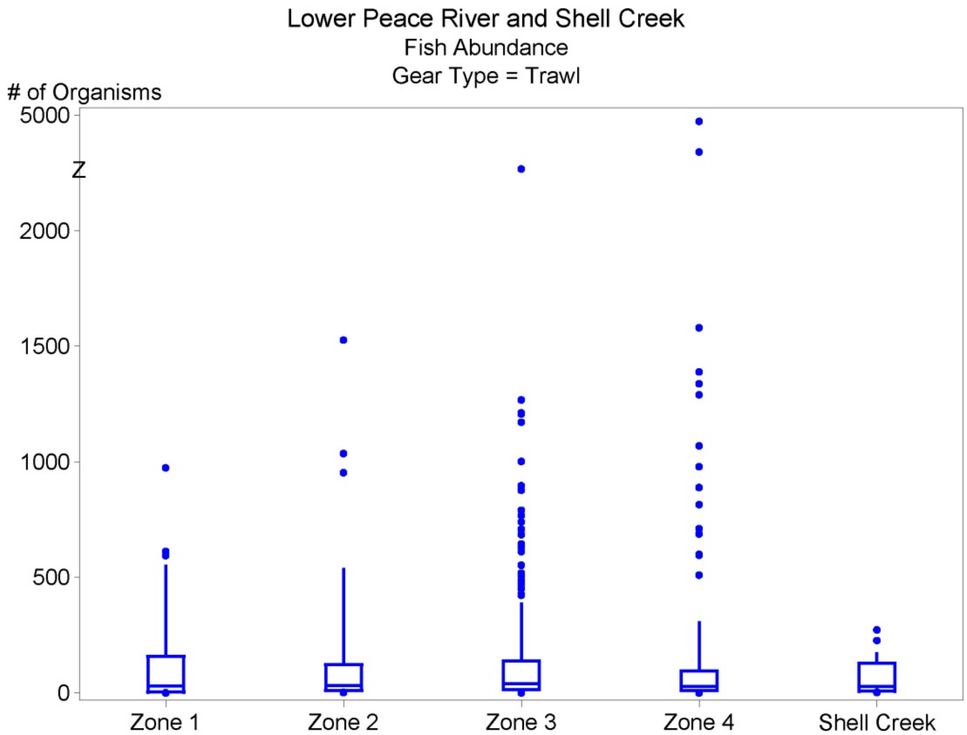


Figure 5-10. Box-and-whisker plots of the total abundance (individuals/sample) in trawl samples collected in the four LPR zones and SC (Data source: Greenwood *et al.* 2004).

The taxonomic composition of the fish communities in the LPR and SC is summarized in Tables 5-4 and 5-5. Dominance is calculated as (% Occurrence * % Composition)$^{-0.5}$.

In both seine and trawl samples hogchokers were the most dominant taxon in Zone 1 with Eastern mosquito fish and bay anchovies being relatively abundant. Bay anchovies, sand seatrout, blue crabs, and Atlantic silversides were most dominant in Zone 2. In Zone 3 bay anchovies, sand seatrout, Atlantic silversides, and hogchokers were dominant in both seine and trawl samples. Further downstream in Zone 4 bay anchovies and Atlantic silversides were abundant. Bay anchovies, sand seatrout, blue crabs, and Atlantic silversides were most dominant in SC.

Table 5-4. Dominant fish taxa captured in seine samples from each of the four LPR zones and SC. Data source: FWRI.

Area	Taxon	Common Name	Dominance
Zone 1	*Trinectes maculatus*	Hogchoker	246
Zone 1	*Gambusia holbrooki*	Eastern mosquito fish	230
Zone 1	*Anchoa mitchilli*	Bay anchovy	98
Zone 1	*Fundulus seminolis*	Seminole killifish	90
Zone 1	*Lucania parva*	Rainwater killifish	62
Zone 1	*Menidia* spp.	Atlantic silverside	50
Zone 1	*Poecilia latipinna*	Sailfin molly	7
Zone 1	*Callinectes sapidus*	Blue crab	4
Zone 1	*Gobiosoma bosc*	Naked goby	4
Zone 1	*Microgobius gulosus*	Clown goby	3
Zone 2	*Anchoa mitchilli*	Bay anchovy	278
Zone 2	*Menidia* spp.	Atlantic silverside	137
Zone 2	*Trinectes maculatus*	Hogchoker	58
Zone 2	*Gambusia holbrooki*	Eastern mosquito fish	56
Zone 2	*Lucania parva*	Rainwater killifish	35
Zone 2	*Eucinostomus harengulus*	Tidewater mojarra	27
Zone 2	*Eucinostomus* spp.	Silvery mojarra	22
Zone 2	*Fundulus seminolis*	Seminole killifish	15
Zone 2	*Callinectes sapidus*	Blue crab	5
Zone 2	*Microgobius gulosus*	Clown goby	5
Zone 3	*Anchoa mitchilli*	Bay anchovy	268
Zone 3	*Menidia* spp.	Atlantic silverside	194
Zone 3	*Eucinostomus harengulus*	Tidewater mojarra	35
Zone 3	*Eucinostomus* spp.	Silvery mojarra	22
Zone 3	*Farfantepenaeus duorarum*	Pink shrimp	15
Zone 3	*Mugil cephalus*	Striped mullet	12
Zone 3	*Callinectes sapidus*	Blue crab	7
Zone 3	*Sciaenops ocellatus*	Red drum	6
Zone 3	*Cynoscion arenarius*	Sand seatrout	5
Zone 3	*Lucania parva*	Rainwater killifish	5
Zone 4	*Anchoa mitchilli*	Bay anchovy	109
Zone 4	*Menidia* spp.	Atlantic silverside	101
Zone 4	*Eucinostomus harengulus*	Tidewater mojarra	47
Zone 4	*Eucinostomus gula*	Silver jenny	42
Zone 4	*Eucinostomus* spp.	Silvery mojarra	18
Zone 4	*Callinectes sapidus*	Blue crab	15
Zone 4	*Farfantepenaeus duorarum*	Pink shrimp	15
Zone 4	*Fundulus majalis*	Striped killifish	13
Zone 4	*Mugil cephalus*	Striped mullet	12
Zone 4	*Mugil gyrans*	Fantail mullet	11
Shell Creek	*Anchoa mitchilli*	Bay anchovy	394
Shell Creek	*Lucania parva*	Rainwater killifish	169
Shell Creek	*Menidia* spp.	Atlantic silverside	105
Shell Creek	*Gambusia holbrooki*	Eastern mosquito fish	41
Shell Creek	*Eucinostomus harengulus*	Tidewater mojarra	21
Shell Creek	*Fundulus seminolis*	Seminole killifish	16
Shell Creek	*Trinectes maculatus*	Hogchoker	10
Shell Creek	*Poecilia latipinna*	Sailfin molly	8
Shell Creek	*Gobiosoma bosc*	Naked goby	8
Shell Creek	*Eucinostomus spp.*	Silvery mojarra	6

Table 5-5. Dominant fish taxa captured in trawl samples from each of the four Lower Peace River zones and Shell Creek. Data source: FWRI.

Area	Taxon	Common Name	Dominance
Zone 1	*Trinectes maculatus*	Hogchoker	1572
Zone 1	*Anchoa mitchilli*	Bay anchovy	97
Zone 1	*Callinectes sapidus*	Blue crab	83
Zone 1	*Cynoscion arenarius*	Sand seatrout	70
Zone 1	*Ictalurus punctatus*	Channel catfish	12
Zone 1	*Fundulus seminolis*	Seminole killifish	3
Zone 1	*Ameiurus catus*	White catfish	2
Zone 1	*Notropis petersoni*	Coastal shiner	1
Zone 1	*Gobiosoma bosc*	Naked goby	0
Zone 1	*Eucinostomus* spp.	Silvery mojarra	0
Zone 2	*Cynoscion arenarius*	Sand seatrout	412
Zone 2	*Anchoa mitchilli*	Bay anchovy	353
Zone 2	*Callinectes sapidus*	Blue crab	206
Zone 2	*Trinectes maculatus*	Hogchoker	136
Zone 2	*Menticirrhus americanus*	Southern kingfish	10
Zone 2	*Ameiurus catus*	White catfish	7
Zone 2	*Farfantepenaeus duorarum*	Pink shrimp	6
Zone 2	*Ictalurus punctatus*	Channel catfish	2
Zone 2	*Dasyatis sabina*	Atlantic stingray	1
Zone 2	*Eucinostomus harengulus*	Tidewater mojarra	0
Zone 3	*Anchoa mitchilli*	Bay anchovy	231
Zone 3	*Cynoscion arenarius*	Sand seatrout	209
Zone 3	*Trinectes maculatus*	Hogchoker	169
Zone 3	*Farfantepenaeus duorarum*	Pink shrimp	112
Zone 3	*Callinectes sapidus*	Blue crab	111
Zone 3	*Menticirrhus americanus*	Southern kingfish	39
Zone 3	*Bairdiella chrysoura*	Silver perch	3
Zone 3	*Prionotus tribulus*	Bighead searobin	2
Zone 3	*Symphurus plagiusa*	Blackcheek tonguefish	2
Zone 3	*Eucinostomus harengulus*	Tidewater mojarra	2
Zone 4	*Anchoa mitchilli*	Bay anchovy	203
Zone 4	*Cynoscion arenarius*	Sand seatrout	94
Zone 4	*Farfantepenaeus duorarum*	Pink shrimp	89
Zone 4	*Menticirrhus americanus*	Southern kingfish	51
Zone 4	*Callinectes sapidus*	Blue crab	50
Zone 4	*Trinectes maculatus*	Hogchoker	47
Zone 4	*Prionotus scitulus*	Leopard searobin	13
Zone 4	*Prionotus tribulus*	Bighead searobin	8
Zone 4	*Eucinostomus gula*	Silver jenny	6
Zone 4	*Eucinostomus spp.*	Silvery mojarra	6
Shell Creek	*Trinectes maculatus*	Hogchoker	395
Shell Creek	*Anchoa mitchilli*	Bay anchovy	217
Shell Creek	*Cynoscion arenarius*	Sand seatrout	181
Shell Creek	*Callinectes sapidus*	Blue crab	122
Shell Creek	*Microgobius gulosus*	Clown goby	36
Shell Creek	*Eucinostomus* spp.	Silvery mojarra	29
Shell Creek	*Lucania parva*	Rainwater killifish	25
Shell Creek	*Farfantepenaeus duorarum*	Pink shrimp	13
Shell Creek	*Eucinostomus harengulus*	Tidewater mojarra	4
Shell Creek	*Ictalurus punctatus*	Channel catfish	2

To assess the relationship between fish community structure and salinity in the LPR, Principal Components Analysis (PCA) was used to identify generalized salinity classes based upon the ranges over which the fish taxa occurred. Bulger *et al*. (1993) used this approach in developing taxa specific salinity classes for mid-Atlantic estuarine nekton. The analysis described below is a critical element in the identification of various habitat types as defined by their salinity and resultant fish community structure.

The approach initially involves establishment of a data matrix of salinities (in 1 ppt increments) and taxa presence. The matrix is completed by noting the ranges of salinity where each of the taxa are present (1) and absent (0). PCA is then used to identify Principal Components Axes that express commonalities with respect to the occurrence among taxa across the range of salinities encountered in the Lower Peace River. Factor loadings from Varimax rotation of the PCA axes were plotted against the original salinity increments and scores greater than 0.60 were used as a criterion for identifying the significantly correlated salinity classes.

Since different life stages of a particular fish species may exhibit different salinity preferences within the Lower Peace River, "pseudo-species" were created by separately considering the salinity ranges for each species in size classes of: less than 40 mm standard length; 40-150 mm standard length and greater than 150 mm in standard length. If the total catch for any species or "pseudo-species" was less than 30 individuals, they were removed prior to analysis to avoid the influence of rare catch on the PCA groupings. In a *post-hoc* comparison, the species contributing most to differences among the PCA groups were identified using SIMPER analysis (Clarke and Warwick, 2001).

Four salinity classes were identified, separately for seines and trawls, using PCA (Figure 5-11 and 5-12):

Seines:

- Class 1= 1 - 3 ppt,
- Class 2 = 4 - 14 ppt,
- Class 3 = 15 -23 ppt, and
- Class 4 = >24 ppt.

Trawls:

- Class 1= 1 - 2 ppt,
- Class 2 = 3 - 14 ppt,
- Class 3 = 15 -28 ppt, and
- Class 4 = > 29 ppt.

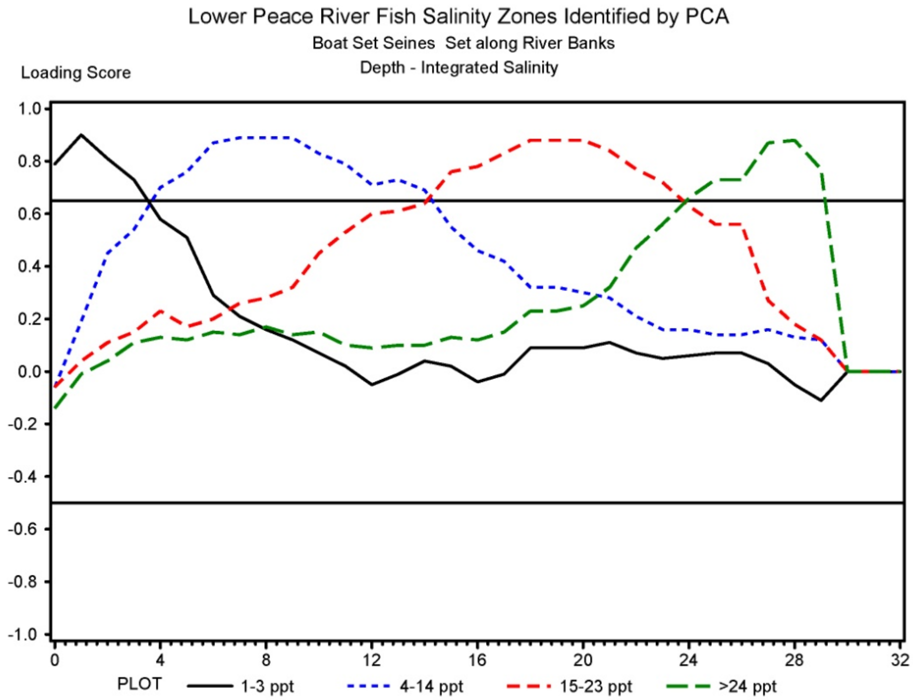


Figure 5-11. Salinity classes identified by Principal Components Analysis for the Lower Peace River, based upon the distribution of fish captured in seine samples. (Data source: FWRI).

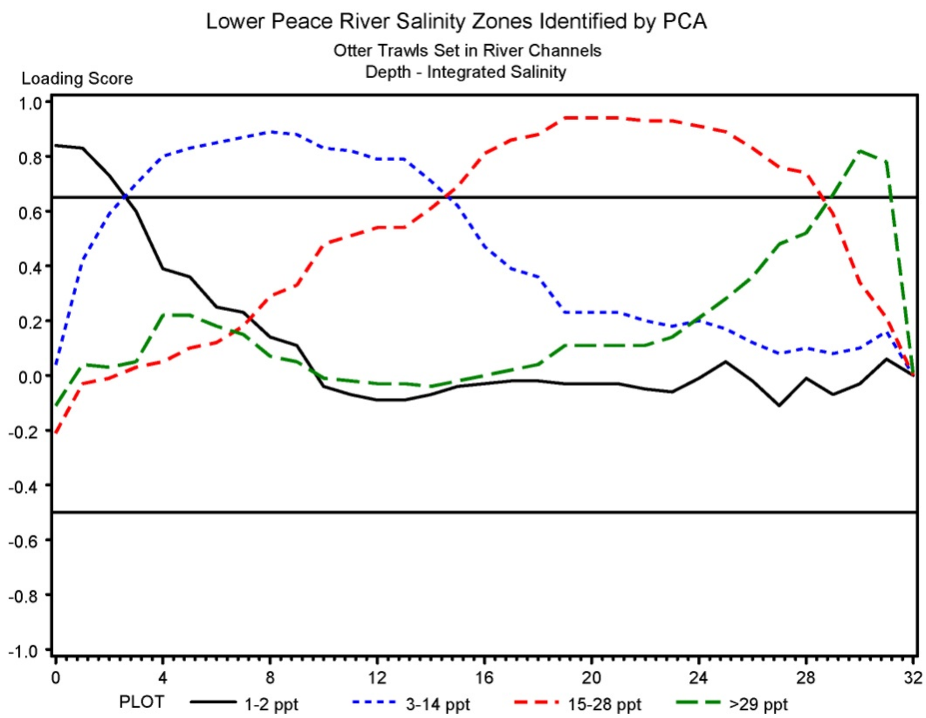


Figure 5-12. Salinity classes identified by Principal Components Analysis for the Lower Peace River, based upon the distribution of fish captured in trawl samples. (Data source: FWRI).

For the seine data, fantail mullet and various species of gobies (naked goby, code goby, clown goby, and frillfin goby) were commonly collected in Classes 1-3 and contributed most to the similarity among the catch in these zones. The absence of gobies, increased presence of blackcheek tongue fish, and the occurrence of southern puffer and rough silverside, were the notable characteristics which separated Class 4. Subtler differences in species composition were seen between Classes 1-3. The most notable differences between Class 1 and 2 were the presence of redear sunfish, a freshwater species, in Class 1 but not 2. Additionally, the following estuarine species were in Class 2 but lacking in Class 1: Gulf pipefish, leopard searobin, redfin needlefish. Class 2 and 3 differed mainly in Class 2 having a much higher occurrence of freshwater-low salinity species than Class 3, namely bluegill, sailfin molly, marsh killifish, Seminole killifish and the least killifish. The main differences between Class 3 and 4 were the presence of silver jenny, sheepshead, sheepshead minnow and striped anchovy in Class 3 and not 4.

For the trawl data, various species of gobies, along with hogchoker and blackcheek tongue fish were commonly collected in Classes 1 and 2. These species were also collected in Class 3, with the additional occurrence of the Atlantic spadefish. Class 4 was comprised of similar species as Class 3, with the absence of gobies and the presence of grass shrimp. The most notable differences between Class 1 and 2 were the occurrence of lower salinity species, namely Seminole killifish and coastal shiner, in Class 1 but not 2. Additionally, the higher salinity species spotted seatrout and big head searobin occurred in Class 2 but not 1. The main differences between Class 2 and 3 were the occurrence of lined sole, striped mojarra, and spotted seatrout in Class 2, but not 3, and the occurrence of sand seatrout in Class 3 but not 2. Class 3 and 4 differed with higher occurrences of a number of species in Class 3 as opposed to 4 (i.e., green goby, naked goby, pinfish, silverperch).

6 RELATIONSHIP BETWEEN FLOW AND WATER QUALITY CONSTITUENTS

The objective of this section is two-fold:

1) to review historical studies of the relationships between flow and water quality constituents in the LPR and SC, and
2) to review observed empirical relationships that describe how freshwater inflow affects responses in salinity, DO, chlorophyll *a*, and other water quality constituents in the LPR and SC.

These empirical relationships can be developed into suitable tools (e.g., regressions) that can be used to examine expected responses in the river to alternative minimum flow levels.

6.1 Historical Studies Relating Flow to Water Quality Constituents

Studies that examine the response of salinity, residence time, and water quality in the estuary to freshwater inflow are briefly summarized in this chapter. Other studies, such as those of streamflow trends in watershed or the general physical or water quality characteristics of the estuary, were reviewed in previous chapters.

6.1.1 Stoker *et al.* (1989)

Stoker *et al.* (1989) addressed hydraulic and salinity characteristics of the tidal reach of the Peace River. The authors concluded that the hydraulic characteristics of the tidal river are influenced primarily by fluctuations in tidal stage. Salinity characteristics in the tidal portion of the Peace River are influenced by freshwater inflows, tide, and the salinity in Charlotte Harbor. They also concluded that wind effects may occasionally become important by affecting the normal tidal patterns. Regression analyses of surface and bottom salinity in the tidal river indicated that gauged flows at Arcadia (02296750) and Horse Creek near Arcadia (02297310) and the daily mean tide were the most significant explanatory variables in predicting the high-tide location of various salinities. The authors concluded that a permanent reduction of streamflow upstream of the tidal portion of the Peace River would cause an upstream migration of the surface isohalines.

6.1.2 Hammett (1990)

Hammett (1990) examined land use, water use, streamflow characteristics, and water-quality characteristics of the Charlotte Harbor inflow area. Water-quality data through 1985 were presented and described. Hammett (1990) performed trend analyses of approximately 50 years of streamflow data and found a statistically significant decreasing trend for the Peace River stations at Bartow (02294650), Zolfo Springs (02295637), and Arcadia (02296750). She speculated that the decrease in flow may have been related to a long-term decline in the potentiometric surface of the Floridan aquifer system, which resulted from ground-water withdrawals. In addition to trend analyses of flow at several locations in the Peace River, trend analyses of water quality constituents at Arcadia (02296750) were also performed. A significant increase was detected in specific conductance at the Arcadia (02296750) gauge.

6.1.3 Stoker (1992)

Stoker (1992) investigated salinity variation due to freshwater inflow and tides and the potential changes in salinity due to altered freshwater inflow into Charlotte Harbor. The results of the study indicated that seasonal fluctuations in salinity in Charlotte Harbor occur primarily in response to fluctuations in freshwater inflow from the Peace, Myakka, and Caloosahatchee rivers. Correlation analyses showed that daily minimum, maximum, and mean salinities at several continuous recorders were inversely related to discharge from the rivers, whereas the daily range in salinity was directly related to stream discharge (Stoker 1990).

6.1.4 PBS&J (1999b, 2002, 2004, 2006)

PBS&J (1999b) summarized historical information relevant to the hydrobiological monitoring of the Lower Peace River and Upper Charlotte Harbor. Regressions were developed to predict surface salinity at HBMP stations 10, 12, 14, and 18 based on 28-day mean flow at Arcadia (02296750). At the more upstream stations (18 and 14), the relationship was generally L-shaped, with relatively high salinities at low flows and primarily fresh water at low to moderate flows. As you move downstream, the relationship changes from being strongly curvilinear to being somewhat more linear.

Relationships between bottom dissolved oxygen and 28-day mean flow at Arcadia (02296750) were also discussed and the following observations were made relative to the Lower Peace River:

- Periods of hypoxia at station 10 occur only during periods of high flow.
- Hypoxic conditions are not common in the Lower Peace River upstream of the I-75 bridge. Though dissolved oxygen concentrations near the bottom seem to decline with flow, this relationship may be confounded by higher oxygen consumption during the wet season (June-September).
- High dissolved oxygen concentrations during period of low flow are reflective of two conditions:

    - higher saturation during colder winter months and
    - increases in phytoplankton during the periods of low flow during the spring and fall.

Subsequent reports reports prepared for the HBMP have reexamined relationships presented revised empirical models for relating inflow to salinity in the Lower Peace River and Upper Charlotte Harbor (PBSJ 2002, 2004, 2006, 2008).

6.1.5 Janicki Environmental, Inc (2001)

Coastal Environmental (1997) used data from the PRMRWSA HBMP to develop regressions to predict the locations of salinity zones as a function of freshwater inflows. Janicki Environmental, Inc (2001) re-evaluated the regressions developed by Coastal Environmental of salinity and streamflow in the Peace River estuary. There is considerable natural variation in salinity for a given flow condition, but there is a clear and predictable decrease in the overall distribution of salinity values at any given location in the river for an increase in flow. The relationships between salinity at several HBMP fixed stations (11, 13, 14, and 15) were described well by regression models. In addition, the relationships between isohaline locations and river flow fit the regression models well for all the isohaline locations tested (0.5 ppt, 6 ppt, 12 ppt, and 20 ppt). The authors also analyzed the proportion of flow to the lower river comprised of Arcadia (02296750) flow. Peace at Arcadia typically comprises 72% of the flow at the PRMRWSA plant (Peace at Arcadia [02296750] + Joshua Creek at Nocatee [02297100] + Horse Creek near Arcadia [02297310]). Peace at Arcadia typically comprises 56% of the flow in the lower river (Peace at Arcadia [02296750] + Joshua Creek at Nocatee [02297100] + Horse Creek near Arcadia [02297310] + Shell Creek near Punta Gorda [02298202]).

6.1.6 Janicki Environmental, Inc (2003)

Janicki Environmental, Inc (2003) conducted an analysis of status and trends of water quality conditions within the Charlotte Harbor National Estuary Program (CHNEP) study area. The results of rainfall analyses indicated that there were no overall trends in rainfall for the period of record (1950's to 2000), and, therefore, it is unlikely that any changes in water quality data for the Peace River could be attributed to changes in rainfall alone. The results of streamflow trend analyses indicated that there have been statistically significant changes in streamflow for the period of record analyzed.

A statistically significant increase in conductivity was observed in the Lower Peace River between the mouth of the river and just upstream of Arcadia. While there was a significant increase in conductivity in the lower Peace River, there was significant increase in conductivity detected at the mouth of the Peace River or Charlotte Harbor.

6.1.7 PBS&J (2006)

PBS&J (2006) performed analyses in order to evaluate and address whether the biological communities of the SC/LPR estuarine system would be adversely impacted as a result of the proposed "gap" increased permitted freshwater withdrawals. Within the SC reservoir, concentrations of most parameters, including specific conductance, hardness, DO, pH, total dissolved solids, total Kjeldahl nitrogen (TKN), total phosphorus, orthophosphorus, total organic carbon, and alkalinity increased with increasing flows, while color, sulfate, and chloride decreased (PBS&J, 2006). This study also described at what rates of flow various locations in Shell Creek become freshwater.

6.2 Empirical Analyses to Relate Flow to Water Quality in the Lower Peace River and Shell Creek.

The objective of the empirical analyses was to increase the knowledge of the observed relationships that describe how freshwater inflow affects responses in salinity, DO, chlorophyll *a*, and other water quality constituents in the Lower Peace River. The relationships include the response of water quality constituents at a representative group of HBMP fixed stations (Figure 2.3) with a period of record that extends back to the 1970's. These stations represent a broad range of geographic locations. The inflow is defined as the sum of flows at Peace at Arcadia (02296750), Joshua Creek at Nocatee (02297100), and Horse Creek near Arcadia (02297310), minus the withdrawals at the PRMRWSA plant.

6.2.1 Relationship Between Flow and Salinity

In the Lower Peace River, the general expectations for salinity response to freshwater inflow are well-known based on many years of review of the observed data and knowledge from other similar systems (Stoker *et al.* 1989; Stoker 1992; PBS&J 1999b; Janicki Environmental Inc. 2001). Salinity declines in the lower river in response to increasing freshwater inflow. Due to higher salinity waters being denser than lower salinity waters, salinity concentrations are expected to be lower near the water surface and higher near the water bottom for any particular location in the lower river.

As discussed in Section 3, a high degree of variation in salinity is expected due to freshwater inflows and the influences of tide, wind, and vertical stratification. Salinity can vary significantly over the course of each day as the tide moves upstream and downstream. Lateral variation in salinity is also expected due to the highly braided nature of the river.

Salinity field observations from a representative group of PRMRWSA HBMP fixed monitoring stations were plotted against freshwater inflow to empirically describe the relationship of freshwater inflow to salinity in the Lower Peace River (Figures 6-1 to 6-2). The salinity observations were in agreement with the expectations described above. As expected, salinity was more responsive to freshwater inflow at the most upstream station (Station 18), and least responsive to flow at the most downstream station (Station 10).

In addition to the monthly HBMP fixed station salinity data presented in Figures 6-1 and 6-2, daily mean salinity as a function of flow for two continuous recorders in the LPR are also presented. The Peace River at Harbor Heights continuous recorder (USGS 02297460) is located at rkm 15.5. The Peace River at Peace River Heights continuous recorder (USGS 02297350) is located at rkm 26.7. Mean daily surface and bottom salinity for Peace River at Harbor Heights as a function of LPR flow are presented in Figure 6-3. Mean daily surface and bottom salinity for Peace River at Peace River

Heights as a function of LPR flow are presented in Figure 6-4. As anticipated, the range of salinities at Harbor Heights was greater than that at Peace River Heights.

Salinity field observations from the PRMRWSA HBMP moving stations were plotted against freshwater inflow to empirically describe the relationship of freshwater inflow to isohaline location in the Lower Peace River (Figures 6-5 to 6-8). As expected, the 0 ppt isohaline exhibited the widest range of locations. At very low flows, the 0 ppt isohaline was as high as rkm 38, while at very high flows the 0 ppt isohaline was as low as rkm 3. The location of the 6 ppt isohaline ranged from rkm 1 to rkm 27. The 12 ppt isohaline ranged from rkm 0 at high flows to rkm 24 at the lowest flows. As expected, the 20 ppt isohaline exhibited the smallest range of locations in the LPR, ranging from rkm 0 to rkm 18.

As mentioned in Section 6.1.5, regressions have been developed that relate salinity to freshwater inflow at several fixed locations in the Lower Peace River based on PRMRWSA HBMP fixed station observations. The general form of the regression that predicts salinity as a function of flow is:

$$\hat{S} \quad = \quad \alpha + \beta\,(mean\ 30\ day\ \ flow)$$

A summary of the regression models is presented in the Table 6-1. In addition, regressions have been developed based on PRMRWSA HBMP moving station observations that predict surface isohaline locations based on freshwater inflows to the system. The general form of the regression that predicts the location of a particular isohaline as a function of flow is:

$$Rkm \quad = \quad \alpha + \beta \ast \ln\,(mean\ 8\ day\ \ flow)$$

A summary of the regression models is presented in the Table 6-2.

Though there is considerable natural variation in salinity for a given flow condition, there is a clear and predictable decrease in the overall distribution of salinity values at any given location in the river for an increase in flow. The regressions discussed above can be used as a tool to corroborate predictions from other tools such as a hydrodynamic model.

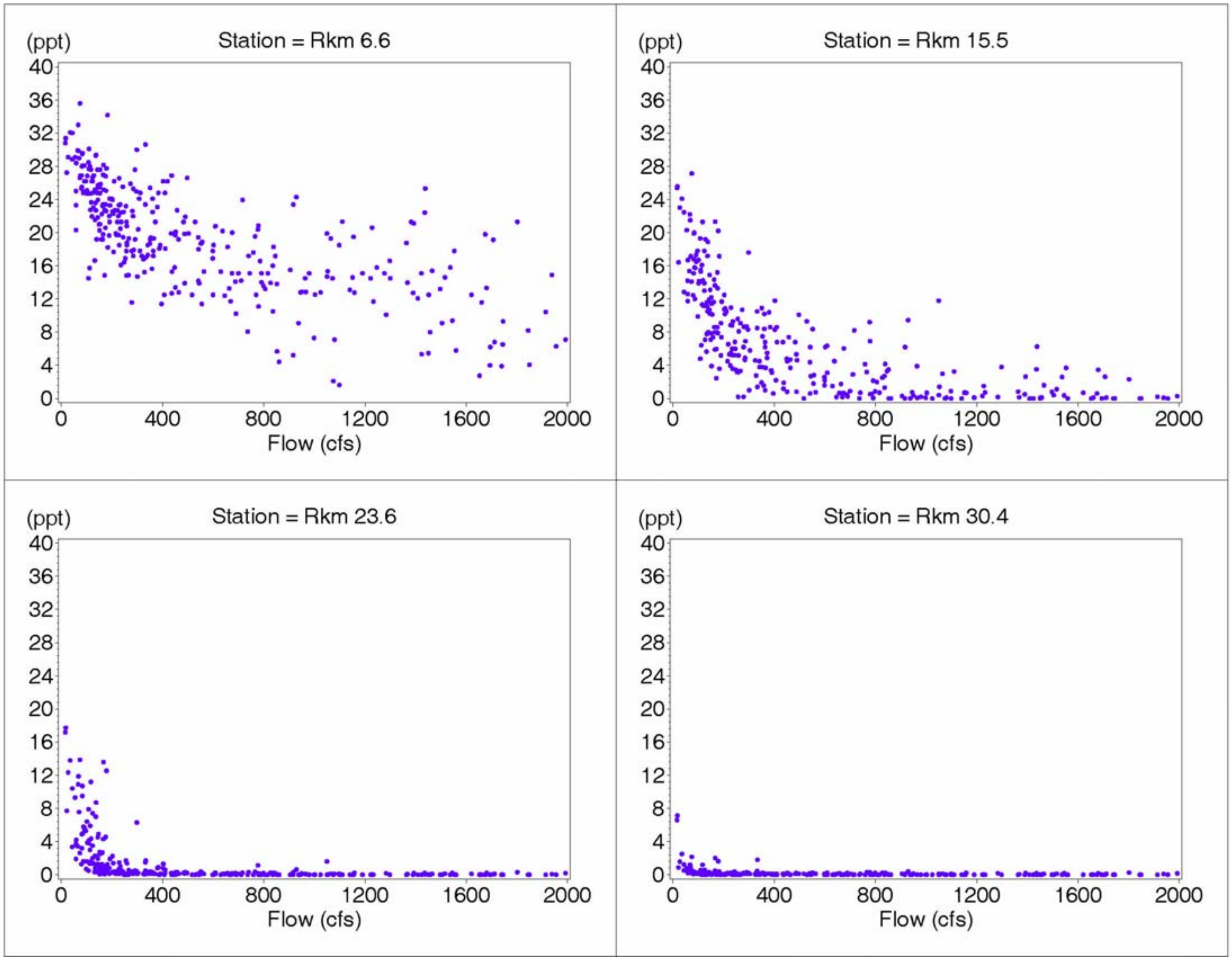


Figure 6-1. **Long-term HBMP surface salinity observations at Stations 10, 12, 14, and 18 (see Figure 2-3 for locations) as a function of flow in the Lower Peace River. Lower Peace River flow was calculated as the sum of Peace at Arcadia (USGS 02296750), Joshua Creek at Nocatee (USGS 02297100), and Horse Creek near Arcadia (USGS 02297310), minus the withdrawals taken out at the PRMRWSA plant.**

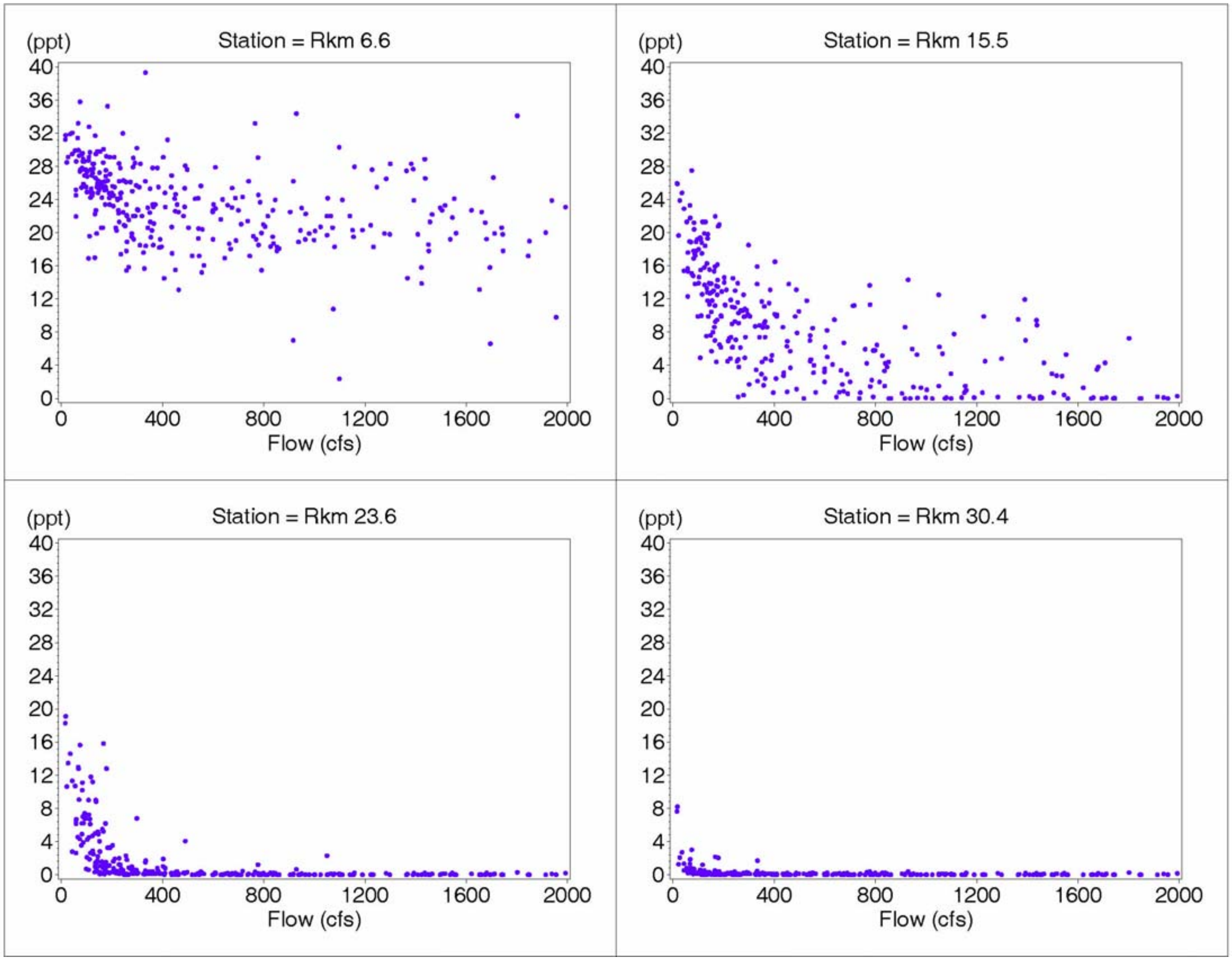


Figure 6-2. Long-term HBMP bottom salinity observations at Stations 10, 12, 14, and 18 (see Figure 2-3 for locations) as a function of flow in the Lower Peace River. Lower Peace River flow was calculated as the sum of Peace at Arcadia (USGS 02296750), Joshua Creek at Nocatee (USGS 02297100), and Horse Creek near Arcadia (USGS 02297310), minus the withdrawals taken out at the PRMRWSA plant.

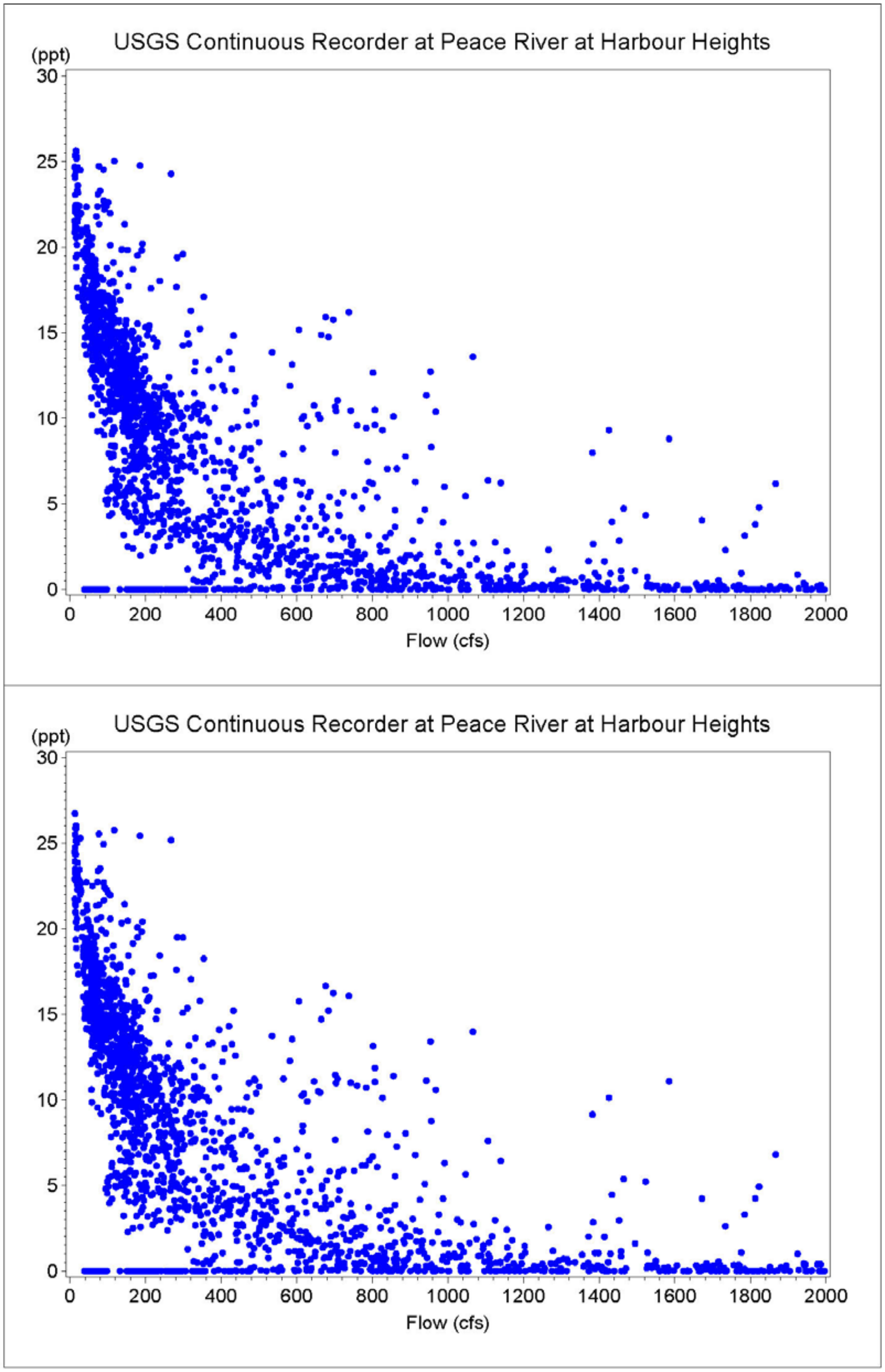


Figure 6-3. Peace River at Harbor Heights continuous recorder (USGS gauge 02297460) daily mean surface salinity (upper figure) and bottom salinity (lower figure) as a function of flow in the Lower Peace River.

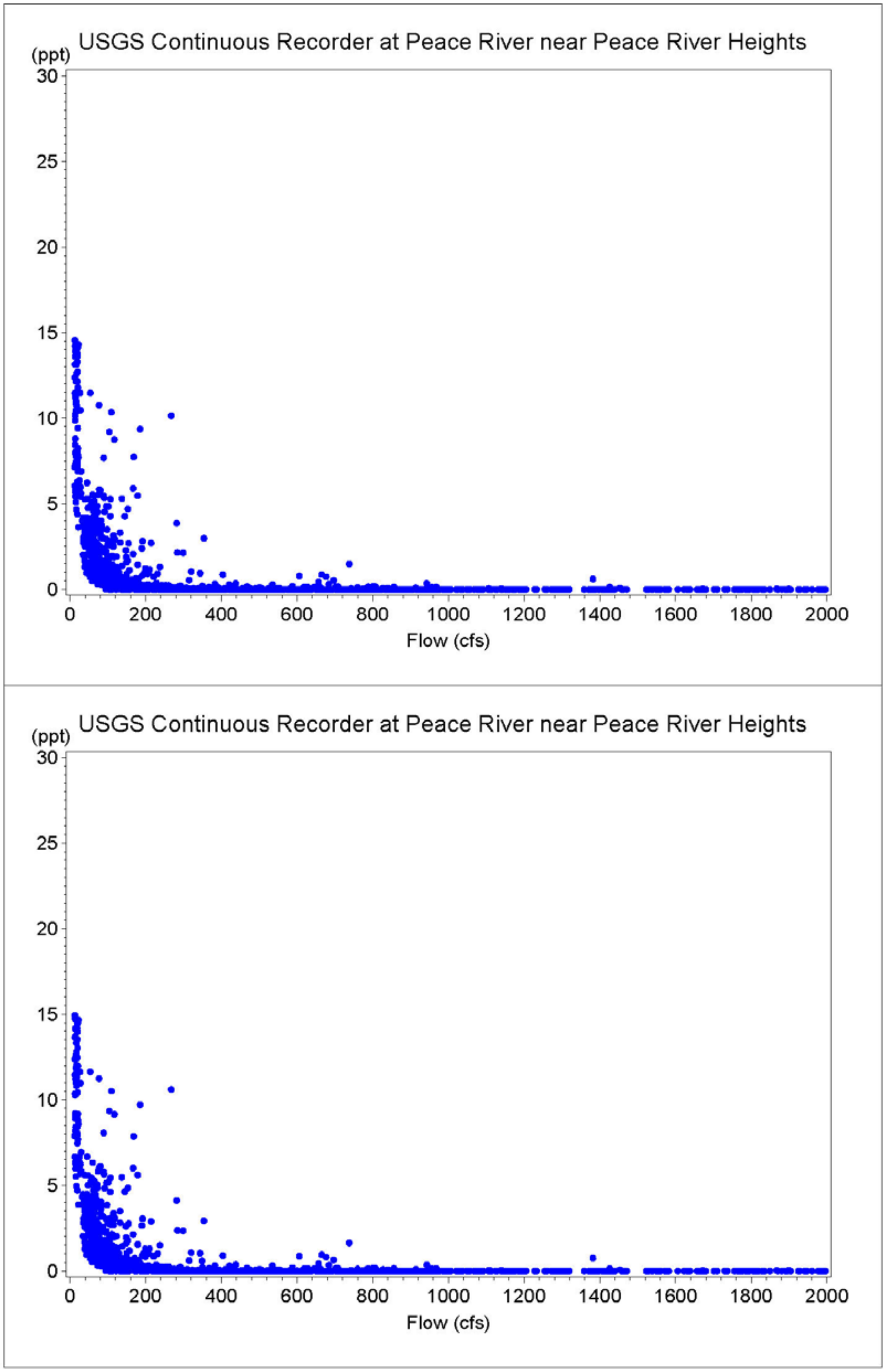


Figure 6-4. Peace River at Peace River Heights continuous recorder (USGS gauge 02297350) daily mean surface salinity (upper figure) and bottom salinity (lower figure) as a function of flow in the Lower Peace River.

Table 6-1. Summary of fixed station regression models (Source: Janicki Environmental, Inc., 2001).

Station	Depth	Intercept Estimate	Slope Estimate	Prob>F H_0: slope not equal 0	Prob>|t| H_0: slope Not equal 0	R-square Value
9	Surface	56.2857	-5.1052	< 0.0001	< 0 .0001	0.77
9	1 meter	55.3533	-4.9143	< 0.0001	< 0 .0001	0.76
9	2 meter	51.4360	-4.1807	< 0.0001	< 0 .0001	0.71
9	Bottom	44.8194	-2.9656	< 0.0001	< 0 .0001	0.48
10	Surface	55.7390	-5.8103	< 0.0001	< 0 .0001	0.76
10	1 meter	52.8787	-5.1426	< 0.0001	< 0 .0001	0.69
10	2 meter	48.4570	-4.1215	< 0.0001	< 0 .0001	0.58
10	Bottom	46.2886	-3.6889	< 0.0001	< 0 .0001	0.55
11	Surface	50.1617	-5.9070	< 0.0001	< 0 .0001	0.67
11	1 meter	48.9276	-5.5575	< 0.0001	< 0 .0001	0.61
11	2 meter	47.1649	-5.0642	< 0.0001	< 0 .0001	0.57
11	Bottom	43.2533	-4.2843	< 0.0001	< 0 .0001	0.47
12	Surface	39.1579	-5.1913	< 0.0001	< 0 .0001	0.71
12	1 meter	40.3856	-5.3147	< 0.0001	< 0 .0001	0.70
12	2 meter	41.2220	-5.3514	< 0.0001	< 0 .0001	0.69
12	Bottom	42.4495	-5.4786	< 0.0001	< 0 .0001	0.69
13	Surface	35.7949	-5.3488	< 0.0001	< 0 .0001	0.60
13	1 meter	38.8002	-5.7623	< 0.0001	< 0 .0001	0.60
13	2 meter	41.8546	-6.1637	< 0.0001	< 0 .0001	0.65
13	Bottom	39.6592	-5.8482	< 0.0001	< 0 .0001	0.60
14	Surface	39.3733	-7.2944	< 0.0001	< 0 .0001	0.49
14	1 meter	40.5885	-7.4985	< 0.0001	< 0 .0001	0.48
14	2 meter	42.1987	-7.7630	< 0.0001	< 0 .0001	0.48
14	Bottom	45.5255	-7.7268	< 0.0001	< 0 .0001	0.53
15	Surface	20.4275	-3.8658	< 0.0001	< 0 .0001	0.48
15	1 meter	20.7830	-3.9235	< 0.0001	< 0 .0001	0.48
15	2 meter	23.6838	-4.3632	< 0.0001	< 0 .0001	0.58
15	Bottom	21.7795	-4.0964	< 0.0001	< 0 .0001	0.48

Table 6-2. Summary of isohaline location regression models (Source: Janicki Environmental, Inc., 2001).

Isohaline	Intercept Estimate	Slope Estimate	Prob>F H_0: slope not equal 0	Prob>|t| H_0: slope Not equal 0	R-square Value
0 ppt	5.01278	-0.03478	< 0.0001	< 0.0001	0.65
6 ppt	4.95031	-0.03634	< 0.0001	< 0.0001	0.71
12 ppt	4.90144	-0.03448	< 0.0001	< 0.0001	0.63
20 ppt	4.83565	-0.03145	< 0.0001	< 0.0001	0.52

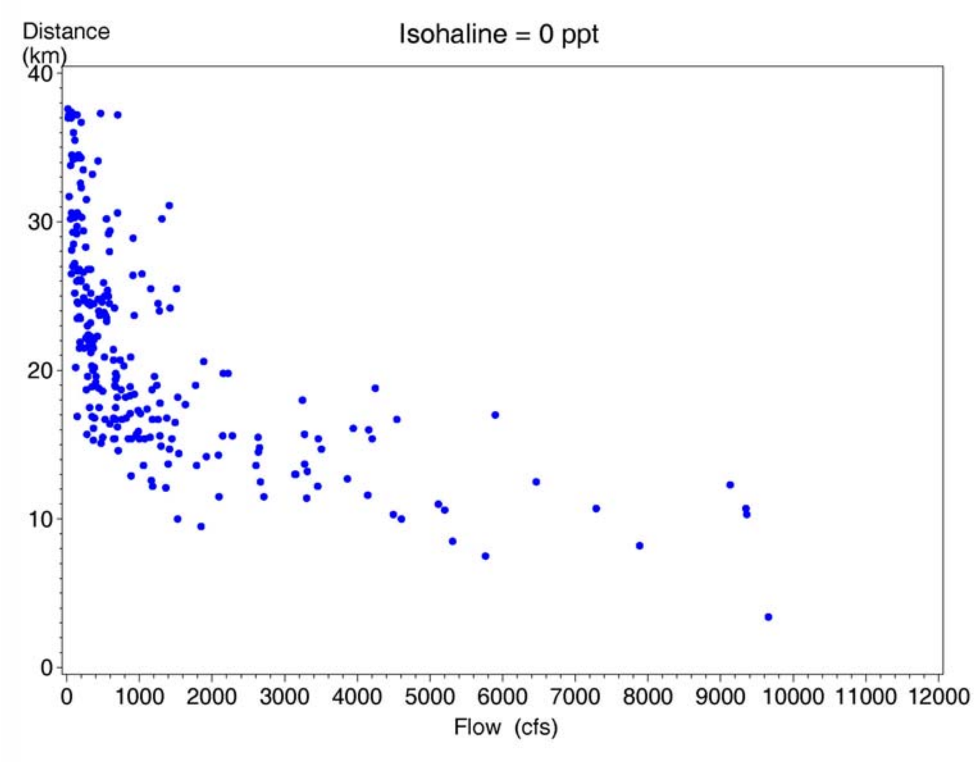


Figure 6-5. **Plot of the relationship between HBMP 0 ppt isohaline location as a function of flow in the Lower Peace River.**

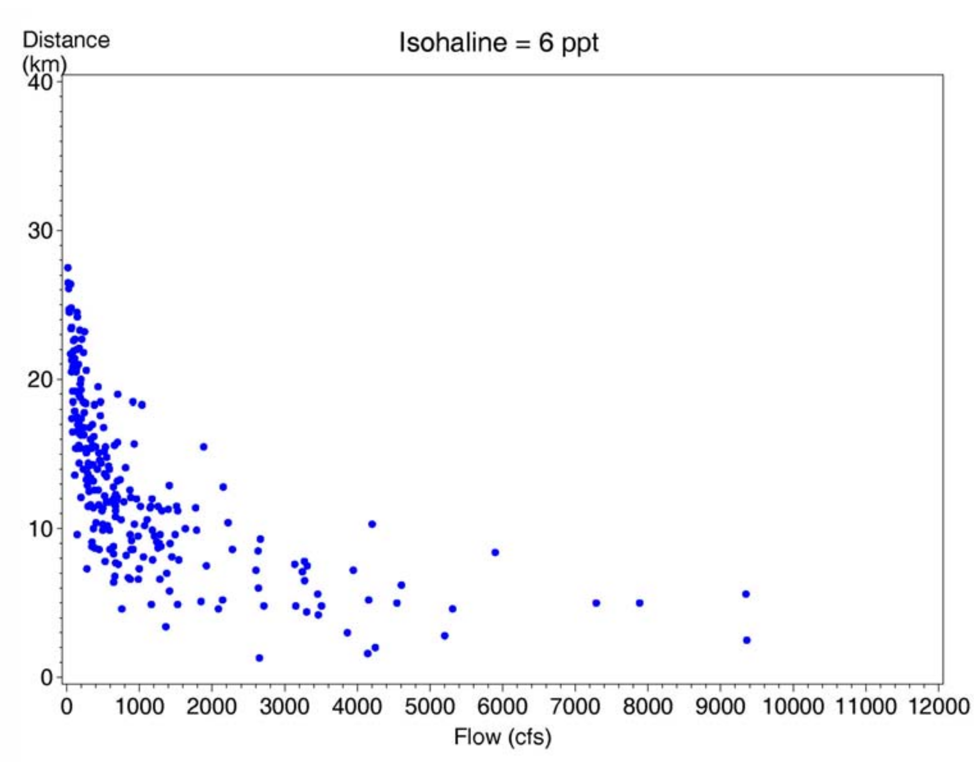


Figure 6-6. **Plot of the relationship between HBMP 6 ppt isohaline location as a function of flow in the Lower Peace River.**

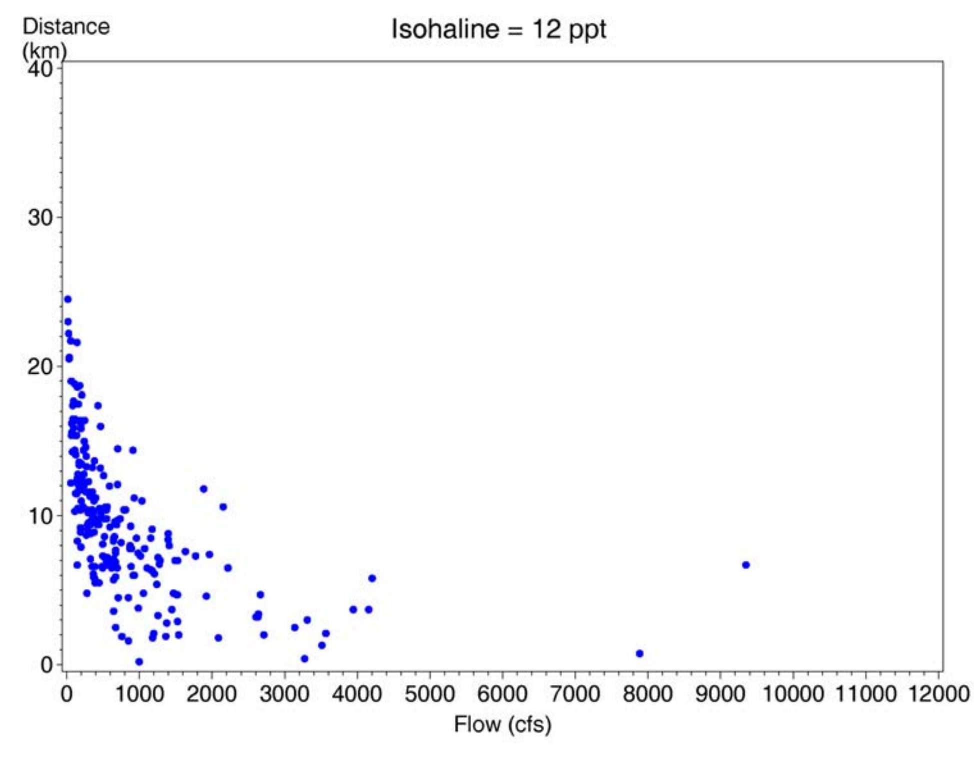


Figure 6-7. Plot of the relationship between HBMP 12 ppt isohaline location as a function of flow in the Lower Peace River.

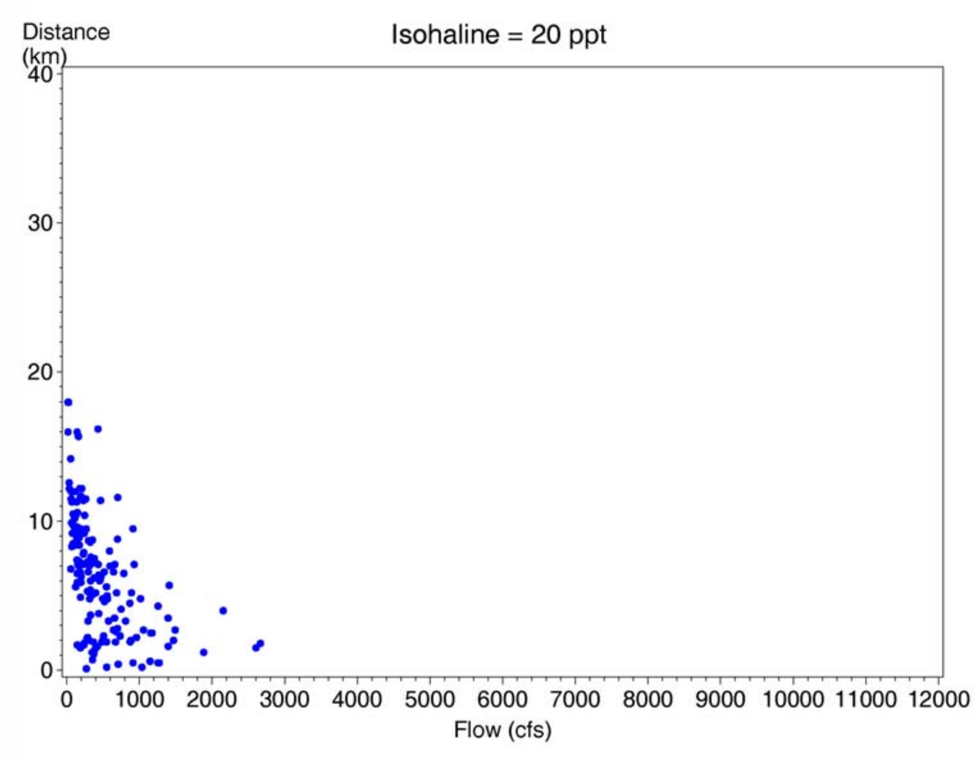


Figure 6-8. Plot of the relationship between HBMP 20 ppt isohaline location as a function of flow in the Lower Peace River.

6.2.2 Relationship Between Flow and DO

The spatial and temporal variation in DO has been described in Section 3. The spatial and temporal variations in DO are expected to be relatively high, and are expected to be particularly responsive to location, depth, temperature, salinity, and time of day. A series of empirical analyses were conducted using the PRMRWSA HBMP stations to quantify the expected relationship of dissolved oxygen responses to freshwater inflow. As documented by the PRMRWSA HBMP, hypoxic conditions are not common in the Lower Peace River upstream of the I-75 bridge (PBS&J 1999b). Previous work by Camp, Dresser & McKee (1998) revealed a general pattern of hypoxic conditions in the upper portion of Charlotte Harbor between June and October. Plots of bottom dissolved oxygen and flow are presented in Figure 6-9. Though dissolved oxygen concentrations near the bottom generally decline with flow, this is not a strong relationship due to confounding factors. While general patterns have been documented between dissolved oxygen and freshwater inflows, statistically defensible relationships have yet to be identified.Therefore, appropriate tools relating DO to freshwater inflows the LPR and SC do not currently exist.

6.2.3 Relationship Between Flow and Chlorophyll a

Although chlorophyll *a* concentrations are expected to be highly variable in the Lower Peace River, they are expected to follow a predictable pattern in response to the combined effects of nutrient supply and residence time. Managing nutrient loading is expected to be the primary driver for aquatic eutrophication, and the best understanding of this relationship depends upon knowledge of other factors such as residence time. The relationship between nutrient loading and estuarine responses (such as changes in algal biomass) is mediated significantly by hydrologically-controlled residence times (Rudek *et al.* 1991, Valiela *et al.* 1997, Hubertz and Cahoon 1999, Caffrey *et al.* 2007). As freshwater inflow initially increases from a near zero flow condition, chlorophyll *a* is expected to increase in response to the increased nutrient supply. As inflow rate increases even higher, the increase in nutrient supply becomes offset by the reduction in residence time, and the resulting chlorophyll *a* concentrations will peak. At higher inflow rates, the negative effects of shortening residence time become greater than the positive effects of increasing nutrient supply, and the chlorophyll *a* concentrations decline. The effects are expected to be less responsive downstream than upstream due to physical dilution effects. Chlorophyll *a* concentrations in the Lower Peace River exhibit distinct spring and fall peaks that are influenced by both the timing and volume of freshwater inflows (PBS&J 2004). These peaks generally move downstream as freshwater inflows increase. Plots of the relationship between surface and bottom chlorophyll a and flow are presented in Figures 6-10 and 6-11.

A regression model was developed to predict the location of the chlorophyll *a* maximum based on Peace River flow (Peace at Arcadia + Horse Creek + Joshua Creek) and season. The regression model fit the observed data well, explaining 64 % of the variation in the location of the chlorophyll *a* maximum. This regression can be used to predict the impact of proposed management actions on the location of the chlorophyll *a* maximum.

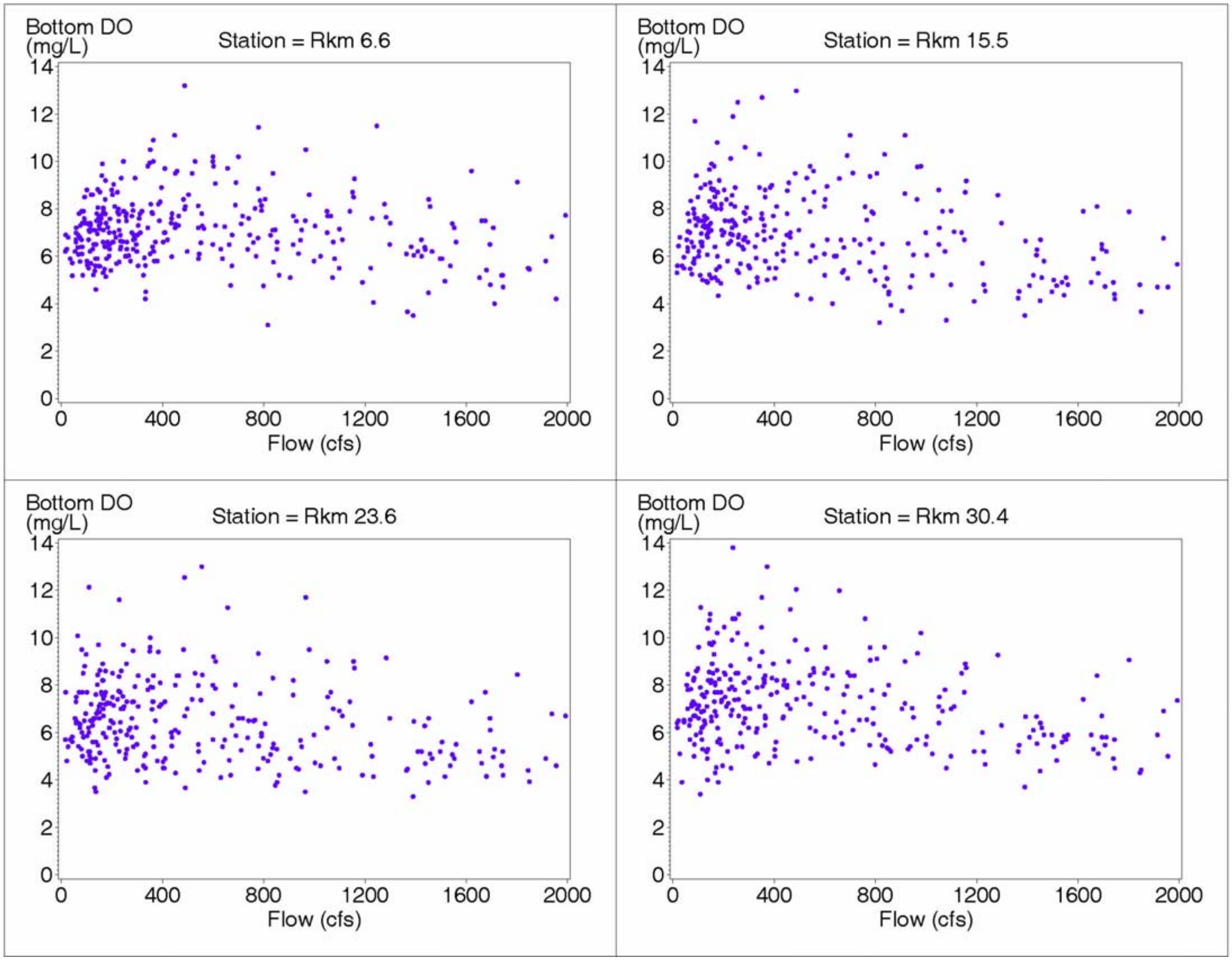


Figure 6-9. **Long-term HBMP bottom dissolved oxygen observations at Stations 10, 12, 14, and 18 (see Figure 2-3 for locations) as a function of flow in the Lower Peace River. Lower Peace River flow was calculated as the sum of Peace at Arcadia (USGS 02296750), Joshua Creek at Nocatee (USGS 02297100), and Horse Creek near Arcadia (USGS 02297310), minus the withdrawals taken out at the PRMRWSA plant.**

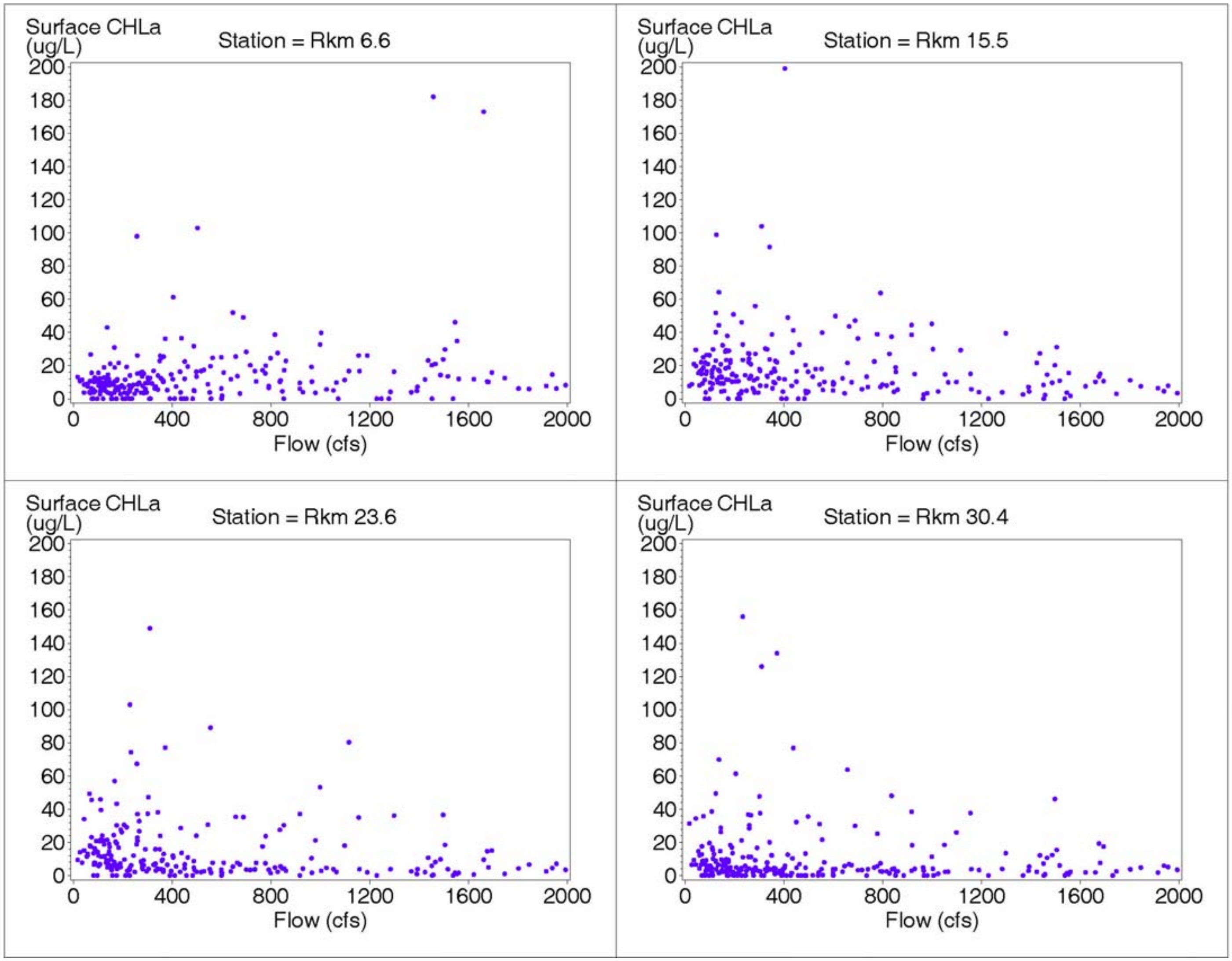


Figure 6-10. Long-term HBMP surface chlorophyll a observations at Stations 10, 12, 14, and 18 (see Figure 2-3 for locations) as a function of flow in the Lower Peace River. Lower Peace River flow was calculated as the sum of Peace at Arcadia (USGS 02296750), Joshua Creek at Nocatee (USGS 02297100), and Horse Creek near Arcadia (USGS 02297310), minus the withdrawals taken out at the PRMRWSA plant.

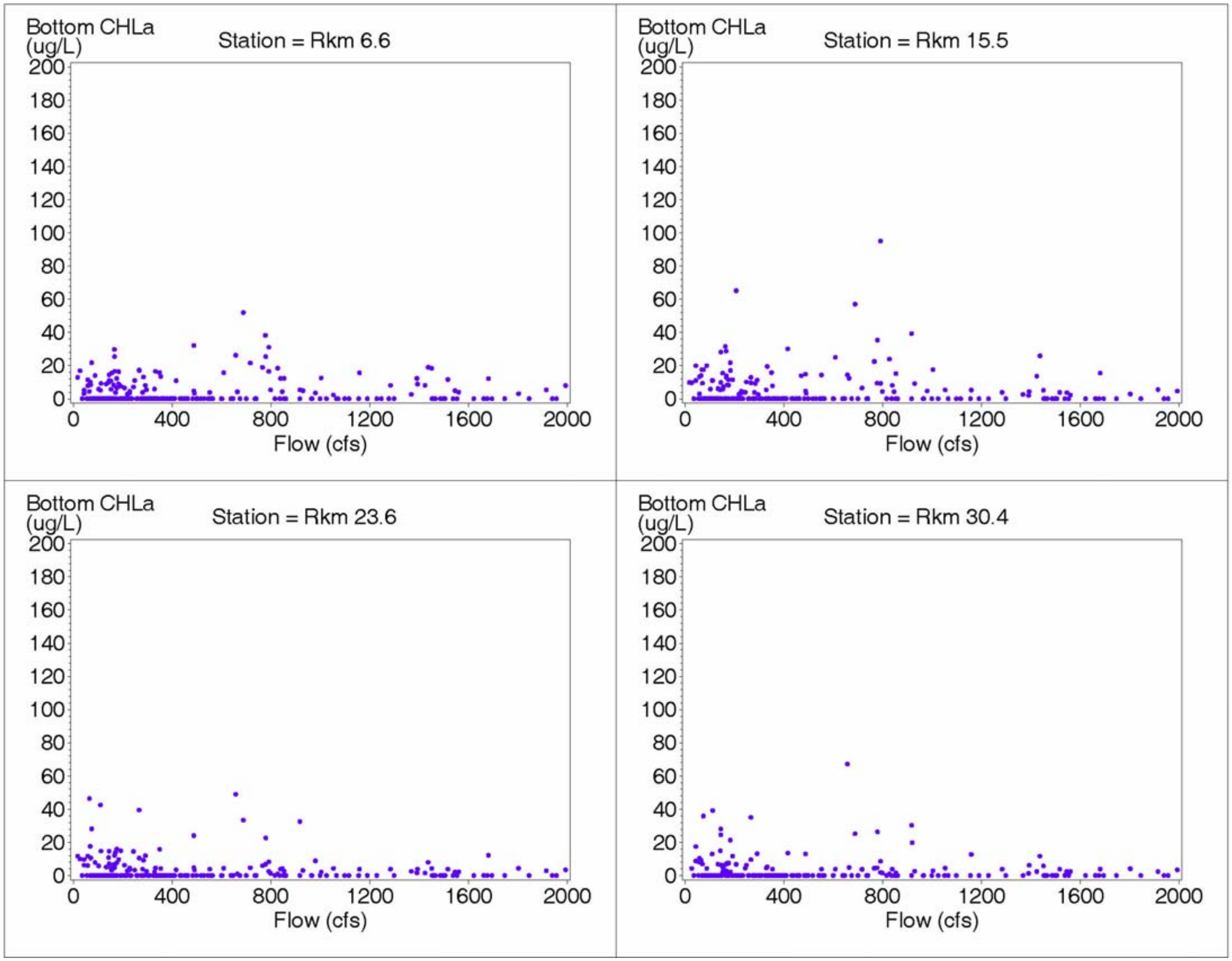


Figure 6-11. Long-term HBMP bottom chlorophyll a observations at Stations 10, 12, 14, and 18 (see Figure 2-3 for locations) as a function of flow in the Lower Peace River. Lower Peace River flow was calculated as the sum of Peace at Arcadia (USGS 02296750), Joshua Creek at Nocatee (USGS 02297100), and Horse Creek near Arcadia (USGS 02297310), minus the withdrawals taken out at the PRMRWSA plant.

6.2.4 Relationship Between Flow and Nutrients

Total nitrogen field observations from the HBMP were plotted against freshwater inflow to describe responses (Figures 6-12 and 6-13). As anticipated, total nitrogen concentrations did not have a strong relationship to freshwater inflows. Total phosphorous field observations from the HBMP were plotted against freshwater inflow to describe responses (Figures 6-14 and 6-15). Similar to total nitrogen, the total phosphorous concentrations did not have a strong relationship to freshwater inflows. Therefore, appropriate tools relating total nitrogen and total phosphorus to freshwater inflows the LPR and SC do not currently exist.

6.3 Conclusions

Statistically significant relationships between salinity and freshwater inflow have been identified in several previous studies (Stoker *et al.* 1989, Stoker 1992, PBS&J 1999b, Janicki Environmental, Inc. 2001). A statistically significant relationship between the location of the chlorophyll *a* maximum and freshwater inflow was developed as part of this study. While general patterns have been documented between dissolved oxygen and freshwater inflows, statistically defensible relationships have yet to be defined.

In addition to regression models, hydrodynamic models are also appropriate tools to be used to understand the implications of proposed management actions. A hydrodynamic model has been developed for the Lower Peace River by District staff. This model will be discussed briefly in Section 7 and in greater detail in the Appendix.

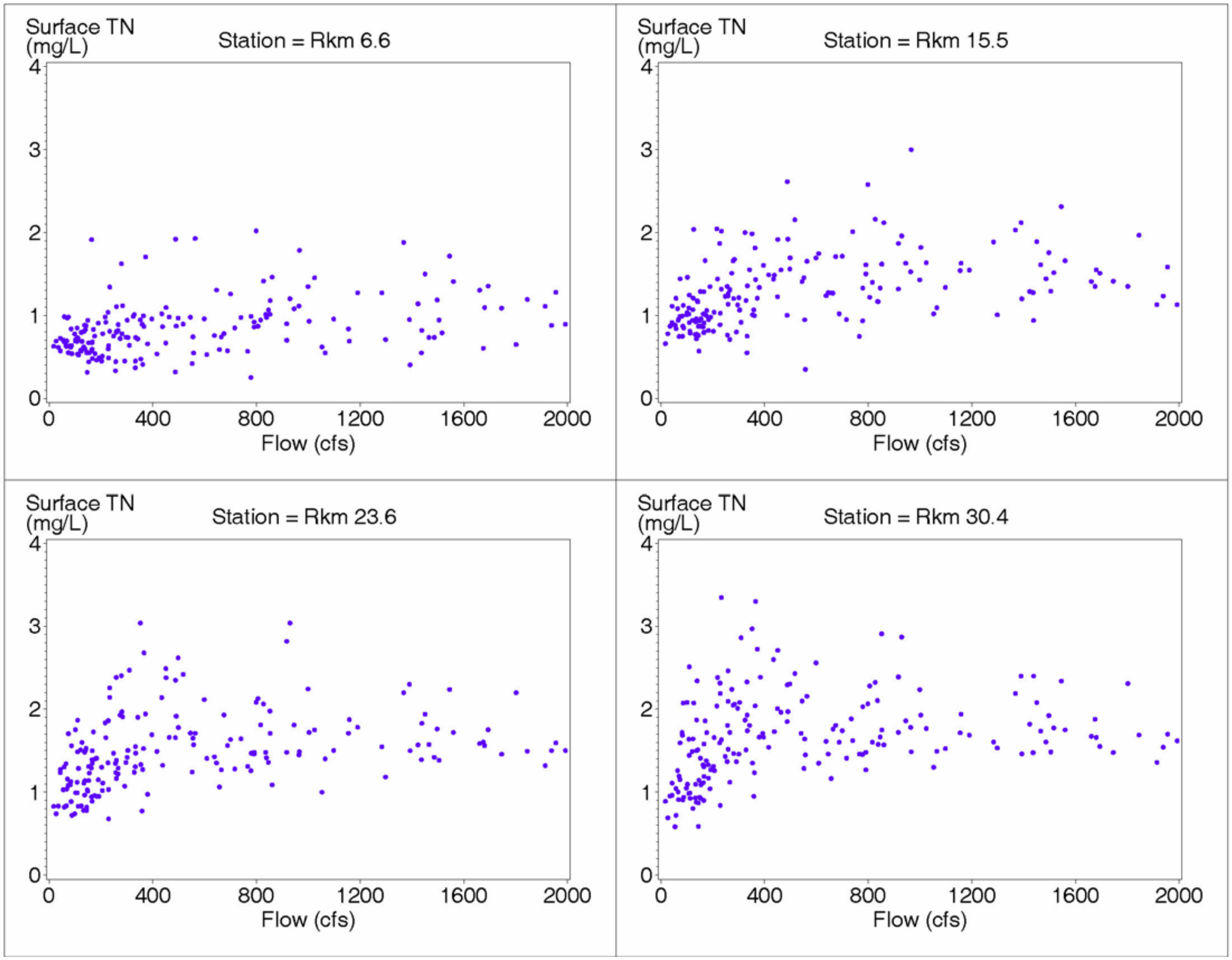


Figure 6-12. Long-term HBMP surface total nitrogen observations at Stations 10, 12, 14, and 18 (see Figure 2-3 for locations) as a function of flow in the Lower Peace River. Lower Peace River flow was calculated as the sum of Peace at Arcadia (USGS 02296750), Joshua Creek at Nocatee (USGS 02297100), and Horse Creek near Arcadia (USGS 02297310), minus the withdrawals taken out at the PRMRWSA plant.

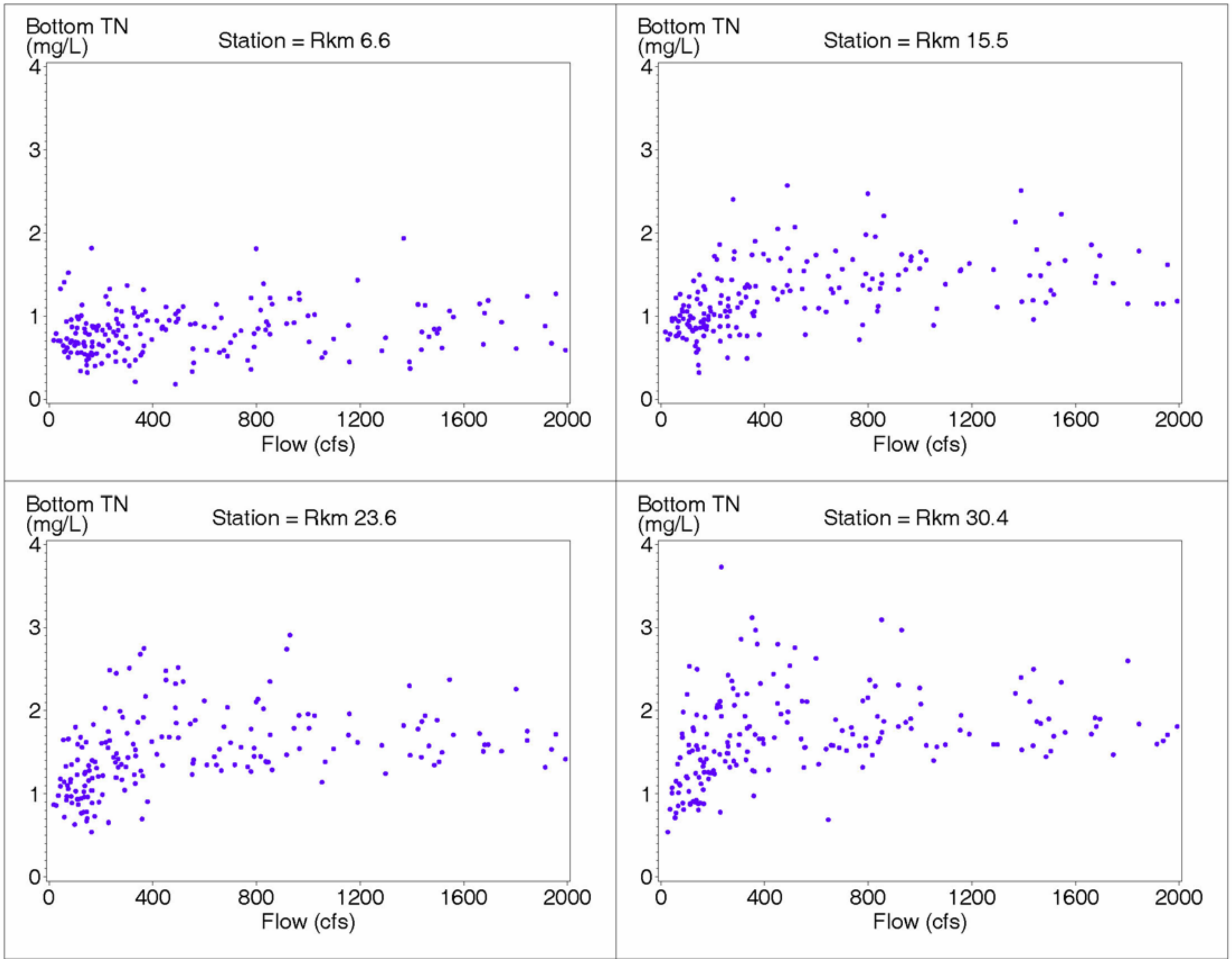


Figure 6-13. Long-term HBMP bottom total nitrogen observations at Stations 10, 12, 14, and 18 (see Figure 2-3 for locations) as a function of flow in the Lower Peace River. Lower Peace River flow was calculated as the sum of Peace at Arcadia (USGS 02296750), Joshua Creek at Nocatee (USGS 02297100), and Horse Creek near Arcadia (USGS 02297310), minus the withdrawals taken out at the PRMRWSA plant.

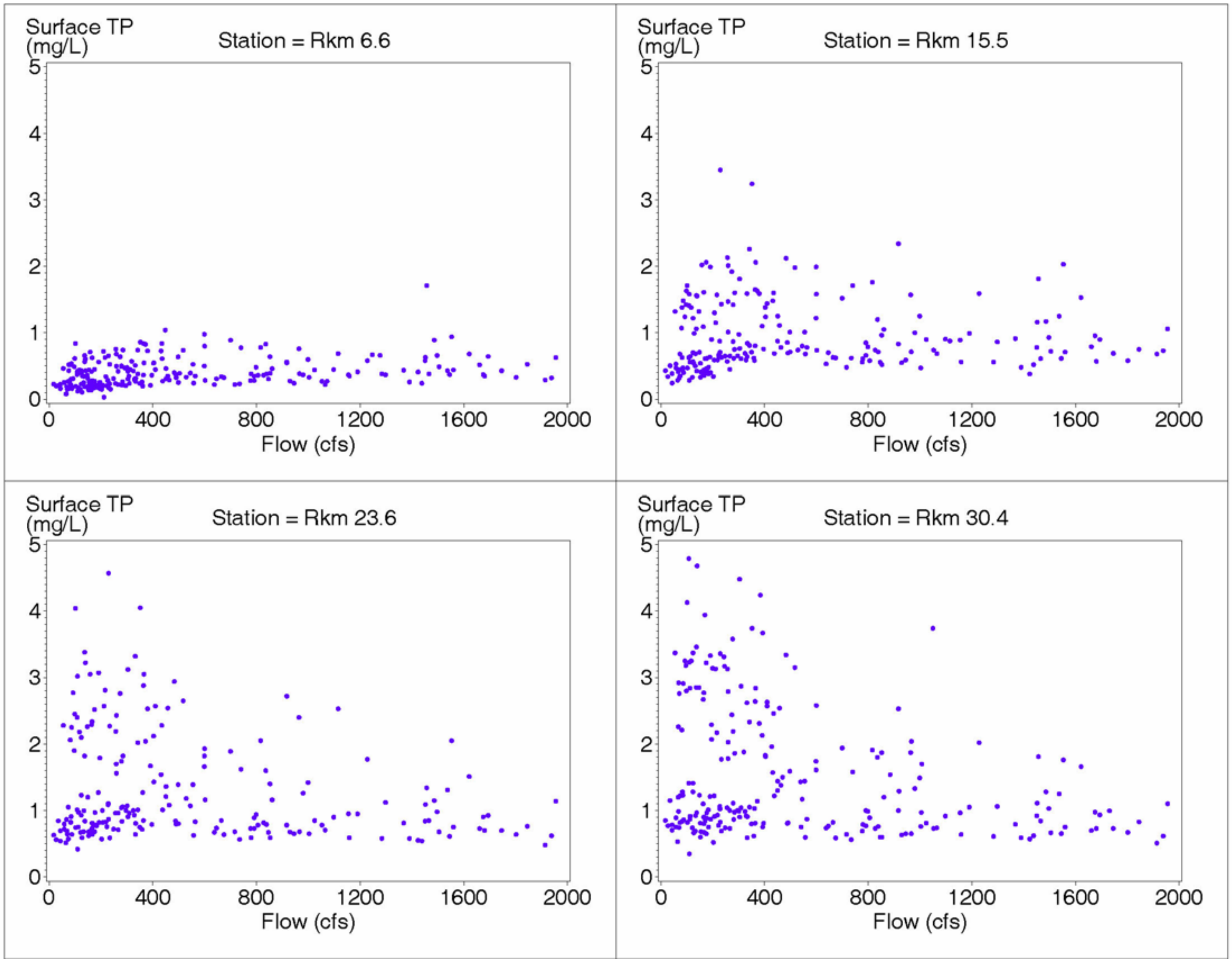


Figure 6-14. **Long-term HBMP surface total phosphorus observations at Stations 10, 12, 14, and 18 (see Figure 2-3 for locations) as a function of flow in the Lower Peace River. Lower Peace River flow was calculated as the sum of Peace at Arcadia (USGS 02296750), Joshua Creek at Nocatee (USGS 02297100), and Horse Creek near Arcadia (USGS 02297310), minus the withdrawals taken out at the PRMRWSA plant.**

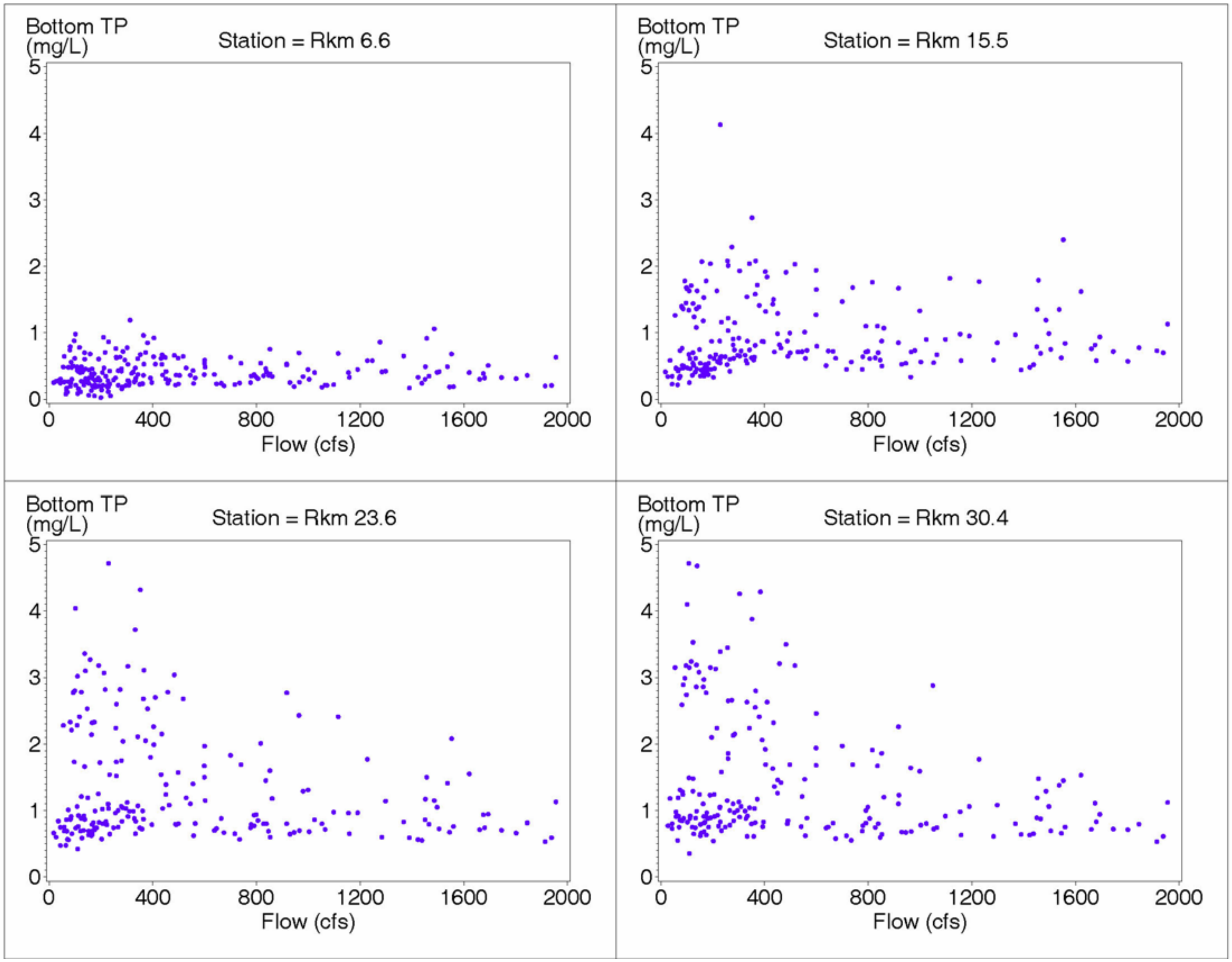


Figure 6-15. Long-term HBMP bottom total phosphorus observations at Stations 10, 12, 14, and 18 (see Figure 2-3 for locations) as a function of flow in the Lower Peace River. Lower Peace River flow was calculated as the sum of Peace at Arcadia (USGS 02296750), Joshua Creek at Nocatee (USGS 02297100), and Horse Creek near Arcadia (USGS 02297310), minus the withdrawals taken out at the PRMRWSA plant.

7 APPLICATION OF MODELING TOOLS THAT RELATE FRESHWATER INFLOWS TO SALINITY IN SHELL CREEK AND THE LOWER PEACE RIVER

In this section, the following elements to be used in establishing MFLs will be presented for both LPR and SC:

- Selection of an appropriate low-flow threshold for Peace River
- Definition of biologically-relevant salinities,
- Description of the metrics used to quantify habitat,
- Definition of seasonally specific assessment periods,
- Description of analytical tools used to quantify habitat,
- Definition of the study area,
- Definition of the reference period for minimum flow evaluation,
- Definition of the modeling period for minimum flow evaluation,
- Definition of the Baseline Scenario,
- Definition of alternative modeling scenarios, and
- Review of the results provided by the analytical tools.

This chapter begins with a discussion of the rational for establishing a low-flow threshold for the Lower Peace River. The remainder of this chapter describes an evolution of approaches evaluated to set MFLs in two systems where habitat protection is partially dependent on withdrawals in the other system. A number of changes were implemented between the August 24, 2007 draft (SWFWMD 2007c.) provided to the peer review , the April 2009 (SWFWMD 2009) revised draft responding to the peer review comments and this, the final report which incorporates suggestions and comments received after the 2007 review period. Major changes are summarized in the preface of the present report. Changes between the draft and final report are noted in Chapters 7 and 8 by referring to the previous report as the 'peer review draft'.

Following the peer review of the draft document, a step-wise approach was envisioned that would begin by estimating baseline habitat in each system with no withdrawals in either system and with excess agricultural water removed from the SC record. Once baseline habitat was established, the SC MFL was determined in the presence of Peace River baseline flows. The third step involved imposing the SC MFL derived in step 2, and determining the Peace River MFL. For reasons described later, this approach did not result in the desired level of protection. A discussion of these steps follows.

Section 7.2 describes the habitat metrics and seasonal blocks common to both, followed by a description of adjustments necessary to re-create a naturalized baseline flow in SC.

Section 7.3 describes the modeling tools and post-processing steps used to establish seasonal MFLs for SC using the full period of record.

Section 7.4 describes the analogous evaluation of the Lower Peace River using shorter evaluation periods required because of the extended execution time required by computer-intensive numeric modeling. Also included in Section 7.3 is a discussion of the change in the LPR evaluation period between the peer review draft (1996-1999) and this final report (1999-2002).

Section 7.5 includes a discussion of the approach adopted to evaluate flow reductions in both systems simultaneously. This discussion is included in response to a peer review comment concerning the order of determination.

7.1 *Determination of Low-Flow Threshold for Lower Peace River*

The percent reduction scenarios will be compared to the Baseline Scenario to determine the impact the reductions have relative to the Baseline. Besides the percent reduction in flow, it is necessary to investigate whether there is a critical flow at which further reductions in flow would be detrimental to the system. This concept of a low-flow threshold is currently being applied to the Lower Alafia River minimum flow (SWFWMD 2008).

Initially, the low-flow threshold was set at 90 cfs (SWFWMD 2007a), a value which was retained for subsequent re-evaluation (SWFWMD 2009a) and establishment of seasonal withdrawal limits for the protection of salinity habitat. Comments received in response to the 2009 draft report prompeted a reconsideration of this value that was subsequently increased to 130 cfs. The rational for the change is further described in this section, but it should be noted that seasonal limits were not recalculated for the higher low-flow threshold presented in the present report.

Models were developed that relate flow to ecological criteria in the Lower Peace River (e.g., salinity, chlorophyll *a*). However, there were no breakpoints or inflections in these relationships at low flows, thus it was concluded that a low flow threshold based on ecological criteria was not necessary.

The PRMRWSA plant withdraws water from the Lower Peace River for potable water supply. It is important to maintain freshwater at the PRMRWSA withdrawal point, because saline water hinders the treatment process for the plant. Therefore, an operational criterion of maintaining freshwater (< 0.5 ppt) at the PRMRWSA plant is an acceptable criterion since no defensible ecological criteria were established.

The operators of the Peace River water treatment facility typically only withdraw water when specific conductance values in the river at the plant intake are below 633 µmhos/cm, in order to keep the treated water within the state potable water quality standard for total dissolved solids (PRMRSA written communication). To examine the rate of streamflow that results in river water less than 633 umhos/cm near the plant intake, the District accessed data from a specific conductance recorder in the river channel at rkm 30.6, very close to the mouth of the slough on which the water treatment facility is located (Figure 7-1). This recorder, which measures specific conductance in surface and bottom waters every 15 minutes, is part of a suite of recorders maintained in the river as part of the hydrobiological monitoring program conducted by the PRMRWSA (Figure 7-1. The recorder became operational in May 2008 and measured valuable specific conductance data in the river during very low flows in the spring of 2009.

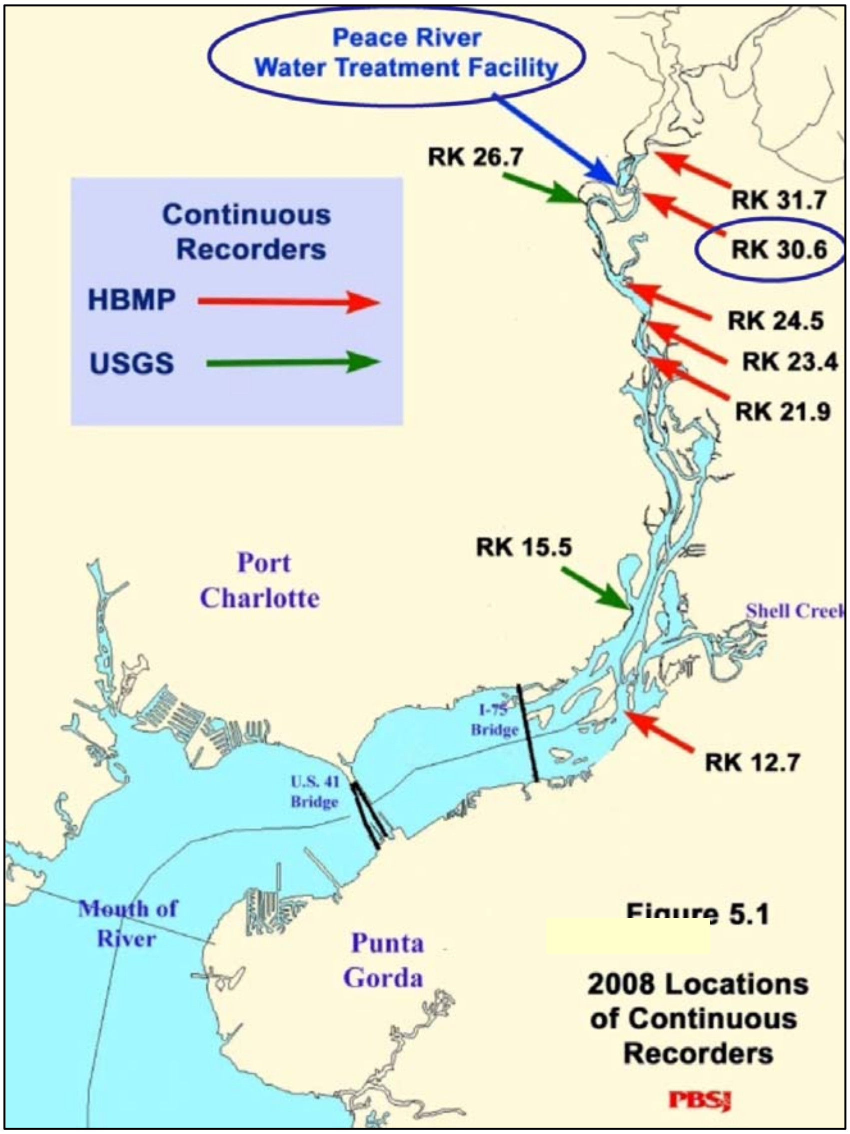


Figure 7-1 **Location of continuous specific conductance recorders in the Lower Peace River operated by the USGS or PBS&J Inc. as part of the hydrobiological monitoring program conducted by the Peace River Manasota Regional Water Supply Authority. River kilometers listed for each recorder. Data for the recorder at RK 30.6 are shown in Figure 7.2 (Source PBS&J, 2009).**

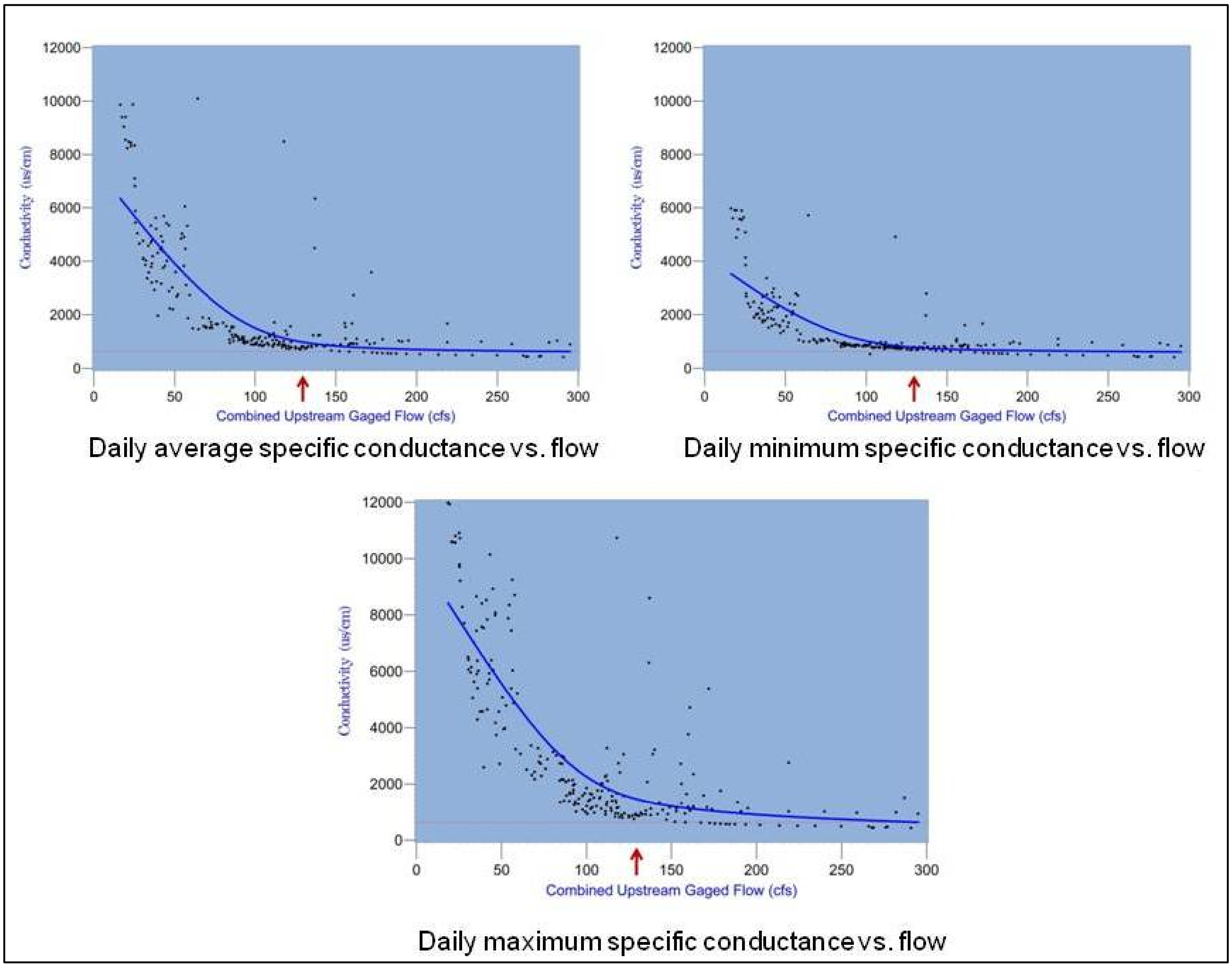


Figure 7-2 **Plots of average, minimum, and maximum daily surface values for specific conductance at a continuous recorder at river kilometer 30.6 vs. same-day flow for the combined gaged flows at the Peace River at Arcadia, Horse Creek near Arcadia and Joshua Creek at Nocatee. Reference arrow at 130 cfs on x axis. Results truncated at 300 cfs for clarity. Adapted from PRWSA (written communication)**

Surface specific conductance values are plotted as this best corresponds to the water layer captured by the plant intake, but bottom values show a very similar response as the river is usually well mixed at low flows. Minimum daily specific conductance values can be considered typical of low tide conditions, while maximum daily values represent specific conductance in the river near the time of the peak daily high tides. A reference line is included on all plots at 633 umhos/cm and non-linear regression lines fitted to the data by PBSJ are also included (PRMRWSA written communication). The District did not use these regressions directly, but instead examined the general scatter of the data in relation to the 633 umhos/cm reference value.

Preceding streamflow, tide, and wind conditions can all affect the flow-specific conductance relationship resulting in scatter in the plots. However, all the plots show that brackish water can extend to near the water treatment plant at low flows. Specific conductance values over 8,000 umhos/cm (equal to about 4.4 ppt salinity) can reach the location of the plant at very low flows (< 55 cfs), with a maximum value near 12,000 umhos/cm (≈ 6.8 ppt salinity) recorded during at a flow rate of 20 cfs. The flow rate at which specific conductance was reduced to near the 633 umhos/cm reference line varied between the average, minimum, and maximum values. Minimum daily (low tide) values largely remained close to 633 umhos/cm reference line at flows greater than 90 cfs. However, both the average and especially the maximum daily values showed somewhat of a break in the flow-conductance relationship at flow rates of about 120 to 130 cfs (a reference arrow at 130 cfs is included on the x axis in the plots in Figure 7-2).

The existing regulation contained in the water use permit issued to the PRMRWSA requires that no withdrawals be allowed from the river when the flow rate for the preceding day at the Peace River at Arcadia gauge is below 130 cfs. This regulation was established in 1994 based on a data base comprised of a series of specific conductance measurements taken from boats in the upper reaches of the lower river. Using a more extensive data base of values recorded every 15 minutes at a location near the water treatment plant, the current analysis suggests that 130 cfs remains a suitable low-flow threshold, but it should be based on the sum of the three gauges that contribute flow above the water treatment plant, acknowledging that the Peace River at Arcadia contributes the large majority of this flow.

Accordingly, a flow rate of 130 cfs measured as the sum of flows from the Horse Creek bear Arcadia, Joshua Creek at Nocatee, and the Peace River at Arcadia is recommended as the low-flow threshold to be applied as part of the minimum flows rule for the Lower Peace River. Prohibiting withdrawals from the river below 130 cfs will largely prevent water users from reducing flows to a rate that will induce brackish water occurring at the PRMRSA intake. Strong tides and winds can cause variation in this relationship, and there may be some days when water over 633 umhos/cm occurs near the plant intake when flows are over 130 cfs. However, water near the plant intake is almost always near the 633 umhos/cm criterion at low tide at 130 cfs, and the recommended 130 cfs low-flow threshold will allow flexibility for the PRMRWSA flexibility to withdraw water at low or average tides when specific conductance values at the intake are suitable.

Although clear breakpoints in ecological relationships were not observed at low flows, the 130 cfs low-flow threshold will benefit the ecology of the river by prohibiting withdrawals when flows are at their lowest and ecological resources are most sensitive to flow related impacts. Based on the period from 1985-2004, the summed flows for the three gauges were below 130 cfs 12.4% percent of the time, or an average of 45 days per year. However, this varies considerably by month, with flows below 130 cfs an average of over 12 days per month in May, but zero days per month in August and September (Figure 7-3). The duration that flows are below 130 cfs also varies considerably between wet and dry years (Figure 7-4). During 1985 and 1991, flows were below the 130 cfs low-flow threshold 151 and 140 days, respectively, with the largest number of days below the 130 cfs threshold (214 days) recorded during the year 2000. During such drought years the low-flow threshold will prevent withdrawal related impacts when the river is in a critical low flow condition. Conversely, the low-flow threshold will not affect withdrawals during wet years. The number of days per year that flows were less than 130 cfs ranged from zero to nine for the five of the wettest years (1987, 1993, 1995, 2003, 2004) in the twenty-year period shown in Figure 7-4.

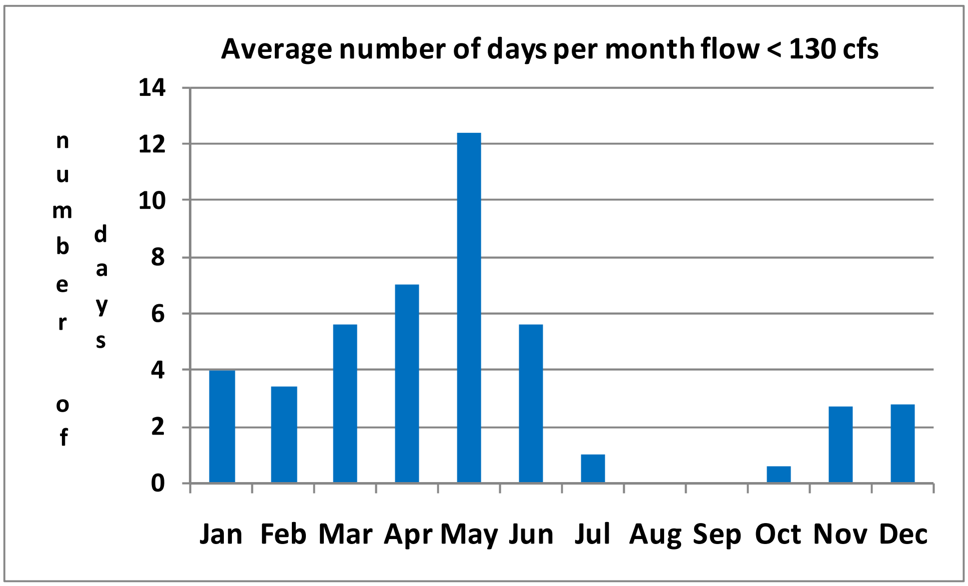


Figure 7-3. Average number of days per month that combined flows at the Peace River at Arcadia, Horse Creek near Arcadia and Joshua Creek at Nocatee were below 130 cfs for the period 1985-2004.

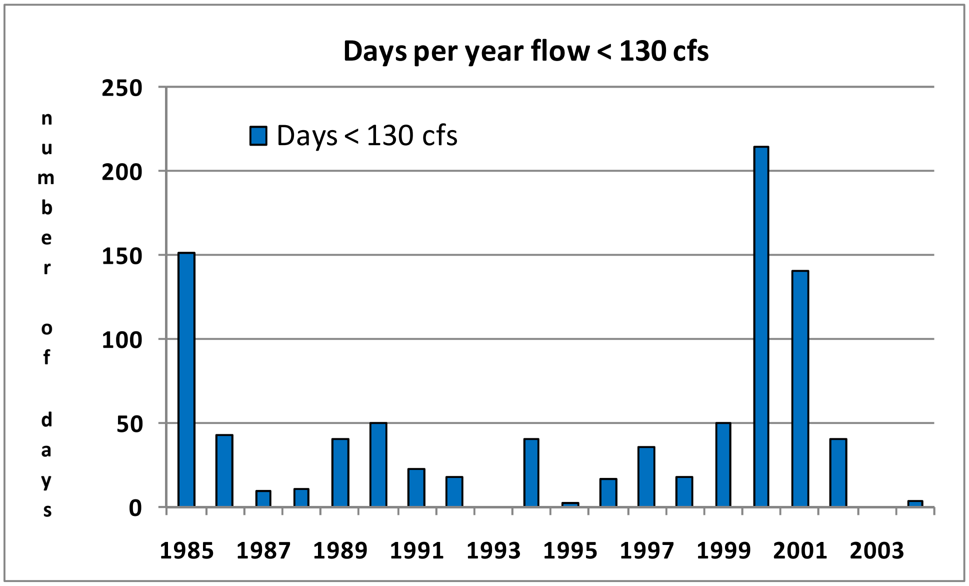


Figure 7-4. Average number of days per year that combined flows at the Peace River at Arcadia, Horse Creek near Arcadia and the Joshua Creek at Nocatee gages were below 130 cfs for the years 1985-2004.

In sum, the 130 cfs low-flow threshold is a critical part of the proposed minimum flow rule for the Lower Peace River. The low-flow threshold provides important protection for the ecological resources of the river by prohibiting withdrawal related impacts during critical low flow periods and it will largely prevent water users from reducing flows to rates that will result in brackish water at the PRMRWSA intake.

It should be noted that the seasonal MFL withdrawal percentages described in this report were derived using a low-flow threshold of 90 cfs and without transitional trigger flows (See Section 8.2). Increasing the low-flow threshold and incorporating the transitional trigger flows increases the protection afforded by the MFL.

7.2 Definition of Biologically-Relevant Salinities, Habitat Assessment Metrics, and Seasonally-Specific Assessment Periods

Clearly, establishment of an MFL requires identification of a critical biologically-relevant variable that can be defensibly and quantitatively related to variation in freshwater flows. The results presented in Section 6 indicate that salinity is the most quantifiable and defensible link to variation in freshwater flow. Therefore, the first step in the establishment of an MFL is the definition of biologically-relevant salinities to provide a focus to the analysis of the effect of freshwater flow on LPR and SC.

7.2.1 Definition of Biologically-Relevant Salinities

The following biologically relevant salinities were used in minimum flow development for LPR and SC:

- <2 ppt - this critical salinity is supported by several pieces of evidence – Jassby *et al.* (1995) use the 2 ppt isohaline as an indicator of overall ecosystem productivity in the Sacremento - San Joaquin estuary system; fish studies on the LPR and SC showed that many freshwater fish and invertebrates have mean salinity of capture values of less than 2 ppt; analysis of fish community structure in the Lower Peace River (Figures 5-11 and 5-12) reveals break points for distinct groups of these organisms at approximately 2, 5, and 15 ppt; Clewell *et al.* (1999) and Clewell *et al.* (2002) described glycophytes as having low salinity tolerances with several species being most abundant where median yearly salinities are below 2 ppt; and the Lower Suwannee River MFL was based on "average salinities of high tide waters flooding the swamps should be kept <2 ppt, with briefer periods of higher salinity tolerable." (WRA *et al.* 2005).

- <5 ppt - this critical salinity is also supported by several lines of evidence - oligohaline river habitats with salinities in the range less than 5 ppt have been disproportionately lost throughout the Gulf Coast (Beck *et al.* 2000), and that there is an opportunity to maintain such habitats in LPR and SC given appropriate minimum flows for these systems; analysis of fish community structure in the LPR (Figures 5-11 and 5-12) reveals break points for distinct groups of these organisms at approximately 2, 5, and 15 ppt; and the Sulphur Springs MFL (SWFWMD 2004) and Lower Hillsborough River MFL reevaluation (SWFWMD 2006) both had the goal of maintaining low salinity (less the 5 ppt) habitat in the Lower Hillsborough River.

- <15 ppt - this critical salinity is also supported by several lines of evidence - analysis of fish community structure in the LPR (Figures 5-11 and 5-12) reveals transition points for distinct groups of these organisms at approximately 2, 5, and 15 ppt; and analysis of benthic community structure in the LPR and Myakka River also shows salinities in the range of 15-18 ppt are important to maintain the integrity of a healthy mesohaline community type.

7.2.2 Definition of Habitat Assessment Metrics

In order to estimate the amount of available habitat that meets the biologically-relevant salinities discussed above under various flow conditions, the following metrics were used:

- the volume of water in the system less than a given salinity, since the fishes in the LPR and SC generally utilize the entire water column,

- the bottom area in the system less than a given salinity, since the benthic macroinvertebrates inhabit the bottom substrate in the LPR and SC,

- the shoreline length in the system less than a given salinity, since this metric best defines the amount of shoreline vegetation habitat available in the system.

7.2.3 Seasonally-Specific Assessment Periods

Definition of an MFL that maintains biologically-relevant salinities over a range of flow conditions must also consider the expected variation on flows within given portions (hydroperiods) of the year. 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 (SWFWMD 2005a).

The approach used by the District for development of MFLs for the LPR is consistent with the building block approach. Available flow records were summarized and used to describe flow regimes for specific historical periods. For development of minimum flows and levels for the middle segment of the Peace River, the District explicitly identified three building blocks in its approach (SWFWMD 2005a). 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 (Figure 7-1). 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 (June 26 to October 26), the 123 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 in early to mid-March. The remaining 176 days constitute an intermediate or medium flow period, which is referred to as Block 2. For development of minimum flows and levels for LPR and SC, the same Blocks as defined for the middle Peace River were applied.

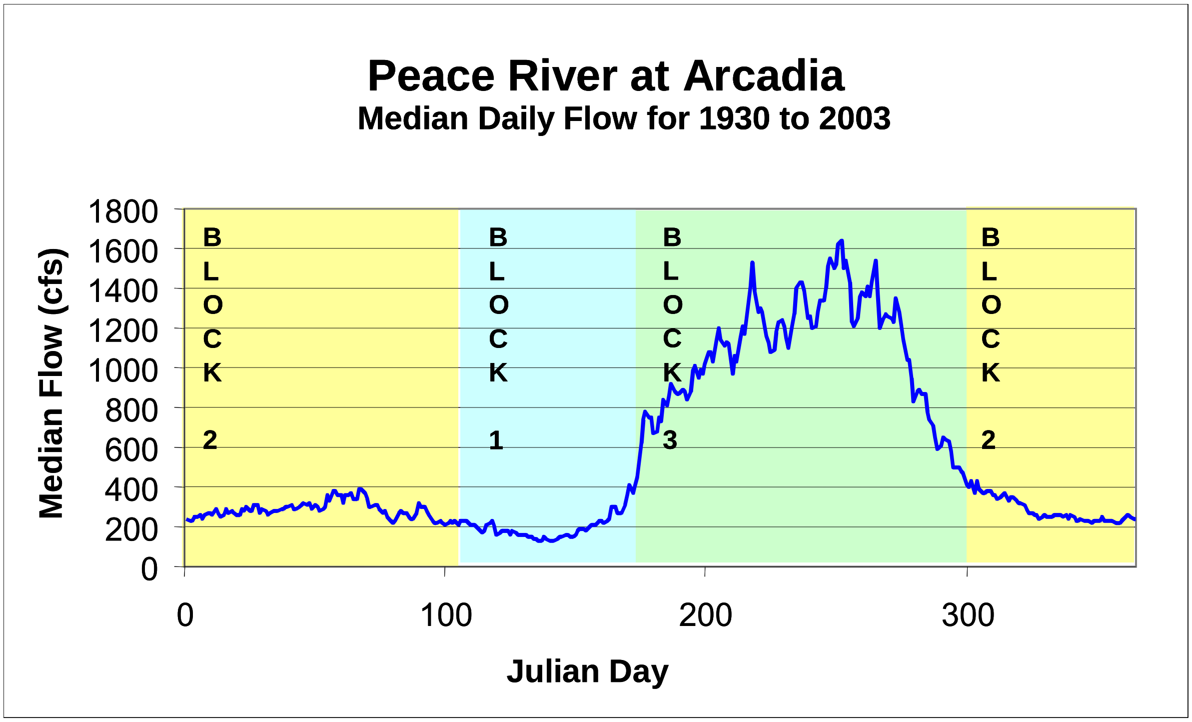


Figure 7-5. Building blocks developed for a building block approach to the development of minimum flows. Blocks corresponding to low (Block 1), medium (Block 2) and high (Block 3) flows are shown along with period of record median daily flows for the USGS Peace River at Arcadia gauge (from: SWFWMD 2005a).

7.3 Application of Modeling Tools that Relate Freshwater Inflows to Salinity in Shell Creek

In this subsection, the following elements will be met for SC:

- Description of analytical tools used to quantify habitat,
- Definition of the study area,
- Definition of the reference period for minimum flow evaluation,
- Definition of the modeling period for minimum flow evaluation,
- Definition of the Baseline Scenario,
- Definition of alternative modeling scenarios, and
- Review of the results provided by the analytical tools.

7.3.1 Analytical tool that relates flow to salinity for Shell Creek

The purpose of the analytical tool is to estimate the volume, bottom area, and shoreline length meeting the biologically relevant salinities as a function of flow. To this end, a regression model of SC was developed. The regression model is described in Appendix 5-1. The regression model predicts daily salinity at any point in the study area as a function of flow and other confounding factors. Factors besides flow include the location in the river, season, tide stage, Peace River flow, and salinity in the northeastern portion of Charlotte Harbor. Because the system is relatively well mixed vertically, the model predicts water column average salinity. The final form of the regression model is as follows:

$$Salinity = \alpha + \beta_1 Month + \beta_2 Q_{SC}^{-0.05} + \beta_3 S_{BM} + \beta_4 Tide + \beta_5 (\ln Q_{PR}) + \beta_6 RK^{1.5} + \beta_7 Q_{SC} RK$$

where:

Salinity	=	Water Column-Average Salinity
Month	=	Calendar Month
Q_{SC}	=	Shell Creek Flow
S_{BM}	=	Salinity in Upper Charlotte Harbor at Black Marker
Tide	=	Tide Height at Boca Grande
Q_{PR}	=	Peace River Flow (Peace at Arcadia + Horse Creek + Joshua Creek)
RK	=	River Kilometer

Salinity observations from fixed station sampling by the Shell Creek HBMP were used to develop this model. The model was based on data collected from 1997 through 2004. Although additional HBMP fixed station sampling data were available prior to 1997, the time of data collection was not recorded. Therefore, these data could not be used since there was no way to determine the tide phase at the time of sampling.

The salinity-flow model was statistically significant and accounted for more than 80% of the variation in salinity in SC (p<0.0001, r^2 = 0.82). The parameter estimates, model statistics, and residual analyses are presented in Appendix 5-1.

7.3.2 Shell Creek Study Area

The physical domain of the salinity-flow regression model is shown in Figure 7-2. This area is comprised of the main stem of SC from HBMP Station 7 (rkm 2.35) to the Hendrickson Dam (rkm 9.9).

7.3.3 Shell Creek Baseline Period

The Reference Period is defined as the period from 1966 through 2004. This period reflects the significant year-to-year variation in flows that have occurred historically within SC.

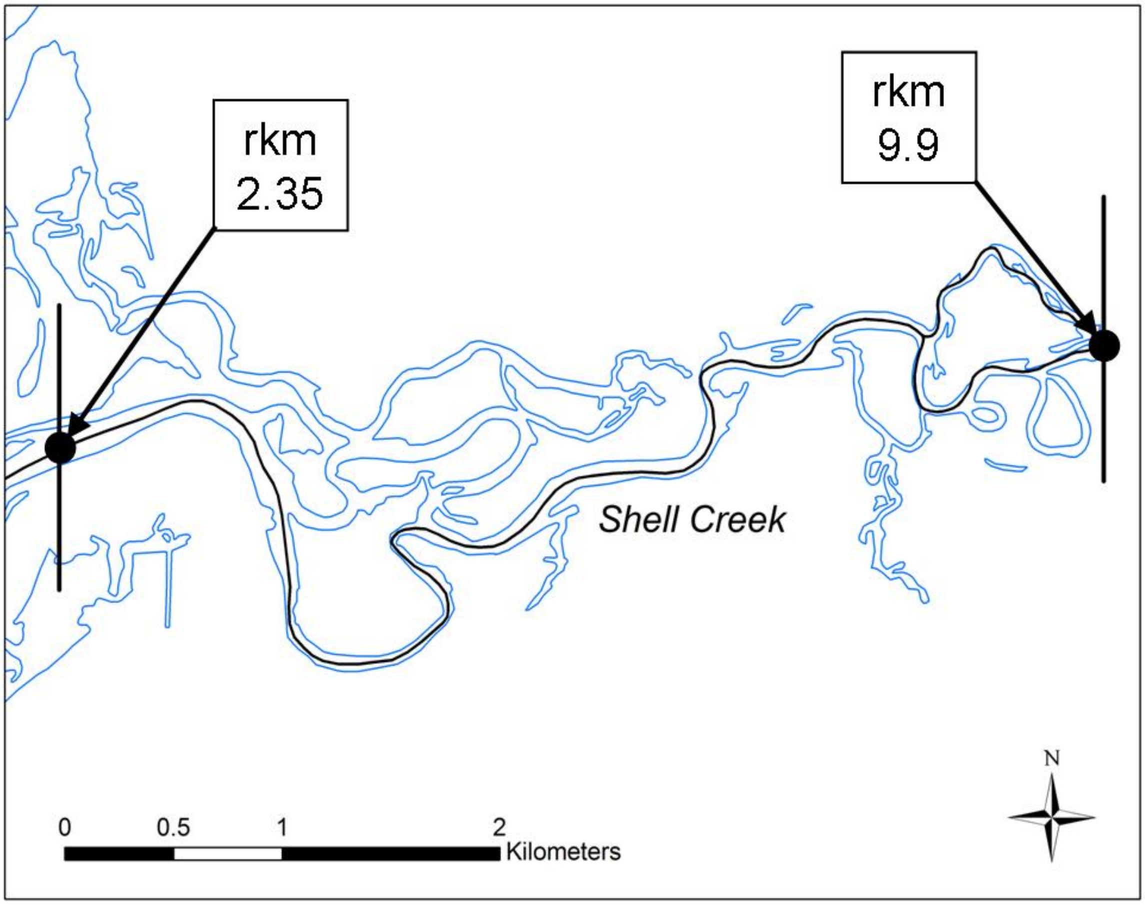


Figure 7-6. **Study area for SC whole river regression. The physical domain of the regression is comprised of the main stem of SC and extends from river km 2.35 to river km 9.9 at the base of the dam. The map includes the centerline (black line) of the main stem of SC.**

7.3.4 Shell Creek Modeling Period

In the peer review draft, the modeling period, i.e., the period to which the salinity-flow regression model is to be applied, was also defined as the period from 1966 to 2004. (In the final analysis a sub-set of this period corresponding to the simulation period of the Peace River hydrodynamic model was used. See section 7.4) Because tide and Black Marker Salinity were not available for the entire period of record, the median tide and Black Marker salinity were calculated by calendar month for the period 1997 to 2004. These median values were then applied to the daily flow record by calendar month and predictions were made for each day between January 1, 1966 and December 31, 2004.

7.3.5 Definition of Baseline and Model Scenarios for Shell Creek

The initial Baseline Scenario for SC consisted of the entire reference period of observed daily flows at the Shell Creek near Punta Gorda gauge (USGS 02298202) corrected for the withdrawals by the City of Punta Gorda and reject irrigation groundwater as described. Additional model runs were made based on a series of percent reductions from the Baseline SC flows. The series of percent flow reductions that defined the Percent Flow Reduction Modeling Scenarios ranged from 1% to 99 % in 1% increments.

7.3.6 Modifying the Shell Creek Flow Record to Generate a Flow Record that is Unimpacted by Withdrawals

The observed discharge from the City of Punta Gorda's reservoir (Hendrickson Dam) has been increased by the addition of excess groundwater (pumped for agricultural purposes) and decreased by the City's withdrawals from the reservoir. Hendrickson's Dam was constructed in 1965. Discharge records begin in 1966 and the record of potable withdrawals begin in 1972 when the mean annual withdrawal was 2.0 cfs. Corrections to the observed record were prepared for each effect and the corrected record was used to represent naturalized baseline conditions.

The initial approach used to generate a baseline flow record for Shell Creek was simply to take the existing USGS flow record for Site 02298202, which measures flow over the City of Punta Gorda's reservoir, and add back in the City's withdrawals. However, this approach is flawed, because it fails to appropriately address water removed from storage when the water level in the reservoir is lower than the spillway crest. For example, on days when USGS reports flow over the dam as 0 cfs, but the City withdrew 5 cfs from the reservoir, this approach would result in reporting the flow as 5 cfs. While it is possible that 5 cfs, may have flowed over dam and the withdrawal offset the flow precisely, this is unlikely in most cases. Once the City begins to withdraw from storage, this approach would lead to a reported daily flow equivalent to the City's withdrawal regardless of the elevation in the reservoir. As long as water remained in storage below the reservoir crest, there would be no zero flow days estimated.

Because of the backwater effects from the reservoir, there is no gauge immediately upstream that can be used to estimate inflow to the reservoir. In order to correct the record in a more reasonable way, an alternate strategy was employed. As long as measurable flow over the dam exists, the unimpacted flow can be calculated as originally proposed by adding the City's withdrawal to the flow over the dam. However, when there is no flow over the dam, a different approach is needed. When flow is reported as zero at the USGS gauge, we examined flow at the Prairie Creek gauge. Prairie Creek is a major tributary to Shell Creek, accounting for approximately 62% of the Shell Creek watershed above the USGS gauge. Record of the City's withdrawals for the period 1966 to 1971, are unavailable, but averaged 2.0 cfs during the first year (1972) of recorded withdrawals. For purposes of correcting the discharge record, the City's impact on flow over the dam is considered negligible (e.g. < 2 cfs) and the period 1966 and 1971 was used to estimate unimpacted flow in subsequent years when the recorded flow over the dam was zero.

The period 1/1/1966 – 9/30/1968 was used to establish the primary relationship of zero discharge at the reservoir with flow in Prairie Creek. It was observed that when flow at the Shell Creek gauge was zero in the absence (assumed) of withdrawals, flow at Prairie Creek averaged 3.6 cfs. Therefore, when USGS observed a flow of zero at Shell Creek, and the flow on that day was 3.6 cfs or less at Prairie Creek, we assumed that the Shell Creek flow was zero. If the flow at Prairie exceeded 3.6 cfs and flow was reported at Shell to be zero, we used the reported Punta Gorda withdrawals as the flow for Shell Creek.

Unfortunately, Prairie Creek flow was not monitored from October 1, 1968 to September 30, 1977, and an alternate site was needed to complete the evaluation. The next correction was to compare Shell Creek flows to Charlie Creek flows using a similar approach. It was observed that when flow at the Shell Creek gauge was zero in the absence of withdrawals, that flow at Charlie Creek averaged 3.1 cfs. Therefore when USGS observed a flow of zero at Shell Creek and did not monitor flow at Prairie Creek, and flow at Charlie Creek was 3.1 cfs or less, we assumed that Shell Creek flow was zero.

Using this approach, the number of days that Shell Creek was reported to be zero naturally for the period 1966 to 2004 was 274 days of the 14,245 day period of record (2.0% of days). Using this approach, the greatest number of no flow days was 56 and occurred in 1967, while 41 no flow days were reported for 1975 and 2000.

The second correction to the observed discharge record was to adjust for anthropogenic groundwater discharges that result from agricultural practices. Two approaches were evaluated to estimate the contribution of reject irrigation water to the reservoir volume. The first approach was based on recommended irrigation rates and application inefficiencies for crops specific to the watershed, and the second approach was based on the mass balance of chloride measured in the reservoir.

The reservoir was constructed in 1965 by impounding (Hendrickson Dam) Shell Creek approximately 10 km upstream of the confluence with Peace River. Various estimates of size and yield have been developed over the years as shown in Table 7-1

Table 7-1 Reported Dimensions and Capacities.

Source	Area (acres)	Stage (ft)	Volume (mg)	Safe Yield (mgd)
Russell & Axon 1962 (Design Report)	892	5.0	908	
Russell & Axon 1963 (possibly a subset of above)		4.36		10
Watson Engineering (1974)		5.0	860	8.75
Reynolds Smith & Hill (1975)	660		860	10.8
SWFWMD (1981)	660	~5	697	
PBSJ (2007)	800			

Carollo Engineering (L. Baumberger, personal communication) provided a spreadsheet titled *Harper_Rescap-T.xls* that contains a tabular listing of volume by stage at 0.1-foot increments. The source of the data is unconfirmed but most likely was taken from the

District's report, or from the original Russell and Axon (1962) design report. For the present application, it was converted to a polynomial expression of the form below:

$$\text{Volume} = -51.4 + 158.6 * \text{stage} + 11.43 * \text{stage}^2$$

Where Volume is in million gallons and stage is in gauge feet ($n = 56$, $r^2 = 0.999$)

Typical seasonal fluctuations are minor as reflected in Table 7-2 which is derived from period of record (1973-2008) reservoir stage reported by the USGS (02298202 Shell Creek nearPunta Gorda FL)

Table 7-2 Mean and Median Monthly Water Level in Shell Creek Reservoir (1973-2008).

MONTH	median	mean	MONTH	median	mean
1	5.15	5.19	7	5.39	5.52
2	5.15	5.23	8	5.49	5.55
3	5.17	5.26	9	5.50	5.61
4	5.11	5.16	10	5.28	5.36
5	5.09	5.10	11	5.17	5.21
6	5.24	5.36	12	5.14	5.19

Total drainage area of Shell Creek is reported at 434 mi^2 (SWFWMD, 2008). Slight discrepancies exist regarding the fraction of watershed above Hendrickson Dam. PBSJ (2007) reports 334 mi^2 but SWFMWD GIS coverage indicates a minimum of 341 mi^2 (99.4 mi^2 from Shell Creek watershed and 241.4 mi^2 from the Prairie Creek watershed). SWFWMD's GIS coverage excludes a small portion of the watershed that is within the South Florida Water Management District.

Chloride levels in the reservoir vary seasonally in response to the fraction of excess irrigation water pumped from the Floridan aquifer. Table 7-3 gives the median monthly reservoir chloride level from 1965 – 2008.

Table 7-3 Median Monthly Chloride (mg/l) in Shell Creek Reservoir 1965-2008.

Month	**Cl (mg/l)**	**Month**	**Cl (mg/l)**
1	152	7	100
2	156.	8	107
3	137	9	104
4	115	10	116.
5	100	11	126
6	91	12	135

The Shell Creek Reservoir receives inflows from both Shell Creek watershed and the Prairie Creek watershed. Flow from both watersheds includes excess groundwater applied for agricultural activities. Shell Creek contains 12,647 acres of citrus and 2,400 acres of row crops, while Prairie Creek houses 35,004 acres of citrus and 1,170 acres of row crops. The chloride content of groundwater varies considerably between the two basins, with an average concentration of 160 mg/l in the Prairie Creek watershed and an average of 809 mg/l in the Shell Creek watershed. Chloride concentrations in surface waters at Peace Creek and SR 31 between July and October, which is assumed to be minimally impacted with excess groundwater, average 91 mg/l.

The first estimate of the excess irrigation water in the reservoir was developed as the product of irrigation application rates and application periods were multiplied by an irrigation efficiency factor. Rates and periods of application were taken from IFAS recommendations for nearby Manatee County. It was assumed that row crops were irrigated using open ditch sub-irrigation techniques (ridge and furrow) and that citrus was irrigated using drip (trickle irrigation). Irrigation efficiency was assumed to be 60 % and 85% respectively. Application rates, periods and excess rate of flow delivered to the reservoir are given in Table 7-4.

Table 7-4 Irrigation Application Rates, Periods and Efficiencies.

Prairie Creek					
Row Crops (acres)	**1,170**	**Application Rates**		**Excess flow (cfs) at Specified Irrigation Inefficiency**	
Start Irrigation	**End Irrigation**	**Rate (in/d)**	**cfs**		**40%**
1/15	5/15	0.375	18.4		7.4
8/15	11/14	0.272	13.4		5.3
11/15	12/15	0.125	6.1		2.5
Citrus (acres)	**35,004**	**Application Rates**			
Start Irrigation	**End Irrigation**	**Rate (in/d)**	**cfs**	**15%**	
4/1	5/31	0.058	55.1	8.3	
10/1	12/15	0.032	30.4	4.6	

In the second approach, an estimate of the monthly fraction of excess irrigation in the reservoir was developed from the observed reservoir chloride level and the ratio of groundwater to surface water. An irrigation weighted chloride concentration of 540 mg/l was developed to represent the groundwater concentration and the surface water concentration was taken as 91 mg/l. The protocol is illustrated in Table 7-5.

Table 7-5 Weighted Approach to Estimating Groundwater Chloride Concentrations.

	Average Daily Excess Irrigation (cfs)	Observed Groundwater Cl (mg/l)		Weighted Cl (mg/l)
Shell Creek	9.1	809	$\frac{(9.1*809) + (6.3*160)}{(9.1 + 6.3)} =$	542
Prairie Creek	6.3	160		

Unfortunately, the weighted result is partially dependent on the assumed application rates and inefficiencies defined in Table 7-4. As such, the two approaches are not entirely independent.

A monthly estimate of the volume of excess irrigation water within the reservoir was developed by combining the fraction of irrigation water with mean stage coupled with the stage storage relationship presented earlier. The results are given in Table 7-6 and expressed as million gallons and an equivalent monthly flow rate.

Table 7-6 Reservoir Volume (mg) and Equivalent Rate of Flow (cfs) Based on Differences in Chloride Concentration in Surface Water and Ground Water.

Mean Monthly Results - Shell Creek Reservoir					
Month	**Observed Cl (mg/l)**	**Stage (ft)**	**Reservoir Volume (mg)**	**Groundwater Volume (mg)**	**Equivalent Flow (cfs)**
1	152	5.2	1080	147	7.6
2	156	5.2	1091	158	8.1
3	137	5.3	1100	112	5.8
4	115	5.2	1071	58	3.0
5	100	5.1	1056	21	1.1
6	91	5.4	1127	1	0.0
7	100	5.5	1171	23	1.2
8	107	5.6	1182	42	2.2
9	104	5.6	1199	35	1.8
10	116	5.4	1127	61	3.2
11	126	5.2	1085	84	4.3
12	135	5.2	1078	104	5.4

Figures 7-3 and 7-4 compare the results of the two approaches and indicate that the timing of maximum excess irrigation flows lags the month of maximum observed chloride concentration in the reservoir. The difference may be the result of winter pumpage for freeze protection and/or pumpage above and beyond irrigation needs in order to purge salt build-up in the soil. Considering the lack of temporal agreement and the relative magnitude of flows predicted from the application rate approach, the chloride mass balance approach was adopted and used to estimate the contribution of pumped groundwater to the reservoir volume keeping in mind that these results are partially dependent upon the application rates used to estimate the weighted groundwater chloride concentration.

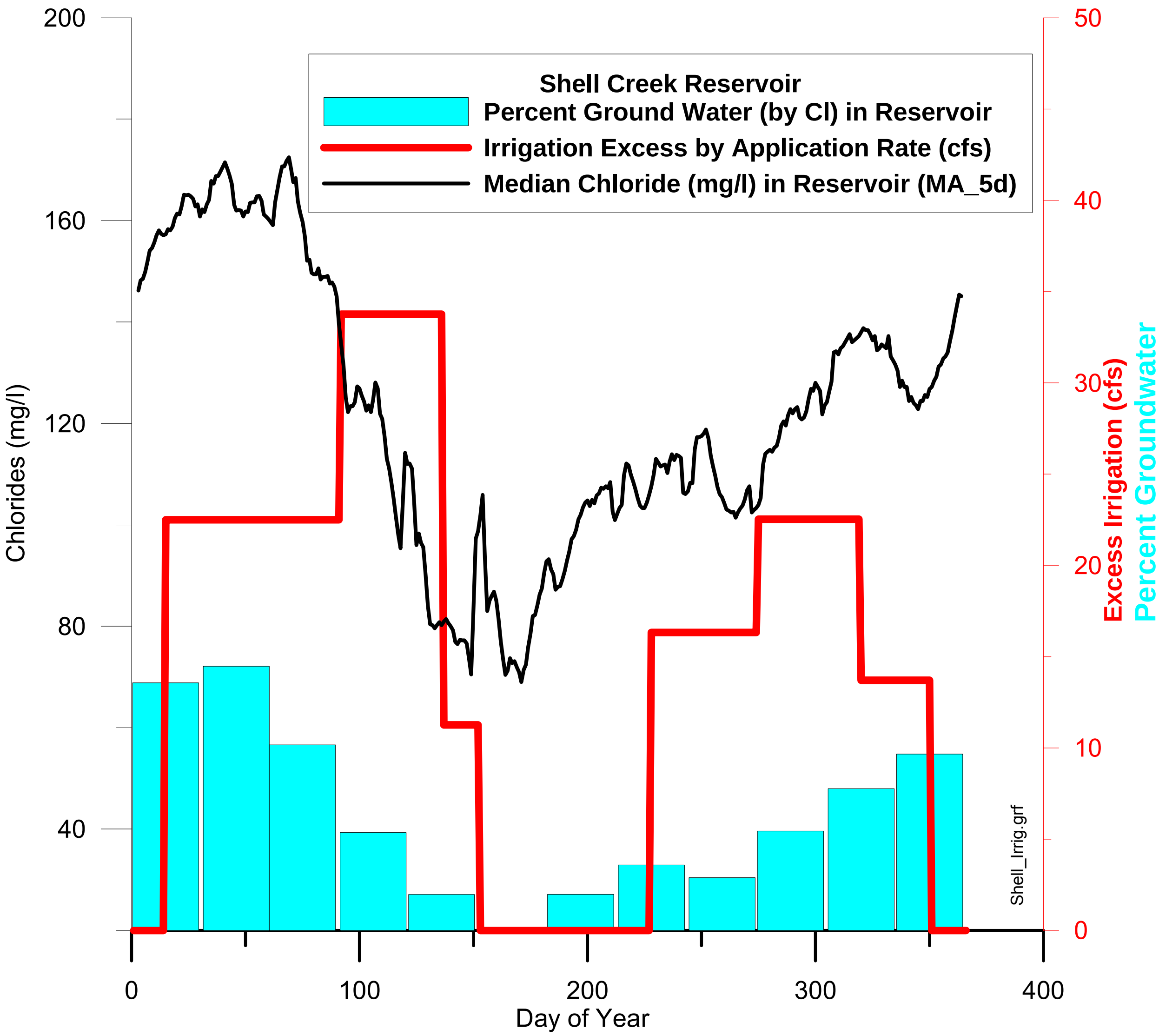


Figure 7-7. **Observed chloride levels (black trace), estimated groundwater fraction (blue bar chart) and estimated excess irrigation (red trace) in Shell Creek Reservoir.**

.

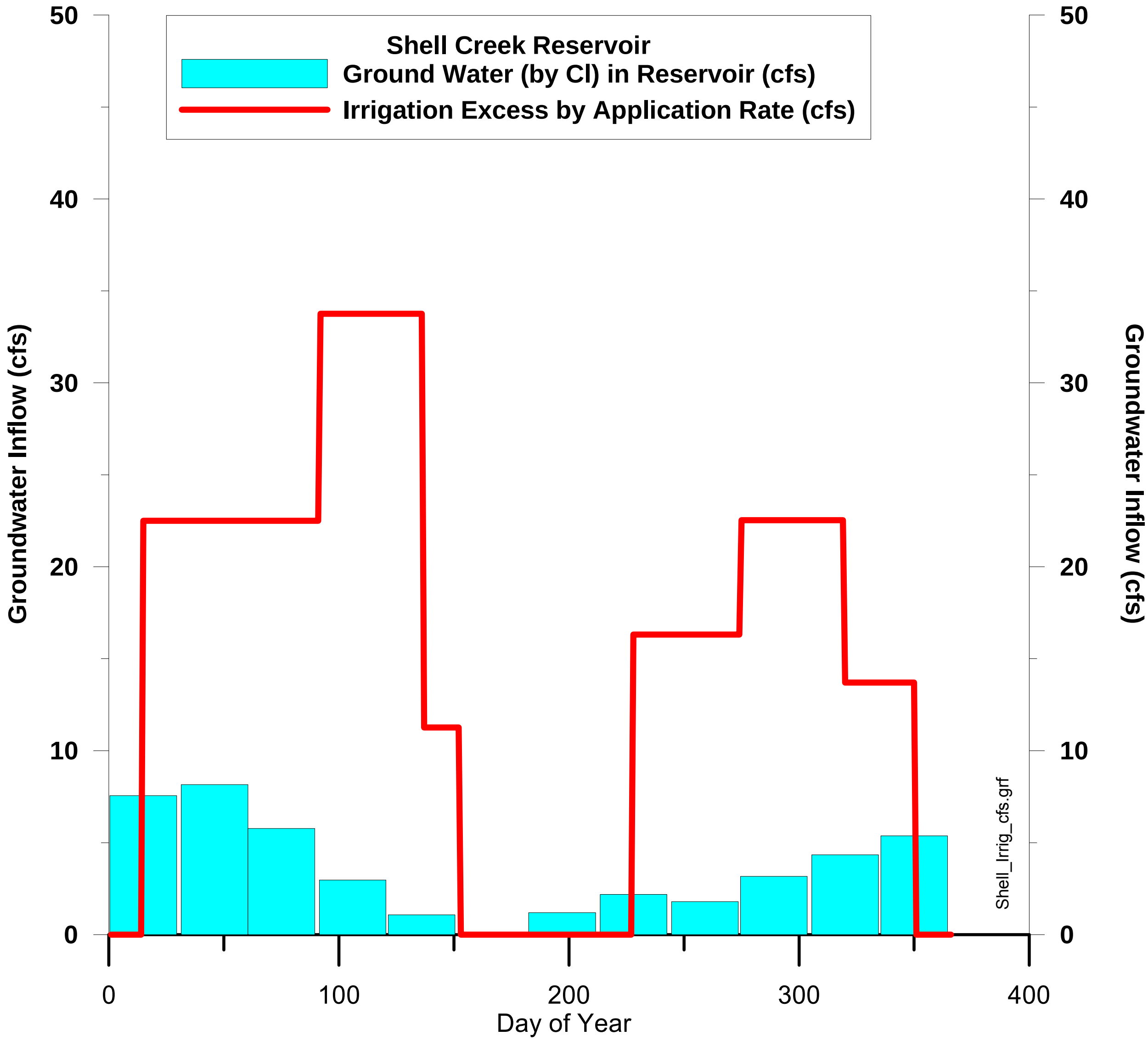


Figure 7-8. Estimates of Excess Irrigation Flows (cfs) to Shell Creek Reservoir

7.3.7 Results of the Quantification of Habitat Availability as a Function on Inflow in Shell Creek

Habitat availability is quantified in terms of space and time. Since the three habitat metrics (i.e., volume, bottom area, and shoreline length) are highly correlated in the portion of SC that was modeled, only one metric, volume, has been used in the following analyses. This physical domain of the regression model applies to the main stem of Shell Creek as shown in Figure 7-2.

7.3.8 Shell Creek – Alternative Determinations of 15% Habitat Loss

Loss of habitat in Shell Creek was determined using the empirical model described in section 7.2.1. Empirical models are generally solved at a daily time step and thus have an advantage over hydrodynamic models in terms of speed of execution, making multi-decadal simulations possible. But this speed comes at the expense of failing to incorporate prior conditions as efficiently as a hydrodynamic model. In essence, an empirical model has no memory, and each day is calculated independent of the prior day. While some lag effects can be incorporated, the result is the 'average' response over the flow domain of the empirical model.

Stepped flow reductions and NAUC post-processing analogous to those presented in the peer review draft and used with hydrodynamic models may also be applied to the empirical model results as well and were used to develop the results in the peer review draft of the SC MFL. Ninety-nine flow reduction scenarios were executed representing one percent steps from one to ninety-nine. Table 7-7 illustrates a sub-set of the results for the daily volume of water with a salinity of 2 ppt or less.

The first approach considered was to tabulate the daily flow reduction that results in a 15% loss over baseline volume as shown in column C of Table 7-7. One drawback to this approach is that it is based on daily percentages disregarding the magnitude of the lost habitat. Thus, a 22% loss of baseline volume might represent only a few cubic meters, or thousands of cubic meters depending upon the baseline volume.

The second approach evaluated was based on the sum of the habitat for each annual block using the period 1966 - 2004. For example, the daily volume of water < 2 ppt salinity was summed for April 21 – June 26 1966 for the baseline scenario and each of the 98 flow reduction scenarios. An annual seasonal habitat loss was calculated by dividing the sum of each flow reduction volume by the sum of the baseline volume. Table 7-8 provides representative results for Block 1 and several flow reduction scenarios. Table 7-9 illustrates the last step of the second approach. The average and median of the 39 annual block results was taken, and the flow reduction resulting in retention of 85% of the annual baseline volumes was determined. The mean values were found to be more protective (Figure 7-5). It is recognized that the approach remains based on percentages, but using the sum of seasonal volumes instead of daily values tends to down-weight the impact of high percentage reductions of very small baseline volumes.

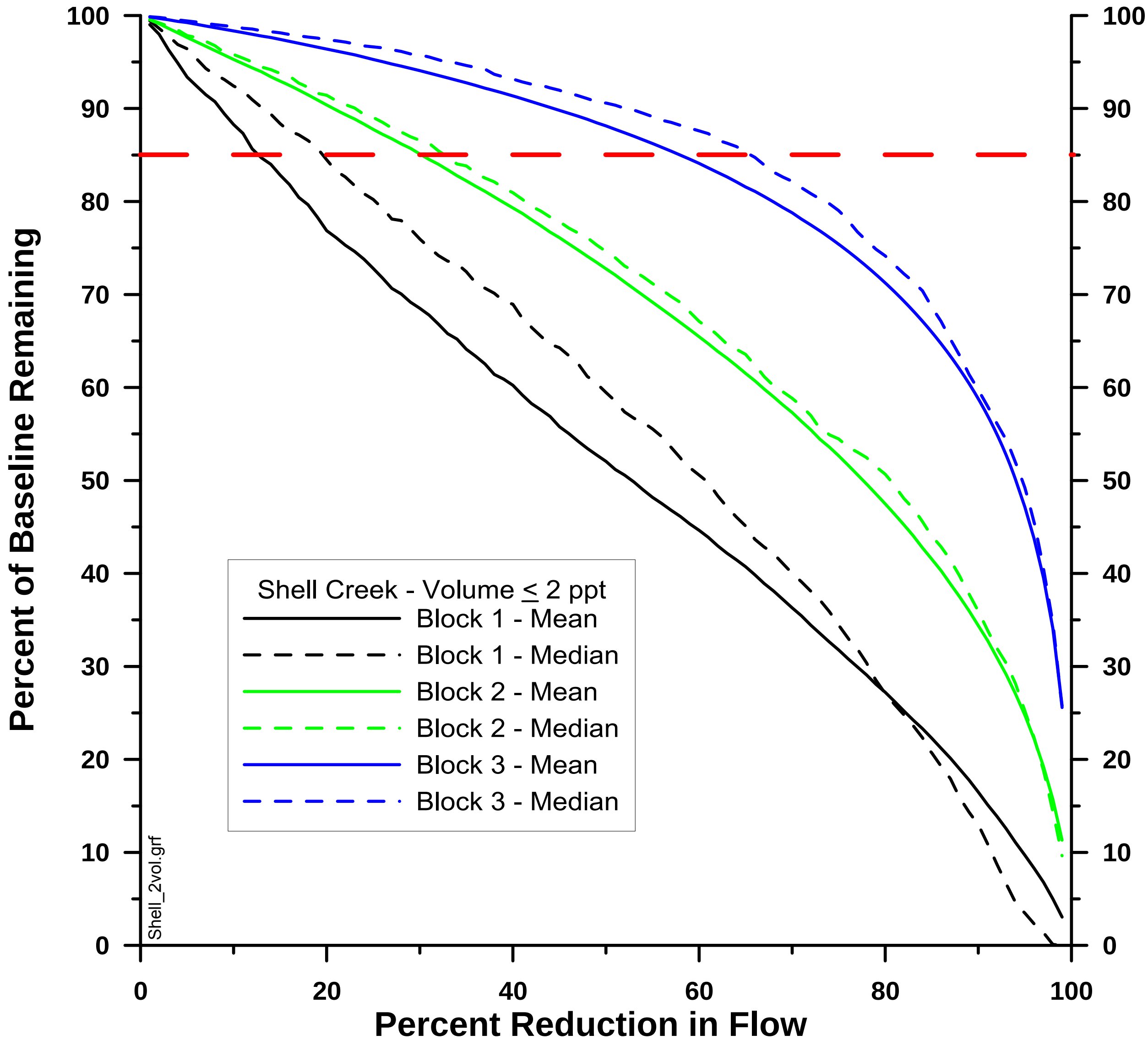


Figure 7-9. Seasonal flow reductions resulting in 15% loss of < 2ppt volume in Shell Creek for 1966-2004.

Evaluating the Shell Creek flow record from 1966 through 2004 in this manner results in the following seasonal reductions from naturalized baseline flows. These values result in a 15% loss of the volume < two ppt in SC.

Block 1	Apr 20 – Jun 25	13%
Block 3	Jun 26 – Oct 26	58%
Block 2	Oct 27 – Apr 19	30%

Table 7-7 Example Block 1 daily output. Volume (m^3) ≤ 2 ppt. Flow reduction from 1% to 20% shown.(Note – Column C is interpolated percent flow reduction resulting in 15% loss of baseline volume.)

				< === Flow Reductions From 1% to 99% ===>																			
Date	Year	Flow reduction equal to 15% loss	Baseline	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%	16%	17%	18%	19%	20%
4/20/1970	1970	4	412	412	412	412	320	320	320	320	320	320	320	320	320	320	238	238	238	238	238	238	238
4/21/1970	1970	4	25	25	25	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/22/1970	1970	.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/23/1970	1970	4	139	139	139	139	80	80	80	80	80	80	25	25	25	25	0	0	0	0	0	0	0
4/24/1970	1970	3	80	80	80	25	25	25	25	25	0	0	0	0	0	0	0	0	0	0	0	0	0
4/25/1970	1970	2	25	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/26/1970	1970	6	238	238	238	238	238	238	189	189	189	189	189	189	189	189	189	139	139	139	139	139	139
4/27/1970	1970	6	412	412	412	412	412	412	320	320	320	320	320	320	320	320	320	238	238	238	238	238	238
4/28/1970	1970	14	478	478	478	478	412	412	412	412	412	412	412	412	412	412	320	320	320	320	320	320	320
4/29/1970	1970	11	478	412	412	412	412	412	412	412	412	412	412	320	320	320	320	320	320	320	320	238	238
4/30/1970	1970	7	189	189	189	189	189	189	189	139	139	139	139	139	139	139	80	80	80	80	80	25	25
5/1/1970	1970	22	595	595	595	595	595	595	595	595	595	595	595	540	540	540	540	540	540	540	540	540	540
5/2/1970	1970	13	645	645	595	595	595	595	595	595	595	595	595	595	595	540	540	540	540	540	540	540	540
5/3/1970	1970	12	645	645	595	595	595	595	595	595	595	595	595	595	540	540	540	540	540	540	540	540	540
5/4/1970	1970	13	716	716	716	716	645	645	645	645	645	645	645	645	645	595	595	595	595	595	595	595	595
5/5/1970	1970	17	716	716	716	716	716	716	716	716	645	645	645	645	645	645	645	645	645	595	595	595	595
5/6/1970	1970	17	716	716	716	716	716	716	716	645	645	645	645	645	645	645	645	645	645	595	595	595	595
5/7/1970	1970	13	716	716	716	645	645	645	645	645	645	645	645	645	645	595	595	595	595	595	595	595	595
5/8/1970	1970	11	716	716	645	645	645	645	645	645	645	645	645	595	595	595	595	595	595	595	595	595	540
5/9/1970	1970	15	716	716	716	716	716	716	645	645	645	645	645	645	645	645	645	595	595	595	595	595	595
5/10/1970	1970	13	716	716	716	645	645	645	645	645	645	645	645	645	645	595	595	595	595	595	595	595	595
5/11/1970	1970	11	716	645	645	645	645	645	645	645	645	645	645	595	595	595	595	595	595	595	595	595	540
5/12/1970	1970	12	716	716	716	645	645	645	645	645	645	645	645	645	595	595	595	595	595	595	595	595	595
5/13/1970	1970	11	645	595	595	595	595	595	595	595	595	595	595	540	540	540	540	540	540	540	540	540	478
5/14/1970	1970	19	595	595	595	595	595	595	595	595	595	595	540	540	540	540	540	540	540	540	540	478	478
5/15/1970	1970	18	540	540	540	540	540	540	540	540	540	478	478	478	478	478	478	478	478	478	412	412	412
5/16/1970	1970	11	540	478	478	478	478	478	478	478	478	478	478	412	412	412	412	412	412	412	412	412	320
5/17/1970	1970	8	412	412	412	412	412	412	412	412	320	320	320	320	320	320	320	320	238	238	238	238	238
5/18/1970	1970	15	595	595	595	595	540	540	540	540	540	540	540	540	540	540	540	478	478	478	478	478	478
5/19/1970	1970	16	478	478	478	478	478	478	412	412	412	412	412	412	412	412	412	412	320	320	320	320	320
5/20/1970	1970	10	478	412	412	412	412	412	412	412	412	412	320	320	320	320	320	320	320	320	238	238	238
5/21/1970	1970	4	412	412	412	412	320	320	320	320	320	320	320	320	238	238	238	238	238	238	238	238	189
5/22/1970	1970	2	320	320	238	238	238	238	238	238	238	238	189	189	189	189	189	189	189	189	139	139	139
5/23/1970	1970	13	478	478	478	478	412	412	412	412	412	412	412	412	412	320	320	320	320	320	320	320	320
5/24/1970	1970	23	987	987	987	987	952	952	952	952	952	952	919	919	919	919	919	919	919	888	888	888	888
5/25/1970	1970	30	1071	1029	1029	1029	1029	1029	1029	1029	1029	987	987	987	987	987	987	987	952	952	952	952	952
5/26/1970	1970	37	952	952	952	952	952	952	952	919	919	919	919	919	919	919	919	919	919	888	888	888	888
5/27/1970	1970	39	1071	1071	1071	1071	1071	1029	1029	1029	1029	1029	1029	1029	1029	1029	987	987	987	987	987	987	987

Table 7-8 Sum of Block 1 volume (m^3) ≤ 2 ppt. Flow reductions from 1% to 20% shown.

Year	Baseline	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%	16%	17%	18%	19%	20%
1966	33,083	32,896	32,896	32,825	32,652	32,600	32,517	32,436	32,436	32,364	32,162	32,162	32,113	31,971	31,826	31,755	31,706	31,621	31,566	31,435	31,281
1967	9,181	9,018	9,018	9,018	9,018	8,895	8,658	8,605	8,605	8,605	8,438	8,438	8,206	8,206	8,206	8,029	7,959	7,887	7,732	7,732	7,650
1968	39,059	39,010	38,976	38,893	38,893	38,822	38,822	38,822	38,717	38,717	38,684	38,631	38,581	38,548	38,495	38,495	38,495	38,462	38,431	38,360	38,306
1969	50,061	49,873	49,544	49,189	48,953	48,634	48,260	48,178	47,797	47,749	47,534	46,996	46,746	46,535	46,178	46,033	45,708	45,485	45,158	44,618	44,353
1970	57,729	57,251	56,871	56,320	55,616	55,402	54,940	54,683	54,323	54,011	53,558	53,140	52,730	52,135	51,657	51,305	50,926	50,540	50,096	49,727	49,221
1971	1,415	1,324	1,269	1,269	1,244	1,194	1,139	1,057	1,057	938	938	858	858	747	747	692	692	692	692	617	551
1972	21,735	21,527	21,383	21,383	21,281	21,281	21,229	21,146	21,015	20,934	20,934	20,494	20,423	20,328	20,257	20,257	19,964	19,909	19,734	19,626	19,419
1973	426	426	426	371	263	263	263	263	263	238	238	238	238	238	238	238	189	189	189	189	189
1974	7,396	7,280	7,124	6,986	6,986	6,937	6,857	6,619	6,503	6,503	6,257	6,127	5,981	5,889	5,663	5,581	5,531	5,531	5,181	5,132	5,077
1975	8,682	8,682	8,634	8,466	8,375	8,195	8,195	8,062	7,948	7,894	7,753	7,753	7,559	7,509	7,427	7,262	7,262	7,262	7,108	7,059	7,059
1976	43,596	43,395	43,069	42,688	42,324	42,111	41,900	41,646	41,370	41,263	40,667	40,511	40,194	39,983	39,621	39,408	38,961	38,737	38,336	38,160	37,978
1977	759	700	649	540	540	540	540	540	540	478	478	478	478	478	478	412	412	412	412	412	320
1978	42,100	41,758	41,389	41,035	40,663	40,387	40,039	39,532	39,273	39,088	38,672	38,330	38,071	37,912	37,703	37,075	36,733	36,504	36,200	35,708	35,637
1979	31,654	31,469	31,323	31,323	31,102	31,012	30,798	30,350	30,168	29,968	29,848	29,626	29,241	29,063	29,063	28,723	28,672	28,672	28,486	28,437	28,037
1980	18,170	18,067	17,808	17,742	17,647	17,543	17,543	17,439	17,283	17,074	16,773	16,566	16,514	16,388	16,189	16,098	15,943	15,943	15,802	15,617	15,365
1981	189	189	189	189	189	139	139	139	139	139	139	139	80	80	80	80	80	25	25	-	-
1982	57,800	57,581	57,510	57,444	57,348	57,110	57,060	56,884	56,770	56,624	56,456	56,331	56,281	56,195	55,862	55,718	55,608	55,608	55,256	55,097	54,987
1983	22,035	21,859	21,747	21,574	21,134	20,899	20,673	20,623	20,502	20,454	20,388	20,283	20,089	19,626	19,388	19,090	18,916	18,714	18,516	18,268	18,164
1984	19,513	19,259	19,147	18,928	18,784	18,516	18,230	17,837	17,751	17,558	17,281	16,933	16,670	16,419	16,035	16,002	15,769	15,550	15,292	15,081	14,717
1985	1,926	1,926	1,840	1,749	1,749	1,749	1,686	1,638	1,638	1,555	1,489	1,437	1,437	1,346	1,346	1,297	1,143	1,143	1,143	1,069	948
1986	12,738	12,662	12,662	12,662	12,613	12,537	12,537	12,537	12,488	12,422	12,337	12,287	12,232	12,232	12,079	12,079	12,079	11,983	11,900	11,818	11,818
1987	18,898	18,855	18,615	18,539	18,448	18,365	18,294	18,015	17,949	17,718	17,685	17,549	17,408	17,309	17,189	17,072	17,014	16,965	16,922	16,881	16,667
1988	5,215	5,133	5,042	4,866	4,693	4,531	4,428	4,320	4,154	4,154	4,029	3,979	3,864	3,864	3,814	3,661	3,561	3,506	3,399	3,339	3,163
1989	1,823	1,773	1,773	1,690	1,619	1,564	1,445	1,420	1,371	1,268	1,078	1,078	1,053	1,003	1,003	949	949	834	834	705	642
1990	11,627	11,627	11,355	11,323	11,192	10,798	10,646	10,521	10,471	10,313	9,996	9,825	9,578	9,392	9,321	9,114	9,023	8,920	8,786	8,616	8,476
1991	86,205	85,895	85,340	85,195	84,754	84,567	84,078	83,705	83,460	83,123	82,254	81,979	81,686	81,567	80,966	80,537	80,204	79,974	79,388	79,097	78,803
1992	18,074	17,921	17,850	17,850	17,661	17,506	17,408	17,002	16,900	16,760	16,760	16,582	16,448	16,265	16,155	15,947	15,796	15,726	15,606	15,475	15,114
1993	24,488	24,314	24,194	24,112	24,027	23,932	23,823	23,620	23,424	23,208	23,128	22,905	22,648	22,473	22,260	22,018	22,018	21,869	21,869	21,784	21,565
1994	30,423	30,211	29,884	29,522	29,402	29,331	29,127	28,760	28,462	28,188	28,088	28,047	27,823	27,549	27,229	26,920	26,920	26,822	26,638	26,502	26,227
1995	36,140	35,959	35,548	35,062	34,737	34,566	34,241	33,965	33,556	33,370	33,210	32,800	32,542	32,041	31,779	31,613	31,317	31,065	30,699	30,421	30,287
1996	28,132	28,058	27,920	27,728	27,417	27,358	27,227	27,175	26,715	26,353	26,026	25,919	25,745	25,566	25,363	25,207	25,073	24,936	24,755	24,476	24,264
1997	37,108	36,784	36,488	36,116	35,675	35,226	34,818	34,620	34,273	33,887	33,571	33,114	32,686	32,433	31,935	31,514	31,201	30,712	30,576	30,312	30,231
1998	13,911	13,911	13,707	13,531	13,355	13,218	13,136	13,076	12,957	12,824	12,719	12,329	12,278	12,163	12,101	12,046	11,930	11,875	11,615	11,443	11,264
1999	15,391	15,332	15,232	15,207	15,207	15,152	14,995	14,995	14,827	14,827	14,682	14,627	14,502	14,447	14,220	14,140	14,115	14,115	14,030	13,959	13,959
2000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2001	4,110	4,057	4,057	3,867	3,867	3,867	3,818	3,818	3,748	3,748	3,654	3,571	3,480	3,428	3,428	3,356	3,356	3,259	3,193	3,193	3,040
2002	23,090	23,090	22,860	22,647	22,503	22,340	22,290	22,113	21,836	21,562	21,562	21,475	21,191	21,066	20,974	20,778	20,595	20,293	20,162	20,112	20,028
2003	48,889	48,638	48,486	48,402	48,252	48,095	47,935	47,619	47,355	47,355	47,147	47,007	46,672	46,421	46,083	46,029	45,880	45,733	45,511	45,098	44,805
2004	18,851	18,737	18,524	18,336	18,227	18,178	18,005	17,838	17,787	17,645	17,543	17,321	17,051	16,998	16,795	16,795	16,560	16,464	16,354	16,183	15,913

Table 7-9 Annual Block 1 volumes ≤ 2ppt, expressed as percentage of baseline. Note – A 13% flow reduction results in an average retention of 85% of baseline volume over the period of record.

		1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%	16%	17%	18%	19%	20%
1966	100%	99%	99%	99%	99%	99%	98%	98%	98%	98%	97%	97%	97%	97%	96%	96%	96%	96%	95%	95%	95%
1967	100%	98%	98%	98%	98%	97%	94%	94%	94%	94%	92%	92%	89%	89%	89%	87%	87%	86%	84%	84%	83%
1968	100%	100%	100%	100%	100%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	98%	98%	98%	98%
1969	100%	100%	99%	98%	98%	97%	96%	96%	95%	95%	95%	94%	93%	93%	92%	92%	91%	91%	90%	89%	89%
1970	100%	99%	99%	98%	96%	96%	95%	95%	94%	94%	93%	92%	91%	90%	89%	89%	88%	88%	87%	86%	85%
1971	100%	94%	90%	90%	88%	84%	81%	75%	75%	66%	66%	61%	61%	53%	53%	49%	49%	49%	49%	44%	39%
1972	100%	99%	98%	98%	98%	98%	98%	97%	97%	96%	96%	94%	94%	94%	93%	93%	92%	92%	91%	90%	89%
1973	100%	100%	100%	87%	62%	62%	62%	62%	62%	56%	56%	56%	56%	56%	56%	56%	44%	44%	44%	44%	44%
1974	100%	98%	96%	94%	94%	94%	93%	89%	88%	88%	85%	83%	81%	80%	77%	75%	75%	75%	70%	69%	69%
1975	100%	100%	99%	98%	96%	94%	94%	93%	92%	91%	89%	89%	87%	86%	86%	84%	84%	84%	82%	81%	81%
1976	100%	100%	99%	98%	97%	97%	96%	96%	95%	95%	93%	93%	92%	92%	91%	90%	89%	89%	88%	88%	87%
1977	100%	92%	86%	71%	71%	71%	71%	71%	71%	63%	63%	63%	63%	63%	63%	54%	54%	54%	54%	54%	42%
1978	100%	99%	98%	97%	97%	96%	95%	94%	93%	93%	92%	91%	90%	90%	90%	88%	87%	87%	86%	85%	85%
1979	100%	99%	99%	99%	98%	98%	97%	96%	95%	95%	94%	94%	92%	92%	92%	91%	91%	91%	90%	90%	89%
1980	100%	99%	98%	98%	97%	97%	97%	96%	95%	94%	92%	91%	91%	90%	89%	89%	88%	88%	87%	86%	85%
1981	100%	100%	100%	100%	100%	74%	74%	74%	74%	74%	74%	74%	42%	42%	42%	42%	42%	13%	13%	0%	0%
1982	100%	100%	99%	99%	99%	99%	99%	98%	98%	98%	98%	97%	97%	97%	97%	96%	96%	96%	96%	95%	95%
1983	100%	99%	99%	98%	96%	95%	94%	94%	93%	93%	93%	92%	91%	89%	88%	87%	86%	85%	84%	83%	82%
1984	100%	99%	98%	97%	96%	95%	93%	91%	91%	90%	89%	87%	85%	84%	82%	82%	81%	80%	78%	77%	75%
1985	100%	100%	96%	91%	91%	91%	88%	85%	85%	81%	77%	75%	75%	70%	70%	67%	59%	59%	59%	56%	49%
1986	100%	99%	99%	99%	99%	98%	98%	98%	98%	98%	97%	96%	96%	96%	95%	95%	95%	94%	93%	93%	93%
1987	100%	100%	99%	98%	98%	97%	97%	95%	95%	94%	94%	93%	92%	92%	91%	90%	90%	90%	90%	89%	88%
1988	100%	98%	97%	93%	90%	87%	85%	83%	80%	80%	77%	76%	74%	74%	73%	70%	68%	67%	65%	64%	61%
1989	100%	97%	97%	93%	89%	86%	79%	78%	75%	70%	59%	59%	58%	55%	55%	52%	52%	46%	46%	39%	35%
1990	100%	100%	98%	97%	96%	93%	92%	90%	90%	89%	86%	85%	82%	81%	80%	78%	78%	77%	76%	74%	73%
1991	100%	100%	99%	99%	98%	98%	98%	97%	97%	96%	95%	95%	95%	95%	94%	93%	93%	93%	92%	92%	91%
1992	100%	99%	99%	99%	98%	97%	96%	94%	94%	93%	93%	92%	91%	90%	89%	88%	87%	87%	86%	86%	84%
1993	100%	99%	99%	98%	98%	98%	97%	96%	96%	95%	94%	94%	92%	92%	91%	90%	90%	89%	89%	89%	88%
1994	100%	99%	98%	97%	97%	96%	96%	95%	94%	93%	92%	92%	91%	91%	90%	88%	88%	88%	88%	87%	86%
1995	100%	99%	98%	97%	96%	96%	95%	94%	93%	92%	92%	91%	90%	89%	88%	87%	87%	86%	85%	84%	84%
1996	100%	100%	99%	99%	97%	97%	97%	97%	95%	94%	93%	92%	92%	91%	90%	90%	89%	89%	88%	87%	86%
1997	100%	99%	98%	97%	96%	95%	94%	93%	92%	91%	90%	89%	88%	87%	86%	85%	84%	83%	82%	82%	81%
1998	100%	100%	99%	97%	96%	95%	94%	94%	93%	92%	91%	89%	88%	87%	87%	87%	86%	85%	83%	82%	81%
1999	100%	100%	99%	99%	99%	98%	97%	97%	96%	96%	95%	95%	94%	94%	92%	92%	92%	92%	91%	91%	91%
2000																					
2001	100%	99%	99%	94%	94%	94%	93%	93%	91%	91%	89%	87%	85%	83%	83%	82%	82%	79%	78%	78%	74%
2002	100%	100%	99%	98%	97%	97%	97%	96%	95%	93%	93%	93%	92%	91%	91%	90%	89%	88%	87%	87%	87%
2003	100%	99%	99%	99%	99%	98%	98%	97%	97%	97%	96%	96%	95%	95%	94%	94%	94%	94%	93%	92%	92%
2004	100%	99%	98%	97%	97%	96%	96%	95%	94%	94%	93%	92%	90%	90%	89%	89%	88%	87%	87%	86%	84%
Average 1966 - 04	100%	99%	98%	96%	95%	93%	92%	91%	91%	89%	88%	87%	86%	85%	84%	83%	82%	80%	80%	78%	77%

7.4 Application of Modeling Tools that Relate Freshwater Inflows to Salinity in the Lower Peace River

In this subsection, the following objectives will be met for LPR:

- Description of analytical tools used to quantify habitat,
- Definition of the study area,
- Definition of the reference period for minimum flow evaluation,
- Definition of the modeling period for minimum flow evaluation,
- Definition of the Baseline Scenario,
- Definition of alternative modeling scenarios, and
- Review of the results provided by the analytical tools.
-

7.4.1 Analytical Tool That Relate Flow to Salinity in the Lower Peace River

A hydrodynamic model has been developed by District staff that estimates the response in the LPR to variations in freshwater inflows (Chen 2004). A description of the model as well as the calibration of the model is provided in Appendix 1. The domain of the hydrodynamic model includes the northern portion of Charlotte Harbor, the Myakka River, the tidally influenced portion of SC, and the LPR (downstream of Arcadia). The hydrodynamic model cells used for minimum flow development for the LPR are illustrated in Figure 7-6.

7.4.2 Lower Peace River Study Area

The physical domain of the LPR model is presented in Figure 7-7. The study area extends from the mouth of the river to just upstream of the confluence of Horse Creek.

7.4.3 Lower Peace River Baseline Period

The reference period is defined as the period from 1985 through 2004. This period represents a wide range of hydrologic conditions including a significant wet period and a significant dry period due to the Atlantic Multidecadal Oscillation (Kelly 2004).

7.4.4 Lower Peace River Modeling Period

Establishment of an MFL for the Lower Peace River requires the hydrodynamic model to provide predicted salinities for a Baseline Scenario and a series of flow scenarios with different percent flow reductions. The hydrodynamic model requires a significant amount of computer time to simulate changes in water levels and salinities in the LPR. As such, it is impractical to simulate the entire 20-year reference period for the series of modeling scenarios that is necessary to support development of an MFL for the LPR. Because of this impracticality, it was necessary to identify a shorter surrogate time period on the order of 3-5 years that reflects a similar range of hydrologic conditions to that observed over the entire 20-year reference period.

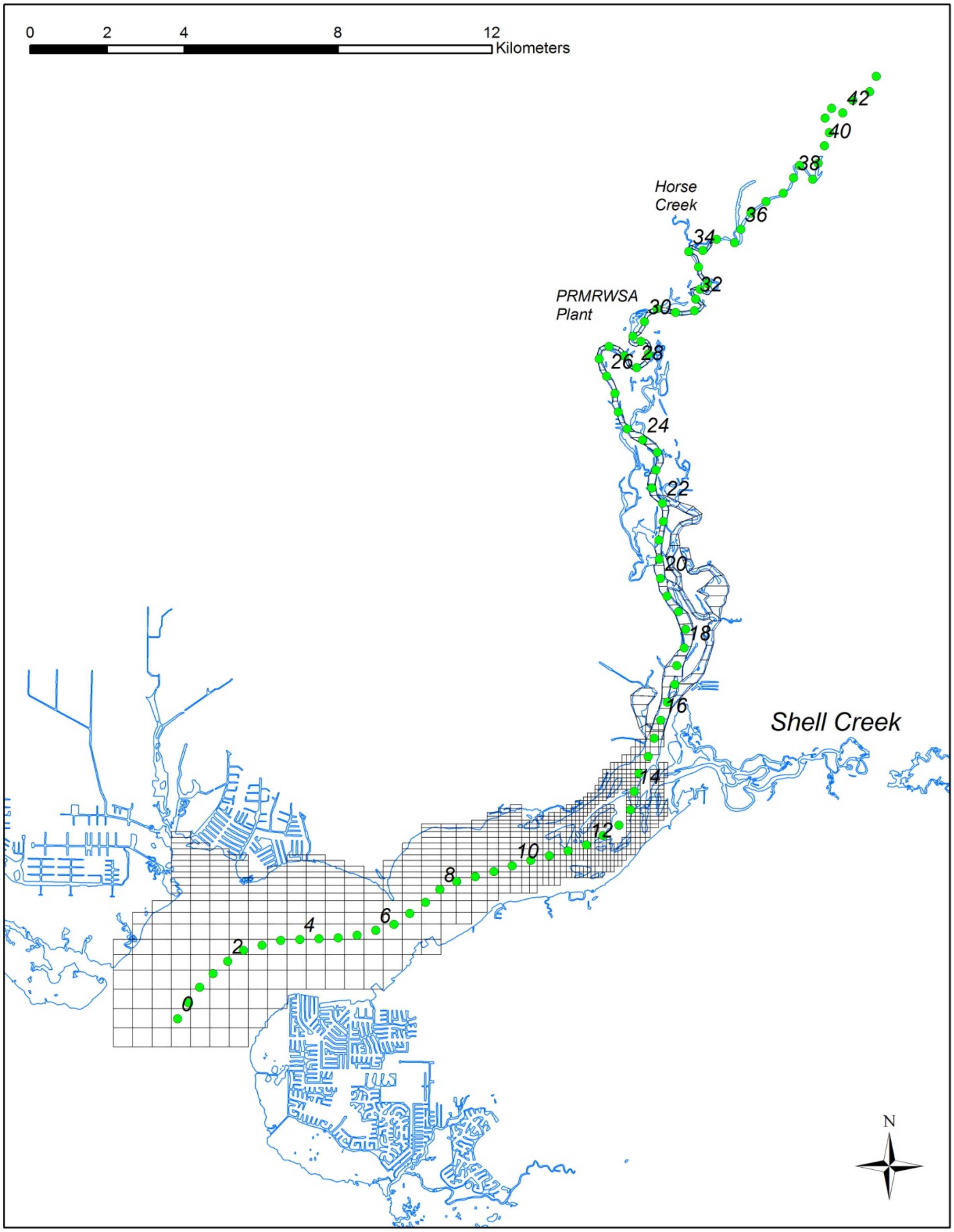


Figure 7-10. Lower Peace River hydrodynamic model cells used for minimum flow development. The river centerline with river kilometer is also presented.

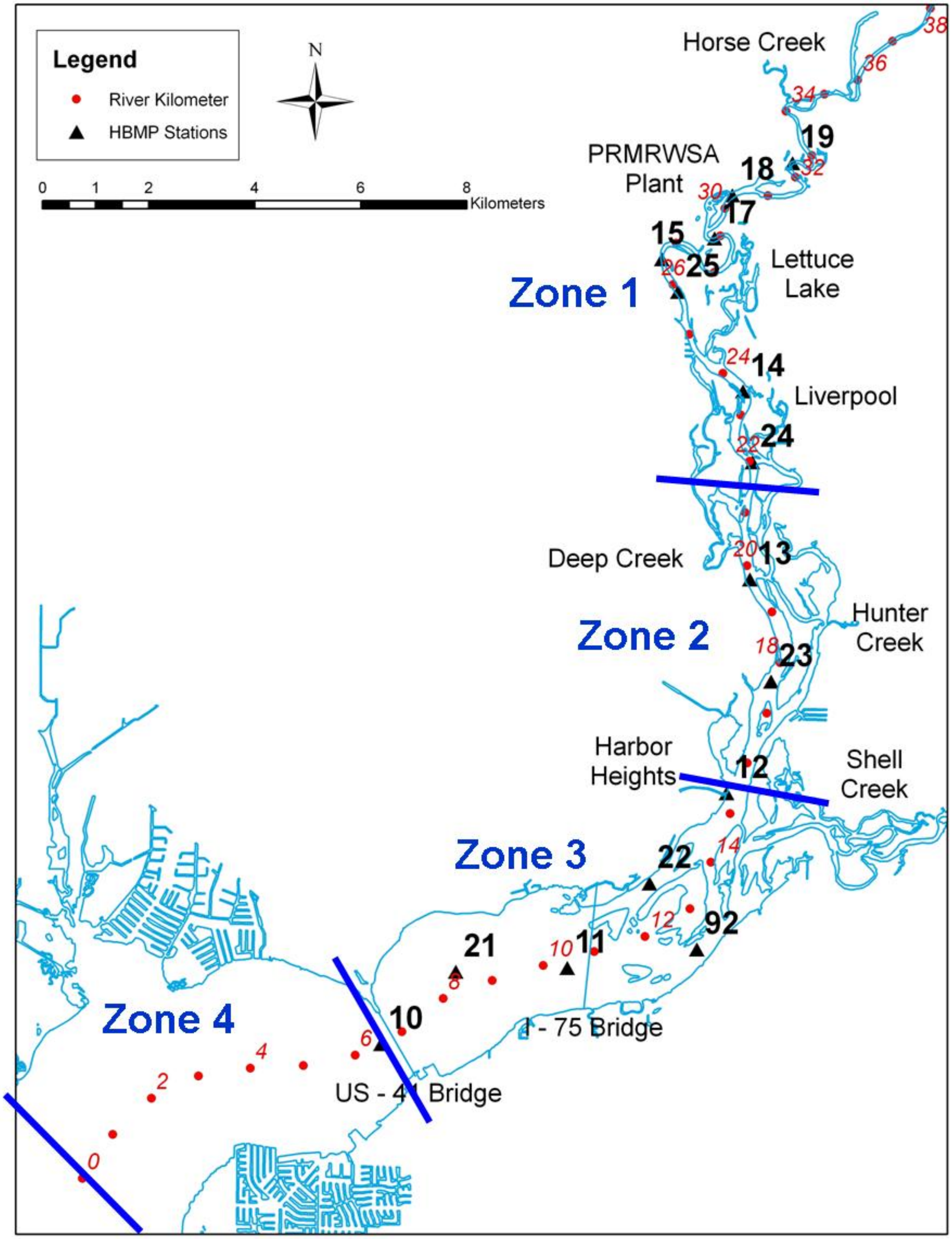


Figure 7-11. **Map of the Lower Peace River study area including salinity zones (in blue) as defined by Mote (2002), PRMRWSA HBMP fixed station sampling sites (black triangles), and the centerline of the river with river kilometers (in red).**

A number of candidate modeling periods were examined. This was accomplished by defining the flow duration curve for the reference period (1985 to 2004) and comparing the flow duration curves for each candidate modeling period. It was found that a minimum 4-year period is necessary to attain reasonable concordance to the 20-year flow duration curve. Evaluating daily discharge without regard to seasonal Blocks, the flow duration curve for the 1996-1999 period most closely resembled the 1985 to 2004 flow duration curve (Figure 7-8). In the initial evaluation reported in the peer review draft, 1996 to 1999 was selected as the period to be used for modeling of the Lower Peace River.

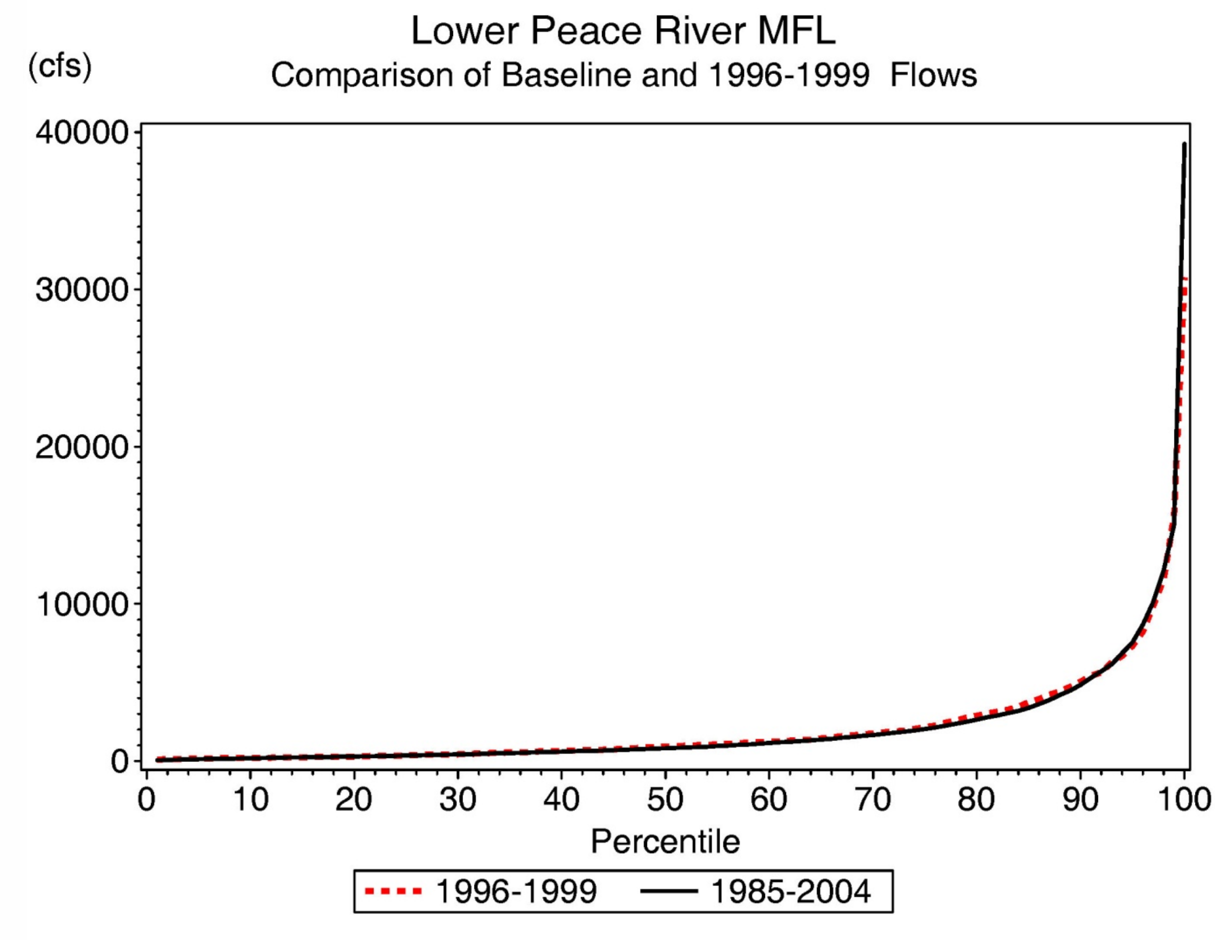


Figure 7-12. Comparison of flow CDF for the Baseline Period (1985-2004) and the Modeling Period (1996-1999).

However, the intial selection was based on CDF plots of daily flow values without regard to seasonal Blocks. Later examination of flow duration characteristics by seasonal blocks revealed major deviations in Block 2 during the winter of 1997 through the spring of 1998 due to unusually high flows that occurring as a result of the 1997-1998 El Nino. Examination of flow duration characteristics by blocks found that a four-year window from 1999-2002 provided a more representative period to serve as the period for hydrodynamic salinity modeling of the Lower Peace River.

7.4.5 Definition of Baseline and Model Scenarios for Lower Peace River

As defined above, the LPR flow is the sum of the gauged flows at:

- Peace River at Arcadia (USGS gauge 02296750),
- Horse Creek near Arcadia (USGS gauge 02297310), and
- Joshua Creek at Nocatee (USGS gauge 02297100).

The Baseline Scenario flows for 1999-2002 were defined as the sum of the LPR gauged flows. The withdrawals at the PRMRWSA were not simulated, representing a naturalized flow. In order to be conservative, the SC flows used for the LPR Baseline Scenario consisted of the SC flows minus the maximum daily allowable withdrawals under the proposed SC MFL.

The scenarios that were run to support development of the MFL for the LPR included the following:

- Baseline Scenario,
- 10% Reduction Scenario,
- 20% Reduction Scenario,
- 30% Reduction Scenario, and
- 40% Reduction Scenario.

7.5 Simultaneous Evaluation of Lower Peace River and Shell Creek MFLs

In the peer review draft report (SWFWMD 2007c.), the District evaluated the SC and LPR MFLs sequentially, setting the SC MFL first. Following this, the SC baseline flow record was reduced by the maximum withdrawals allowable under the proposed SC MFL, and this reduced flow record was applied to the LPR modeling effort along with naturalized (PRMRWSA withdrawals added back to gauge records) baseline flow in the Peace River (sum of Peace River at Arcadia, Horse Creek near Arcadia and Joshua Creek at Nocatee). With these flows as inputs, the hydrodynamic model was used to determine the seasonal flow reductions resulting in a 15% loss of habitat (volume, area or shoreline).

One complication of sequentially establishing the respective MFLs is that the simulated withdrawals established for the second MFL change the salinity boundary conditions that were used to determine the MFL for SC. For example, assume that the salinity at the confluence of SC and the Peace River was initially 10 ppt when the SC MFL was determined. After the Peace River MFL is established, the salinity at the confluence might increase to 12 ppt. If the SC were to be established under conditions that are more saline, then the volume < 2 ppt in SC is reduced and the subsequent reduction in flows resulting in 15% loss will be different from those obtained with 10 ppt salinity boundary.

In order to overcome this issue, the District chose to combine the Peace baseline habitat with the SC baseline habitat in a system-wide reduction in baseline flows. For example, a 10% flow reduction scenario consisted of reducing the Peace baseline flows by 10% and the SC baseline flows by 10% simultaneously. While this approach resolves one issue, it is not without limitations. First, the extent of baseline habitat in LPR is significantly larger than in the SC, resulting in a disproportionate emphasis on the LPR. Secondly, because of the time constraints imposed by numeric models, the initial simulation periods differed and a standardized evaluation period is needed. The period 1999 – 2002 was chosen to conform to the hydrodynamic modeling period. Unfortunately, during the drought of 2000, there was no habitat less than 2 ppt in the SC. Thus, in the final analysis, only the years 1999 and 2001-2002 were used to establish the combined MFL. Prior analyses indicated that the most sensitive habitat metric is the volume less than two ppt. Consequently, in the final analysis, the recommended MFL is based on volume of water less than two ppt. Additional details and comparisons are given in Sections 8.2 and 8.3.

8 DISTRICT RECOMMENDATION FOR SHELL CREEK AND LOWER PEACE RIVER MINIMUM FLOWS

The objectives of this section are:

1. to define the minimum flow criterion to be used in estimating the minimum flows for LPR and SC,
2. to define the method to be used to establish the minimum flows for LPR and SC,
3. to apply the method to results of the analytical tools that relate flow to salinity in LPR and SC,
4. to recommend minimum flows for LPR and SC, and
5. to describe the influence of the proposed minimum flows on other water quality constituents and ecological components in LPR and SC.

8.1 Minimum Flow Criterion

Section 373.042, F. S. defines the minimum flow for a surface watercourse as “the limit at which further withdrawals would be significantly harmful to water resources or ecology of the area”. “Significant” harm has been operationally defined as a 15% loss of available habitat. 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 (SWFWMD 2005a). This definition of significant harm has been used in minimum flow studies for the Middle Peace River (SWFWMD, 2005a), Upper Alafia River (SWFWMD, 2005b), Upper Myakka River (SWFWMD, 2005c), Braden River (SWFWMD 2007a), and Upper Hillsborough River (SWFWMD, 2007b).

The minimum flow criterion for Shell LPR and SC is the flow that results in no more than a 15% reduction in available habitat relative to the Baseline flow condition. To this end, results from Section 7 were summarized in order to define seasonal and flow-specific minimum flows for both systems. These recommended minimum flows have been defined as an allowable percent reduction in flow for each system. Therefore, the proposed minimum flow is the seasonal and flow specific percent flow reduction that maintains at least 85% of the habitat that is available under the Baseline condition.

8.2 Method to Define Minimum Flows – Salinity Habitat

As discussed in Section 3.1, the District applied the percent-of-flow method to determine minimum flows for the LPR and SC. The percent-of-flow method allows water users to take a percentage of streamflow at the time of the withdrawal. The percent-of-flow method has been used for the regulation of water use permits since 1989, when it was first applied to withdrawals from the Lower Peace River.

In application, both the LPR and SC minimum flows protecting the volume of water < 2 ppt were determined simultaneously using the period 1999, 2001-2002. Baseline flows corrected for withdrawals and excess agricultural flows for each system were used for the evaluation, and a 90 cfs low-flow threshold was imposed for the simulated LPR reductions.

The daily volume < 2ppt predicted for the LPR hydrodynamic model scenarios (0%, 10%, 20%, 30% and 40% reductions in flow) were interpolated to one percent increments of flow reduction. The SC incremental reductions were simulated directly using the salinity regression model. Daily volumes in each system were summed by year and Block and then summed together (LPR+SC). For example, the 1999 Block 1 daily volumes were computed and summed in SC for baseline (eg. the 0% reduction), 1% flow reduction, 2% flow reduction etc. up to 40% flow reduction. This process was repeated for LPR and SC for all remaining blocks and years. Year 2000 was not included because there was no baseline volume less than 2 ppt predicted during Block 1 for Shell Creek.

The summed habitat volumes (LPR+SC) were then converted to a combined habitat reduction for each of the flow reductions similar to that described in Table 7-9. Block results were averaged, and the flow reduction resulting in a 15% loss[1] in combined LPR+SC habitat was determined for each block across the three years.

The method described above was applied to salinity volume < 2ppt for all blocks and scenarios. The results of this analysis for LPR and SC are presented in Table 8-1. After determining the flow reduction resulting in a 15% loss of combined habitat, the resulting loss within each system was also determined.Little difference is noted between the combined habitat loss, and the loss in LPR because the LPR contains significantly more low salinity habitat than SC.

Table 8-1. Summary of allowable percent reduction in flow based on the volume of water < 2 ppt for Lower Peace River and Shell Creek by Block. (90 cfs low-flow threshold)

Period 1999, 2001 - 2002				
	Flow Reduction	Combined Loss (by definition)	Peace Habitat Loss	Shell Creek Habitat Loss
Block 1	16%	15%	15%	13%
Block 2	29%	15%	15%	13%
Block 3	38%	15%	15%	5%

8.3 Application of Method to Define Minimum Flows – Specific Locations

[1] In practice and to be conservative, the nearest whole percent of flow reduction resulting in less than or equal to a 15% loss of habitat is reported.

In addition to examining the river-wide extent of the biologically-relevant salinities, a more spatially-specific assessment of salinity within a portion of the LPR was also deemed critical. As discussed above, studies have shown that the area of the river approximately located at Zone 3 (Figure 7-7) has a significantly abundant and diverse fish community. Earlier work has shown that this region is characterized by salinities typically in the range of 8-16 ppt (Mote 2002). Therefore, the volume of water meeting the appropriate salinity range in Zone 3 (i.e., volume of water with salinity between 8 and 16 ppt) was also analyzed using the normalized area under the curve (NAUC) (See Chapter 8.2 of peer review draft - SWFWMD 2007c for description of NAUC). Plots of the NAUC by block and flow condition for the volume of water between 8 and 16 ppt in Zone 3 are presented in Figures 8-1 to 8-3.

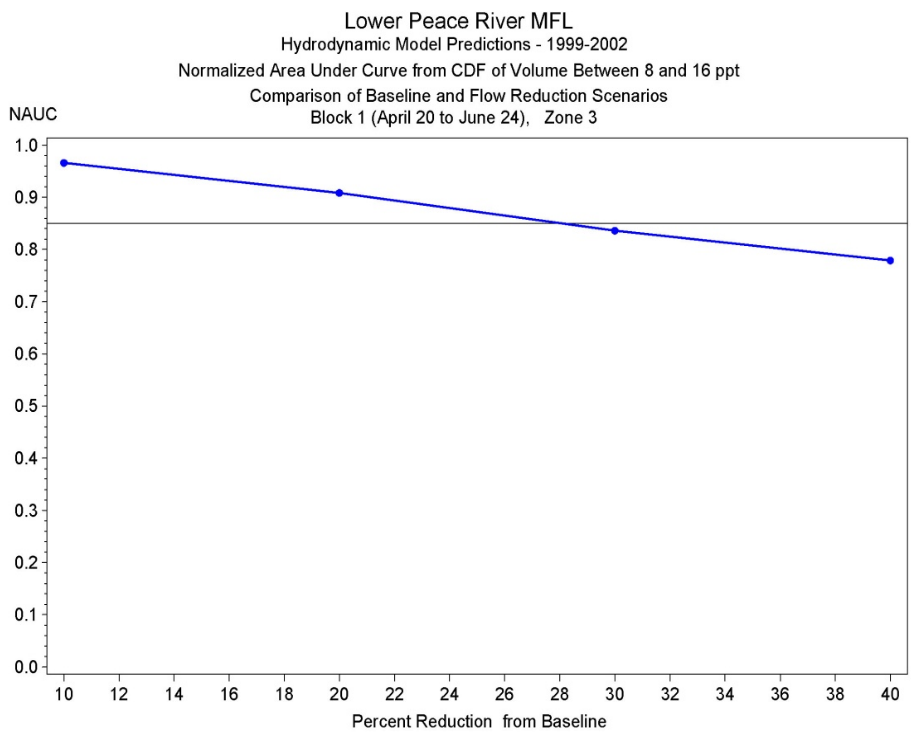


Figure 8-1. Plot of normalized area under the curve from CDF plots of water volume in Lower Peace River Zone 3 between 8 and 16 ppt for Block 1.

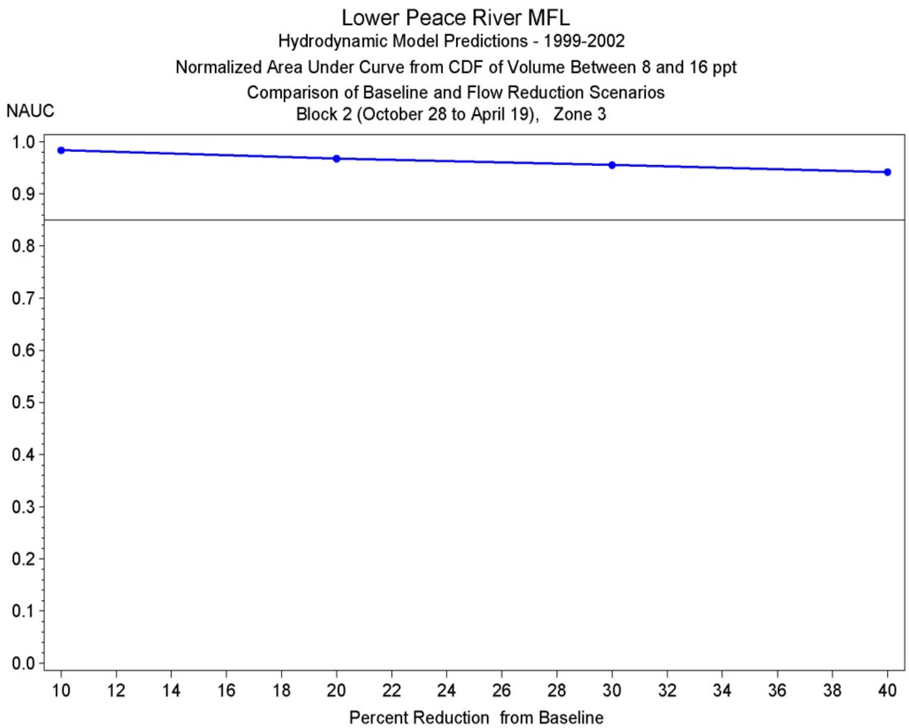


Figure 8-2. **Plot of normalized area under the curve from CDF plots of water volume in Lower Peace River Zone 3 between 8 and 16 ppt for Block 2.**

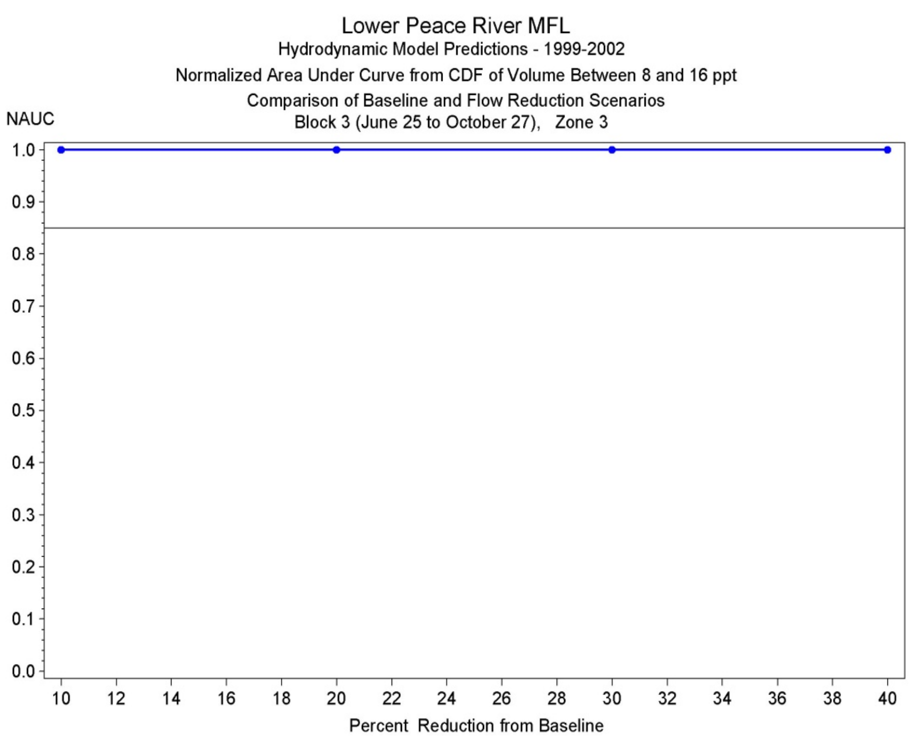


Figure 8-3. **Plot of normalized area under the curve from CDF plots of water volume in Lower Peace River Zone 3 between 8 and 16 ppt for Block 3.**

The allowable percent flow reduction by block and flow condition based on the volume of water between 8 and 16 ppt in Lower Peace River Zone 3 is presented in Table 8-2. As with other habitat metrics that were analyzed, the volume between 8 and 16 ppt in Zone 3 was less sensitive than the volume less than two ppt.

Table 8-2. Summary of allowable percent reduction in flow based on the volume of water between 8 and 16 ppt for Lower Peace River Zone 3 by Block.

Block	Allowable Percent Reduction in Flow Under:
Block 1 (April 20 – June 25)	28%
Block 2 (October 27 – April 19)	+40%
Block 3 (June 26 – October 26)	+40%

The allowable withdrawals based on maintenance of salinity in Zone 3 (Figure 7-7; Rkm 6-15.5) are higher than allowable percentages based on maintenance of volume < 2 ppt. Therefore, the more conservative (Table 8-2) were adopted.

8.4 Additional Minimum Flow Criteria

The method described above was used to determine the low-flow threshold and the allowable seasonal percentage withdrawals that were presented in the District draft report dated April 9, 2009. Upon publication of that report, concerns were expressed by various citizens and groups regarding the magnitude of the percentage withdrawal limits. In particular, concern was expressed that withdrawals that comprise 38% of Peace River flow could result in very large flow reductions to the Charlotte Harbor system. To address these concerns, the District investigated the effect of capping withdrawals at various maximum diversion rates. Development of a maximum diversion limit is described in Chapter 8.4.1

The water volume < 2 ppt was selected for investigation because previous analyses indicated this was the salinity zone most sensitive to change as a result of flow reductions. The percentage withdrawals were developed to maintain 85 % of the habitat summed for each seasonal block under mean flow conditions. This means that for some days, greater than 85% of the habitat is maintained, but also for some days, less than 85% of the habitat is maintained. District staff examined the effect of the proposed withdrawal rates for the three blocks (16, 29%, 38%) on the daily reductions of salinity zone habitats at various rates of flow. This was in keeping with the discussion on page 8-10 of the April 9, 2009 draft report that flow-based thresholds could be implemented to ensure that flows reach a suitably high rate within a seasonal block before a higher percentage withdrawal limit is implemented (e.g., switch from 16% withdrawals in Block 1 to 38% withdrawals in Block 3). To address this concern, staff examined reductions in the daily percentages of water volumes less < 2 ppt as a function of the rate of flow within each block. This analysis resulted in the establishment of transitional flow triggers as further described in Chapter 8.4.2

8.4.1 Determination of Maximum Flow Diversion

Figure 8.4 compares the actual flow of the lower Peace River for the period 1985 to 2004 with the flow that would result under the following conditions:

A Low-flow threshold of 90 cfs
An allowable Block 1 withdrawal of 16%
An allowable Block 2 withdrawal of 29%
An allowable Block 3 withdrawal of 38%

This was the MFL as proposed in the draft April 9, 2009 MFL report. It was noted by a number of reviewers that it was theoretically possible under this scenario to remove up to one third of the mean annual flow of the lower Peace River without violating the proposed MFL. One reviewer was particularly concerned that this had the potential to seriously reduce nutrient loading and affect fish production under highest flow conditions. Actual calculation of the theoretically maximum possible withdrawal yielded a mean annual percentage of 33.6%.

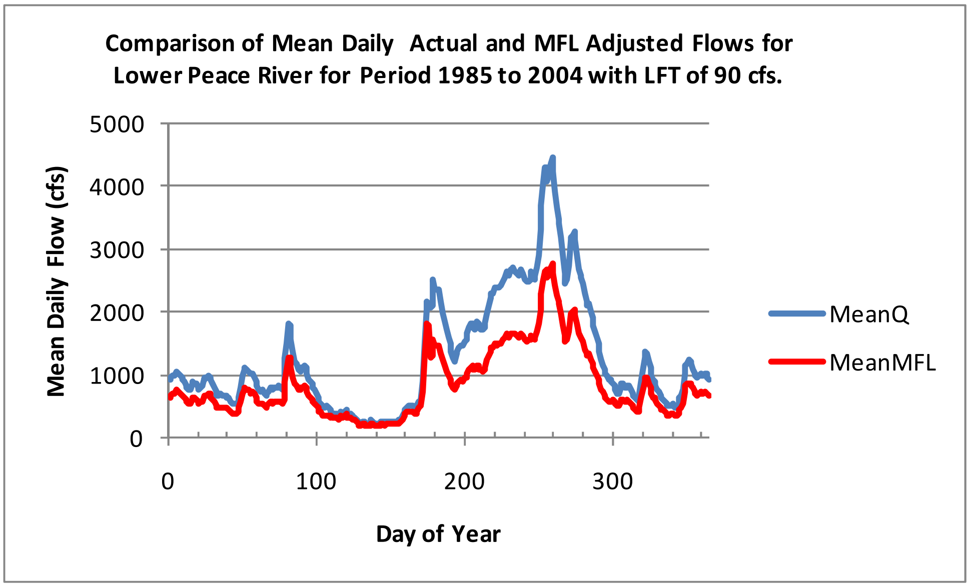


Figure 8-4. Comparison of mean daily flow with, and without 90 cfs LFT and maximum seasonal withdrawals

Changing the LFT from 90 to 130 cfs (Figure 8-5) while preventing unwanted saline incursions further upstream and further protecting the ecology of the river as discussed previously would only reduce the theoretical maximum withdrawal percentage from 33.6% to 33.4%.

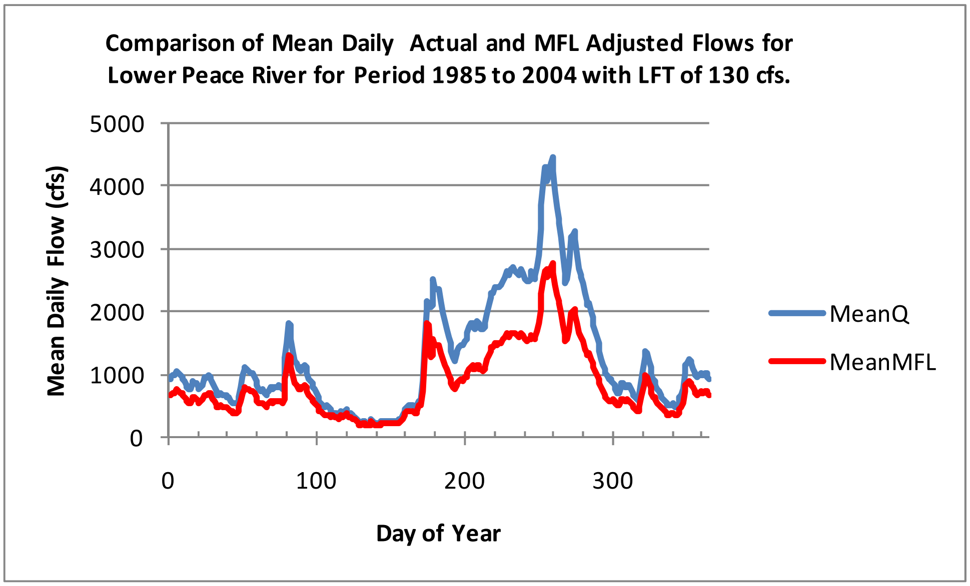


Figure 8-5. **Comparison of mean daily flow with, and without 130 cfs LFT and maximum seasonal withdrawals**

Implementation of the flow trigger of 625 cfs as proposed in Section 8.4.2 below is shown graphically in Figure 8-6. The implementation of this trigger while important in some individual years has little noticeable effect on the theoretically possible withdrawal because Block 3 flows have a disproportionately greater influence on the mean annual flow. Under the scenario as outlined above and shown in Figure 8-6, it would still be theoretically possible to remove an average of 32% of the mean annual flow.

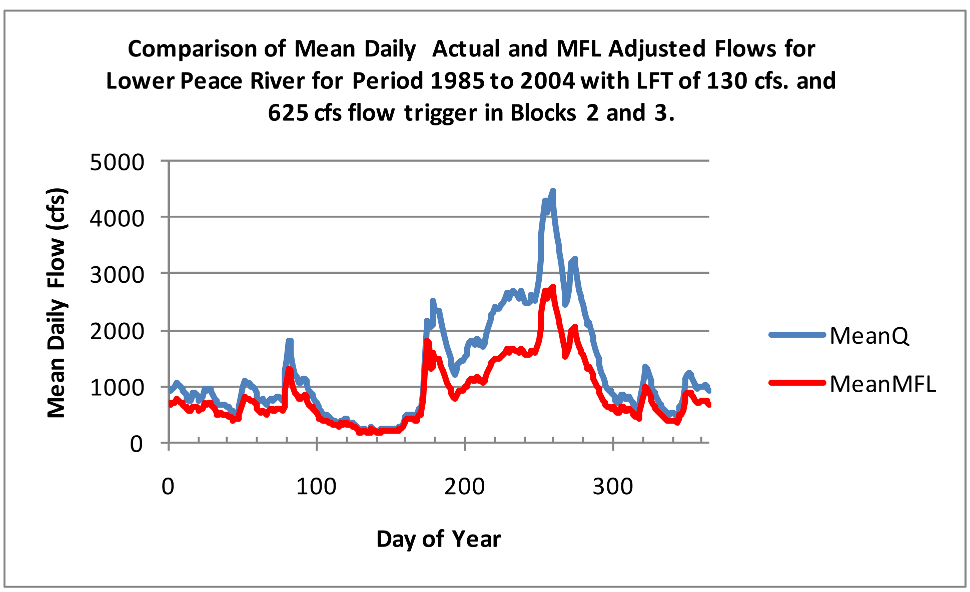


Figure 8-6. **Comparison of mean daily flow with, and without 130 cfs LFT, 625 cfs transition triggers and maximum seasonal withdrawals**

Despite the fact that a relatively high annual percentage rate of withdrawals is theoretically possible with the previously proposed MFL, there is a practical limit to the amount of water that can be taken from an unregulated river based on constraints related to withdrawal (pump size) and storage capacity. For example, the PRMRWSA is currently limited by their permit to a maximum daily withdrawal of 90 mgd (139 cfs) regardless of how high the flow of the Peace River may go. If for example, the PRMRWSA or some other utility were permitted to withdraw according to the following formula:

A LFT of 130 cfs
An allowable Block 1 withdrawal of 16%
An allowable Block 2 withdrawal of 16% below 625 cfs and 29% above
An allowable Block 3 withdrawal of 16% below 625 cfs and 38% above
Limiting maximum diversion to 139 cfs

By limiting (either through their pumping capacity or by permit) withdrawals to no more than 139 cfs on a daily basis, the maximum amount that could be withdrawn on an annual basis would average only 6.5% of the combined flow of the lower Peace River as measured at the three gages. The allowable maximum diversion poses a very real and practical limit on the total amount of water that can be withdrawn.

After reviewing the District’s regional water supply plan for projected demands over the foreseeable future, it was recognized that future demands could be met while imposing an upper cap or maximum diversion limit on the proposed MFL. For example, Using the above formula, but with a maximum diversion capacity limit of 400 cfs, the potential yield off the Peace River for the period 1985 to 2004 could have averaged 113 mgd while limiting withdrawals to 13.7% of the mean annual flow. The resuts are illustrated in Figure 8-7.

It is, therefore, recommended that the District incorporate a maximum diversion rate in MFL for the lower Peace River. This will insure that high flows are protected. It is further recommended that the MFL as presented in this document be re-evaluated within five years of adoption.

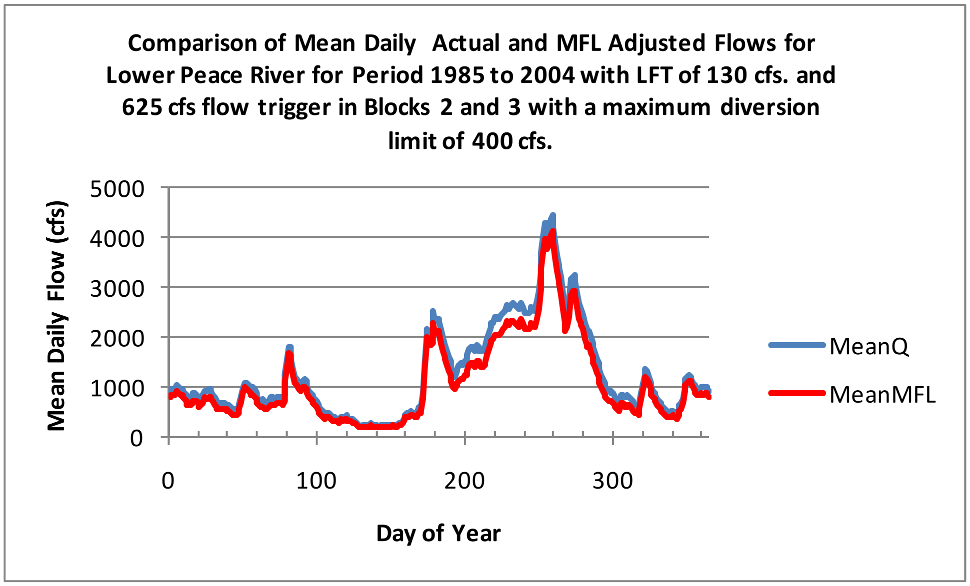


Figure 8-7 **Comparison of mean daily flow with, and without 130 cfs LFT, 625 cfs transition triggers and maximum seasonal withdrawals**

8.4.2 Determination of Transitional Flow Triggers

The development of withdrawal limits based on season was incorporated into the MFL in order to provide additional protection during the dry season when the ecology is more sensitive to freshwater flows. The definition of season Blocks was based on median day of year flows over a 54-year period. In the strictest sense of application, the allowable withdrawal in the Peace river would transition from 16% on June 25 (representing the end of Block 1) to 38 % on June 26 (representing the beginning of Block 3). However, if the actual Block 3 flows remained depressed due to climatological conditions, the increase in percentage of withdrawals could be stressful on the biological resources. In consideration of this possibility, the criteria previously described (seasonal percentages, 130 cfs low-flow threshold and 400 cfs maximum diversion) were applied to the baseline flow and plots of the percentages of daily water volumes < 2 ppt in the lower river vs. flow were developed (Figure 8-8). The flow term used in the plots is combined same-day flow at the three upstream gages for baseline conditions to illustrate how specified withdrawal limits would affect reductions of water volumes < 2 ppt at various rates of baseline flow.The flow range on the x-axis is limited to 1,000 cfs (truncating 28% of the flow values) to better illustrate salinity/flow relationships at low flows, since reductions of water volume < 2 ppt are typically less at higher flows. A LOWESS smoothed line was fitted to the data in each plot to illustrate the moving central tendency of the salinity/flow relationship.

The plots of water volume < 2 ppt for all blocks combined indicates that reductions in daily water volumes tended to be greater than 15% at very low flows (<40 cfs) and within a flow range of about 150 to 500 cfs (Figure 8-8A). Inspection of the remaining plots by block indicates that the 38% withdrawal in Block 3 (June 26 to October 26) tends to keep reductions in percent daily volumes of the < 2 ppt salinity zone less than the 15% habitat loss criterion (Figure 8-8D). Reductions in daily water volumes < 2 ppt during Block 1 (Figure 8-8B) fluctuated very close to the 15% loss criterion over much of the flow range for that block, with greater reductions at very low flows (< 60 cfs). However, it should be noted the comparatively large percent habitat losses at very low flows represent small water volumes, as the < 2 ppt salinity zone was very small and compressed near the upstream study boundary. On 49 days during the year 2000, the baseline value for water less than < 2 ppt was zero, meaning the < 2 ppt zone had moved upstream past the study boundary. It should be stressed this occurred during very unusual conditions at the peak of the dry season during one of the worst droughts on record.

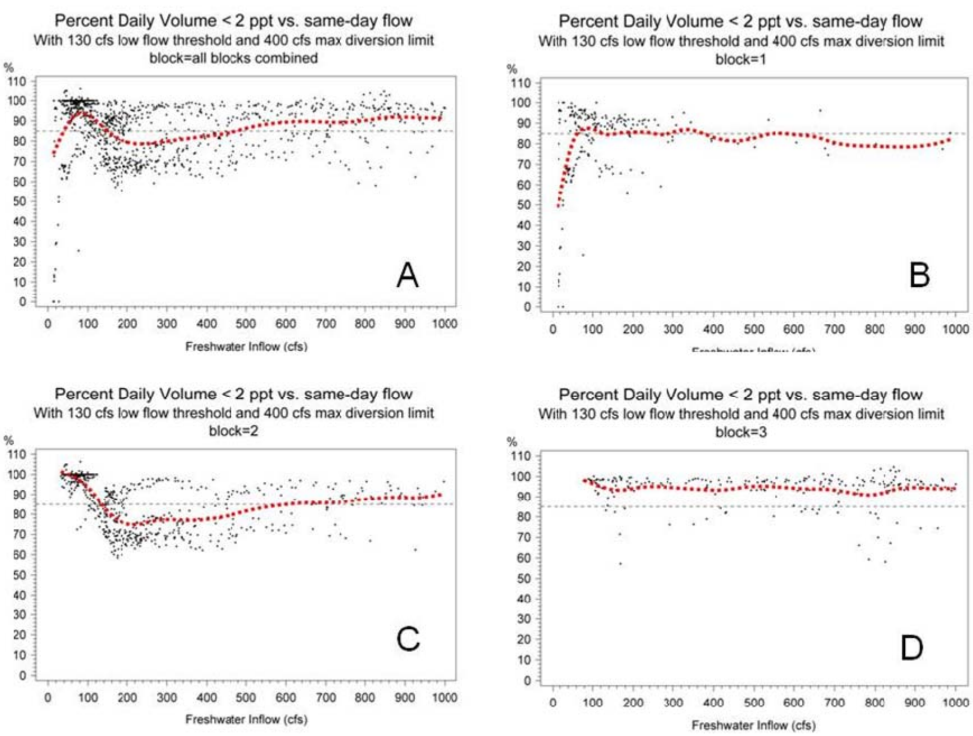


Figure 8-8. **Percentages of daily water volumes < 2 ppt vs. combined baseline flows for the three upstream. (130 cfs low-flow threshold, 400 cfs maximum diversion)**

The most striking finding of this graphical analysis was that during Block 2 (Figure 8-8C), reductions in daily salinity volumes < 2 ppt were greater than 15% over a range of flows from about 150 cfs to 625 cfs. The largest reductions occurred over a flow range of about 160 cfs to 440 cfs, when reductions in daily water volumes < 2 ppt were about 20% to 25%. These results indicate that application of the 29% withdrawal limit in Block 2 could result in reductions in daily salinity zone volumes < 2 ppt that tend to exceed the 15% habitat loss criterion.

Based on these findings, the District concluded that a minimum flow of 625 cfs should be exceeded before allowing a switch from the 16% Block 1 withdrawal rate to the 29% Block 2 withdrawal rate or the 38% Block 3 withdrawal rate. In other words, withdrawals during Blocks 2 and 3 above the 130 cfs low flow threshold would remain at 16% until the combined daily flows from the three upstream gages reached a value of 625 cfs. The 625 cfs flow rate was selected because the fitted line for Block 2 indicated 29% withdrawals at higher flow rates would not result in greater than 15% reduction in daily salinity zones (Figure 8-8C). Applying this threshold to Block 3 is conservative, for the graphical analysis indicated that percent reductions of volumes < 2 ppt greater than 15% did not occur with the application of the 130 cfs low-flow threshold and the 400 cfs maximum diversion limit. However, it was desired that a flow-based transitional trigger be implemented to ensure that flows in Block 3 rise to typical wet season flows before the 38% withdrawal rates are permitted.

The impact of imposing the transitional trigger flows, coupled with the 130 cfs low-flow threshold, the 400 cfs maximum diversion and the seasonal percentage withdrawals is shown in Figure 8-8. The fitted line remains above the 15% loss reference line when the results from all blocks are combined (Figure 8-9A). However, during Block 1 (Figure 8-9B), the fitted line dropped below 15% only at very low flow rates (< 50 cfs) that occurred during the 2000 drought. As described in Section 7.1, simulated withdrawals from the river did not occur for 214 days during 2000, so these results indicate the very small changes in actual salinity volumes, which may be near the resolution of the model to discern actual changes. The fitted line for Block 1 also dipped slightly below the 15% reference line at flows above 350 cfs.

The greatest improvement in the reduction of the salinity zone volumes resulting from implementation of the 625 cfs flow trigger occurred in Block 2 (Figure 8-9C). The fitted line remained above the 15% loss reference line, except for a very small dip near 200 cfs. These results indicate that keeping withdrawals at 16% in Block 2 until flows reach 625 cfs is an effective tool for preventing reductions of low salinity water from the period from late October to late April. For Block 3, the percent reductions in salinity zone are well less than 15%, indicating that the sliding 16% - 38% withdrawal schedule combined with the 400 cfs maximum diversion limit results in small salinity zone reductions in the summer wet season (Figure 8-9D).

Although the analyses used to establish these withdrawal limits were based on simulations of salinity distributions during the 1999-2002 modeling period, the different withdrawal limits can be applied to longer time periods to assess the durations they would be in effect. Figure 8-10shows on average the percent of time that flows would have been in the ranges that allow no withdrawals (<130 cfs), or 16%, 29%, and 38% withdrawals of river flow for the 1985-2004 baseline period. Results rounded to the nearest integer are shown for the entire baseline period and separately within the three seasonal blocks during those years. Viewed on a yearly basis, no withdrawals will be implemented 12% of the time, with withdrawals limited to sixteen percent rate 46% of the time. Twenty-nine percent withdrawals will be allowed 15% of the time during the year (all within block 2), while 38 % withdrawals will be allowed of 26% of the time (all within block 3). Results within blocks show that withdrawals will be limited to 16% of flow or less a total of 68% of the time in block 2 (13% of time at no withdrawals and 55% of time at 16% withdrawals). The maximum withdrawal rate for block 2 (29%) will be allowed 32% of the time on average, but more frequently during wet periods such as the 1997-1998 El Nino. In contrast, the maximum withdrawal in Block 3 will be allowed 77% of the time on average, due to the frequency of flows above the 625 cfs trigger in the summer wet season. It is reiterated that maximum withdrawals during any of the blocks will be limited to 400 cfs.

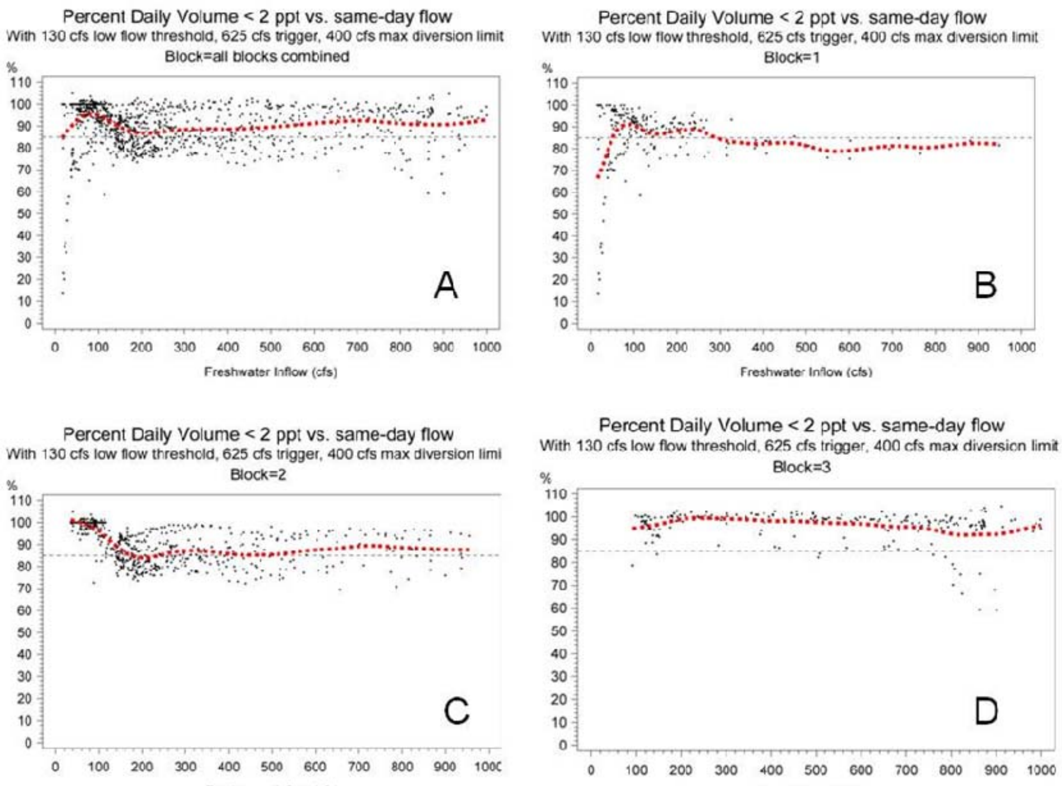


Figure 8-9. **Percentages of daily water volumes < 2 ppt vs. combined baseline flows for the three upstream gages for the entire year (all blocks combined) and the three separate blocks given the following constraints: a 130 cfs low flow threshold; a 400 cfs maximum diversion limit for withdrawals from the Peace River; a 625 cfs trigger; and the block specific percentage withdrawals rates specified in Table 8.1.**

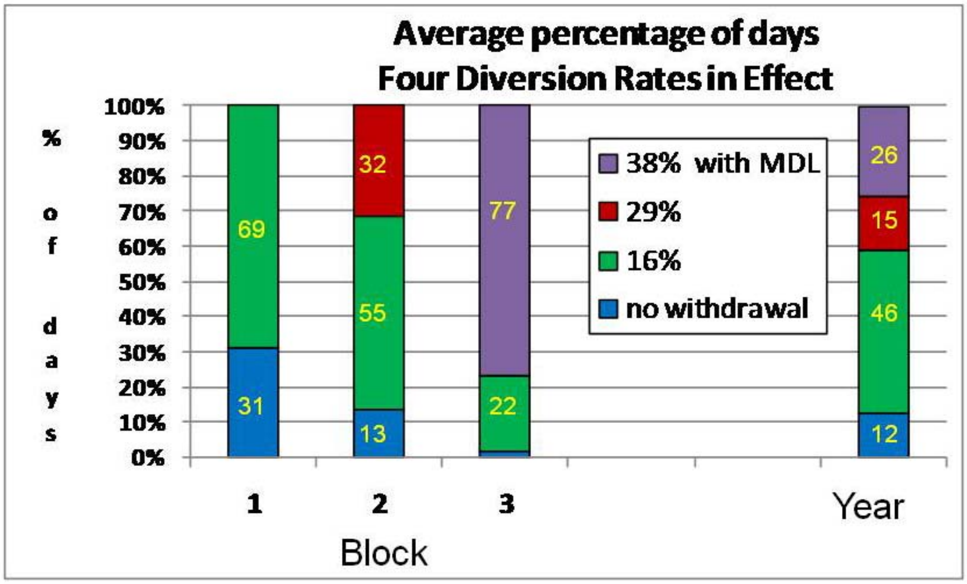


Figure 8-10 Percent of time that flows were in ranges that allow for four different withdrawal rates (0%, 16%, 29%, and 38%) for the entire year and the three seasonal blocks for the period 1984-2004. Yellow numerals within columns denote percent of days.

8.5 Summary of Combined MFL Criteria on Lower Peace

The combined effect of the low-flow threshold, maximum diversion limit, transitional trigger flows and the seasonal percant of allowable withdrawals is summarized in Table 8-3 through Table 8-5.

Table 8-3. Summary of percent change in volume of water < 2 ppt, < 5 ppt, and < 15 ppt for Lower Peace River by block under the proposed MFL relative to the Baseline Scenario using Normalized Area Under Curve approach (SWFWMD 2007c).

	Percent Change between MFL and Baseline		
Block	< 2 ppt	< 5 ppt	< 15 ppt
Block 1 (April 20 – June 25)	-12.6%	-12.5%	-5.0%
Block 2 (October 27 – April 19)	-10.3%	-8.3%	-3.5%
Block 3 (June 26 – October 26)	-3.7%	-3.8%	-1.6%

Table 8-4 Summary of percent change in bottom area < 2 ppt, < 5 ppt, and < 15 ppt for Lower Peace River by block under the proposed MFL relative to the Baseline Scenario. using Normalized Area Under Curve approach (SWFWMD 2007c)

	Percent Change between MFL and Baseline		
Block	< 2 ppt	< 5 ppt	< 15 ppt
Block 1 (April 20 – June 25)	-12.0%	-11.4%	-3.9%
Block 2 (October 27 – April 19)	-8.8%	-6.7%	-2.3%
Block 3 (June 26 – October 26)	-2.4%	-2.2%	-1.0%

Table 8-5. **Summary of percent change in shoreline length < 2 ppt, < 5 ppt, and < 15 ppt for Lower Peace River by block under the proposed MFL relative to the Baseline Scenario using Normalized Area Under Curve approach (SWFWMD 2007c)**

	Percent Change between MFL and Baseline		
Block	< 2 ppt	< 5 ppt	< 15 ppt
Block 1 (April 20 – June 25)	-8.2%	-9.3%	-2.9%
Block 2 (October 27 – April 19)	-7.5%	-4.5%	-1.6%
Block 3 (June 26 – October 26)	-1.7%	-1.2%	-0.5%

8.6 Influence of MFL on Water Quality Constituents and Ecological Parameters

As mentioned in Section 7, attempts were made to develop empirical models that relate flow to ecological criteria for the LPR in order to identify a low-flow threshold. No defensible relationships were found between flow and DO or between flow and chlorophyll *a* in various segments or locations in the LPR. Therefore, it was not possible to define a flow that would preclude low DO values or high chlorophyll *a* values.

However, a statistically significant relationship between the location of the chlorophyll *a* maximum and freshwater inflow was developed for the LPR as part of this study. In addition, regressions have been developed to predict the location of the center of abundance of numerous fish and plankton species in the LPR based on flows (Peebles 2002, Greenwood *et al.* 2004).

In order to quantify the impact of the proposed minimum flows, predictions were made using the baseline flows and the proposed minimum flows. The Baseline flow condition consisted of the sum of the gauged flows at Peace River at Arcadia (USGS gauge 02296750), Horse Creek near Arcadia (USGS gauge 02297310), and Joshua Creek at Nocatee (USGS gauge 02297100). For the proposed MFL scenario, the maximum allowable daily withdrawals were taken out based on Table 8-1 while maintaining at least 130 cfs after withdrawals for the combined flow (Peace+Johsua+Horse). If the daily combined flow was less than 130 cfs, no withdrawals were taken out. The results of the empirical models are presented in the following sections.

8.6.1 Shell Creek

No empirical relationships between flow and water quality constituents or between flow and ecological parameters were established for SC.

8.6.2 Lower Peace River

As discussed above, two analyses were performed for the LPR, the location of the chlorophyll *a* maximum and fish and plankton center of abundance. The predicted median location of the chlorophyll *a* maximum for the period 1999 to 2002 is presented in Table 8-6. The results are based on application of a 130 cfs low-flow threshold, a 400 cfs maximum diversion and the 625 cfs Block transition triggers previously described.

The differences between the median location of the chlorophyll *a* maximum[2] for the Baseline and MFL scenarios were not deemed significant as the differences were within the error of prediction for the estimates.

Table 8-6. Summary of median predicted location (river kilometer) of the chlorophyll *a* maximum for Lower Peace River for the Baseline and MFL scenarios.

Block	Median Location of the Chlorophyll *a* Maximum Under:	
	Baseline	MFL
Block 1 (April 20 – June 25)	28.3	28.3
Block 2 (October 27 – April 19)	24.5	25.2
Block 3 (June 26 – October 26)	16.7	18.8

The predicted median center of abundance (river kilometer) for selected species is presented in Table 8-7. The differences between the median center of abundance for the Baseline and MFL scenarios were not significant as the differences were well within the error of prediction for the estimates.

Table 8-7 Summary of median predicted location (river kilometer) of the Center of Abundancefor Lower Peace River for the Baseline and MFL scenarios.

Species	Median Center of Abundance (rkm)	
	Baseline	MFL
Hogchoker juveniles	19.7	20.2
Sand Seatrout juveniles	16.6	17.8
Bay Anchovy juveniles	20.1	21.0
Bay Anchovy adults	11.9	12.6
Amphipods	18.1	18.7
Mysids	16.5	17.3

8.7 Summary of MFL Recommendations

A summary of the MFL recommendations for SC and LPR is presented in this subsection.

8.7.1 Shell Creek

The SC MFL encompasses the portion of SC from HBMP station 7 (rkm 2.35) to the SC dam (rkm 9.9) (Figure 7-2). This portion of SC is relatively shallow (less than 2 m) and the shoreline is primarily buffered by wetlands.

[2] Rkm = 45.204+(1.606*Season) - (4.314*Ln(Q) where Q = flow in cfs and season = 2 for months 6-8 and season =1 for all others.

The City of Punta Gorda is permitted to withdraw water from the SC reservoir according to WUP (#200871.008). The current permit allows for an average permitted withdrawal of 8.1 mgd (12.5 cfs) and a maximum peak monthly withdrawal of 11.7 mgd (18.1 cfs).

The criterion used for MFL development in SC was the combined available volume less than two ppt in SC and the LPR. An empirical model was developed to predict salinity in SC as a function of flow and other appropriate variables.

The empirical model was used to estimate available habitat for the observed flows at the SC dam (baseline scenario) and flow reduction scenarios ranging from 1% to 99% reductions in observed flows by 1% intervals (i.e., baseline, 99% of observed flows at SC dam, 98% of observed flows at SC dam, … , 1% of observed flows at SC dam). The amount of available habitat (volume) less than two ppt was determined for each scenario for the period 1999, 2001-2002 for each of the three blocks, and combined with the equivalent habitat reductions in the LPR. The threshold used to determine the MFL was a 15% reduction in available combined habitat compared to the baseline.

As mentioned in Section 6.2, no empirical relationships between flow and water quality constituents or between flow and ecological parameters have been established for SC. For this reason, no low-flow threshold was used for SC. The recommended MFLs for SC by Block and flow condition are presented in Table 8-8.

Table 8-8. Summary of allowable percent reduction in flow for SC by Block .

Block	Allowable Percent Reduction in Flow:
Block 1 (April 20 – June 25)	16%
Block 2 (October 27 – April 19)	29%
Block 3 (June 26 – October 26)	38%

Implementation of the SC MFL should be accompanied by matinenance of the reservoir discharge measurements and the installation and operation of a new reservoir inflow measuring station.

The hydrographs of the SC median daily flows for the Baseline and flow remaining after the maximum allowable withdrawals were taken is presented in Figure 8-11 for the period 1966 to 2004.

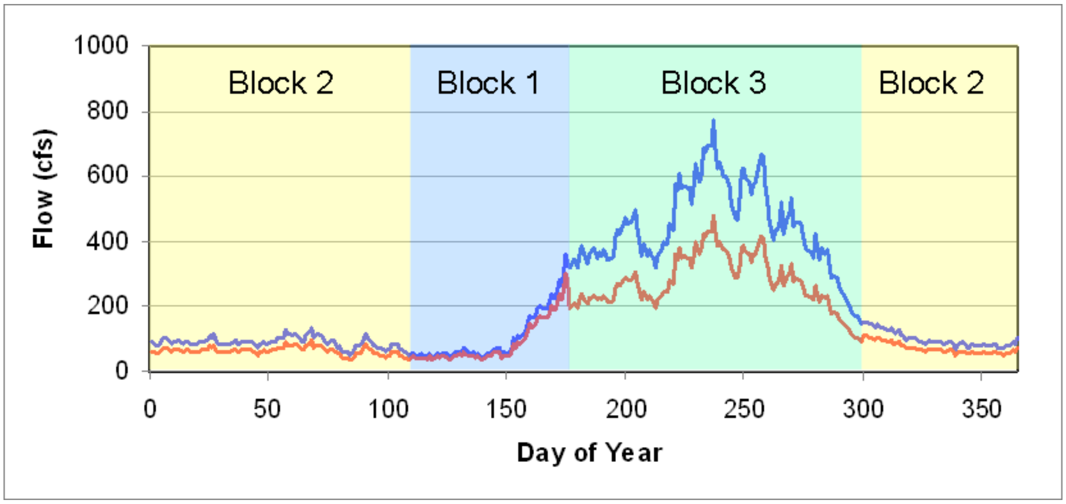


Figure 8-11. Hydrographs of the median daily SC flows for the Baseline (blue line) and flow remaining after the maximum allowable withdrawals were taken (orange line).

8.7.2 Lower Peace River

The Peace River watershed is one of the largest in Florida, draining approximately 2,350 square miles. The watershed extends from its headwaters in northern Polk County to the river mouth in Charlotte Harbor. The LPR MFL encompasses the portion of the river from the mouth to Arcadia. There are three major tributaries that flow into the LPR, Joshua Creek, Horse Creek, and SC. The lower portion of the LPR, between the mouth and SC, is broad and strongly influenced by tides. Between the confluence of SC (rkm 15) and the PRMRWSA plant (rkm 30), the system is highly braided.
There is one permitted surface water withdrawal on the LPR at the PRMRWSA plant. The PRMRWSA began withdrawing water in 1980. The WUP (#2010420.02) held by the PRMRWSA, as modified on 18 December 1998, permits:

- withdrawals on days when the previous days flow at the USGS Arcadia gauge was at least 130 cfs,
- a daily maximum withdrawal of 139 cfs (90 mgd),
- a monthly maximum of 59 cfs (38.1 mgd); and
- an annual average of 51 cfs (32.7 mgd).

The criteria used for MFL development in LPR was maintenance of 85% of the combined (LPR plus SC) available habitat less than two ppt. As discussed in Section 7.4, though multiple salinities and metric were investigated for the Lower Peace River, volume less than two ppt most the most sensitive metric. A hydrodynamic model was developed by District staff to predict salinity in LPR as a function of flow and other variables.

The hydrodynamic model was used to estimate available habitat in the study area (rkm 0 to rkm 58) for the observed flows in the LPR (baseline scenario) and various flow reduction scenarios for the period 1999 to 2002. Unlike SC, a low-flow threshold for the combined flows at Arcadia, Joshua Creek, and Horse Creek of 130 cfs was used. In other words, if the combined flow (Arcadia + Joshua Creek + Horse Creek) was less than 130 cfs, no water was taken out. Additionally, the combined flow was never allowed to be reduced to less than 130 cfs by withdrawals.

In addition to examining the extent of the biologically-relevant salinities over the entire study area, a more spatially-specific assessment of salinity within a portion of the Lower Peace River was also deemed critical. As discussed above, studies have shown that the area of the river approximately located at Zone 3 (Figure 7-7 has a significantly abundant and diverse fish community. Earlier work has shown that this region is characterized by salinities typically in the range of 8-16 ppt (Mote 2002). Therefore, the volume of water meeting the appropriate salinity range in Zone 3 (i.e., volume of water with salinity between 8 and 16 ppt) was also analyzed.

The amount of available habitat was determined for each scenario for the period 1999-2002 for each of the three Blocks and the most conservative criterion was selected amongst the metrics discussed above for the entire study area or volume between 8 and 16 ppt in Zone 3. As mentioned previously, the volume less than two ppt was the most sensitive and therefore the most conservative metric.

The recommended MFLs for LPR by are presented in Table 8-9.

Table 8-9. Summary of allowable percent reduction in flow for Lower Peace River by Block after meeting transitional flow thresholds.

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Block	Allowable Percent Reduction in Flow Under:
Block 1 (April 20 – June 25)	16%
Block 2 (October 27 – April 19)	29%
Block 3 (June 26 – October 26)	38%

As stated in Section 1.3, the goal of the percent-of-flow method is to maintain the natural flow regime, albeit with some dampening allowed due to withdrawals. In the LPR a low flow threshold of 130 cfs is in effect. Therefore, the combined flow (Arcadia + Joshua Creek + Horse Creek) is never allowed to go below 130 cfs as a result of withdrawals. The percentages in Table 8-9 should be applied as described in the following example. For example, if the flow on a given day in Block 1 is 135 cfs, then the maximum allowable withdrawal would be 135*16% = 21.6 cfs. However, a reduction of 21.6 cfs would cause a flow below the low flow threshold. Therefore, only 5 cfs would be taken thus maintaining the 130 cfs low flow threshold.

The hydrographs of the LPR median daily flows for the Baseline and flow remaining after the maximum allowable withdrawals were taken is presented in Figure 8-12 for the period 1951 to 2004.

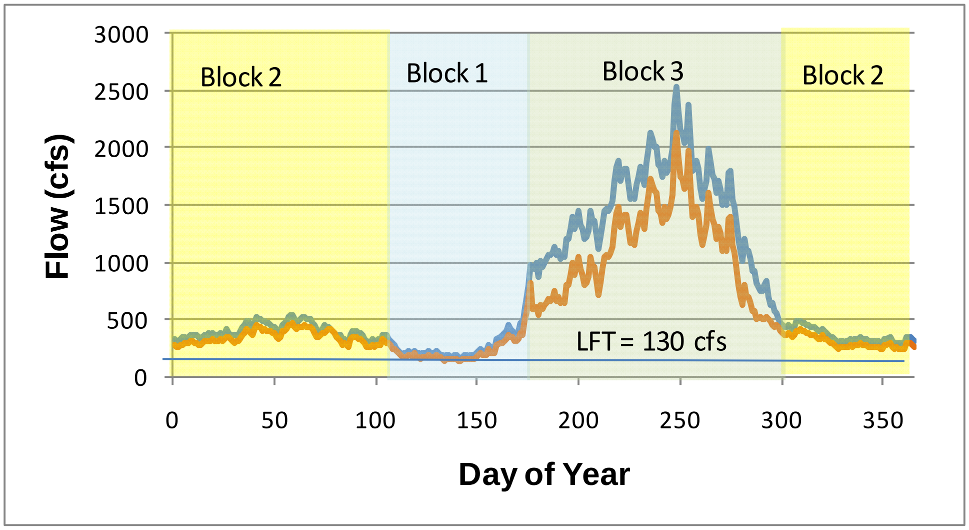

Figure 8-12. Hydrographs of the median daily Lower Peace River flows for the Baseline (blue line) and flow remaining after the maximum allowable withdrawals were taken (orange line).

Figure 8-13 illustrates the application of the combined MFL criteria. The District also recognizes that establishing estuarine MFL's is an evolving science. To this end, the District is committed to verifying the models and assumptions applied in the current determination and intends to conduct a re-evaluation in the future.

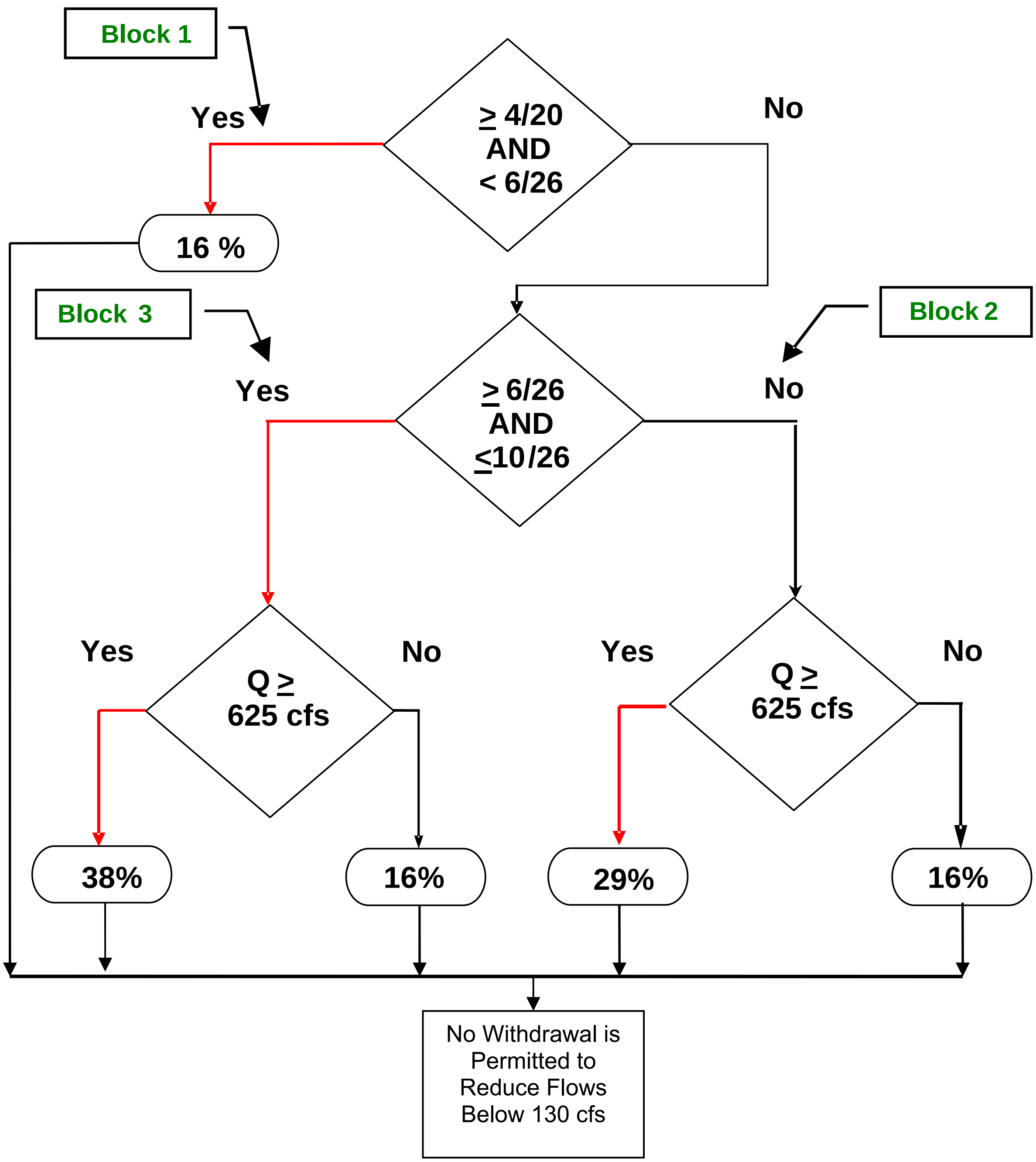

Figure 8-13. Example of MFL Application

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10 Appendices

(Note – Appendices are numbered separately from report. Appendix 1 is bound to main report. Appendices 2 -7 are bound separately)

Appendix 1

Scientific Peer Review and Correspondences Related to the Peer Review Draft Report

Scientific Peer Review of the Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek

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April 30, 2008

Scientific Peer Review of the Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek (LPRSC)

EXECUTIVE SUMMARY

The Southwest Florida Water Management District (District) has completed a study to establish Minimum Flows and Levels (MFL) for the Lower Peace River and Shell Creek (LPRSC)[1]. The approach was to determine a flow regime that would protect ecology of the river system by analyzing data on historical flows, current flows, and biological responses to flows. The analyses produced salinity habitat zone limits where salinity models were used to determine the flow regimes necessary to protect the habitats. The ecologically relevant salinity criterion for Shell Creek was two (2) psu. The ecologically relevant salinity criterion for the Lower Peace River was two (2), five (5), and 15 psu. The recommended flow regime consisted of allowable percent flow reductions for three seasonal blocks to provide different minimum flows in spring, summer, and fall. A low-flow threshold was not recommended because no statistically significant relationship was found between salinity and biological criteria in either the Lower Peace River or Shell Creek.

The proposed MFL starts with a management goal to provide a "flow that results in no more than 15% reduction in the available habitat relative to the baseline flow condition." The methodology to meet this goal depends on linking assumptions, past practices, data analyses, and salinity models. The District starts with an assumption, that a 15% loss of habitat is acceptable as being protective. This assumption is not explored in the study, but it is based on previous practices. It is true that estuaries exist in a continuum from fresh water habitats to hypersaline habitats, and that alteration of flow levels simply shifts the state of the estuary. This fact implies that in order to determine the limit at which further withdrawals would be significantly harmful to the ecology of the area, the District must determine an acceptable loss of habitat with further withdrawals. Choosing 15% is that management decision. More importantly, the percent-of-flow reduction approach ensures that historical hydrology regimes will be maintained, but with some reduction in flow.

The data analyses and review of previous analyses appear reasonable, and from this the District has defined ecologically relevant salinity criteria to maintain integrity for fish, benthic invertebrates, and plants. The panel is not aware of any data that were excluded from analyses.

One important link in the assumptions is that flow effects are manifested by salinity, because of the dilution of salt water, and that salinity is the main factor affecting biological and ecological interactions. The District acknowledges that factors other than flow affect salinity, and the salinity model is employed to predict salinity under various flow regimens. Thus the critical linkage is: ecological responses > salinity criteria > modeled salinity-flow relationships > MFL recommendations. Error in any of these links will cause error in the end analysis and

[1] Southwest Florida Water Management District, Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek, Peer Review Draft, August 24, 2007.

recommendations. There are two weak links (i.e., sources of error): the variability of ecological responses to salinity, and the model of salinity-flow relationships. Whereas the salinity model predicts the cyclic nature of salinity patterns well, there is often a large gap between predicted and observed salinities. An improvement would be to perform error analyses so that uncertainty can be explored. Uncertainties of estimates that are products of other estimates can be very large, so the error analysis should explicitly derive the linked uncertainties.

Overall, the District is to be commended for preparing an excellent report that summarizes a large quantity of data and analyses, produced from many studies, into a document that is coherent and relatively easy to read. The supporting data and information used to develop the proposed MFL is technically sound. The data collection methods were appropriate, and used in an appropriate manner in all analyses. The District is also to be commended for voluntarily seeking peer review of its technical documents.

Scientific Peer Review of the Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek (LPRSC)

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 (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, a minimum flow is defined as "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.

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 (SWFWMD 2007). It is the job of the Peer Review Panel (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 and enhance the scientific basis that is firmly established for the decision-making process by the SWFWMD.

The scope of the review is to provide a written report that comments on the documents and other materials used to support the concepts and data presented in the Draft Report (SWFWMD 2007). The three members of the Panel (Montagna, Boyer, and Hodges) participated in a field reconnaissance of the LPRSC on Nov. 19, 2007 to view the aquatic habitats of this tidal river segment first hand. The scope also allows the panel to suggest additional data and/or approaches that might be incorporated into the process used for establishing minimum flows.

The process of analyzing minimum flows and levels for the LPRSC is built upon the analyses previously performed on the Upper Peace River (SWFWMD 2002) as peer reviewed by Gore et al. (2002) and the Middle Peace River (SWFWMD 2004) as peer reviewed by Shaw et al. (2005). The Panel also reviewed comments from the PRMRWSA HBMP Scientific Peer Review Panel to this proposed MFL as well as comments from the Charlotte Harbor National Estuary Program. Most useful was the District's clear, cogent, and consistent response to the varied comments of the PRMRWSA HBMP Scientific Peer Review Panel. Finally, the Panel had access to the Peace River Basin Resource Management Plan (FDEP 2007) and the Peace River Cumulative Impact Study (CIS) Final Report (PBS&J 2007) to further enrich their understanding of the regional ecosystem.

GENERAL COMMENTS

Overall, the District is to be commended for preparing an excellent report that summarizes a large quantity of data and analyses, produced from many studies, into a document that is coherent and relatively easy to read. This is no small task because of the legal, social, and economic constraints of recommending a resource use strategy on such a complex ecosystem. Many support the view that setting MFLs in rivers and estuaries is one of the most daunting tasks facing resource managers today. The District is also to be commended for voluntarily seeking peer review of its technical documents.

The supporting data and information used to develop the provisional MFL is technically sound. The data collection methods were appropriate, and used in an appropriate manner in all analyses. The panel was not tasked with conducting a detailed quality assurance audit although it appears from the report and supporting documents that, to the best of our knowledge, standard procedures and protocols were followed, and no indicators of concern were noted.

The panel is not aware of any data that were excluded from analyses. It is clearly evident that the data used for the development of the MFL was the best information available. Technical assumptions are inherent in data collection and analysis. Throughout the report, the District makes reasonable attempts to describe these assumptions. The approach that is most laden with assumptions is the hydrodynamic and conservative mass (i.e., salinity) transport model. Here again the assumptions appear to be based on the best information available.

Overall, the procedures and analyses are technically appropriate and reasonable, and based on the best information available. Given the large amount of data, previous peer review, and extensive public comment, a wide range of factors were incorporated into the District's analysis and are correctly applied.

The District has obviously paid close attention to the previous peer review of similar and/or related MFL determinations and learned from their recommendations. The most important point is that the District now has a clear management goal, which is widely supported among stakeholders in the community. The Management Goal, as stated in the MFL document, is: to provide a "flow that results in no more than 15% reduction in the available habitat relative to the baseline flow condition."

Overview of the logic behind the MFL

The MFL for the Lower Peace River (excluding Shell Creek) is built on a foundation of the following analyses:

1. The intersection between biogeographic zones and salinity zones is used to define biologically relevant salinity criteria and habitat assessment metrics.
2. A hydrodynamic model is used to predict the salinity regimes over the period 1996-1999 for a range of different flow reduction scenarios.
3. Cumulative Distribution Functions (CDF) for each scenario are used estimate the number of days that for which the Lower Peace River volume/area/shoreline length subject to

one of three different salinity conditions {< 2 ppt, <5 ppt, 8-16 ppt} during Block 1, 2 and 3 time periods, and with the further data subdivision into flows above (high flow) and below (low flow) the median flow.

4. The total area under the CDF curve for any flow reduction scenario is considered to represent the integrated time-space habitat for that salinity range.

5. The difference between the integrated time-space habitats (area under CDF) predicted by the hydrodynamic model under a reduced flow condition and the baseline (no reduction) condition is considered the habitat reduction associated with the flow reduction.

6. A 15% reduction in habitat is considered the maximum acceptable loss, so any flow rate that leads to less than a 15% loss (as predicted by the model) is acceptable.

For Shell Creek, the hydrodynamic model was replaced by a regression model using 1966-2004 data, but the analyses are otherwise the same

There are six questions that need to be answered for validation of the MFL:

1. Does the biological analyses support using salinity zones to define habitats?
2. Does the hydrodynamic model (or regression model) adequately predict the salinity regimes under a variety of flow rates for the purposes of the CDF analysis?
3. Are the divisions used (Blocks, low/high flow, salinity ranges) appropriate for the critical habitat?
4. Is the conflating of space and time in the CDF curve reasonable for habitat prediction?
5. Does the difference between the areas under the CDF curve reasonably predict the habitat loss expected?
6. Is a 15% measure of habitat loss appropriate and supported by the uncertainty of the method?

Overview of the peer review conclusions

Relative to the logic underlying the MFL (as enumerated above), we find that the overall procedures and scientific methods to be sound and using all available data. However, there are three principal deficiencies in the MFL:

1. The error in the hydrodynamic model predictions of salinities has not been adequately quantified, so the underlying physical foundations of the MFL are still open to question.
2. The relationship of the hydrodynamic model error to the error in the CDF curves has not been quantified.
3. There is no error analysis for the area of habitat lost. This error could be substantial because it is a compound function of biological-salinity relationship error, salinity-flow relationship error, and hydrodynamic model error.

SPECIFIC COMMENTS

Benthos response to flow
Starting with a conceptual model to define the factors controlling ecological integrity of the benthos community as it is affected by flow is an excellent idea. The District has summarized these factors in Figure 4-1, and the main sources are well covered. One small suggestion is to change “nutrients” to “nutrients/dissolved organic matter (DOM),” because we know that flows cause loading of DOM as well as inorganic matter. Depending on the source and quality of the DOM, the labile fraction of the dissolved organic carbon, nitrogen, and phosphorus may be rapidly remineralized to inorganic forms. Because of this, loading models must take the DOM pool into account because of the direct effects to primary production and further trophic interactions. The conceptual model is essentially a “bottom up” and thus lacks “top down” controls. For example, all of the physical factors driven by flow can affect predators of benthos, and thus there are trophic cascades that can account for benthic change in the absence of food or nutrient limitation. Typically, trophic cascades are thought of as indirect effects, and in this context all the processes listed in Figure 4-1 are direct effects.

A key concept presented is the coincidence between biogeographic zonesand salinity zones. The zones are introduced in section 4.4.1 and prior to this; Figure 4-3 lists zones. However, the figure caption and first mention of zones should state explicitly if these are salinity zones or biogeographic zones, and text is required to describe how this was determined. Assuming the zone definitions are from analyses performed here, then this should be listed in section 4.3 as well.

The statistical analyses of benthos are very well done, using standard parametric and non-parametric multivariate techniques to discover the relationship between benthos distribution and abiotic characteristics. There is a clear indication of salinity requirements for maintaining ecological integrity of benthos given in Figure 4-4, but a key to the colored lines (as given in Figure 5-11) would increase the value of this chart tremendously.

Fish response to flow

Statistical analysis of the fish data was a little less sophisticated than that of the benthos data, but still adequate to elucidate salinity-fish relationships and identify salinity zones needed to maintain ecological integrity of the fish community. But again, when zones are discussed, there needs to be a specific identification on whether these are salinity zones or biogeographic zones (especially in Figs. 5-7 – 5-10 and Table 5-4 – 5-5). Finally, on page 5-31, there is a switch to “salinity class.” What is the difference between a class and a zone? If none, then why is there a need for a parallel construction?

One of the most important analyses in the fish section is presented in Figures 5-11 and 5-12, because this analysis demonstrates a clear indication of salinity requirements for maintaining ecological integrity.

Water response to flow

One important detail that has an enormous impact on trying to perform error analysis is the large degree of variability in the relationship between salinity and flow (Figures 6-1 – 6-4). This is not unusual, and always leads to great uncertainty in the empirical statistical regressions.

Another important finding is that dissolved oxygen is not related to flow, which is unusual but important because it means that dissolved oxygen can be ignored when setting the MFL. However, caution must be taken because if substantial new withdrawals are approved and as flow is reduced in the future, this relationship could change due to the change in average residence time.

Assessment Metrics

Overall, the sections describing benthos, fish, and water, translate well into the biologically relevant salinities and habitat assessment tools, which translate to calculating the volume and bottom area of a salinity range under different flow scenarios.

Modeling inflow versus salinity

A key component of the MFL is to predict salinity under various flow regimes. This leads to a key question: Does the hydrodynamic model adequately predict the salinity regimes in the Lower Peace River under a variety of flow rates for the purposes of the CDF analysis?

The present report and appendices do not provide sufficient information to conclude that the hydrodynamic model is adequate for use with the CDF analysis; however, neither is there evidence that the modeling approach is fundamentally inadequate. The model itself is a state-of-the-art model that is appropriate to apply to the system. However, the present use to predict salinity regimes has not been adequately validated in the MFL (specifically in Appendix 7-2).

There are several issues of concern:

1. The study in Appendix 7-2 is cited as validating the salinity predictions, but is based on a prior study focused on using the model to estimate the Estuarine Residence Time (ERT). The validation of salinity was not a focus of the ERT study, and validation for ERT does not imply validation of the salinity predictions. In general, the model is quite good at representing the water surface elevations, and thus can be argued to be validated for the tracer modeling used to predict ERT, which is arguably a strong function of the tidal and river current fluxes (technically the “barotropic mode”) and only a weak function of salinity fluxes (i.e., the “baroclinic mode”). Unfortunately, the model results for predicting salinities are fairly poor (e.g., Figures C-3 to C-15 in Appendix 7-2), which brings into question the CDF results for salinity concentrations in volumes/areas/shoreline lengths. This appendix could be improved by providing a study focused on validating salinity predictions rather than general model validation for ERT.

2. In Appendix 7-2, the model and salinity field data have been compared in a qualitative manner as simple line graphs that show good agreement in the tidal oscillation (i.e., timing of peak/trough salinity), and very poor agreement in maximum/minimum salinities. One simple improvement to represent the error in Figures C1 – C15 is to graph the difference, i.e., the model minus the observed to demonstrate the scale and patterns of the residuals. The mean of such a graph should be zero (a non-zero mean indicates a bias in longer-term predictions). It would be interesting to see if the model over-predicts or under-predicts salinity in specific seasons, events, or time scales that might affect block and flow regime criteria.

3. There should be a quantitative statistical analysis of the model/field salinity agreement. For example, what is the overall error in salinity prediction and standard deviation? Does this error change significantly during different block/flow conditions? What are the errors in peak/trough salinities and standard deviation? How does this error change in block/flow conditions? The SWFWMD appears to have a significant amount of data that can provide a quantitative understanding of the model error magnitudes during the validation period of 2004. Performing a quantification of the error will provide greater confidence in the underlying model predictions.

4. With a quantitative understanding of the model error in the calibration/validation period (as suggested above), the SWFWMD should analyze the model/data error for the 1996-1999 data set and compare to the error in the 2004 data set. Although the 1996-99 data set is not complete enough or comprehensive enough for model calibration and validation, any available data from this time period can be used to compute model error and compare to the 2004 model error. This effort will provide confidence that the model runs of 1996-99 are sufficiently similar to the 2004 model runs such that subsequent analysis is valid.

5. The quantified error in the model (described above) should be used to estimate the uncertainty/error in the computation of CDF curves. Using a Monte-Carlo method of uncertainty analysis through multiple model runs is neither necessary nor practical. Indeed, unless the error analysis shows particular deficiencies in the previous model, we do not expect additional model runs should be necessary. However, using the quantification of salinity prediction error from the model validation runs, it should be possible to estimate how the error in salinity translates into an uncertainty in the volume/area/length of habitat at a particular range of salinity. This point is absolutely crucial: the MFL depends on a model-to-model comparison of salinity areas under baseline flow conditions and salinity areas under reduced flow conditions; thus, we must know whether the difference between the model results is larger than or smaller than the uncertainty in the model. With the present analysis, we have no evidence that the difference between the baseline and reduced flow conditions is principally a change in some form of model error, or reasonably reflects the actual change in salinity regimes. The approach to this analysis should be documented in an appendix.

The above points should be considered within the context of the 15% estimated habitat loss as a management goal. Recognizing that this 15% is a rough rule of thumb, the modeling should provide management with insight as to the habitat area uncertainty associated with the model predictions. We suggest that the model-produced CDF curves should be accompanied by lower/upper uncertainty bounds based on error quantification. Management should be able to understand whether or not the 15% habitat loss predicted by the model actually suggests a range of 10% to 20% or perhaps 5% to 25%. This information would give confidence in the robustness of the model predictions and analysis methods. It is also important that the managers should be apprised of any bias in the model that would result in a 15% estimate having a biased uncertainty range (e.g. a range of 12% to 30% when 15% is biased to the low side of habitat loss)

Recommendation for Shell Creek and Lower Peace River

We concur with the District's statement: "The greatest changes in flow related habitat and associated biota are believed to occur in those reaches likely to see the greatest changes in salinity, which are the tidal rivers…(A)ssessing freshwater inflows to the harbor is important, but the tidal rivers are more sensitive to potential impacts from freshwater flow reductions, and are the first places to look for significant harm." In addition, "withdrawals cannot cause a violation of established minimum flows and levels for any waterbody that would be affected. (A) withdrawal on the middle segment of the Peace River upstream of Arcadia…could not cause the minimum flow for the middle Peace River (segment between Zolfo Springs and Arcadia) or for the lower Peace River to be violated."

The minimum flows for Shell Creek are determined first, and the maximum withdrawals allowed are included in determination of the minimum flows for the Lower Peace River. While the sequence for establishing minimum flows in these two segments may have little effect on the reach above the confluence of Shell Creek with the Peace River, it is possible that different percentages may have been obtained within each block for the Lower Peace River and Shell Creek had the Lower Peace River MFL determination been made prior to that for Shell Creek, as was done in the report. The recommend assessment of flow reductions is based on individual salinity blocks of 0-2, 2-5, 5-15, psu etc. These salinity zones and blocks are justified based on the biological analyses.

A key assumption is that up to a 15% loss of estuarine habitat is a reasonable and protective management strategy. The District defends this assumption based on past practices and guidance from previous scientific reviews by saying that "changes in available habitat due to flow reductions occur along a continuum with few inflections or breakpoints where the response dramatically shifts. We have found that loss or reduction in a given metric occurs incrementally as flows decline, and in the absence of any clear statutory guidance, believe that the use of a 15% threshold for loss of habitat is 'reasonable and prudent (Shaw et al. 2005)' . . . In some cases, there is a fairly linear decrease with percent flow reduction… and in other cases the reduction is curvilinear… but in all cases there are no clear breakpoints." The review panel agrees with the stated reasons for this assumption.

The Panel expects that the District will have a difficult road ahead in that it must harmonize three separate MFL implementation plans into a coherent whole which will serve to protect, maintain, and even improve the physical, chemical, and biological components of the whole Peace River Estuary ecosystem. Our continued interest in further developments and resolutions is a given.

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MEMORANDUM

To: Marty Kelly
Date: April 3, 2008
From: Paul Montagna, Joe Boyer, and Ben Hodges
Re: Question regarding the Scientific Peer Review of the proposed Minimum Flows and Levels (MFLs) for the Lower Peace River and Shell Creek

Marty, in order for the panel to complete the review, we find that we are in need of some further information. We were wondering if you could help by providing answers to the following three main questions:

1) The assumption of a 15% loss of habitats appears arbitrary. How has the assumption that 15% loss of estuarine habitat is reasonable and protective been verified?

2) How is the sequence for establishing the MFLs for the Lower Peace River and Shell Creek relate to the Blocks (low/high flow, salinity ranges)? Does the order of establishing the MFL matter? Related to question 1, is a static assumption of 15% loss good for every block?

3) Does the hydrodynamic model adequately predict the salinity regimes in the Lower Peace River under a variety of flow rates for the purposes of the CDF analysis? This question might be best responded to by answering this series of questions:

a) How is the model validated? The verification studies in Appendix 7-2 focused on estimating Estuarine Residence Time (ERT) for a 2004 data set. However, verification for ERT does not imply verification of the salinity predictions, and does not act as a verification of the model for a 1996-99 data set. Because the model has been run for the 1996-99 data, it should be compared to the available 1996-99 field data for verification.

b) What is the uncertainty associated with the model predictions of salinity? How has it been used in the MFL to quantify the reliability of the volumes and areas used for the CDFs?

c) Can the change in the CDFs be shown to be principally related to the physics rather than the model itself? That is, does any field data shows that the changes in CDFs predicted by the model are fair representations of actual salinity regimes? And, through the use of CDFs does the District assume that high salinity over a small area for a long duration has the same biological effects as high salinity over a large area for a short time? These two types of phenomena appear to be indistinguishable within a CDF.

MEMORANDUM

To: Paul Montagna, Joe Boyer, and Ben Hodges

Date: April 10, 2008

From: Marty Kelly

Re: Response to: Question regarding the Scientific Peer Review of the proposed Minimum Flows and Levels (MFLs) for the Lower Peace River and Shell Creek

With the aid of District staff and Dr. Tony Janicki, I have attempted to respond to your recent request for additional information. For clarity, I have repeated your question, followed with our response in **bold**. Hopefully these responses will address your concerns.

1) The assumption of a 15% loss of habitats appears arbitrary. How has the assumption that 15% loss of estuarine habitat is reasonable and protective been verified?

Kemmerer (2000) as paraphrased in Pierson et al. (2002) has observed that, *"no matter how much flow is altered, there will be a functioning ecosystem in the estuary, so a decision has to be made on where in the continuum of "estuary—ness" people want it to be."* 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."* What constitutes "significant harm" was not defined. The District, after consideration of a recommendation by the peer review panel for the upper Peace River MFLs (Gore et al. 2002), has defined significant harm 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. Instead, loss of habitat in many cases occurs incrementally as flows

decline, often without a clear inflection point. 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 coastal rivers (estuarine reaches) in Australia. 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. The New South Wales EPA (2000), developed twelve coastal river flow objectives, among which were the following goals: 1) no water extractions from streams or wetlands during periods of no flow, 2) fully protect all very low flows (exceeded on 95% of days with flow), and 3) allocate to the environment, 50-70% of the flow in times of low flow (i.e., when the flow is exceeded on 80% of the days with flow). 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."*

In studies of both freshwater and estuarine systems, we have repeatedly observed that changes in available habitat due to flow reductions occur along a continuum with few inflections or breakpoints where the response dramatically shifts. We have found that loss or reduction in a given metric occurs incrementally as flows decline, and in the absence of any clear statutory guidance, believe that the use of a 15% threshold for loss of habitat is *"reasonable and prudent"* (see peer review by Shaw et al. 2005). The 15% threshold pertains to reductions in important habitats for the native biota, whether in freshwater or estuarine systems. In the Lower Peace River and Shell Creek, we concluded that reductions in the area, volume, and shoreline length of biologically relevant salinity zones would be the most relevant habitats we could assess with acceptable predictive capability.

A similar approach was used in the recently completed Alafia Estuary MFL document (Flannery et al. 2007), which was peer reviewed by Powell et al. (2008). This peer review panel concluded, *"A criteria of no more than a 15% change in any percentile of abundance, as compared to the estuary's baseline condition, was used as the threshold for 'significant harm.' While the use of 15% as a threshold is a management decision, the Panel agrees that this is a reasonable approach for avoiding the most serious negative impacts on the ecosystem."* Further, we believe this is consistent with Montagna et al. (2002) who noted*, "One of the strategies for choosing an indicator is looking for clear break points in ecosystem response to salinity or flow regimes to use as decision goals. While*

this is sometimes easy, in many instances there is simply a linear response to freshwater inflows". **Since, in our experience, clear break points are rarely found, we have used the 15% reduction in available habitat as a decision point.**

The District's use of the 15% criterion has been a point of discussion on both freshwater and estuarine MFLs, and we are open to methods that would allow us to test this criterion further. For example, the peer review panel who reviewed the proposed MFL for the Braden River (Cichra et al. 2007) commented, *"Arguments can and likely will be made for both lower and higher percentages of habitat loss to be used for defining significant harm. Other work has been done, in addition to the literature that is already cited, and the Panel believes it would be prudent to expand the literature review to gather as much additional supporting documentation as possible, much of which will be gray literature. Where lower or higher percentages have been used elsewhere, it would be illuminating to understand the rationale for these decisions (e.g., lower percentages used where imperiled or more sensitive species are concerned, higher percentages for more degraded systems, etc.)."* As a result of these comments and others regarding the testing of the 15% criterion, the District has undertaken two initiatives for freshwater river reaches: a comprehensive search of the primary and secondary literature related to this matter, and a field experimental flow diversion project (please see more detailed project descriptions that are appended).

The District's percent of flow approach (as explained by Flannery et al. 2002) is a unique aspect to permitting in that it ties withdrawals to ambient flow rates. The 15% criterion is used to determine the acceptable percentage withdrawal rates within this approach. Since available habitat is dynamic due to the constantly varying flow rate, we believe no fixed rate of withdrawal can mimic the natural flow regime as well as this approach which is constantly adjusted given existing conditions. It is our experience that most of the literature assumes that environmental flows will be applied to regulated systems or after extensive diversions have occurred with recommendations most often made in a *"bottom up"* approach as discussed by Arthington and Zalucki (1998). Our approach on unregulated rivers develops flow recommendations by replacing existing withdrawals to establish baseline conditions and simulating withdrawals until a significant harm threshold is crossed in a *"top down"* manner.

While it is reasonable to ask, "How has the assumption that 15% loss of estuarine habitat is reasonable and protective been verified?", a continuing review of the literature by District staff suggests that very few environmental flows on estuarine systems have actually been proposed and even fewer established. We conclude, as has Pierson et al. (2002) that, *"In spite of the significance of estuaries within catchment systems, studies of environmental flows to estuaries are relatively scarce."* Of those that have been done, it appears that the majority of work has been on systems already impacted well beyond what the District

would consider to be "significantly harmed" (e.g., San Francisco Bay, Murray-Darling, Nueces Bay, etc.).

2) How is the sequence for establishing the MFLs for the Lower Peace River and Shell Creek relate to the Blocks (low/high flow, salinity ranges)? Does the order of establishing the MFL matter? Related to question 1, is a static assumption of 15% loss good for every block?

As we understand the question, the sequence for establishing the MFLs was not related to the seasonal flow blocks. While the actual order of establishing the MFLs on the Lower Peace River and Shell Creek may have little effect on the reach of the river above the confluence of Shell Creek with the Peace River, it is possible that different percentages may have been obtained within each block for the Lower Peace River and Shell Creek had the Lower Peace River MFL determination been made prior to that for Shell Creek, as was done in the report. This point has been raised by staff of the Peace River Manasota Regional Water Supply Authority (PRMRWSA), and it would be relatively easy to evaluate this alternative strategy using the existing models.

The assumption of a 15% loss criterion in every block essentially preserves 85% of the baseline habitat within each block by integrating the results over space and time using the CDF approach. This approach was applied to low and high flows within each block, so that the integrated 15% habitat loss was applied separately to six different seasonal/hydrologic conditions. This was done to ensure that habitat losses greater than 15% did not occur within any season or flow condition. It should also be noted that a low flow threshold (90 cfs) was applied to the Lower Peace River determination, and that this would have the effect of essentially curtailing any withdrawals under the lowest flow conditions regardless of the block in which they occur.

3) Does the hydrodynamic model adequately predict the salinity regimes in the Lower Peace River under a variety of flow rates for the purposes of the CDF analysis? This question might be best responded to by answering this series of questions:

a) How is the model validated? The verification studies in Appendix 7-2 focused on estimating Estuarine Residence Time (ERT) for a 2004 data set. However, verification for ERT does not imply verification of the salinity predictions, and does not act as a verification of the model for a 1996-99 data set. Because the model has been run for the 1996-99 data, it should be compared to the available 1996-99 field data for verification.

The best data set available for the hydrodynamic modeling study was the real-time (15-minute) data collected at eight stations in Upper Charlotte Harbor, Lower Peace River, Shell Creek, and Lower Myakka River during a 13-month period

between June 13, 2003 and July 11, 2004. Because the first 30 days were used to spin up the model, the actual model calibration/verification was done for 12 months, from mid-July of 2003 to mid-July 2004. The model was first calibrated and then verified against measured real-time data of water levels, velocities, temperatures, and salinities at one UF station in the Charlotte Harbor, one USGS station in Shell Creek, three USGS stations in the Lower Peace River, and three USGS stations in the Lower Myakka River. Model calibration was done during a 3-month period between January 10 and April 9, 2004, while model verification was done during a 6-month period prior to January 10, 2004 and a 3-month period after April 9, 2004. Comparisons of simulated salinities with field data are presented in the appendix report. As an example, Figures C-11 and C-12 in the report are included here to show that verification of the salinity prediction was indeed conducted in the study. The ERT results presented in the report were not for the purpose of model verification. They were simply a by-product of the model simulation. No ERT data were available for model verification.

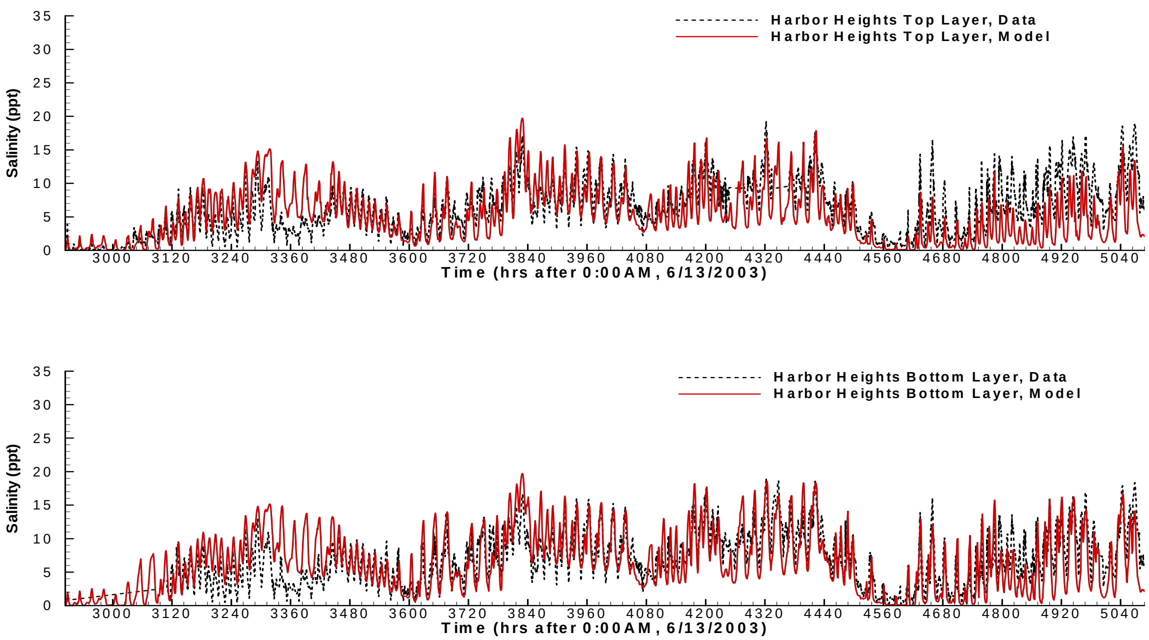
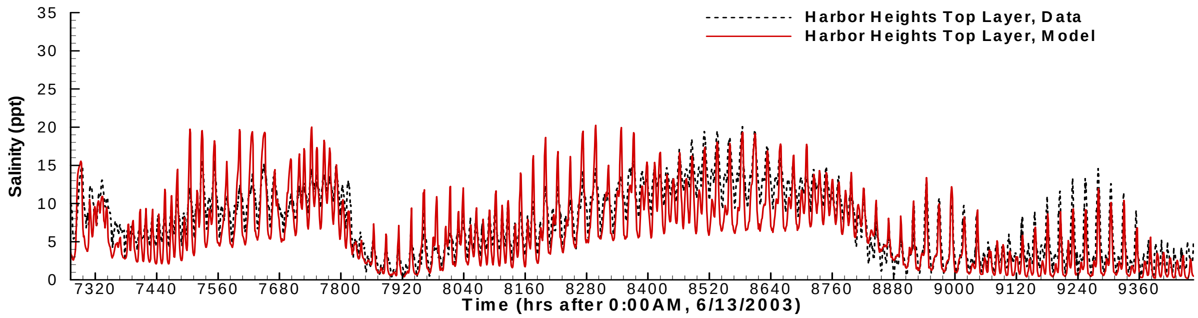


Figure C- 1 Comparisons of simulated and measured salinities at two depths at the Harbor Heights station during October 11, 2003 – January 9, 2004.



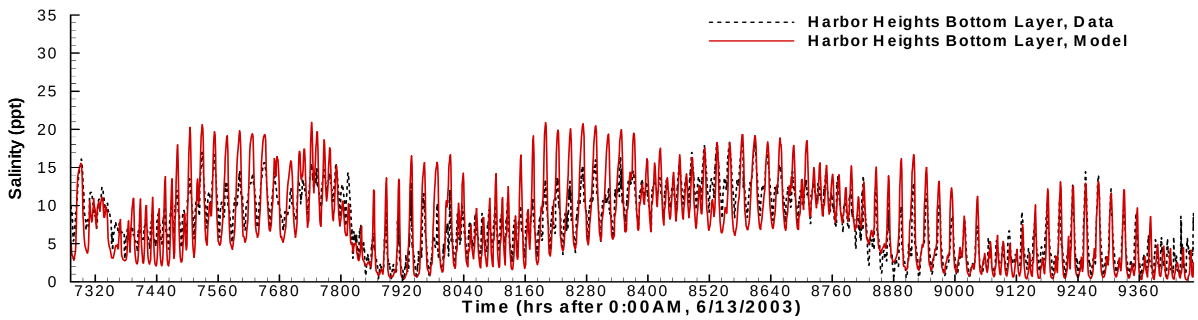


Figure C- 2 Comparisons of simulated and measured salinities at two depths at the Harbor Heights station during April 10 - July 11, 2004.

It is true that the model was not verified against the 1996 – 1999 data set. We understand that it would be preferable if model results were compared with the 1996 -1999 data for verification, as the model has been run for the 1996 – 1999 data. Unfortunately, the available1996 – 1999 data set is not suitable for this kind of model calibration/verification, since only a limited amount of real-time data were collected at two upper reach stations in the Lower Peace River and one Shell Creek station for portions of the four-year period. A complete real-time data set that is suitable for model calibration and verification was not available prior to 2003. The reason for using the 1996 – 1999 period is that the flow data during this period were very similar to that of the long-term flow record for the Lower Peace River based on a comparison of cumulative distribution function plots. Although the flow data during June 2003 - July 2004 may have a different CDF curve from that of 1996 – 1999, they do encompass a critical range of flow variation that determines the salinity values in the Lower Peace River and Shell Creek. Based on inspection of the flow data, it can be seen that the entire Peace River is essentially fresh when flow at the Arcadia gage is greater than ~5000 cfs. On the other hand, salinity at the Peace River Heights station is generally fresh unless the Arcadia flow drops below 200 cfs. During mid-June 2003 through mid-July 2004, Arcadia flow varied between 93 cfs and 10700 cfs, while during 1996 – 1999, Arcadia flow varied between 33 cfs and 18500 cfs. Therefore, the 1996 – 1999 data has a wider range of flow variation in comparison to the 2003 – 2004 flow data,

especially at the high flow end. As mentioned in the report, the model generally performs well when it is not too wet or too dry; however, it under-predicts salinity during the wet days of the first verification period and slightly over-predicts salinity during the driest days of the second verification period. Because the under-prediction of salinity during the wet days only occurred at stations downstream of the LPR and Shell Creek, it did not affect the salinity prediction for the LPR and Shell Creek, as both water bodies were all fresh during these days. The slight over-prediction of salinity during the direst days may to some extent affect the final CDFs in the report, which are likely more conservative than they should be. Please keep in mind that the LPR MFL has a low flow cutoff of 90 cfs. As a result, the slight over-prediction of salinity during the driest days of the year does not have much effect on the final determination of MFL for the LPR.

b) What is the uncertainty associated with the model predictions of salinity? How has it been used in the MFL to quantify the reliability of the volumes and areas used for the CDFs?

Given the complexity of the model and the simulation domain, a detailed analysis of the uncertainty associated with the model prediction of salinity was not feasible within the time frame of this modeling study, because such an uncertainty analysis (UA) involves a Monte Carlo simulation that often requires hundreds, if not thousands, of model runs. It would take a year or two to conduct an UA, because it takes about 20 hours of cpu time to run a 12-month simulation. As mentioned in the report, there are many uncertainties in the input data (bathymetry, gauged flows, un-gauged flows, wind, downstream boundary conditions, etc.) and calibration data (water levels, velocities, salinities, and temperatures). All these uncertainties can contribute to the final uncertainty in the simulated salinity results, although some may have more significant effects on salinity than the others. In addition, the model itself (e.g., some of the assumptions used in the model, uncertainties of some model parameters, etc.) and the way it is applied to the LPR-LMR-UCH system (e.g., the special resolution, inclusion of some of the small braches, etc.) also contribute certain degree of uncertainty to the predictions of salinity.

Without conducting a detailed UA, we can gain an understanding of the relative uncertainty of salinity predictions by comparing simulated salinity results with field data during the verification periods. It can be seen form the comparisons made in the report that the model performed reasonably well in predicting salinities in the LPR and Shell Creek under most conditions. Although some over-predictions or under-predictions are evident, they are generally within an acceptable range for LPR and Shell Creek stations. This means that even with the many aforementioned uncertainties that contribute to the final uncertainty of the salinity prediction, the error of salinity prediction is within an acceptable range, indicating that the uncertainty range of salinity prediction in the LPR and Shell,

although not quantified, appears to be not large. Furthermore, because we compared the volume and area CDFs of scenario runs with those of the baseline (historical) model run, not with the actual volume and area CDFs calculated from field data (they are not available), the CDF differences have a much smaller uncertainty range than that of the salinity prediction. It might be helpful to note the observation of the peer review panel that reviewed Alafia River Estuary MFL (Powell et al. 2008), "Although the salinity validation is not extremely good, the Panel believes that the manner in which the model is used in the MFL analysis negates this issue. In other words, the model wasn't used to predict absolute values of salinity without error, but rather was used to simulate salinity differences due to changes in the freshwater inflows. In this case, changes in water volume and bottom area for ranges of salinity (e.g., < 1 psu, < 6 psu and < 15 psu) were computed as a function of freshwater inflows. These model results were then used by the District to define and support the recommended MFL's operating rules for river management that do not allow changes in water volume and bottom area for the target salinity ranges to be reduced by more than 15%, the point at which larger reductions could cause 'significant harm' to living resources under Florida statutes."

c) Can the change in the CDFs be shown to be principally related to the physics rather than the model itself? That is, does any field data shows that the changes in CDFs predicted by the model are fair representations of actual salinity regimes? And, through the use of CDFs does the District assume that high salinity over a small area for a long duration has the same biological effects as high salinity over a large area for a short time? These two types of phenomena appear to be indistinguishable within a CDF.

The empirical data available to create Cumulative Distribution Function (CDF) plots of salinity for the Lower Peace River and Shell Creek are extremely limited. Therefore, any CDF plots would have a great deal of uncertainty and would not provide for a meaningful comparison with the CDF plots that were created from model output.

As discussed in the response to question 3) a) above, the model output was used to estimate the relative change and the amount of habitat that is available in a defined salinity regime. The utility of the CDF plot is the ability to quantify the temporal and spatial extent of a particular salinity regime in a single plot. Therefore, habitat availability is expressed in terms of both space and time. To develop the CDF curves, every day of each simulation was assigned to a block (based on the day of the year) and a flow condition (based on whether the flow was above or below the median for the block in the Baseline Scenario). Therefore, the same days were compared for each block and flow condition regardless of the scenario that was being analyzed. The CDF curves were

developed by calculating the amount of available habitat in a given Block and flow condition for each day, for each scenario. As discussed in the text on page 8-2, the estimate of habitat loss for a given scenario when compared to the Baseline Scenario was calculated as the area between the two curves (Figure 8-1). Therefore, looking at the area between the two curves, it is possible to determine where the largest differences occur.

The District does not and would certainly not intentionally assume that high salinity over a small area for a long time has the same biological effects as high salinity over a large area for a short time. The CDF plots presented are either for a water volume, bottom area or shoreline length in or exposed to a given salinity range (e.g., <5 ppt), and the comparison of scenario runs (see for example, Figure 7-15) against the baseline tells you essentially the duration within a sub-block (e.g., Block 1 above the median Block flow) that this volume was maintained. Please keep in mind that the water year has essentially been divided into 6 sub-blocks based on season and natural flow conditions (high or low) within a season. For example, referring to the top panel in Figure 7-15 on page 7-26 of our report, without withdrawals (baseline) there is approximately 4 million cubic meters of < 5ppt water present at least 80% of the time and about 9 million cubic meters present 20% of the time. Using this same Figure (7-15) and reducing flows by 30% within this sub-block, there would be approximately 2.5 million cubic meters of < 5 ppt water present 80% of the time, and 4 million cubic meters would now be present 74% of the time. On the other end of the scale, we would expect to find in this sub-block, about 8.6 million cubic meters of water 20% of the time, instead of the 9.0 million cubic meters that would be present in the absence of withdrawals.

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Literature Review and Analysis Related to Significant Harm Criterion - In response to a peer review recommendations stemming from the review of proposed MFLs for the Upper Hillsborough and Braden Rivers staff has retained a consultant (a former peer review panel member) to conduct a recommended review of the relevant literature (both primary and secondary sources) related to the District's use of a 15% reduction in available habitat as a criterion for defining "significant harm."

ATTACHMENT A

SCOPE OF WORK AND DELIVERABLES, COMPENSATION AND EXPENSES SCHEDULE

I. INTRODUCTION

The Southwest Florida Water Management District (hereinafter referred to as the “DISTRICT”) is presently involved in the development of methods and rules for the establishment and implementation of minimum flows and levels (MFLs) for certain priority water bodies of the DISTRICT and is undertaking such effort as required by Sections 373.042 and 373.0421 of the Florida Statutes.

Services and deliverables to be provided by ____ a private corporation, whose address is _____, hereinafter referred to as the "CONSULTANT", in connection with MFL methods and rules development. Compensation for these services and deliverables is described in Section IV.

II. BACKGROUND

Chapter 373, Florida Statutes, directs the DISTRICT to develop minimum flows for watercourses within its boundaries according to a Board adopted priority schedule.

> A minimum flow is the flow of a watercourse below which further water withdrawals will cause significant harm to the water resources or ecology of the area.

The law also provides that MFLs shall be calculated using the <u>best available</u> information, that the Governing Board shall consider and may provide for nonconsumptive uses in the establishment of MFLs, and when appropriate, MFLs may be calculated to reflect seasonal variation. Revised in 1997, the law currently requires that when establishing MFLs, changes and structural alterations to watersheds, surface waters and aquifers shall also be considered (Section 373.0421, Florida Statutes). Current State Water Policy (Chapter 62-40, Florida Administrative Code) includes additional guidance for the establishment of MFLs, providing that “ . . . consideration shall be given to the protection of water resources, natural seasonal fluctuations in water flows and levels, and environmental values associated with coastal, estuarine, aquatic, and wetland ecology, including:

(a) Recreation, in and on the water;

(b) Fish and wildlife habitats and the passage of fish;
(c) Estuarine resources;
(d) Transfer of detrital material;
(e) Maintenance of freshwater storage and supply;
(f) Aesthetic and scenic attributes;
(g) Filtration and absorption of nutrients and other pollutants;
(h) Sediment loads;
(i) Water quality; and
(j) Navigation."

III. DESCRIPTION OF SERVICES

The DISTRICT is committed to developing scientifically defensible methodologies to be used in the establishment of minimum flows on priority watercourses within its boundaries, and the achievement and maintenance of such flows and levels. The DISTRICT has developed and continues to improve methodologies for the establishment of MFLs in freshwater river segments and in their estuarine reaches. An often applied "significant harm" criterion is "a no greater than 15% decline in available habitat." Available habitat has been quantified in several different ways (*e.g.*, no more than a 15% decrease in fish habitat for selected species as determined by use of the Physical Habitat Simulation Model or no greater than a 15% reduction in the volume of water within a given salinity zone). Recent peer review reports concerning the proposed minimum flows and levels for the Upper Hillsborough (Cichra *et al.* 2007a) and Braden (Cichra 2007b) Rivers have commented, "Arguments can and likely will be made for both lower and higher percentages of habitat loss to be used for defining significant harm. Other work has been done, in addition to the literature that is already cited, and the Panel believes it would be prudent to expand the literature review to gather as much additional supporting documentation as possible, much of which will be gray literature. Where lower or higher percentages have been used elsewhere, it would be illuminating to understand the rationale for these decisions (*e.g.*, lower percentages used where imperiled or more sensitive species are concerned, higher percentages for more degraded systems, etc.)."

Specific Areas of Assistance

The CONSULTANT is expected to complete the following tasks necessary to complete a thorough review of the literature where minimum flows and levels or environmental flows have been adopted or proposed.

Task 1. Compile and summarize all relevant literature to include primary literature sources (journal articles, books, book chapters) and "gray literature" (generally government agency reports or presentation abstracts) that addresses the quantitative establishment of minimum flows and levels also referred to as environmental flows. It is expected that the CONSULTANT will provide the DISTRICT a copy (preferably in a digital format) of all literature included in the review.

It is expected that literature presenting proposed or adopted environmental flows will in many cases not be expressed in units that will permit a direct comparison to flows as proposed by the District. In these cases, the CONSULTANT will need to use best efforts to convert or express flows in a comparable format. It some cases, it may be necessary to obtain actual flow data and make the appropriate conversion / interpretations that will make such comparisons possible. This is a significant task beyond that normally associated with a literature review, and it is expected that considerable effort will be needed to complete this task. DISTRICT staff will assist the CONSULTANT to the extent possible in the analysis and interpretation of results as requested by the CONSULTANT.

Task 2. Produce quarterly reports documenting the literature reviewed to date, and any particularly pertinent documents that are readily comparable or convertible to the DISTRICT's approach. It is anticipated that no more than three quarterly reports will be submitted. In addition to quarterly reports, the CONSULTANT may request payment on Task 1 on a percent complete basis.

Task 3. Produce a final, comprehensive review document summarizing all relevant results, and the CONSULTANT's assessment of the comparability of results. This product is specially directed to the establishment of MFLs on freshwater systems; however, relevant estuarine work should be cited if applicable. It is anticipated that a draft of the final report will be delivered to the DISTRICT no later than twelve months after receipt of this purchase order. The DISTRICT will have one month to review the document and provide comments to the CONSULTANT for consideration. The CONSULTANT will deliver the final report to the DISTRICT in electronic format (preferably Microsoft® Word) as well as copies of all literature cited in the review within two months of receiving the DISTRICT's comments on the draft report.

MFL Stream Diversion and Assessment Project – District staff have included in their proposed FY2009 budget a project to quantify to the extent possible the effect of diverting flows from a river reach consistent with quantifiable reductions in habitat. It is envisioned that a series of percent flow or habitat reductions will be evaluated and response of the benthic and fish communities quantified over time. It is also envisioned that such a project will take several years to accomplish as noted below.

Project Form

Edit Close

Project Number	B273
Project Name	MFL Stream Diversion and Assessment Project
Project Manager	Morales, Jon
Task Managers	
Basins	Alafia River , Hillsborough River , Northwest Hillsborough , Coastal Rivers , Pinellas-Anclote River , Withlacoochee River , Peace River , Manasota
AORs	Water Supply (50%), Natural Systems (50%)
PIMS Programs	
Cooperator	

Description

To further validate existing stream Minimum Flows and Levels (MFL) methodology consistent with peer review recommendation. A frequent focus of criticism of the MFL methodology applied by the District to rivers and estuaries is the use of a 15 percent habitat loss criterion as a threshold for assessing "significant harm." Quoting from the peer review of the Braden River MFL, the panel noted:

" The draft report describes the metrics used to define *the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area* as stated in Florida statutes. The authors note that significant harm was not defined in statute. The District chose to interpret significant harm as the loss of flows associated with fish passage and maximization of stream bottom habitat with the least amount of flow and quantifiable reductions in habitat. Overall, this is a reasonable approach from an ecological perspective and likely satisfies the intent of the statute. The authors state that, *[in] 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.* The authors further note, in our opinion, correctly, that *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 flow decline, often without a clear inflection point or threshold.* Nevertheless, the 15% habitat loss criterion remains one of the least rigorous, most subjective aspects of the District's approach to setting MFLs. Justification for this threshold is based on common professional practice in interpreting the results of

PHABSIM analyses (Gore at al. 2002), a review of relevant literature where reported percentage changes ranged from 10 to 33%, and on previous peer reviews that found the 15% threshold to be reasonable and prudent, especially given the absence of clear guidance in the statute or in the scientific literature on levels of change that would constitute significant harm (e.g., Shaw et al. 2005). The draft upper Braden report continues the District's practice of using a 15% change in habitat availability as the threshold for defining significant harm and now applies this threshold broadly to include both spatial and temporal loss of habitat or connectivity. The Panel again acknowledges that the use of this criterion is rational and pragmatic, but also recognizes that the specific value of 15% is subjective and has only modest validation or support from the primary literature. . . . . More importantly, however, is the need for the District to commit the resources necessary to validate the presumption, that a 15% decrease in spatial or temporal habitat availability or a 15% increase in violations of the low-flow threshold, does not cause significant harm. "

This project represents the best means for validating the effect that a given flow reduction has on available habitat and the biota of a stream segment. District staff proposes to locate an acceptable stream segment in order to conduct controlled diversions from a defined stream segment in order to evaluate the impact that a range of flow and habitat reductions has on the biota (e.g., fishes, macroinvertebrates) and water resource values. It is envisioned that such a project will require a number of years to complete (possibly a decade), and an annual commitment of significant resources to accomplish.

Benefits If implemented, this project will provide as definitive a test of the 15 percent habitat loss criterion as is practical under field conditions, and the results will be widely applicable to stream assessments and the development of environmental flows though out the country.

Costs Total requested funding in FY2009 is $150,000. The Basin Board's contribution is one half of the $150,000 total, or $75,000, with the remaining $75,000 to be funded by the Governing Board. A small amount has been budgeted for parts and supplies and travel.

Additional Info

Budget

Timelines

Status Update 2/29/2008

This is a newly introduced project, and staff is still in the planning stages regarding its implementation. Current activities related to this project involve literature searches and draft outlines of project scope for discussion and refinement. Staff intends to come up with a more realistic project milestone list in time for the next PIMS update.

Hydrodynamic Simulations of the Lower Peace River – Lower Myakka River – Upper Charlotte Harbor System in Support of Determining Minimum Flows for the LPR and LMR in Southwest Florida

XinJian Chen, Ph.D., P.E.

Ecological Evaluation Section
Resource Projects Department

Southwest Florida
Water Management District

August 2008

Summary

In an effort to determine the regulatory minimum freshwater inflows to the Lower Peace River (LPR) and the Lower Myakka River (LMR), a sophisticated hydrodynamic model has been developed that simulates circulations, salt transport processes, and thermal dynamics in a simulation domain that comprises not only the LPR and LMR, but also the upper portion of the Charlotte Harbor (UCH) and Shell Creek. The numerical model developed for this complex LPR - LMR - UCH system is a coupled 3D – 2DV model named LESS that dynamically links a laterally averaged two-dimensional hydrodynamic model (LAMFE) with a three-dimensional hydrodynamic model (LESS3D).

Model simulations were conducted for a 13-month period from June 13, 2003 to July 11, 2004, during which the first 30 days of the simulation (June 13 – July 12, 2003) were used for model spin-up. Data used to drive the model included measured freshwater inflows at upstream boundaries, wind speed near the mouth of the Myakka River in UCH, meteorological data (rain, solar radiation, air temperature, air humidity) at an SWFWMD SCADA station near the Peace River/Manasota Regional Water Supply Authority, estimated un-gauged flows, and the downstream boundary conditions of tides, salinity, and temperature which were simulated results of another model simulation effort that included the entire Charlotte Harbor and a coastal area extending almost 45 km off-shore.

The LESS model was calibrated and verified against measured real-time data at a total of eight stations inside the simulation domain, including a University of Florida (UF) station in UCH, a USGS station in Shell Creek, three USGS stations in the LPR, and three USGS stations in the LMR. Model calibration was conducted for a 3-month period between January 10 and April 9, 2004, while the verification of the model was done for a 6-month period between July 13, 2003 and January 9, 2004 and a 3-month period between April 10 and July 11, 2004.

After the model was calibrated and verified, it was used to evaluate estuarine residence times for 16 flow scenarios for the LPR. It was found that the estuarine residence time (ERT) in the LPR is related to the sum of gauged USGS flows (Q) in the Joshua Creek, the Horse Creek, and in the Peace River at the Arcadia station through a power function, with its coefficient and exponent depending on what percentage (L) of remaining conservative mass is used in defining the ERT. An analysis of the estuarine residence times using different L values in the 16 flow scenario runs demonstrated that ERT in the LPR can be expressed as a function of Q and L in the following form: $ERT = [1747.3 - 375.53\ln(L)]Q^{-(0.54+0.00088L)}$.

The calibrated model was then used to evaluate minimum flows for both the LPR and LMR, in conjunction with the minimum flow evaluation of the Shell Creek. Various flow reduction scenarios were simulated for a 4-year period from January 1999 to December 2002 for the determination of the minimum flows for the LPR and the LMR.

1. Introduction

The Peace and Myakka Rivers (Figure 1) are major tributaries to Charlotte Harbor, one of the largest estuaries in Florida and identified by the US Environmental Protection Agency as an estuary with national significance. The Peace River is approximately 120 km long and runs southwestward into the northeast portion of the Charlotte Harbor, while the Myakka River is about 106 km long and flows first southwestward and then southeastward into the northwest portion of the Charlotte Harbor. The entire Peace River watershed is about 6213 km^2. The most downstream segment of the Peace River, from Arcadia to the mouth, is the Lower Peace River (LPR) and is about 58 km long. About 84% of the Peace River watershed is gauged by the United States Geological Survey (USGS) at the Peace River at Arcadia station and in two tributaries downstream of Arcadia: Joshua and Horse Creeks (SWFWMD, 2001). The remaining 16% of the Peace River watershed is un-gauged with unknown freshwater contribution to the Charlotte Harbor. The Lower Peace River is generally narrow and meandering, except for areas near the mouth where the river becomes wider with islands. The majority of the 58 km long Lower Peace River is tidally influenced, and the tidal limit extends to roughly 50 km upstream from the mouth.

The Lower Myakka River (LMR) is about 40 km long and begins at the downstream side of Lower Myakka Lake (Downs' Dam) in the Myakka River State Park. The Myakka River watershed is approximately 608 km^2. Only about 50% of the Myakka River watershed is gauged at the USGS Myakka River near Sarasota station and a few tributary stations downstream of Downs' Dam, and thus about half of the watershed is un-gauged. Similar to the Peace River, the Myakka River is also narrow and meandering except for its very downstream portion where the river is wider and has several islands. The entire Lower Myakka River is tidally influenced as tides can reach to the base of Downs' Dam.

Although they are often treated as three individual water bodies, the LPR, LMR, and the UCH are interconnected with different degrees of interactions among them. On one hand, the LPR and LMR provide the UCH freshwater inflows that are ecologically critical for the health of the harbor. On the other hand, hydrodynamics and salinity in the UCH play a very important role in keeping the ecosystems of the LPR and LMR in balance as both rivers are tidally influenced. Tides and salinity transport in the downstream estuary directly affect habitat distributions in both rivers. To manage the water resources and protect the ecosystems of the LPR and LMR, it is important to understand the hydraulic interactions among the LPR, the LMR, and the UCH. As such, it is necessary to develop a numerical model that can provide detailed information of circulations and salinity and temperature distributions in all three segments of the LPR - LMR - UCH system with the same degree of accuracy.

Because the flow pattern in Charlotte Harbor is generally three-dimensional, a 3D hydrodynamic model is needed to accurately simulate hydrodynamics in the estuary. To include the Lower Peace River and the Lower Manatee River in the simulation, one can extend the 3D model domain upstream to cover the entire reach of the LPR and LMR. However, this way of including the tributary in the simulation is not very efficient. In addition, it is also difficult to correctly represent the cross section of the LPR and LMR in a 3D model because only limited number of grids (usually five or less grids, sometimes just one grid) are used to discretize the width of the river (e.g., Johnson et al, 1991; Sucsy et al, 1997; Mendelsohn et al, 1997). For example, it is impossible to accurately resolve the cross section shown in Figure 2 with just three grids in the latitudinal direction of the tributary (perpendicular to the tributary).

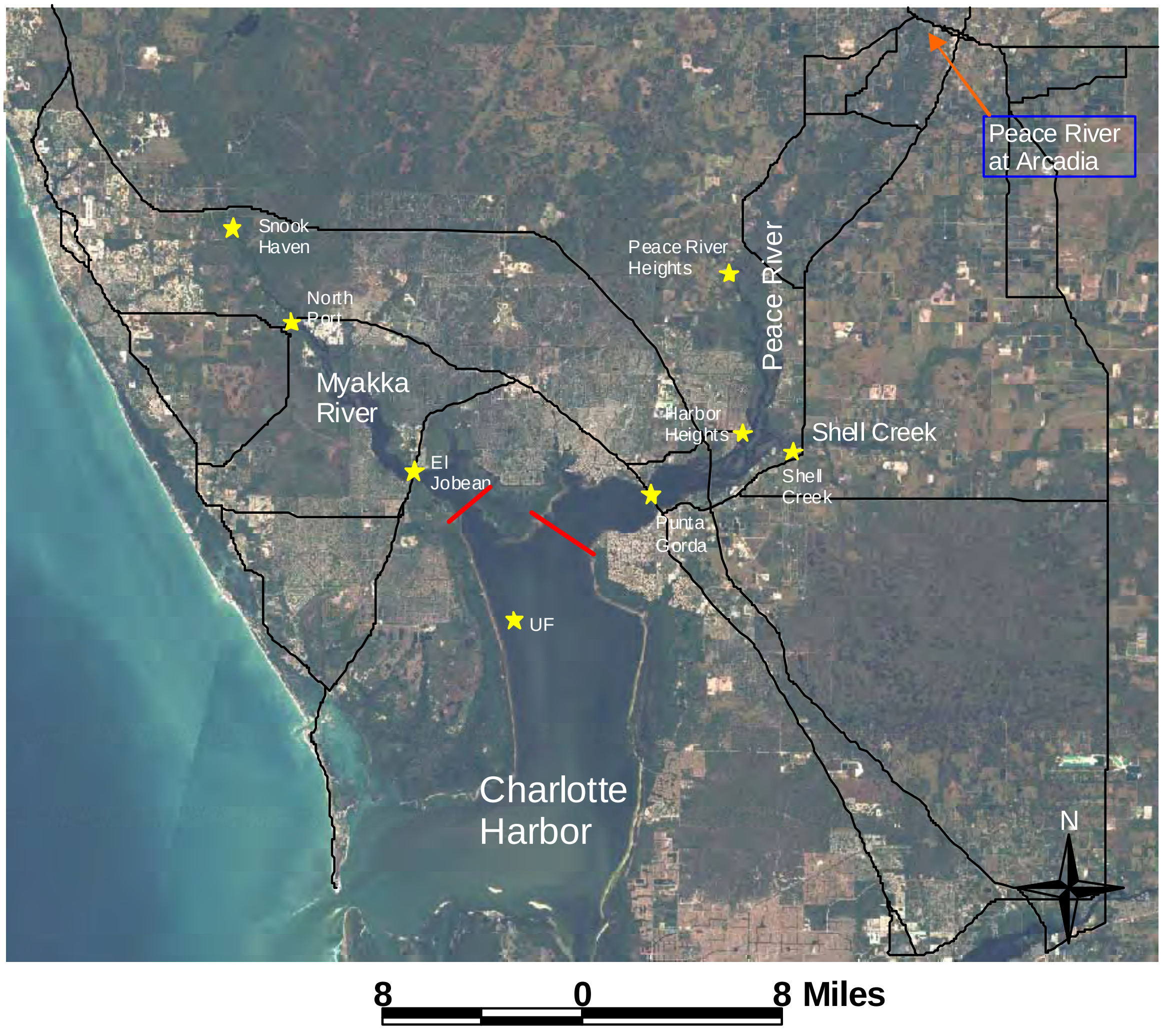


Figure 1 An aerial photo of the LPR - LMR - UCH system. Yellow stars denote real-time data collection sites. The two red bars are the locations of the starting points (River Kilometer 0) for the Peace and Myakka River estuaries.

Although the flow pattern in upper Charlotte Harbor is three-dimensional, the flow pattern is generally vertically two-dimensional in most segments of the LPR and LMR because the rivers are narrow. It is much more efficient to use a laterally averaged 2D (2DV) model for the narrow and meandering portions of the LPR and LMR than to use a 3D model. With enough number of vertical layers (generally eight or more), a 2DV model resolves the bathymetry of a tributary better than a 3D model that has only a limited number of grids in the latitudinal direction. Also, a 2DV model automatically handles the wetting/drying phenomenon in the tributary, while a 3D model require more computational effort to deal with the temporal shoreline change in the narrow and meandering tributary. The cross section shown in Figure 2 is quite typical in the narrow portions of the LPR and LMR. As can be seen from the figure, the cross section is comprised of a main channel and two flood plains on both sides of the river.

While the main channel can be very narrow, in the order of 10 – 20 m, the flood plain can be a few kilometers wide. When flow is low, water only exists in the main channel. However, during a major storm event, the flood plains will be submerged and used for flood conveyance. For a better understanding of the river system, it is critical to accurately simulate emerging/submerging flood plain features. In this circumstance, one needs information about the total flow rate and water elevation, not the detailed velocity distribution in the narrow portions of the LPR and LMR. It is much harder for a 3D model to handle these river areas. The emerging/submerging feature of the cross section can be automatically simulated in a laterally averaged 2D model without any special treatment often required in a 3D model simply because the river width is included in the governing equations for the 2DV model (see Section 3).

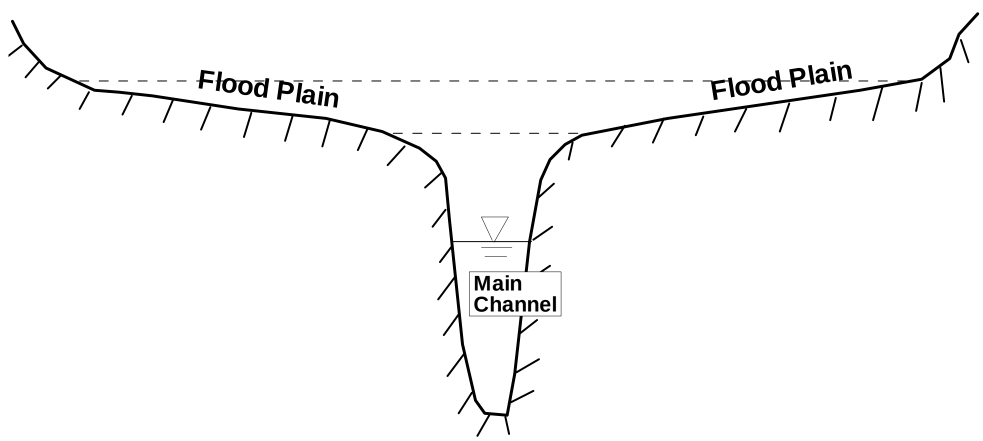


Figure 2. A typical cross section of the narrow part of the Peace (or Myakka) River. It is comprised of a main channel and flood plains on both sides. Most of the time, flow is restricted to the main channel. During a major storm event, the flood plains can be submerged to convey the flood.

The most effective way to simulate the interactions among the upper Charlotte Harbor and the Lower Peace and Myakka Rivers is to use a coupled 3D-2DV model. For this purpose, this study developed and used a dynamically coupled 3D-2DV model to simulate hydrodynamics in the Lower Peace River – Lower Manatee River - Upper Charlotte Harbor system. In the following sections, a dynamically coupled 3D-2DV hydrodynamic model developed for the LPR – LMR - UCH system is briefly presented, followed by a description of available field data used by the model as boundary conditions and for model calibration/ verification. The use of the coupled model to simulate hydrodynamics in the LPR – LMR – UCH system is then described. Model results are presented and discussed before conclusions are drawn.

2. A Dynamically Coupled 3D-2DV Model

The coupled 3D-2DV model (Chen, 2003c, 2005a, 2007) involves a dynamic, two-way coupling of the laterally averaged 2D hydrodynamic model LAMFE (Chen and Flannery, 1997; Chen et al., 2000; Chen, 2003a and 2004a) and the 3D hydrodynamic model LESS3D (Chen, 1999, 2003b, 2004b). In the LAMFE model, the following governing equations are solved:

$$\frac{\partial ub}{\partial x} + \frac{\partial wb}{\partial z} = v \tag{1}$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + w\frac{\partial u}{\partial z} = -\frac{\tau_{wx}}{\rho_o b} - g\frac{\partial \eta}{\partial x} - \frac{g}{\rho_o}\int_z^\eta \frac{\partial \rho}{\partial x} d\zeta + \frac{1}{b}\frac{\partial}{\partial x}(bA_h\frac{\partial u}{\partial x}) + \frac{1}{b}\frac{\partial}{\partial z}(bA_v\frac{\partial}{\partial z}) \tag{2}$$

$$b\frac{\partial c}{\partial t} + \frac{\partial ubc}{\partial x} + \frac{\partial wbc}{\partial z} = \frac{\partial}{\partial x}(bB_h\frac{\partial c}{\partial x}) + \frac{\partial}{\partial z}(bB_v\frac{\partial c}{\partial z}) + vc_t + S_s \tag{3}$$

where t is time; x is the horizontal coordinate along the river/estuary, z is the vertical coordinate, u and w denote velocity components in x- and z-directions, respectively; v is the lateral velocity from lateral inputs (sheet flow of direct runoff, tributary, etc.); b, p, g, and η denote the width, pressure, gravity acceleration, and the free surface elevation, respectively; ρ_o is the reference density; τ_{wx} represents the shear stress due to the friction acting on the side wall (= $\rho C_w u[u^2+w^2]^{1/2}$, where C_w is a non-dimensional frictional coefficient for side walls); A_h and A_v are eddy viscosities in the x- and z-directions, respectively; c is concentration (can be temperature, salinity, suspended sediment concentrations, nutrient concentrations, etc.); c_t is concentration in lateral inputs; B_h and B_v are eddy diffusivities in the x- and z-directions, respectively; S_s denotes source/sink terms; and ρ is density which is a function of salinity and temperature (UNESCO, 1983). In the above transport equation, if the material simulated involves settling, w in the advective term includes the settling velocity of the material.

In the LESS3D model, the governing equations are

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \tag{4}$$

$$\frac{\partial u}{\partial t} + \frac{\partial uu}{\partial x} + \frac{\partial vu}{\partial y} + \frac{\partial wu}{\partial z} = fv - \frac{1}{\rho_o}\frac{\partial p}{\partial x} + \frac{\partial}{\partial x}(A_h\frac{\partial u}{\partial x}) + \frac{\partial}{\partial y}(A_h\frac{\partial u}{\partial y}) + \frac{\partial}{\partial z}(A_v\frac{\partial u}{\partial z})$$

$$\frac{\partial v}{\partial t} + \frac{\partial uv}{\partial x} + \frac{\partial vv}{\partial y} + \frac{\partial wv}{\partial z} = -fu - \frac{1}{\rho_o}\frac{\partial p}{\partial y} + \frac{\partial}{\partial x}(A_h\frac{\partial v}{\partial x}) + \frac{\partial}{\partial y}(A_h\frac{\partial v}{\partial y}) + \frac{\partial}{\partial z}(A_v\frac{\partial v}{\partial z}) \tag{5}$$

$$p = g\int_z^\eta \rho d\zeta \tag{6}$$

$$\frac{\partial c}{\partial t} + \frac{\partial uc}{\partial x} + \frac{\partial vc}{\partial y} + \frac{\partial wc}{\partial z} = \frac{\partial}{\partial x}(B_h\frac{\partial c}{\partial x}) + \frac{\partial}{\partial y}(B_h\frac{\partial c}{\partial y}) + \frac{\partial}{\partial z}(B_v\frac{\partial c}{\partial z}) + S_s \tag{7}$$

where x, y, and z are Cartesian coordinates (x is from west to east, y is from south to north, and z

is vertical pointing upward); *u*, *v*, and *w* are velocities in the *x*-, *y*-, and, *z*-directions, respectively; *f* denotes Coriolis parameter; and A_h and A_v represent horizontal and vertical eddy viscosities, respectively; and B_h and B_v are horizontal and vertical eddy diffusivities, respectively. Again, if the material simulated in Equation (7) involves settling, *w* in the advective term includes the settling velocity of the material.

Both the LAMFE and LESS3D models use a semi-implicit scheme called the free-surface correction (FSC) method (Chen, 2003a, 2003b) to solve the governing equations. The FSC method is a very efficient scheme that is unconditionally stable with respect to gravity waves, wind and bottom shear stresses, and vertical eddy viscosity terms. The FSC method in the 2DV model involves the solution of the following FSC equation

$$\mathbf{r}\Delta\boldsymbol{\eta}_{2DV} = \Delta\boldsymbol{\eta}^*_{2DV} \tag{8}$$

where $\Delta\boldsymbol{\eta}_{2DV}$ and $\Delta\boldsymbol{\eta}^*_{2DV}$ are respectively the final and intermediate surface elevation changes over the time step Δt in the 2DV domain

$$\begin{aligned} \Delta\boldsymbol{\eta}_{2DV} &= [\Delta\eta_1 \quad \Delta\eta_2 \quad . \quad . \quad . \quad \Delta\eta_{N-1} \quad \Delta\eta_N\ ]^{\mathrm{T}} \\ \Delta\boldsymbol{\eta}^*_{2DV} &= [\Delta\eta^*_1 \quad \Delta\eta^*_2 \quad . \quad . \quad . \quad \Delta\eta^*_{N-1} \quad \Delta\eta^*_N\ ]^{\mathrm{T}} \end{aligned} \tag{9}$$

and r is a sparse matrix that can be split into two parts: $\mathbf{r} = \mathbf{r}_0 + \mathbf{r}'$. The first part is a three-diagonal matrix

$$\mathbf{r} = \begin{bmatrix} r_{11} & r_{12} & & & & & \\ r_{21} & r_{22} & r_{23} & & & & \\ & . & . & . & & & \\ & & . & . & . & & \\ & & & . & . & . & \\ & & & & r_{(N-1)(N-2)} & r_{(N-1)(N-1)} & r_{(N-1)N} \\ & & & & . & r_{N(N-1)} & r_{NN} \end{bmatrix} \tag{10}$$

where $r_{i(i-1)} = -R_i^w$, $r_{i(i+1)} = -R_i^e$, $r_{ii} = 1 - r_{i(i-1)} - r_{i(i+1)}$, R_i^w and R_i^e are simply functions of the cross-sectional area and the grid size, and N is the total number of grids in the 2DV domain. The second part ($\mathbf{r}'$) is a very sparse matrix in which only several rows representing connections among the main river stem and its branches have one or two non-zero elements locating outside the three-diagonal block.

In the FSC method for the 3D model, the FSC equation is as follows

$$\mathbf{q}\Delta\boldsymbol{\eta}_{3D} = \Delta\boldsymbol{\eta}^*_{3D} \tag{11}$$

where $\Delta\boldsymbol{\eta}_{3D}$ and $\Delta\boldsymbol{\eta}^*_{3D}$ are respectively the final and intermediate surface elevation changes over the time step Δt in the 3D domain

$$\begin{aligned} \Delta\boldsymbol{\eta}_{3D} &= [\Delta\eta_1 \quad \Delta\eta_2 \quad . \quad . \quad . \quad \Delta\eta_{M-1} \quad \Delta\eta_M\ ]^{\mathrm{T}} \\ \Delta\boldsymbol{\eta}^*_{3D} &= [\Delta\eta^*_1 \quad \Delta\eta^*_2 \quad . \quad . \quad . \quad \Delta\eta^*_{M-1} \quad \Delta\eta^*_M\ ]^{\mathrm{T}} \end{aligned} \tag{12}$$

and

$$
\mathbf{q} = \begin{bmatrix}
q_{11} & q_{12} & & & & q_{1(L+1)} & & & & \\
q_{21} & q_{22} & q_{23} & & & & q_{2(L+2)} & & & \\
 & . & . & . & & & & . & & \\
 & & . & . & . & & & & . & \\
 & & & . & . & . & & & & \\
. & & & & . & . & . & & & \\
 & . & & & & . & . & . & & \\
 & & q_{(M-1)(M-L-1)} & & & & q_{(M-1)(M-2)} & q_{(M-1)(M-1)} & q_{(M-1)M} & \\
 & & & q_{M(M-L)} & & & & q_{M(M-1)} & q_{MM} &
\end{bmatrix} \qquad (13)
$$

where $q_{l(l-L)} = -R^{s}_{i,j}$, $q_{l(l-1)} = -R^{w}_{i,j}$, $q_{l(l+1)} = -R^{e}_{i,j}$, $q_{l(l+L)} = -R^{n}_{i,j}$, $q_{ll} = 1 - q_{l(l-L)} - q_{l(l-1)} - q_{l(l+1)} - q_{l(l+L)}$, $R^{s}_{i,j}$, $R^{w}_{i,j}$, $R^{e}_{i,j}, R^{n}_{i,j}$ are functions of the total side area of the grid cell and the grid sizes in *x*- and *y*-directions, and M is the total number of grids in the 3D domain.

Equation (13) is a five-diagonal matrix and can be saved in five 1D arrays. However, because a rectilinear grid model often involves many land grids that are not included in the computation, it is more efficient to compress the matrix, so that it only contains those grids that have water in them. If it is assumed that only m grids in the 3D domain have water in them, then renumbering these 3D grids will result in a new and compressed matrix (let us call it $\mathbf{q}'$) of order m×m, which sometimes could be much smaller than the original size of in Equation (13).

The compressed form of Equation (13) takes the following form

$$\mathbf{q}' \Delta\boldsymbol{\eta}'_{3D} = \Delta\boldsymbol{\eta}'^{*}_{3D} \qquad (14)$$

where $\Delta\boldsymbol{\eta}'_{3D}$ and $\Delta\boldsymbol{\eta}'^{*}_{3D}$ are compressed forms of $\Delta\boldsymbol{\eta}_{3D}$ and $\Delta\boldsymbol{\eta}^{*}_{3D}$, respectively.

By numbering all grids that possess water in the 3D together with 2DV grids, Equations (8) and (14) can be merged together as follows

$$\begin{bmatrix} \mathbf{q}' & \mathbf{p} \\ \mathbf{s} & \mathbf{r} \end{bmatrix} \begin{bmatrix} \Delta\boldsymbol{\eta}'_{3D} \\ \Delta\boldsymbol{\eta}_{2DV} \end{bmatrix} = \begin{bmatrix} \Delta\boldsymbol{\eta}'^{*}_{3D} \\ \Delta\boldsymbol{\eta}^{*}_{2DV} \end{bmatrix} \qquad (15)$$

Where $\mathbf{p}$ and $\mathbf{s}$ are rectangular matrices of orders m×N and N×m, respectively. They are needed to ensure a proper modeling of the two-way interaction between the 3D and 2DV domains. Both $\mathbf{p}$ and $\mathbf{s}$ only have a limited number of non-zero elements. In fact, the number of non-zero elements in $\mathbf{p}$ and $\mathbf{s}$ is the same as the number of grids that are connected to the 2DV domain (Chen, 2005a).

The sparse matrix system shown in Equation (15) is similar to those in Equations (8) and (14). It has a three-diagonal block with each row having a maximum of one non-zero element on each side of the three diagonals. Equation (15) is solved using the bi-conjugate gradient method of Van der Vorst (1992). After Equation (15) is solved, the final free surface location is found for the entire simulation area, including both the 3D and 2DV domains.

Final velocities at the new time step are calculated after the final free surface elevations in both the 3D and 2DV domains are found. The transport equations are then solved to update distributions of simulated constituents (salinity, temperature, suspended sediment concentration etc.). Details on the numerical schemes for calculating velocities and concentrations can be found in Chen (2003a, 2003b, and 2007).

3. Field Data

This section presents field data used in modeling hydrodynamics and salinity and thermal transport processes in the LPR – LMR - UCH system. As will be described in the next section, the simulation period is a 13-month period from the middle of June 2003 to the middle of July 2004. As such, the focus of the section is only on measured field data during this 13-month period.

Flow Data

Freshwater inflows are critical to the health of an estuary, as they directly affect salinity distributions in the estuary. The purpose of the hydrodynamic simulation of the LPR – LMR - UCH system is to use a hydrodynamic model to find the relationship between freshwater inflows and salinity distributions in the system, so that minimum freshwater inflows for the LPR and LMR can be determined to prevent the two riverine estuaries from significant harms. Therefore, flow data are the most important piece of information needed in every step of the process of determining minimum flows, including the hydrodynamic modeling.

The USGS has been gauging flow rates at several locations in the Peace and Myakka River watersheds for many years. These USGS stations include (1) Peace River at Arcadia (02296750), (2) Joshua Creek at Nocatee (02297100), (3) Horse Creek near Arcadia (02297310), (4) Shell Creek near Punta Gorda (02298202), (5) Big Slough Canal at Tropicaire (02299450), (6) Myakka River near Sarasota (02298830), (7) Deer Prairie Slough near Myakka City (02299060), and (8) Blackburn Canal near Venice (02299692). The gauged USGS flow data were used, either directly or indirectly, as freshwater inputs to the hydrodynamic model described in the next section. In addition to gauged USGS flows, there are also un-gauged flows that contribute a significant portion of the total freshwater budget to the upper Charlotte Harbor. As mentioned before, for the Peace River watershed, the un-gauged area is about 16% of the total watershed, while for the Myakka River, about one half of the watershed is un-gauged. In this study, freshwater flows from the un-gauged sub-basins of the watershed were estimated by Ross et al (2005) using the Hydrological Simulation Program - FORTRAN (HSPF) (Bicknell, 1997). Some of the USGS gauge stations are located at the boundary of the simulation domain of the HSPF model, and gauged flow rates at these stations were used as boundary fluxes in the HSPF model.

Figure 3 shows flow data gauged during the 13-month period from June 2003 to July 2004 at four locations on the Peace River side of the watershed, including Peace River at Arcadia (black solid line), Horse Creek (green solid line), Joshua Creek (red solid line), and Shell Creek (blue solid line). Also shown in the figure is the withdrawal (black dashed line) from the Peace River by the Peace River/Manasota Regional Water Supply Authority. The withdrawal point of the regional water supply authority is located roughly 3.5 km upstream of USGS Peace River Heights station (Figure 1). Withdrawal by the City of Punta Gorda from the upstream of the Shell Creek dam is included in the Shell Creek flow shown in the figure. Figure 4 shows gauged flow rates at the USGS Myakka River near Sarasota station (black solid line) and the USGS Myakkahatchee (Big Slough Canal) at North Port station (blue solid line). The black dashed line shown in Figure 4 is the flow in the Blackburn Canal that connects the Donna/Roberts Bay on the Florida Gulf Coast to the Myakka River at about 3.8 km upstream of the USGS Myakka

River at Snook Haven station. The period of available gauged flow data for the Blackburn Canal at the time of this modeling study was a 209-day period from March 6, 2004 to September 30, 2004. It was found that water in the Blackburn Canal can flow either to or away from the Myakka River, depending on the water levels in the Myakka River and in the Dona/Roberts Bay. Although it drains the Myakka River most of the time, the Blackburn Canal occasionally flows to Myakka River. Figure 5 is a plot of the flow leaving Myakka River through the Blackburn Canal versus the Myakka River flow gauged at the USGS Myakka River near Sarasota station during March 6 – September 30, 2004. From the figure, it can be seen that the two flow rates are fairly correlated. Therefore, water leaving the Myakka River through Blackburn Canal can be roughly estimated using the following equations:

$$\begin{aligned} Q_b &= 0.057Q_m, & Q_m &\le 457 \\ Q_b &= 0.169Q_m - 51.184, & Q_m &> 457 \end{aligned} \qquad (16)$$

where Q_b (in cfs) is the flow rate that drains Myakka River through the Blackburn Canal, and Q_m (in cfs) is the Myakka River flow at the USGS station near Sarasota. The units in the above equation are cubic feet per second. It should be noted that the above equation only estimates flow leaving the Myakka River, as Q_b calculated from in the equation is always positive. From the available Blackburn Canal flow data shown in Figure 5, the negative flow rate is generally very small in magnitude (≤ 2.2 cfs) and occurs only infrequently. Recently, as more data became available, Intera, Inc. (personnel communication) related Blackburn Canal flow with water stage data collected at the USGS Myakka River near Sarasota station when working on Dona/Roberts Bay. With 491 days of Blackburn Canal data (5/6/2004 – 2/4/2006), they found that the rate of water leaving the Myakka River through Blackburn Canal can be expressed as

$$\begin{aligned} Q_b &= 3.981089h_m - 4.58861, & h_m &< 6.5 \\ Q_b &= 129.7358h_m - 846.14, & h_m &\ge 6.5 \end{aligned} \qquad (17)$$

where h_m is measured water level (in ft, NGVD 29) measured at the Myakka River near Sarasota station.

Equations (16) and (17) provide two methods for estimating the Blackburn Canal flow. Although both equations only use measured data at the Myakka River near Sarasota station, not the head difference between Myakka River and Dona/Roberts Bay, to estimate flow, they both work well except for peak values during major storm events. Heyl (2008, personnel communication) used both equations to predict Blackburn Canal flow. It was found that comparing to available data during the 491-day period between May 6, 2004 and February 4, 2006, both equations generated similar flow rates. However, during several major storm events prior to 5/6/2004, Equation (17) yields much smaller peak flows than Equation (16). Because there are no measured Blackburn Canal flows available during these major events, it can not be determined if Equation (17) under-predicts the flow or Equation (16) over-predicts the flow. Intuitively, Equation (17) is expected to give a smaller peak value because it gives a linear relationship between flow and stage, which is not true for most natural streams.

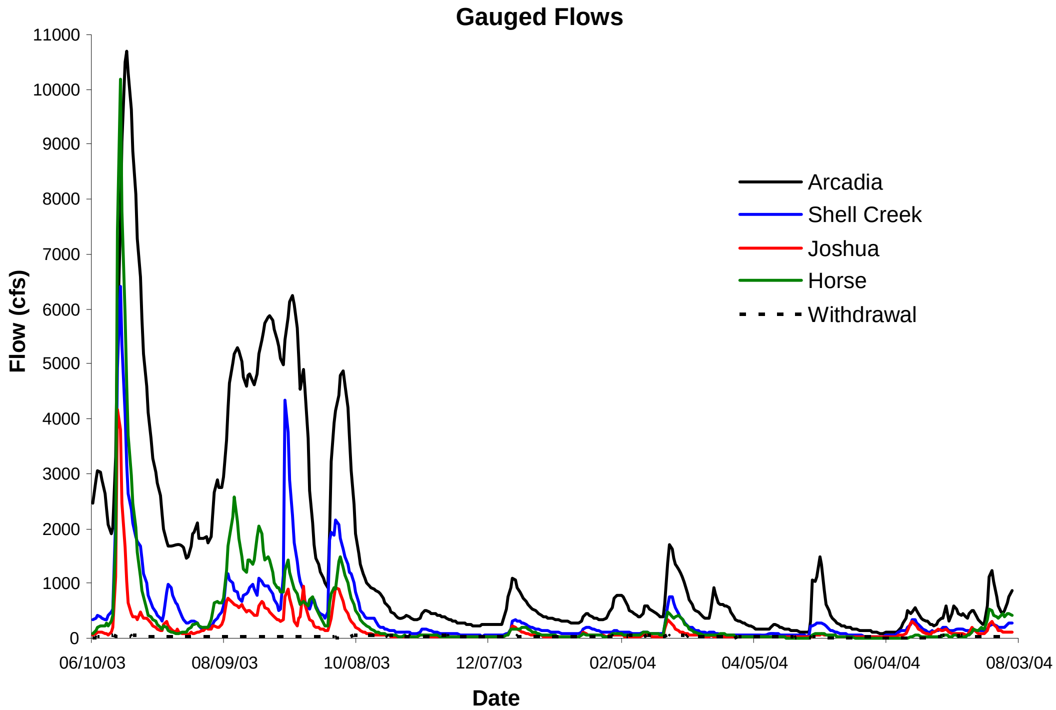


Figure 3. Gauged flow rates on the Peace River side, including USGS gauges at Arcadia, Joshua, Horse, and Shell Creek. The withdrawal by the Peace River/Manasota Regional Water Supply Authority is also shown.

From Figures 3 and 4, several things can be quickly discerned. First, during the 13-month period, the LPR – LMR - UCH received the majority of its freshwater inflows during a 100-day period from June 20, 2003 to the end of September 2003. Second, all gauged flows have their highest peaks around June 24, 2003, with Arcadia, Horse and Myakka flows having similar peak values larger than 10,000 cfs. Rainfall data collected at a SWFWMD rain station close to the Peace River/Manasota Regional Water Supply Authority (Figure 6) indicated that a major storm event passed through the region and delivered about 10 inches of rain during a 3-day period on June 20 - 22, 2003. It is interesting to note that although the Horse Creek and the Myakka River near Sarasota stations gauge much smaller areas than that of the Peace River Arcadia station, they had almost the same peak discharge as the Arcadia station. This might be caused by a relatively low surface water yield with significant buffer areas in the upstream portion of the Peace River watershed after a long dry period. A closer examination of the flow data measured at these stations revealed that the time of concentration for the Arcadia station is much longer than those at the Horse Creek and the Myakka River near Sarasota stations.

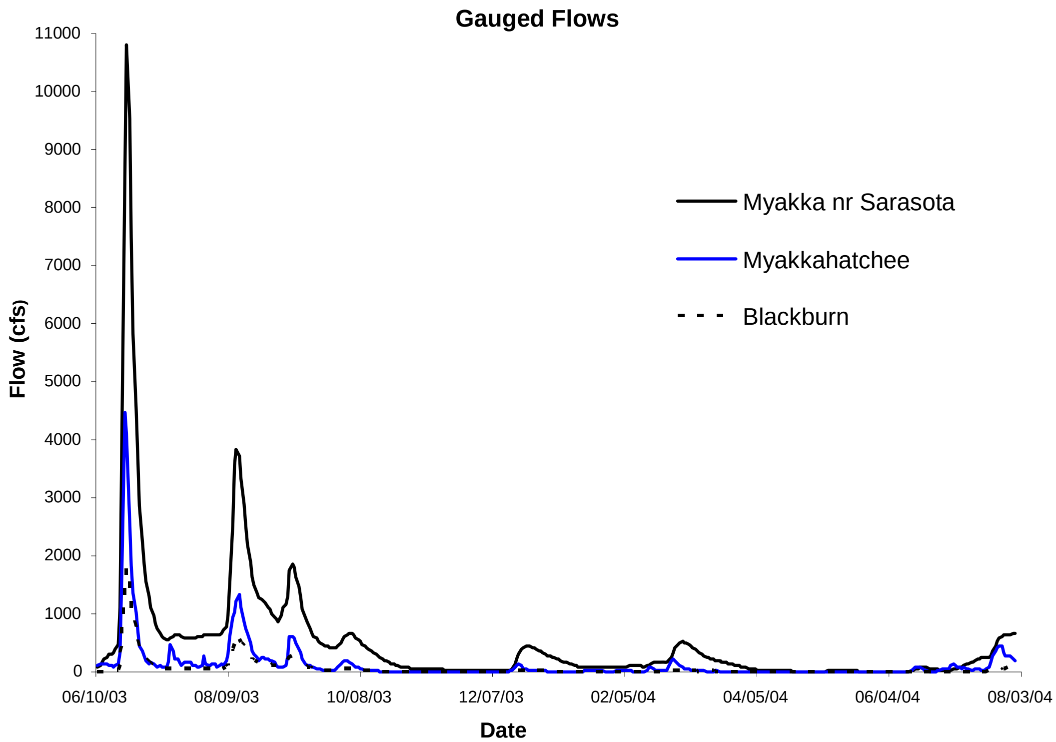


Figure 4. Gauged flow rates on the Peace River, including USGS gauges at Arcadia, Joshua, Horse, and Shell Creek. The withdrawal of the Peace River/Manasota Regional Water Supply Authority is also shown.

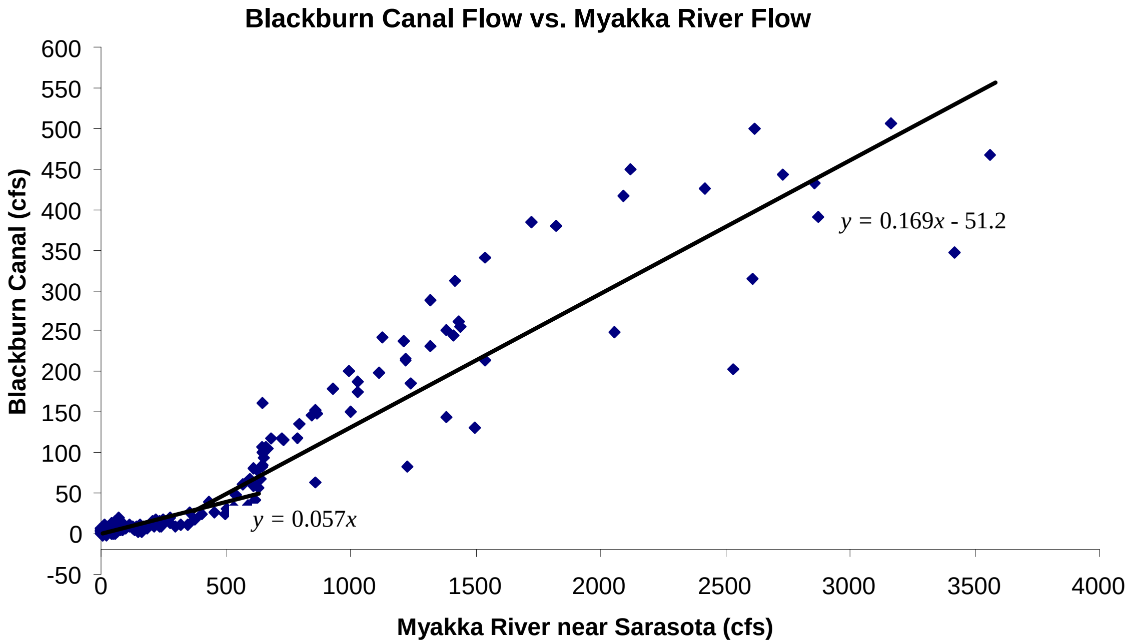


Figure 5. Blackburn Canal flow versus Myakka River flow gauged at the USGS station near Sarasota. Positive Blackburn Canal flow leaves the Myakka River.

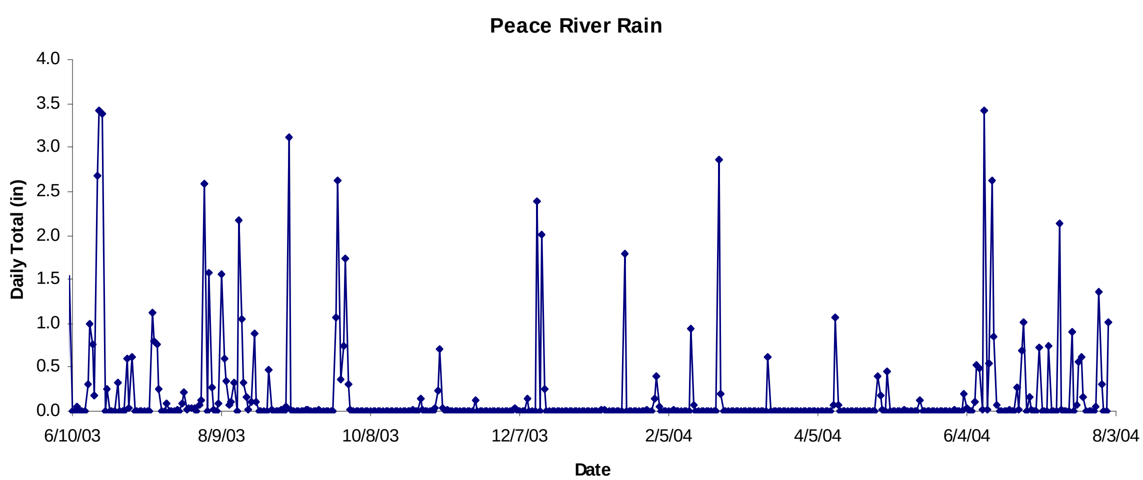


Figure 6. Daily rainfall total measured at a location close to the Peace River/Manasota Regional Water Supply Authority

Water Level, Salinity, Temperature, and Velocity

Real-time data of water level, salinity, and temperature were collected by the University of Florida (UF) and the USGS at the several fixed stations noted with stars in Figure 1. These stations included (1) UF station in the upper Charlotte Harbor near the mouth of the Myakka River, (2) USGS Peace River at Punta Gorda (02298300), (3) USGS Peace River at Harbor

Heights (02297460), (4) USGS Peace River at Peace River Heights, (5) USGS Myakka River at El Jobean (02299496), (6) USGS Myakka River at North Port (02299230), (7) USGS Myakka River at Snook Haven (02298955), and (8) USGS Shell Creek Tidal near Punta Gorda (02298208). The USGS real-time data were collected using a 15 minute time interval, while the UF data had a 30 minute time interval. For salinity and temperature, data were collected at three water depths at the UF station, but only at two depths at the USGS stations. Table 1 lists elevations of the salinity and temperature sensors at all eight stations.

Real-Time Measurement Stations	Sensors	Elevations (ft, NGVD29)
UF in the UCH	Top Middle Bottom	-1.31 -4.14 -7.4
Punta Gorda	Top Bottom	-1.1 -8.0
Harbor Height	Top Bottom	-1.0 -3.0
Peace River Heights	Top Bottom	-1.0 -3.0
El Jobean	Top Bottom	-2.0 -8.0
North Port	Top Bottom	-2.5 -10.0
Snook Haven	Top Bottom	-0.85 -6.0
Shell Creak	Top Bottom	-1.0 -3.0

Table 1. Elevations of salinity/temperature sensors at eight stations in the LPR - LMR - UCH system. Units in the table are ft, NGVD29.

Figure 7 shows measured water levels during a 14-month period from June 2003 to July 2004 at the Punta Gorda, Harbor Heights, Peace River Heights, Shell Creek Tidal (for simplicity, this station is also called Shell Creek hereafter), El Jobean, North Port, Snook Haven, and UF stations. Water levels at all eight stations have strong tidal signals that are mainly semi-diurnal tides with a range of 50 – 60 cm. Unlike downstream stations, upstream stations in both the LPR (Peace River Heights and Harbor Heights) and the LMR (Snook Haven and North Port) recorded considerable water level increases caused by major storm events occurred in 2003 as the tributaries are narrow in these areas. For the downstream stations, including Punta Gorda, El Jobean, and UF stations, although measured water level data do not contain distinctive storm signals, it does appear that average water levels were higher in the wet season than in the dry season. Of course, this kind of seasonal variation in water level is not only caused by storm events, but also caused by other factors, such as the general wind pattern, loop current in the Gulf of Mexico, and the seasonal water temperature variation.

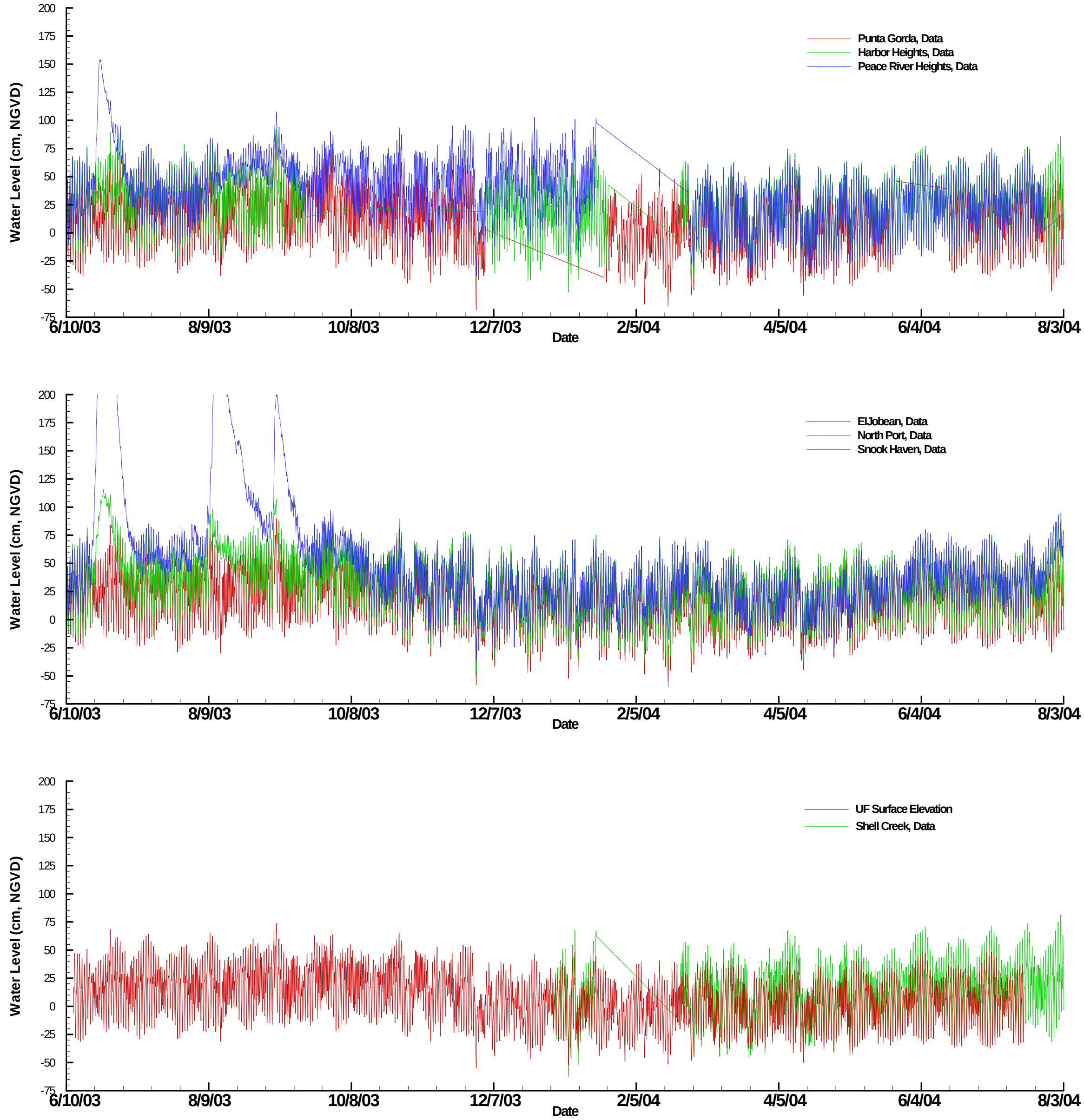


Figure 7. Measured water levels during June 2003 through July 2004 at three Lower Peace River stations (top graph), three Lower Myakka River stations (middle graph), one Shell Creek station (bottom graph), and one Upper Charlotte Harbor station (bottom graph).

Figure 8 shows top- and bottom–layer salinity time series measured at the three LPR stations, while Figure 9 presents top- and bottom–layer salinity time series measured at the three LMR stations. Measured salinity time series in Shell Creek and the UF station in the Upper Charlotte Harbor are plotted in Figure 10. Generally speaking, the vertical salinity stratification is not very strong for upstream narrow channels in the LPR – LMR - UCH system. Measured top- and bottom layer salinities were almost the same for Peace River Heights, Harbor Heights, Shell Creek, North Port, and Snook Haven. The three downstream stations (UF, El Jobean, and

Punta Gorda) did show some vertical salinity stratification, especially during time periods when there were major storm events. The horizontal salinity gradients along the LPR and LMR are quite evident with the salt wedge located between the Punta Gorda and Harbor Heights stations in the LPR and between the El Jobean and North Port stations in the LMR during the wet season. The salt wedge migrated upstream during the dry season and passed the Harbor Heights and North Port stations in the LPR and LMR, respectively. During the driest time period of the year 2004, the salt edge moved passed the Peace River Heights station in the LPR and the Snook Haven station in the LMR.

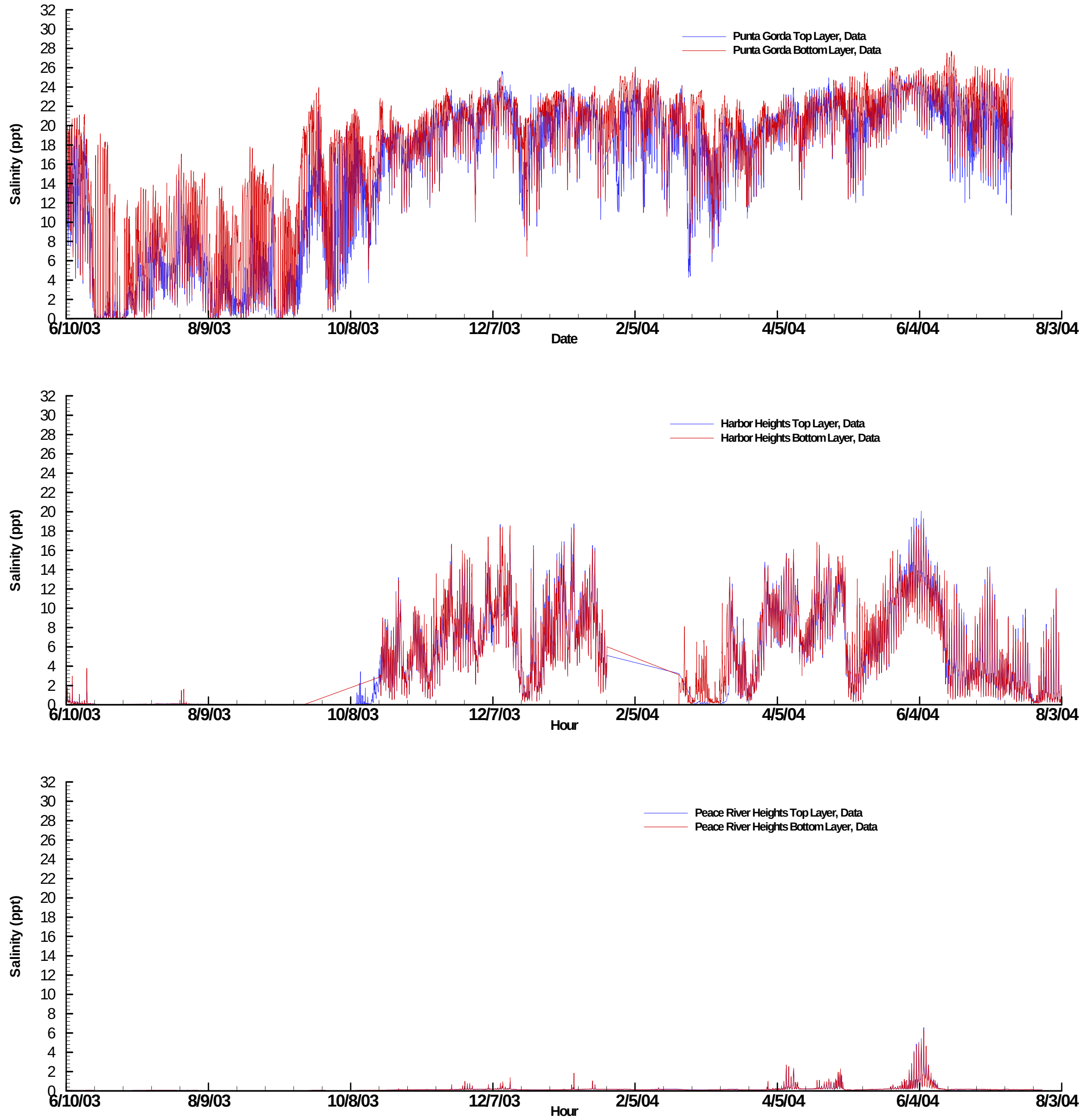


Figure 8. Measured salinity time series at three Lower Peace River stations during June 2003 – July 2004.

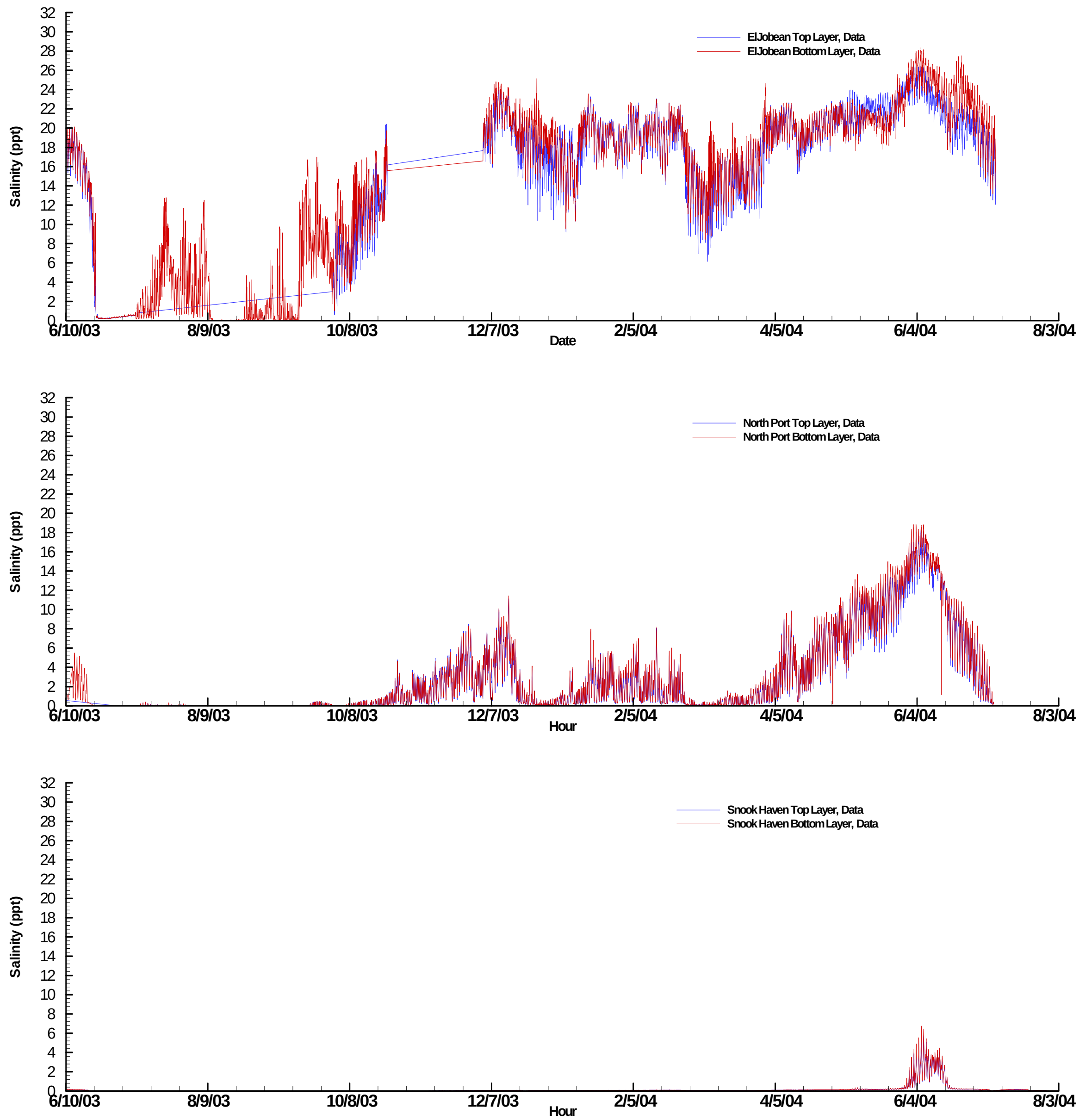


Figure 9. Measured salinity time series at three Lower Myakka River stations during June 2003 – July 2004.

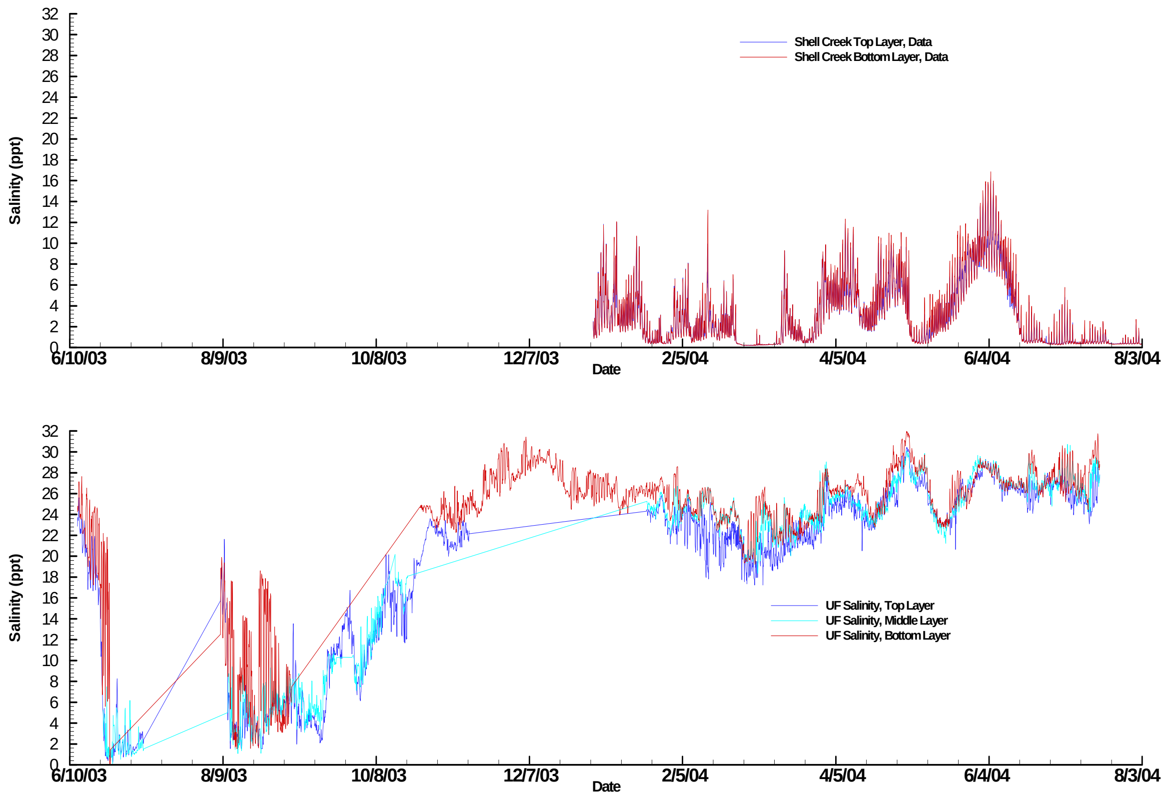


Figure 10. Measured salinity time series in Shell Creek (top graph) and Upper Charlotte Harbor (UF station, bottom graph) during June 2003 – July 2004.

Figures 11 – 13 are measured water temperature time series at the eight measurement stations in the LPR – LMR - UCH system presented in the same order as those of Figures 8 – 10. Figures 11 – 13 clearly show that water temperature does not exhibit much stratification in the LPR – LMR - UCH system. Except for the UF station in the UCH, all other seven stations exhibited only slight temperature differences between the top and bottom layers. It is speculated that the abnormality observed in top-layer temperature at the Peace River Heights station might be due to an equipment failure. The only measurement station that has shown temperature stratification is the UF station. However, the quality of the UF temperature data is questionable. One obvious problem is that the top-layer temperature was consistently higher than the middle- and bottom-layer temperatures during February – June 2004, while the middle-layer temperature was consistently lower than the bottom-layer temperature during the same period. Therefore, it is not certain whether the temperature stratification shown in UF data is real or not.

Overall, the quality of the available real-time water level, salinity, and temperature data measured at the eight stations was judged average. Several stations had many missing data periods. Some of the salinity and temperature data do not make sense. Besides the apparent problems with the UF temperature data, salinity data collected by the USGS in April and May 2004 at the Punta Gorda and El Jobean stations, respectively, appear problematic. The daily high of the top-layer salinity was always greater than that of the bottom-layer salinity in April 2004 at the Punta Gorda station, and in May 2004 at the El Jobean station. Obviously, salinity sensors malfunctioned at the two stations in April – May 2004. At the Peace River Heights station, the stage data appeared to have a datum problem before the missing data period around 2/5/04. For the Shell Creek station, although there are only about six months of data available, there are a number of problematic readings. For example, the stage data at the Shell Creek station appeared to have not only a datum problem, but also an increasing trend between 4/5/04 and 8/3/04.

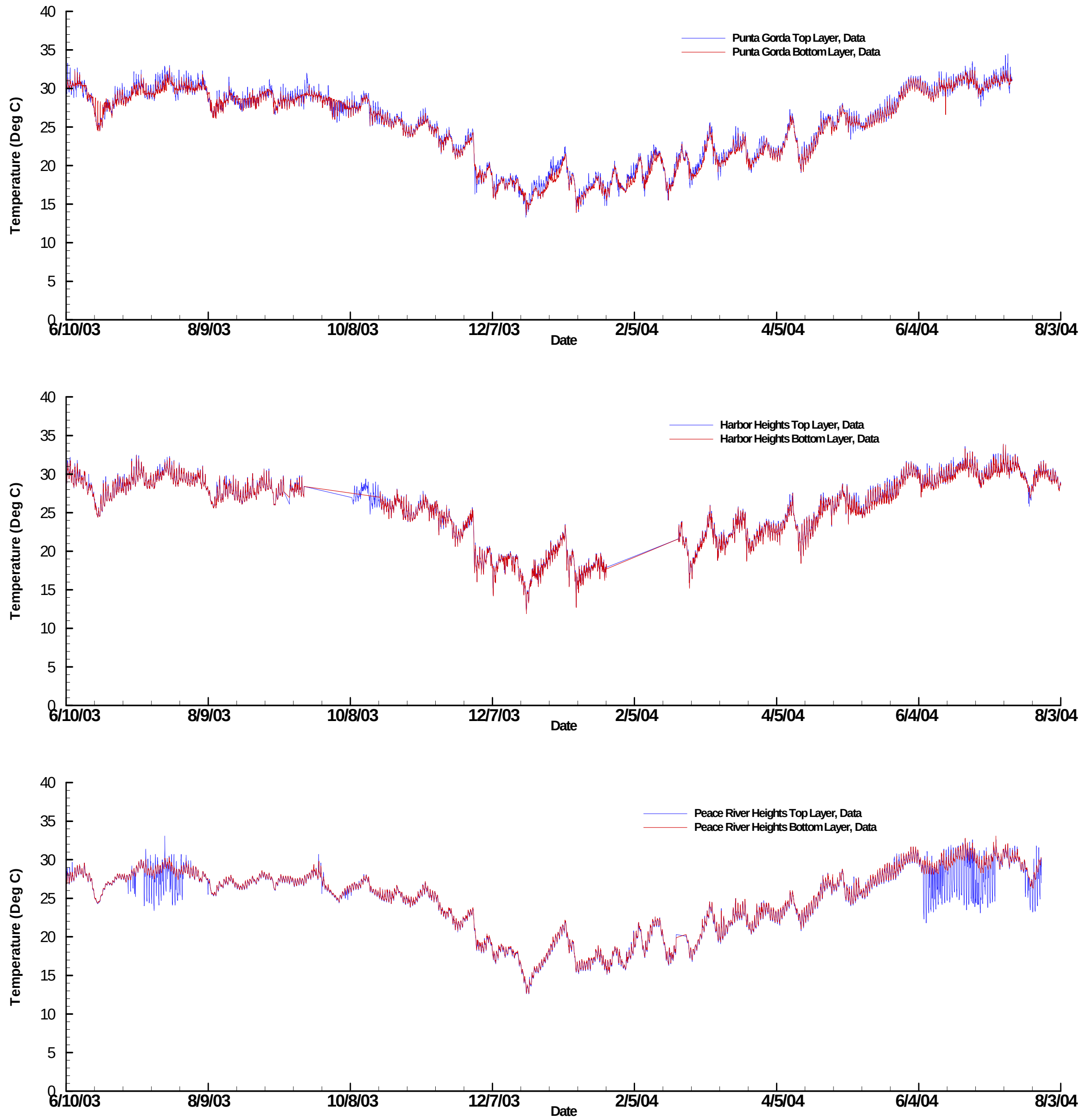


Figure 11. Temperature time series at three Lower Peace River stations during June 2003 – July 2004.

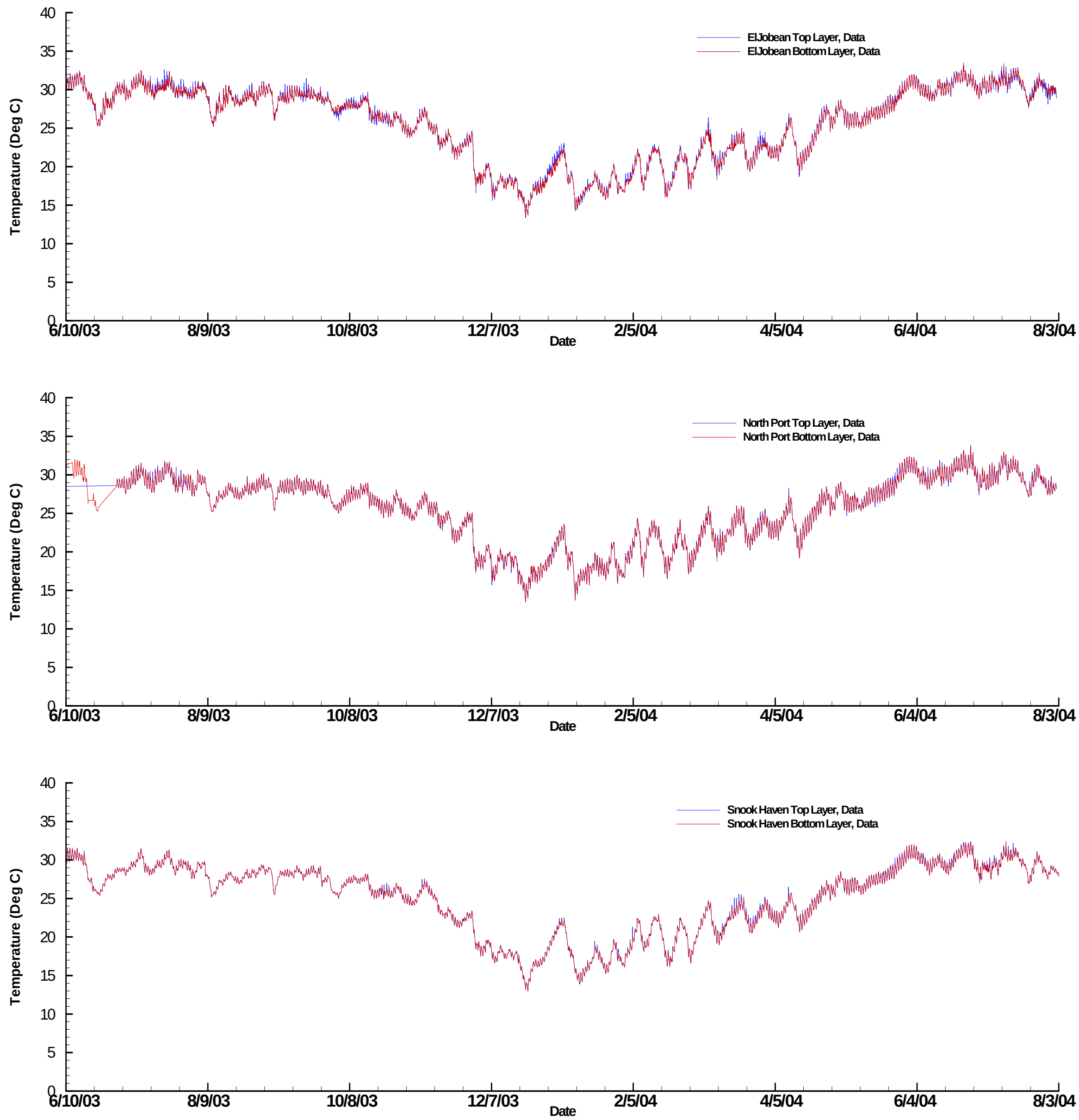
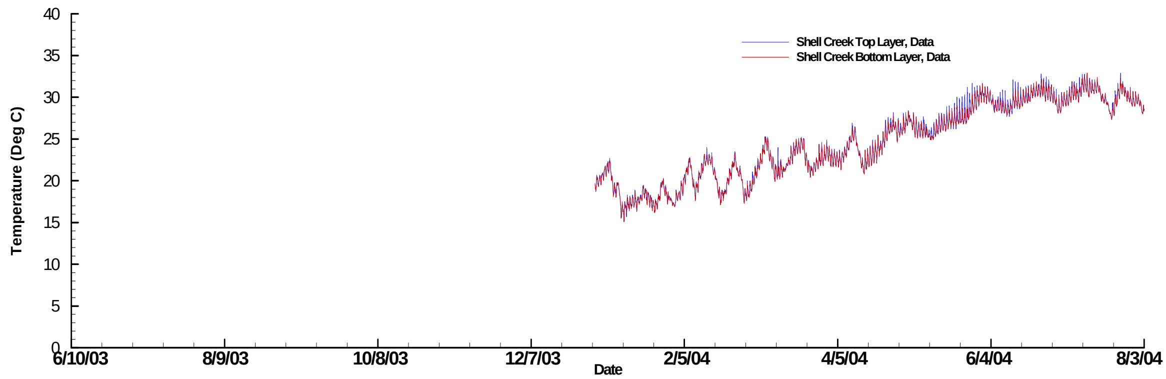


Figure 12. Temperature time series at three Lower Myakka River stations during June 2003 – July 2004.



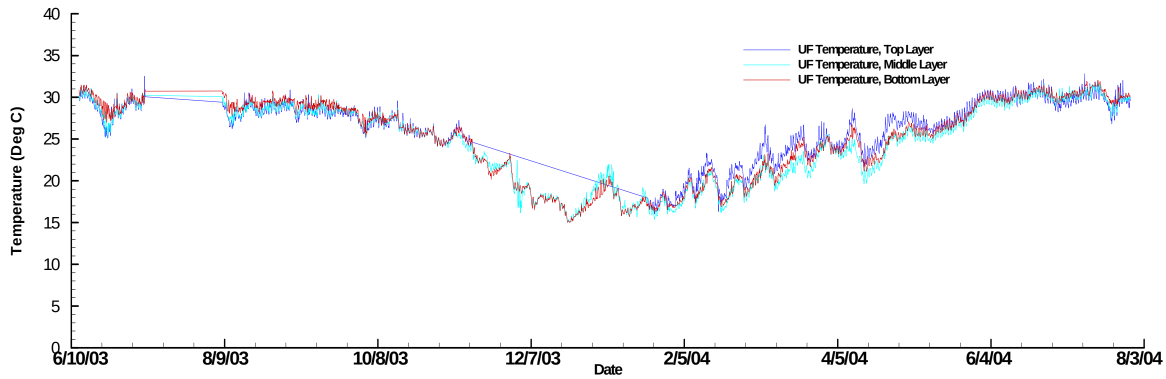
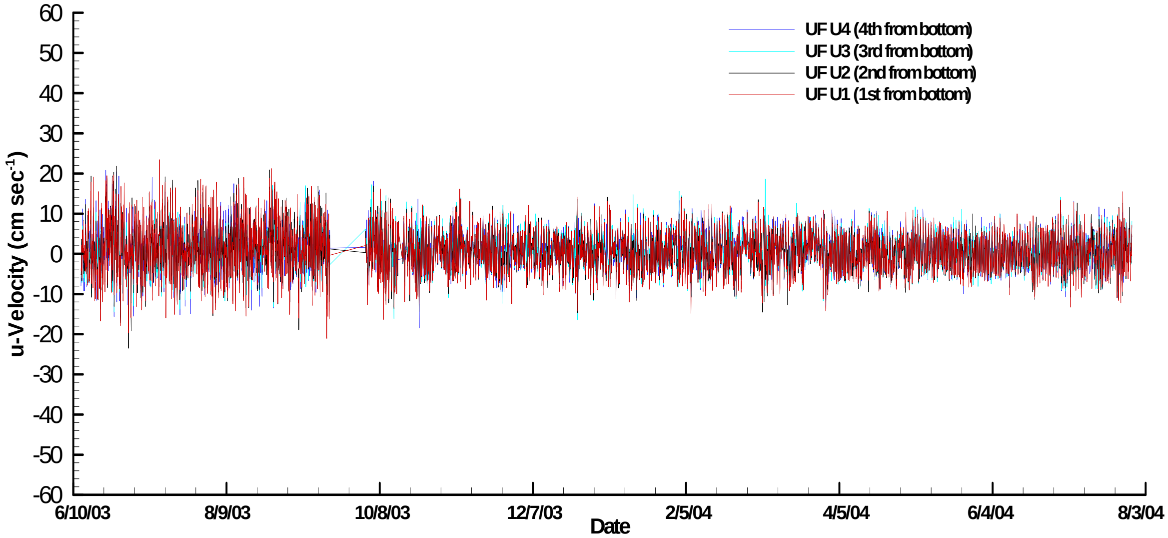


Figure 13. Temperature time series in Shell Creek (top graph) and Upper Charlotte Harbor (UF station, bottom graph) during June 2003 – July 2004.

Real-time water velocity data were measured only at the UF station in Charlotte Harbor (Figure 1). An Acoustic Doppler Current Profiler (ADCP) was deployed to measure velocities at six vertical layers. Unfortunately, current data at the top two layers are not useful because the water level often dropped below these two layers (Sheng et al., 2007). Figure 14 shows measured velocities at the four depths that were always below the water surface. The *u*-velocity is the water velocity component in the *x*-direction that runs from west to east (a positive *u*-velocity means that water particle moves eastward), while the *v*-velocity is the water velocity component in the *y*-direction that points from south to north (a positive *v*-velocity means that water particle moves northward). Because of the physical configuration of Charlotte Harbor, the magnitude of the *v*-component of the current is generally much larger than that of the *u*-component at the UF station. During the dry season when the current was predominantly tidally driven, the magnitude of the *v*-component was about twice of that of the *u*-component. However, during the wet season, the magnitude of the *v*-velocity was as much as three times greater than that of the *u*-component because fresh water coming from the Peace and Myakka Rivers turns south when it exits the Upper Charlotte Harbor. Due to the Coriolis effect and the way the Peace River flows into UCH, fresh water exits the harbor mainly near the west bank, resulting in a negative, long-term averaged *v*-velocity of 4 - 5 cm s^{-1} during the wet season and only about 1 cm s^{-1} during the dry season. On the other hand, although the long-term average of the *u*-velocity component is generally very small (about 0.75 cm s^{-1} in the wet season and about 0.4 cm s^{-1} in the dry season), it is always positive due to the proximity of the UF station to the mouth of the Myakka River.



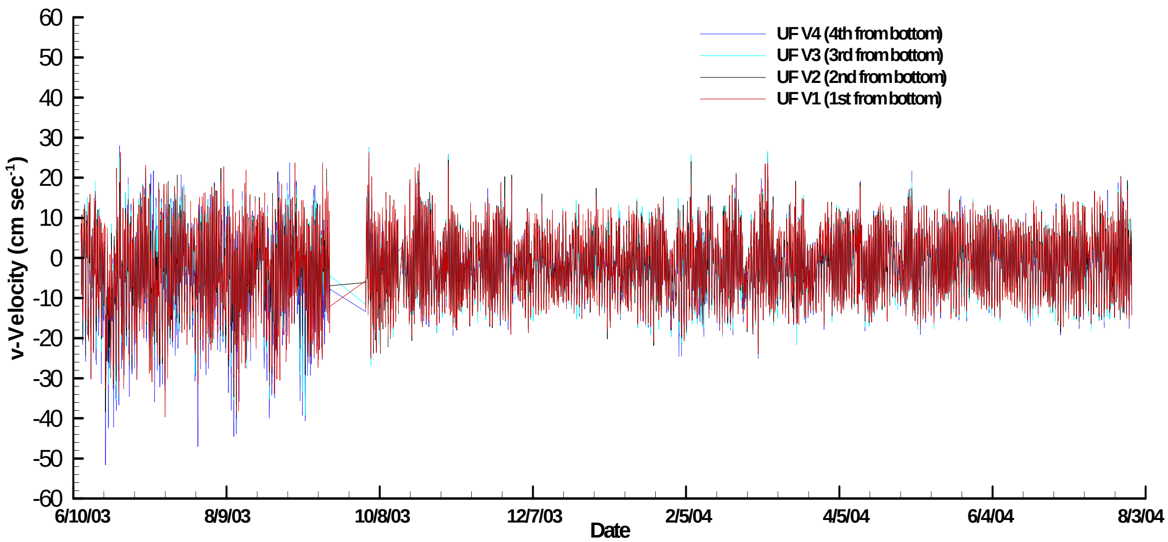


Figure 14. Measured u- (top graph) and v-velocities (bottom graph) in four depths at the UF station in the Upper Charlotte Harbor during June 2003 – July 2004.

Other Field Data

Other field data used in this modeling study included wind data measured at the UF station, air temperature, solar radiation, and air humidity data collected at a SWFWMD station near the Peace River/Manasota Regional Water Supply Authority.

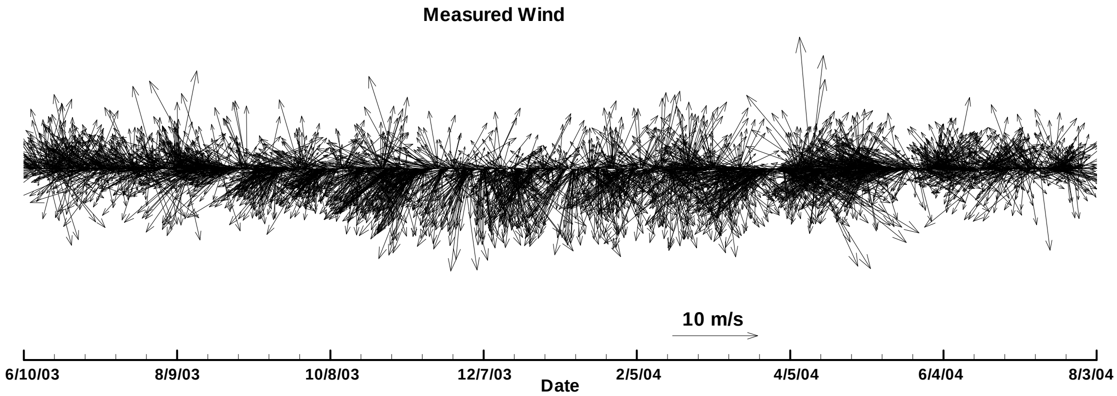


Figure 15. Measured wind at the UF station in Upper Charlotte Harbor during June 2003 – July 2004.

Figure 15 shows vector plots of measured wind at the UF station in the UCH. The figure shows a quite dynamic wind pattern blowing over the UCH during the period from June 2003 to July 2004. It appears that there is not a dominant direction in which the wind consistently blows; however, it does appear that the harbor often experienced either a northwest or a northeast wind during the 14 month period.

Measured solar radiation, relative air humidity, and air temperature collected at a SWFWMD station near the Peace River/Manasota Regional Water Supply Authority are plotted in Figure 16: the top graph is measured solar radiation in kilowatts per square meter (kw m^{-2}), the middle graph is the relative air humidity in percentage, and the bottom graph is the air temperature in degrees Celsius. All these meteorological parameters follow their general patterns for the southwest part of Florida, i.e.: summer is hotter and more humid with stronger solar radiation than winter.

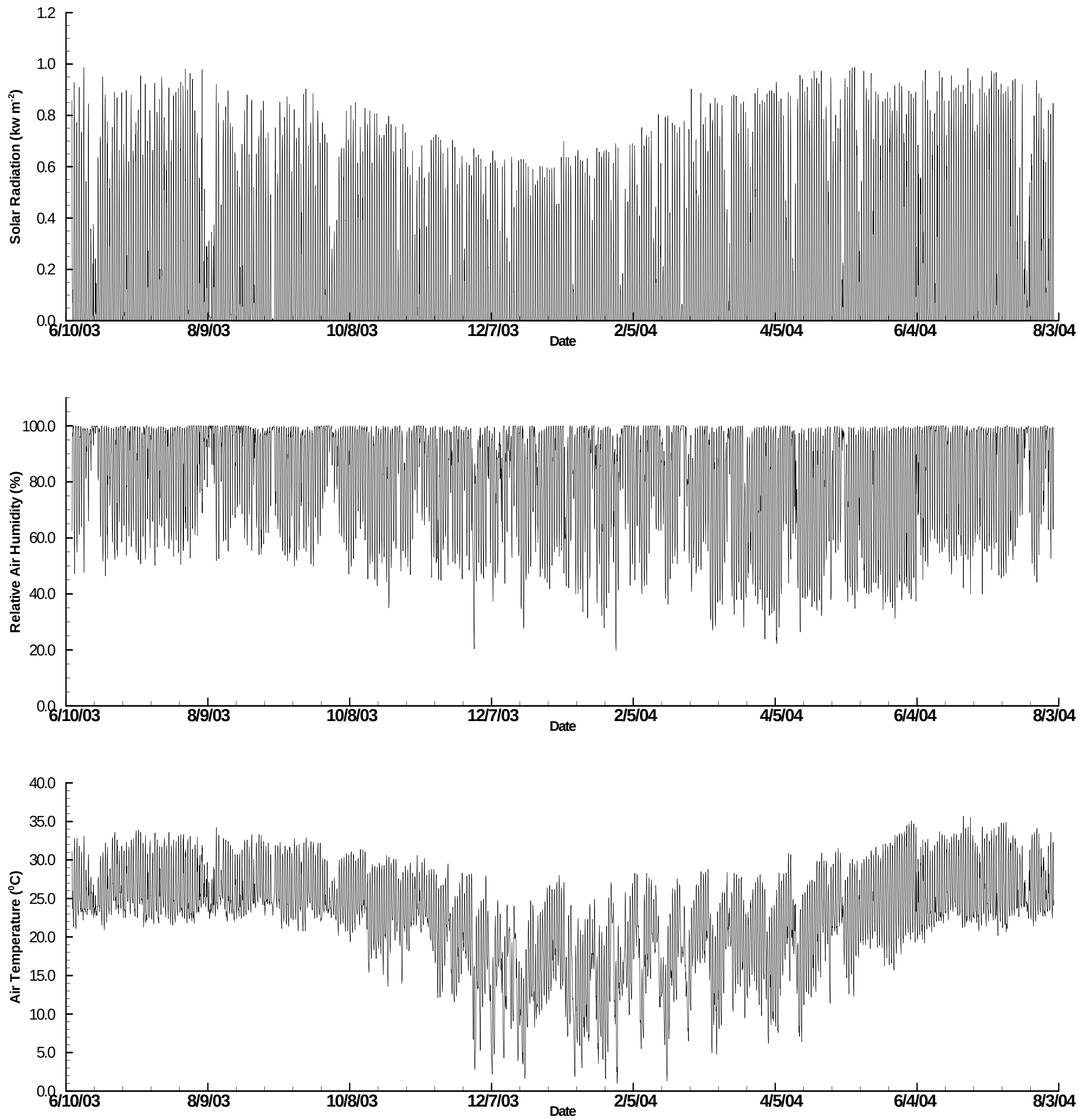


Figure 16. Measured solar radiation, relative air humidity, and air temperature at a SWFWMD station near the Peace River/Manasota Regional Water Supply Authority.

4. Model Applications to the LPR - LMR - UCH System

The dynamically coupled model LESS was applied to simulate hydrodynamics in the LPR - LMR - UCH system in support of the determination of the regulatory minimum freshwater inflow rates for the LPR and the LMR. The 3D domain includes the entire upper Charlotte Harbor, the downstream 15.5 kilometers of the lower Peace River, the downstream 13.8 kilometers of the lower Myakka River, and the most downstream 1.74 km portion of the Shell Creek. A Rectilinear grid system was used to discretize the 3D simulation domain with 108 grids in the *x*-direction, 81 grids in the *y*-direction, and 13 layers in the *z*-direction. The grid size in the 3D domain varies from 100m to 500m in both the *x*- and *y*-directions, while the spacing varied between 0.3m and 1.0m in the vertical direction. The 2DV domain includes three main sub-domains: (1) the LPR from river-km 15.5 to Arcadia, (2) the LMR from river-km 13.8 to river-km 38.4, and (3) and the Shell Creek from river-km 1.74 to the dam. Also included in the 2DV domain were the downstream 4.16km of the Myakkahatchee Creek and major branches of the LPR and the Shell Creek. The 2DV domain was discretized with 356 longitudinal grids and 17 vertical layers. The longitudinal length for 2DV grids varied between 200 m and 400 m. To make the 3D-2DV coupling simple, the first 13 layers for the 2DV domain is set to be the same as the 13 layers used for the 3D domain. Table 2 lists the vertical spacing in both the 3D and 2DV domains. The layer number is counted from the bottom upward, with the first layer being the lowest layer. Also included in Table 2 are the elevations of the layer centers. The bottom of the first layer is located at the elevation of -6.766 m. NGVD29. Basically, the first 10 layers discretize the water column below the NGVD29 datum, while Layers 11 and above discretize the water column above the NGVD29 datum. Because the vertical layers are fixed in space, many grid cells may not contain water at all the times. Although these cells are included in the model, they are excluded in the computation.

Layer No.	DZ for 3D Domain (m)	DZ for 2DV Domain (m)	Layer Center Elevation (m, NGVD29)
17	0.8		3.434
16	0.8		3.034
15	0.7		2.284
14	0.6		1.634
13	0.5	0.5	1.084
12	0.4	0.4	0.634
11	0.3	0.3	0.284
10	0.3	0.3	-0.016
9	0.4	0.4	-0.366
8	0.6	0.6	-0.866
7	0.6	0.6	-1.466
6	0.8	0.8	-2.166
5	0.8	0.8	-2.966
4	0.8	0.8	-3.766
3	0.8	0.8	-4.566
2	0.8	0.8	-5.366
1	1.0	1.0	-6.266

Table 2. Layer thicknesses and layer center elevations for the 3D and 2DV domains.

The reason for having four extra layers for the 2DV domain is to allow the model to simulate major storm events when very high flows cause water surface in the narrow channel areas of the 2DV domain to rise significantly. Also the riverbed near the USGS Peace River at Arcadia station which is about 8 km upstream of the tidal limit is more than 1m above the NGVD 29 datum. Figure 17 is the mesh of the LPR - LMR - UCH model, including model grids for both the 3D and 2DV domains. The red portion of the mesh represents land grids in the 3D domain, while the black portion represents water grids. Only water grids are included in the computation at each time step. Land grids are kept inactive and not included in the computation. As the water level rises, the shoreline also changes. As a result, some land grids may become water grids and will be treated as active grids in the computation at the new time step.

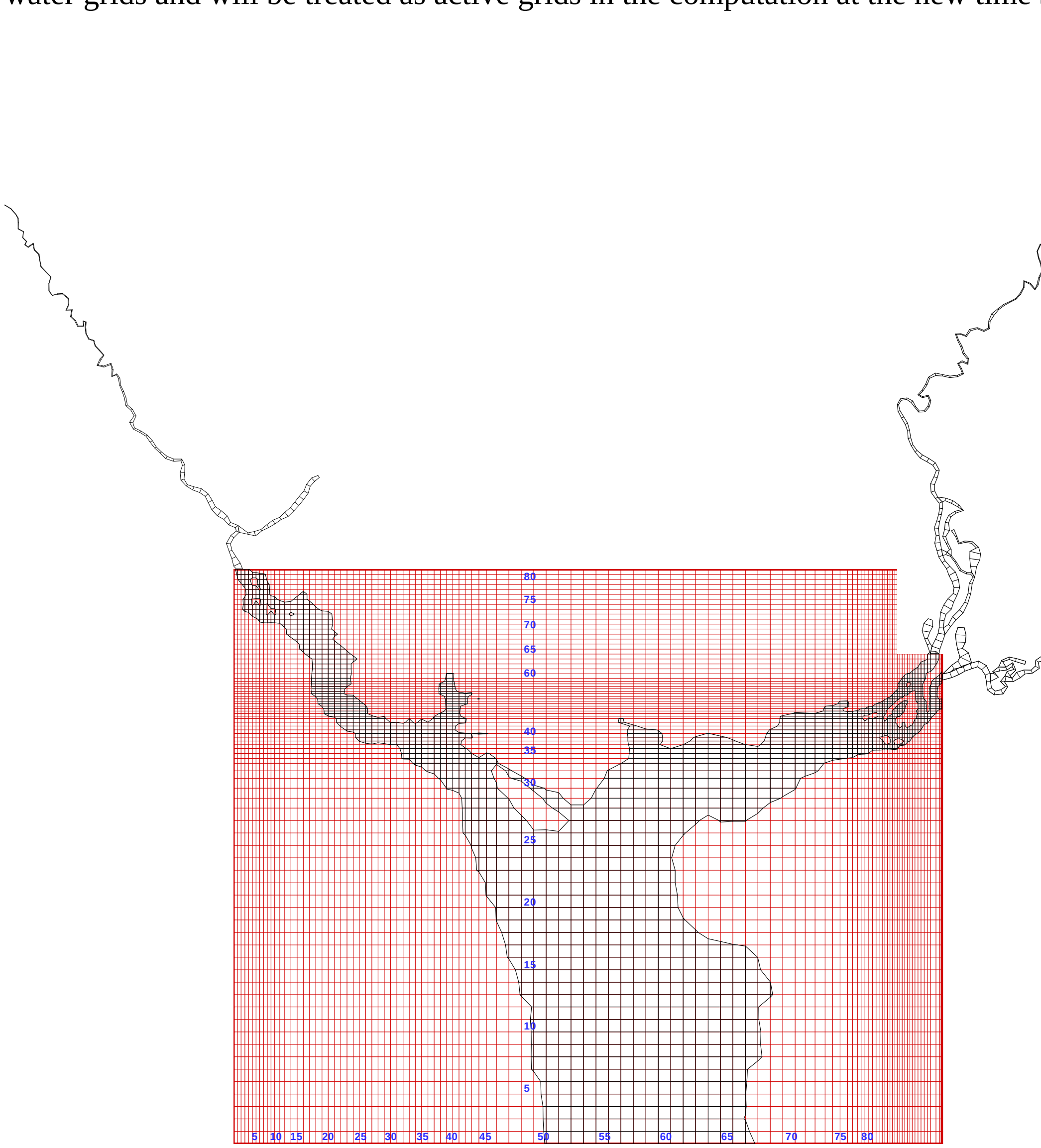


Figure 17. Model grids used in the LPR - LMR - UCH model. The red portion of the mesh represents land grids that are inactive in the computation in the 3D domain.

Hydrodynamic simulations in the complex LPR - LMR - UCH system were conducted for a period of 395 days from June 13, 2003 through July 12, 2004, with a variable time step between 90 and 180 seconds. The dynamically coupled 3D-2DV model was driven by boundary conditions specified at free surface (wind shear stresses and heat fluxes), at the open boundary at the southern side of the 3D domain, and at the upstream boundaries of the LPR, the LMR, and the Myakkahatchee and Shell Creeks of the 2DV domain. At the upstream boundaries of the 2DV domain, measured daily flow rates were uniformly distributed over the cross sections with zero salinity and zero temperature gradient in the longitudinal direction. At the open boundary on the southern side of the 3D domain, the boundary conditions were given using simulated results of water elevation, salinity and temperature by another hydrodynamic model (Sheng, et al., 2007) that covered the entire Charlotte Harbor and a coastal area almost 45 km offshore into the Gulf of Mexico (Figure 18). Wind data measured at the UF station were used to calculate shear stresses at the free surface. The heat exchange with the atmosphere at the free surface was calculated based on measured solar radiation, wind, and air temperature data at the UF station and the SWFWMD station near the Peace River/Manasota Regional Water Supply Authority.

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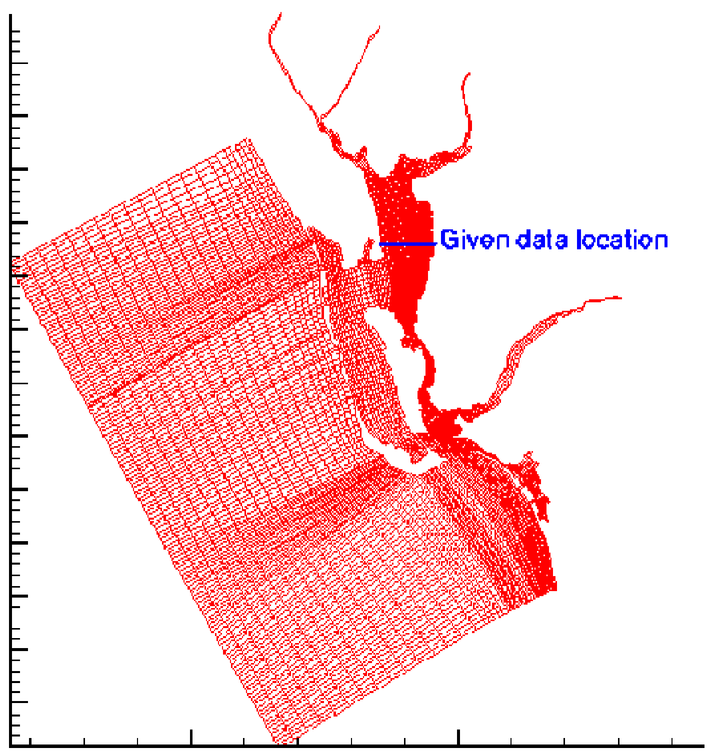

Figure 18. The boundary conditions at the southern boundary of the LPR - LMR - UCH model were provided by another hydrodynamic model by Sheng et al. (2007). The blue bar represents the southern boundary of the LPR - LMR - UCH model.

As mentioned above, because about 16% of the Peace River sub-basin and almost 50% of the Myakka River sub-basin are un-gauged, freshwater inflows from these un-gauged areas comprise a great deal of the total freshwater budget to the Charlotte Harbor and have significant effects on salinity distributions in the LPR – LMR - UCH system. However, it is very challenging to obtain reasonable estimates of un-gauged flows from a very complex system such as the Peace - Myakka River watershed. Although the HSPF model (Bicknell et al., 1997) is a popular model that has been used in many areas of the country, including Florida, it cannot guarantee good model results, especially when it is used as an extrapolation tool for an area that is quite different from the gauged areas in terms of land-use and hydro-geological properties. Moreover, due to the unavailability of freshwater flow data to the tidal reaches, it is impossible to determine the severity of the errors and the confidence interval of the simulated un-gauged flows. The unknown errors in the estimated un-gauged flow will inevitably cause errors in model results of the coupled 3D-2DV model. Unfortunately, without a better way to estimate un-gauged flows, simulated results using the HSPF model by Ross et al. (2005) appeared to be the only choice available for a rough estimate of the freshwater contribution from the un-gauged areas of the watershed. During the calibration process of the model, it was found that the model under-predicted salinity during the wet months of the simulation period (see below), suggesting that un-gauged flows by Ross et al. (2005) could be over-estimated. As such, this study compared the HSPF results to those estimated by Janicki Environmental using a simple method developed by SDI Environmental Services (SWFWMD, 2007). The estimated un-gauged flows using the SDI method are generally 50 – 60% lower than the HSPF results, except for the few peak flows in the first couple of months of the simulation period which are much higher than HSPF peak flows. Based on this comparison, the daily un-gauged flow values generated by the HSPF model were multiplied by constant factors (0.39 for the Peace, and 0.51 for the Myakka) to produce the final adjusted un-gauged flow values that were input to the coupled model.

For the Blackburn Canal flow, Equation (16) was used to estimate how much flow is exchanged between Myakka River and Dona/Roberts Bay during the model calibration and verification periods mentioned below. It was also used in the scenario runs for the LPR MFL simulations. Lately (early 2008), Equation (17) was tested to see how much difference it would make in terms of simulated water levels and salinities at eight measurement stations during the calibration and verification periods. The model results are the same, except for the Snook Haven and North Port stations in the LMR where the difference is very insignificant. To be consistent with the Dona/Roberts Bay study, Equation (17) was used in the LMR MFL scenario runs.

Model Calibration and Verification

During the 13-month simulation period from June 13, 2003 to July 11, 2004, the first 30 days, from June 13m to July 12, were used for spinning up the LESS model because initial conditions on June 13, 2003 were not available. Considering the quality of available data and errors associated with the estimation of un-gauged flows during extreme conditions, a three-month period from January 10, 2004 to April 9, 2004 was chosen for model calibration. During the model calibration process, key model parameters (e.g., bottom roughness, background vertical eddy viscosity and diffusivity, various advection schemes, etc.) were adjusted to obtain the best fit between model results and measured data at the eight stations in the LPR - LMR - UCH system. Because the initial conditions for the calibration period were also unknown, a 30-day spin-up period was included in the model calibration. Therefore, the calibration run was actually performed for a four-month period from December 12, 2003 to April 9, 2004, with the model results during the first 30 days being excluded in model calibration. After the model was calibrated, it was verified against field data measured at the eight stations during a six-month period before the calibration period (July 12, 2003 – January 9, 2004) and a three-month period after the calibration period (April 19 – July 11, 2004).

Figures 19 and 20 are comparisons of simulated water levels with measured field data during the 91-day calibration period from January 10, 2004 to April 9, 2004. While Figure 19 compares at the four stations in the 3D domain (UF, Punta Gorda, El Jobean, and Harbor Heights), Figure 20 compares at the four stations in the 2DV domain (Peace River Heights, Shell Creek, North Port, and Snook Haven). Comparisons of simulated water levels to measured field data at all eight stations during the two verification periods are shown in Figures A-1 through A-6 in Appendix A. As can be seen from these figures, simulated water levels match the data very well, with the exception that the model under-predicts flooding at the Peace River Heights and the Snook Haven stations during extremely high flow events. The under-prediction of the water levels at these two stations is mainly due to the inaccurate bathymetric data for the flood plains of the upstream portions of the LPR and LMR. For the Peace River Heights station, it is also partially due to the datum problem mentioned in Section 2.

Figures 21 and 22 compare simulated u- and v-velocities with measured data at the UF station during the 91-day calibration period. Simulated u- and v-velocities during the two verification periods were plotted and compared with measured data in Figures B-1 through B-6 in Appendix B. For simplicity, comparisons were made only at three depths (second to fourth from the bottom), instead of all four depths, in the figures. The reason for this is that the spatial resolution (500m × 500m) used near the UF station was quite coarse and the actual bottom elevation at the UF station can not be accurately represented in the model. Therefore, in Figures 21-22, "Near Bottom", "Middle Depth", and "Near Surface" are respectively the second, third, and fourth layers from the bottom in Figure 14. From Figures 21 – 22, as well as those shown in Appendix B, it is evident the model worked well in simulating currents in the harbor (at least near the UF station). Both the short-term (semi-diurnal) and long-term variations of the current in the x- and y-directions have been successfully simulated by the model.

Simulated salinities during the calibration period at all eight measurement station are also plotted against measured real-time data for comparison. Figures 23 – 26 are plots of simulated and measured salinities at UF, Punta Gorda, El Jobean, and Harbor Heights, respectively, while Figure 27 - 30 are those of simulated and measured salinities at Peace River Heights, Shell Creek, North Port, and Snook Haven, respectively. These plots suggest that the dynamically coupled model has been successfully calibrated against measured real-time salinities in the LPR - LMR - UCH system, except for the North Port station, where the model under-predicted salinities at both the top and bottom layers during the calibration period. There are many factors that could cause the under-prediction of salinity at the North Port station, including the un-gauged flow from the Myakka River watershed, the Myakka River bathymetry data used in the model, flow estimated for Blackburn Canal, etc. A careful comparison of the bathymetric data used in the model with those surveyed in the Myakka River showed that many deep areas in the river were not correctly represented in the model because of the use of model grids ranging from a 200m × 100m resolution to a 200m × 200m resolution in the Myakka River portion of the 3D sub-domain. Adjusting the bathymetry data in these areas by lowering the bottom elevations a bit, the simulated salinity results at the North Port station did show some degree of improvement. Although one can continue to adjust the bathymetry data to further improve simulated salinity results at North Port, this should be done with caution. We chose to adjust the bathymetry data in the downstream portions of the Peace and Myakka Rivers only slightly to ensure that downstream water volumes of the two rivers have no obvious increases and important physical characteristics in the regions are preserved (e.g., islands are not noticeably shrunk or eliminated).

Comparisons of model results and measured salinities at the eight stations for the two verification periods are presented in Figures C-1 through C-23 in Appendix C. From these figures, it is apparent that the coupled model can reproduce both the long-term and short-term trends of salinity variations at all eight stations during the two verification periods. Nonetheless, it under-predicts salinities in the wet season before the calibration period and slightly over-predicts salinities in the driest months after the calibration period. The best agreement between simulated and measured salinities occurred in last couple weeks of the second verification period when simulated salinities in all eight stations match the data very well. Obviously, the agreement between simulated and measured salinities at all eight stations in the LPR - LMR - UCH system for the verification periods is not as good as that for the calibration period; however, it was judged satisfactory considering the many uncertainties inherent with the input data that drive the model, including the bathymetry data read to the model, un-gauged flow estimates, the boundary conditions provided by another model (Sheng et al., 2007), etc.

Figure 31 – 35 are time series of simulated and measured temperatures during the calibration period at the UF, Punta Groda, El Jobean, Peace River Heghts, and Snook Haven stations. Because the purpose of this modeling effort is to evaluate the effects of freshwater inflows on salinity distributions in the LPR and LMR in support of the establishments of the minimum freshwater flows for the two riverine estuaries, emphasis was placed on calibrating/verifying model results against measured salinity data instead of measured temperature data. Although no special effort was made to calibrate the model for temperature, Figures 31 - 35 illustrate that the agreement between simulated and measured temperatures in the LPR - LMR - UCH system is still good. For simplicity, only five stations during the calibration are included in this report. Comparisons of simulated and measured temperatures during the two verification periods and at the remaining three stations during the calibration period are omitted. As mentioned before, although measured temperature data in the simulation domain show large temporal variations, they exhibit only very small spatial variations. As a result, temperature has only minor effects on circulations and salt transport processes in the LPR - LMR - UCH system. Model runs confirmed that simulated water level, velocity, and salinity results are almost the same with or without including temperature in the simulations.

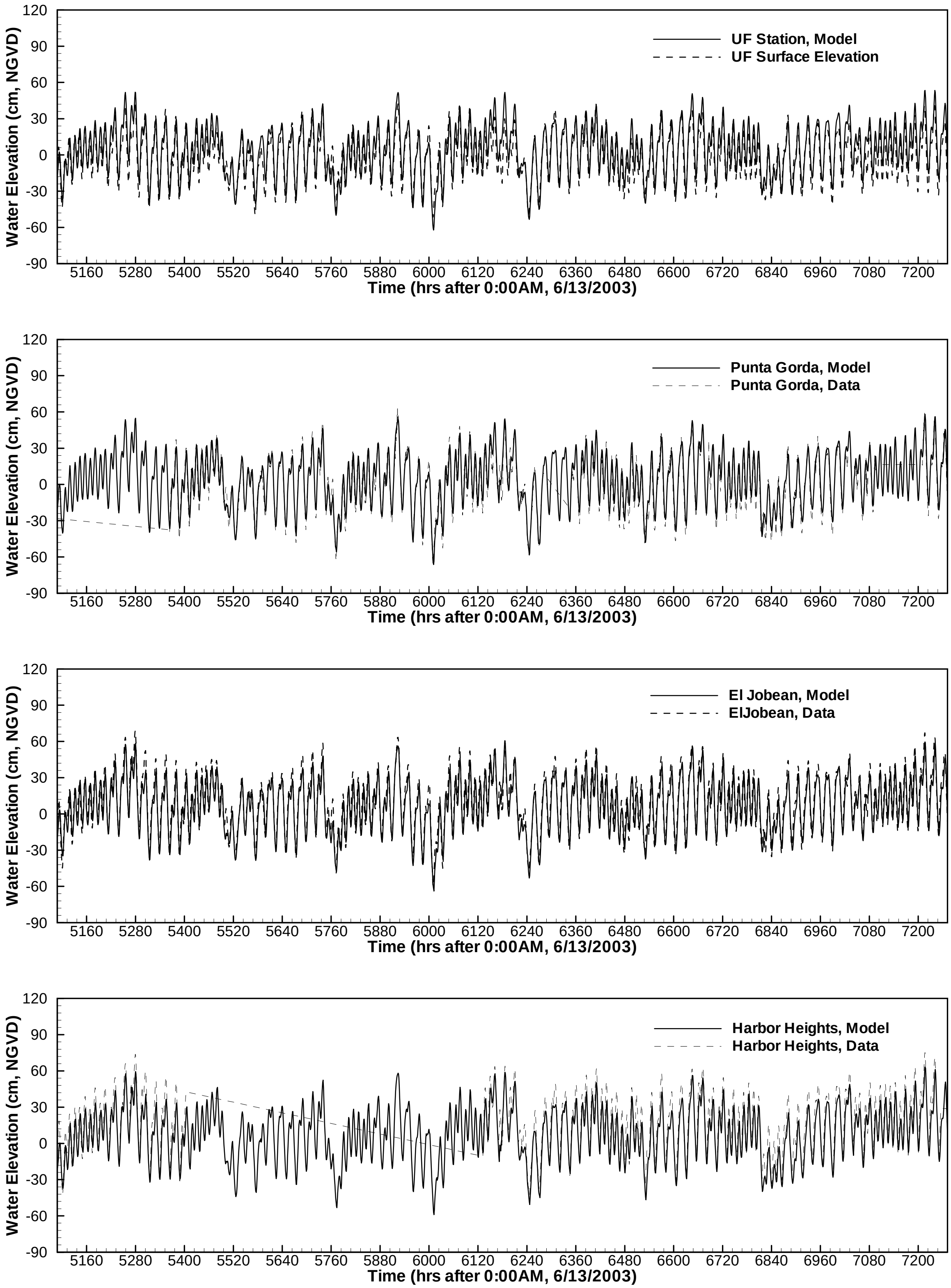

Figure 19. Comparisons of simulated and measured water elevations at UF, Punta Gorda, El Jobean, and Harbor Heights during January 10 – April 9, 2004.

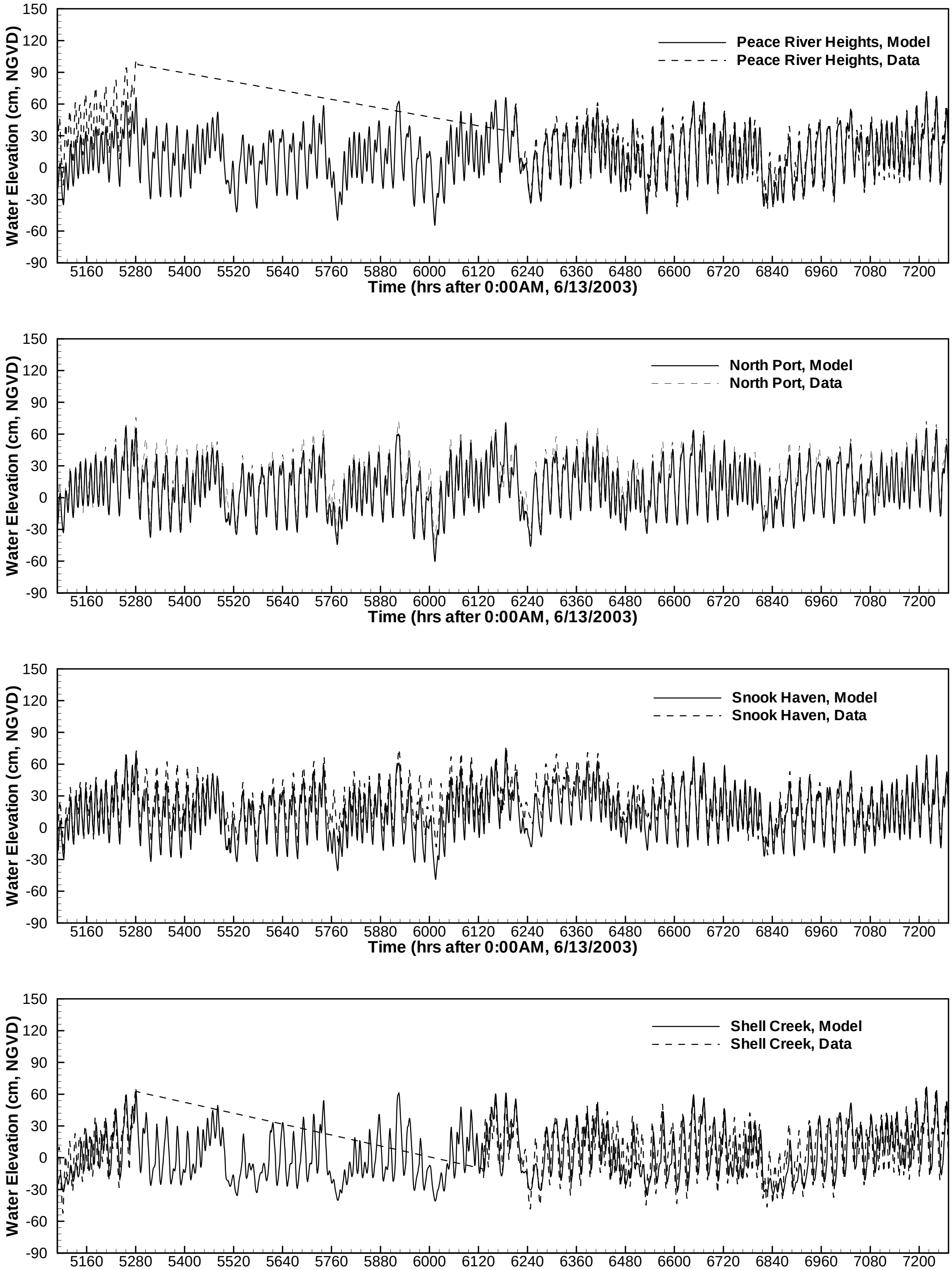

Figure 20. Comparisons of simulated and measured water elevations at Peace River Heights, North Port, Snook Haven, and Shell Creek during January 10 – April 9, 2004.

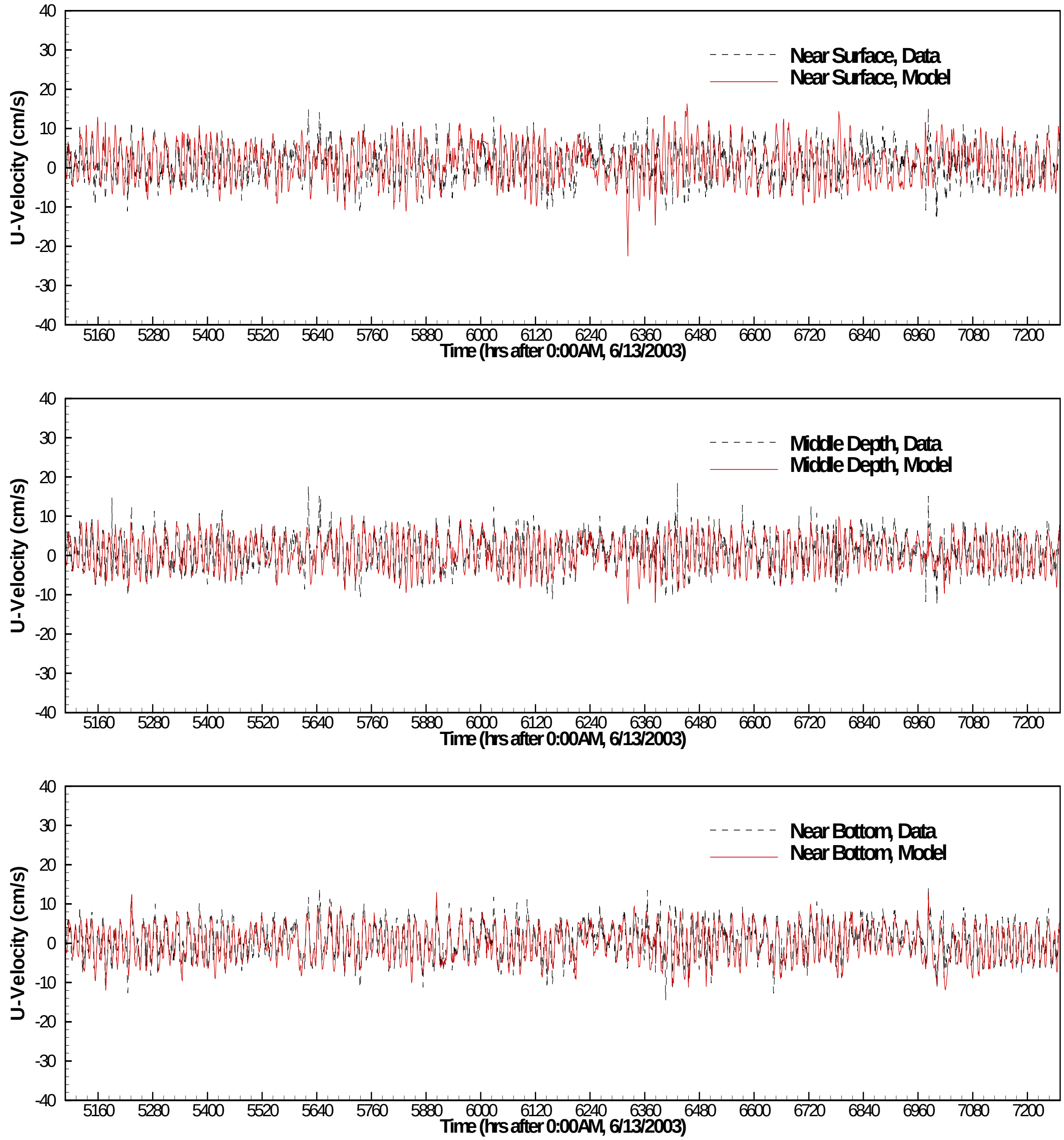

Figure 21. Comparisons of simulated and measured u-velocities at three depths at the UF station during January 10 – April 9, 2004.

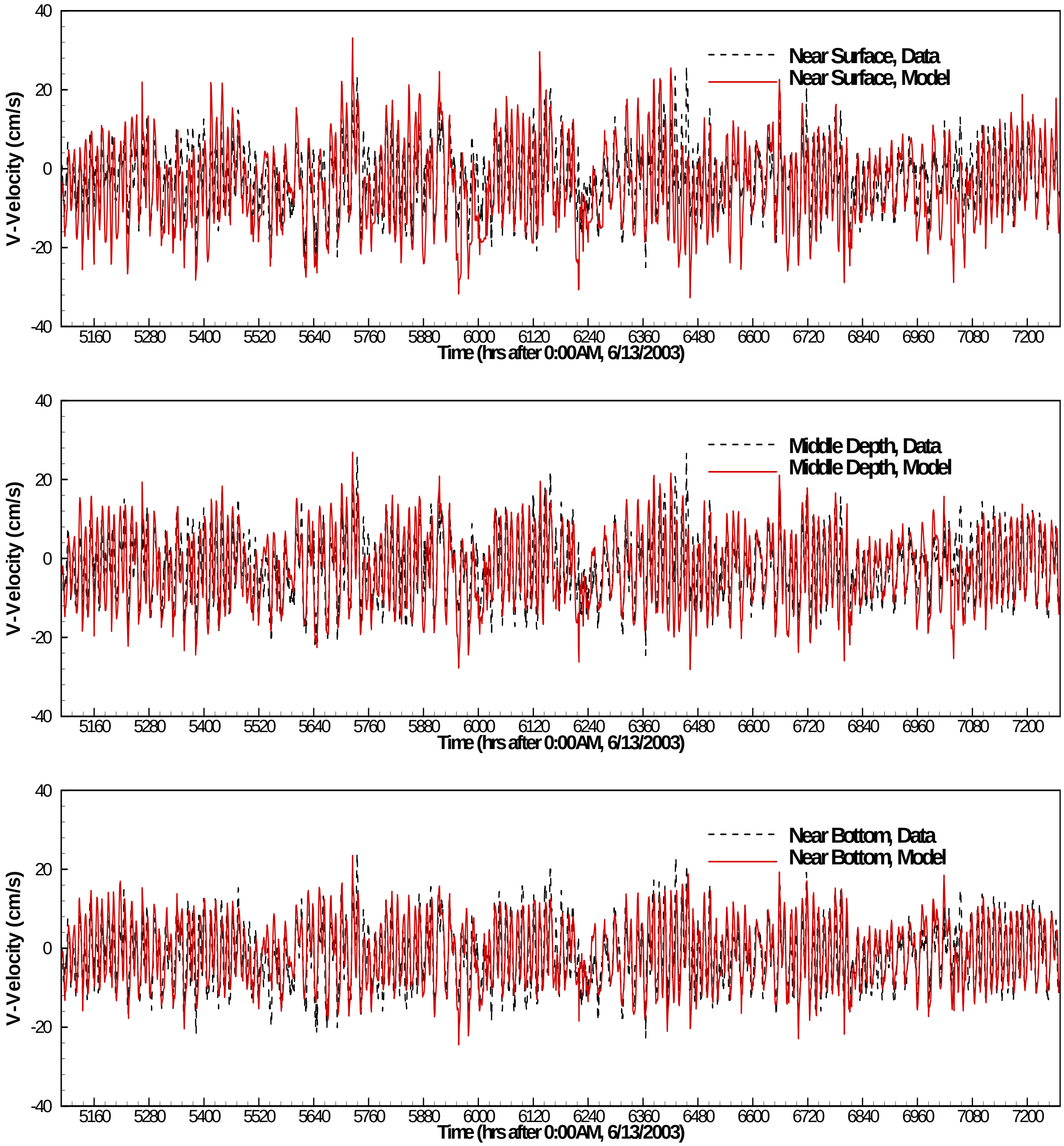

Figure 22. Comparisons of simulated and measured v-velocities at three depths at the UF station during January 10 – April 9, 2004.

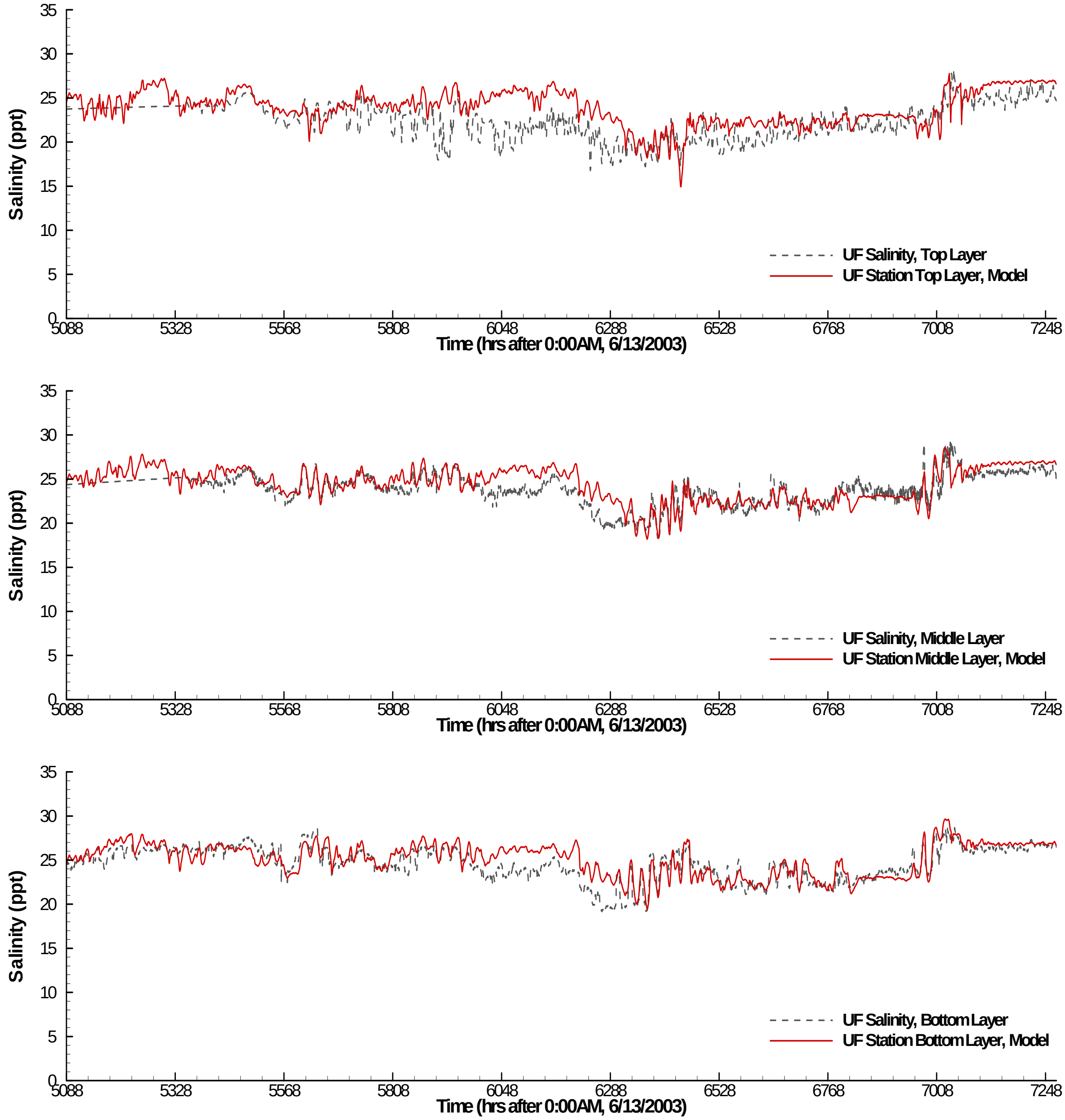

Figure 23. Comparisons of simulated and measured salinities at three depths at the UF station during January 10 – April 9, 2004.

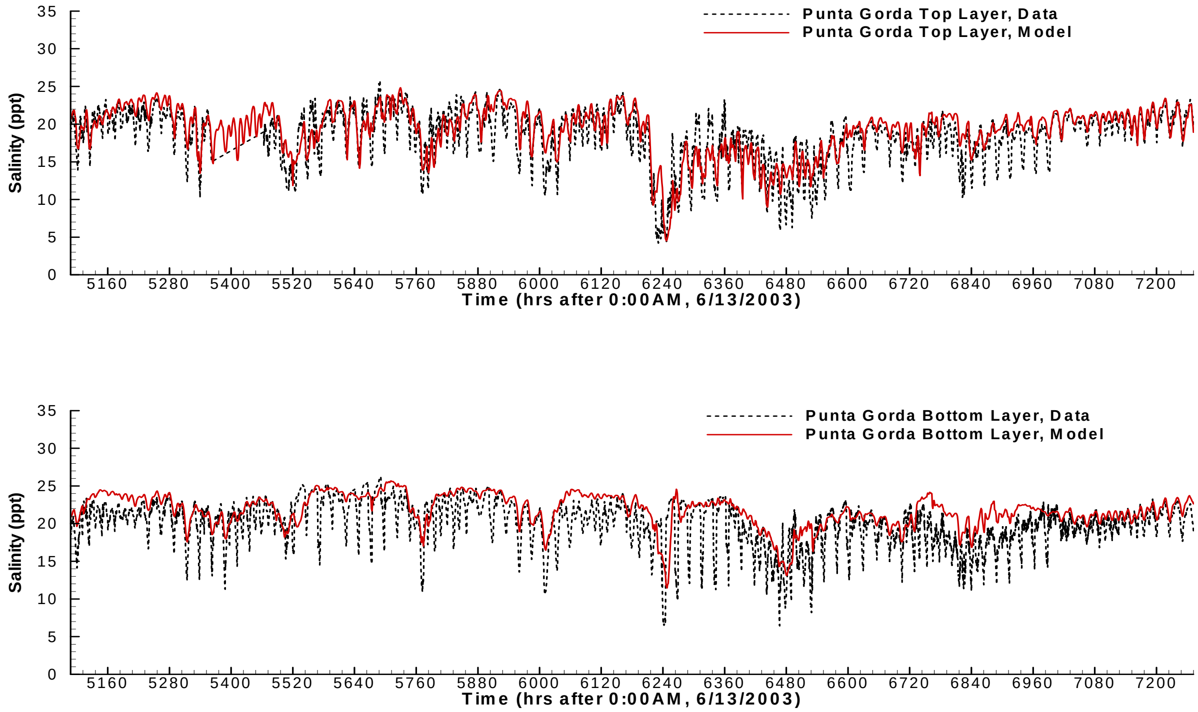

Figure 24. Comparisons of simulated and measured salinities at two depths at the Punta Gorda station during January 10 – April 9, 2004.

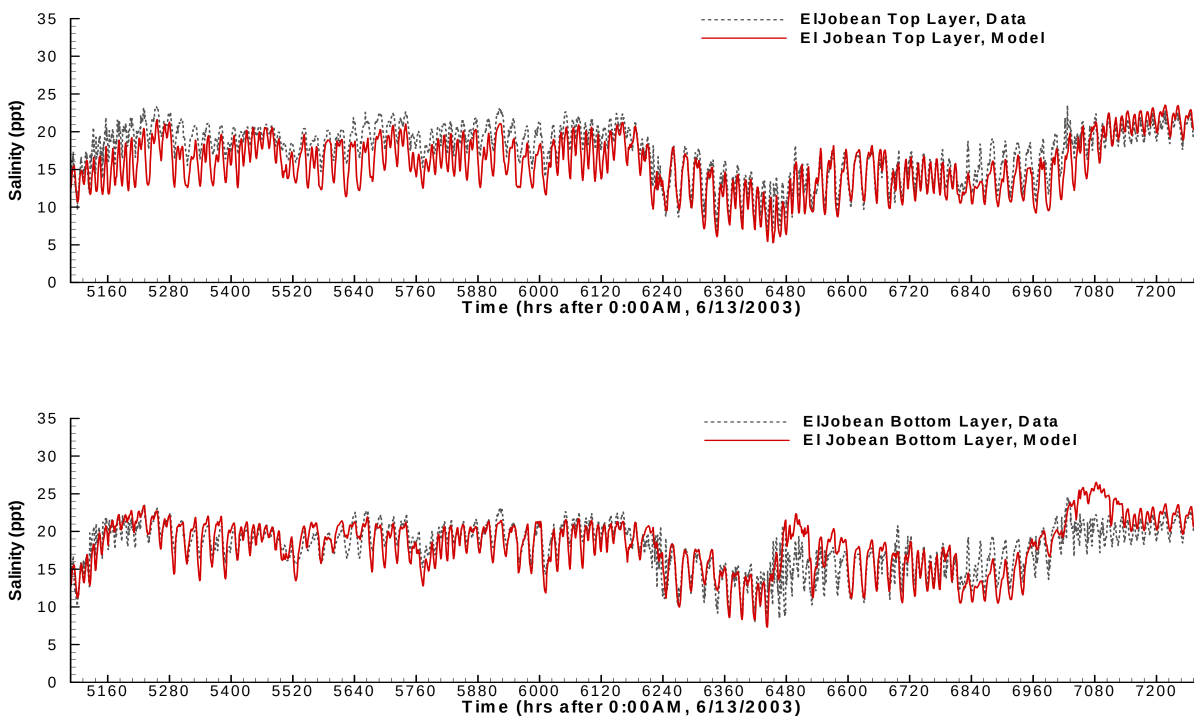

Figure 25. Comparisons of simulated and measured salinities at two depths at the El Jobean station during January 10 – April 9, 2004.

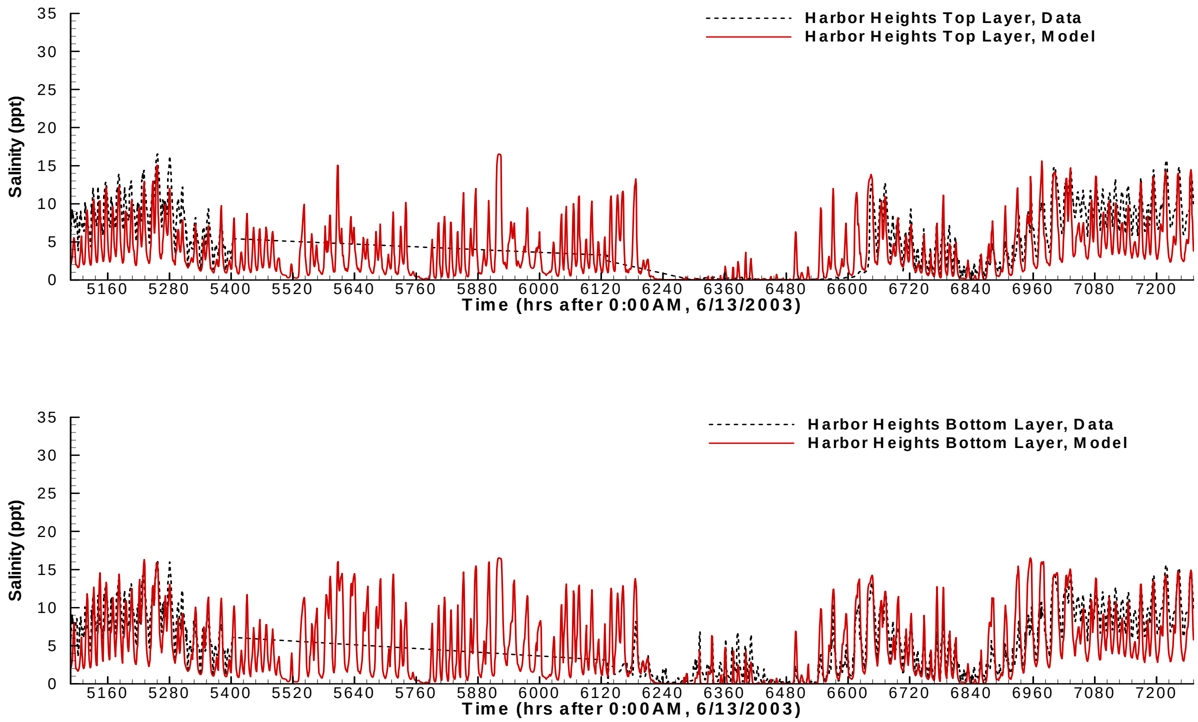

Figure 26. Comparisons of simulated and measured salinities at two depths at the Harbor Heights station during January 10 – April 9, 2004.

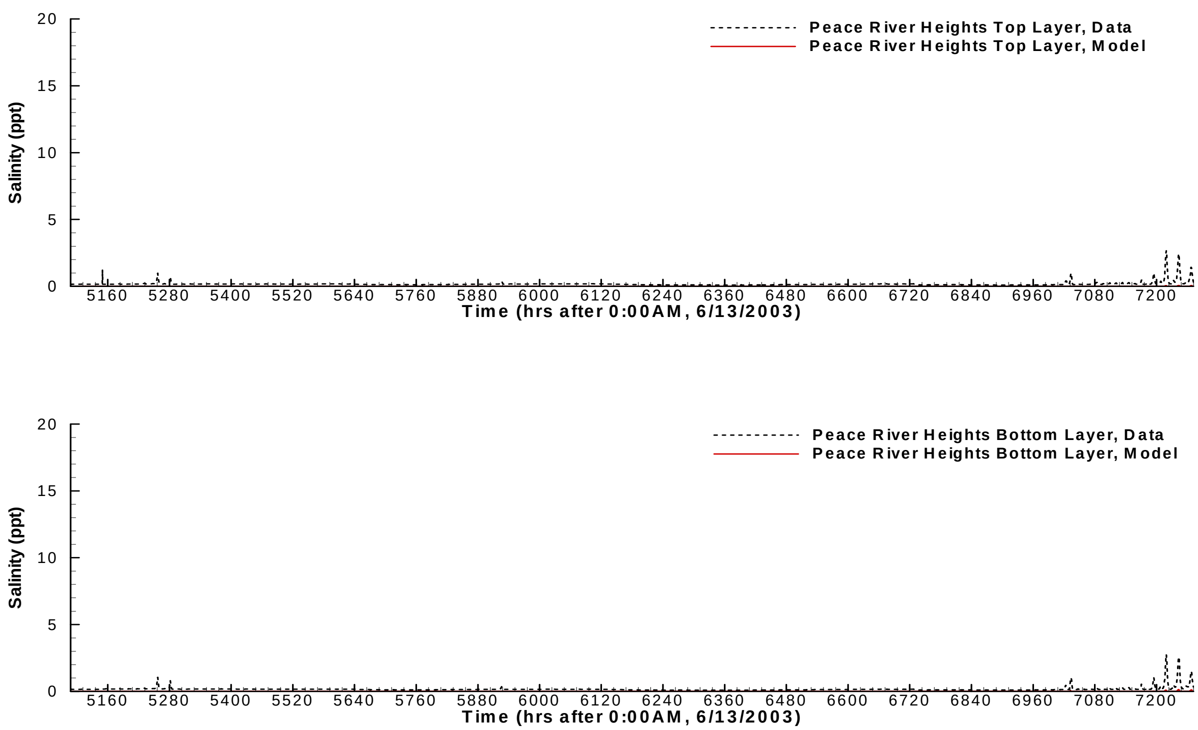

Figure 27. Comparisons of simulated and measured salinities at two depths at the Peace River Heights station during January 10 – April 9, 2004.

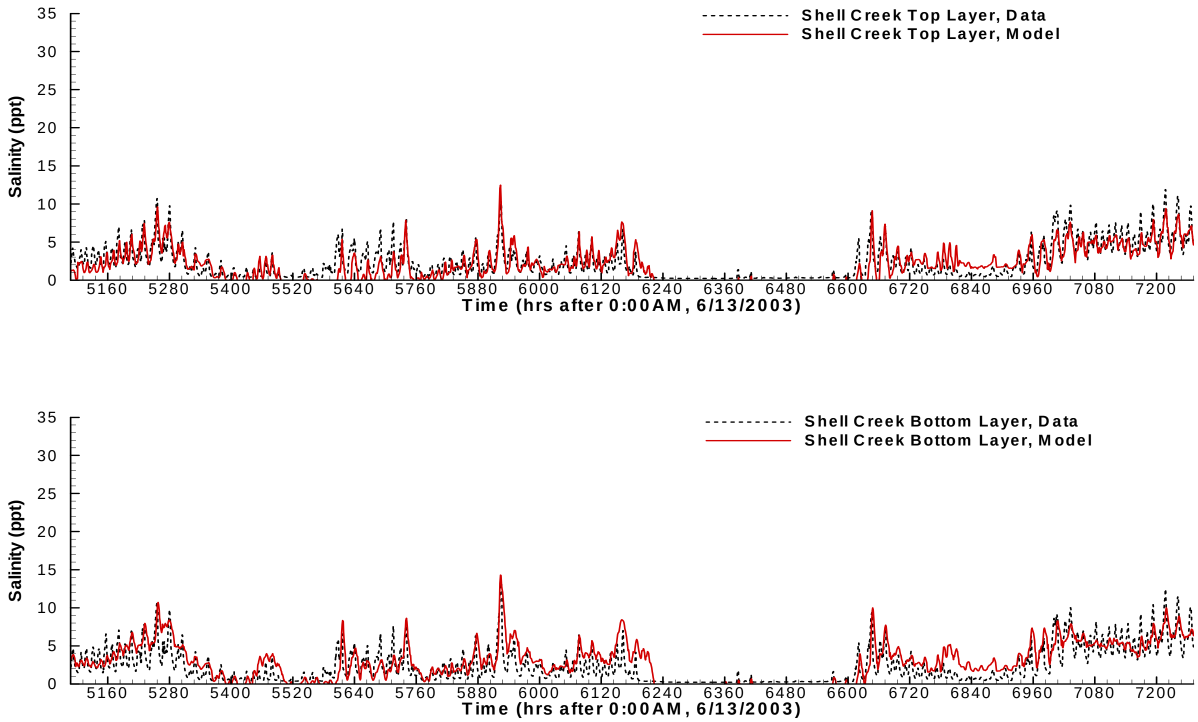

Figure 28. Comparisons of simulated and measured salinities at two depths at the Shell Creek station during January 10 – April 9, 2004.

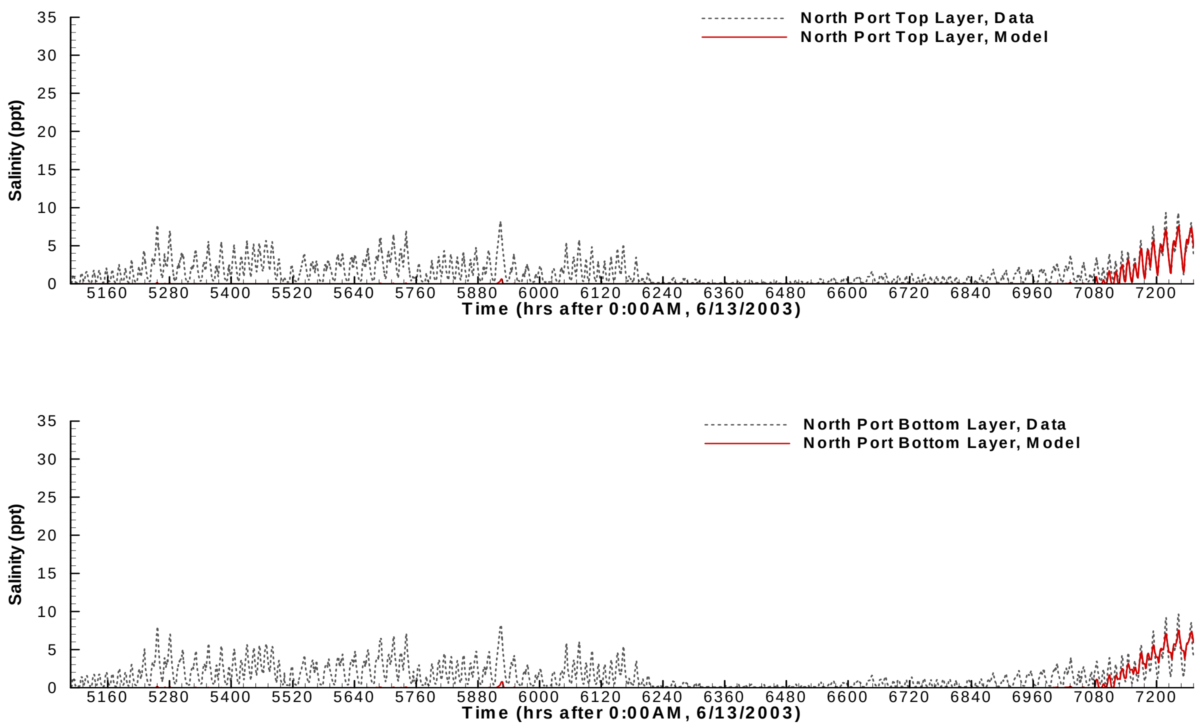

Figure 29. Comparisons of simulated and measured salinities at two depths at the North Port station during January 10 – April 9, 2004.

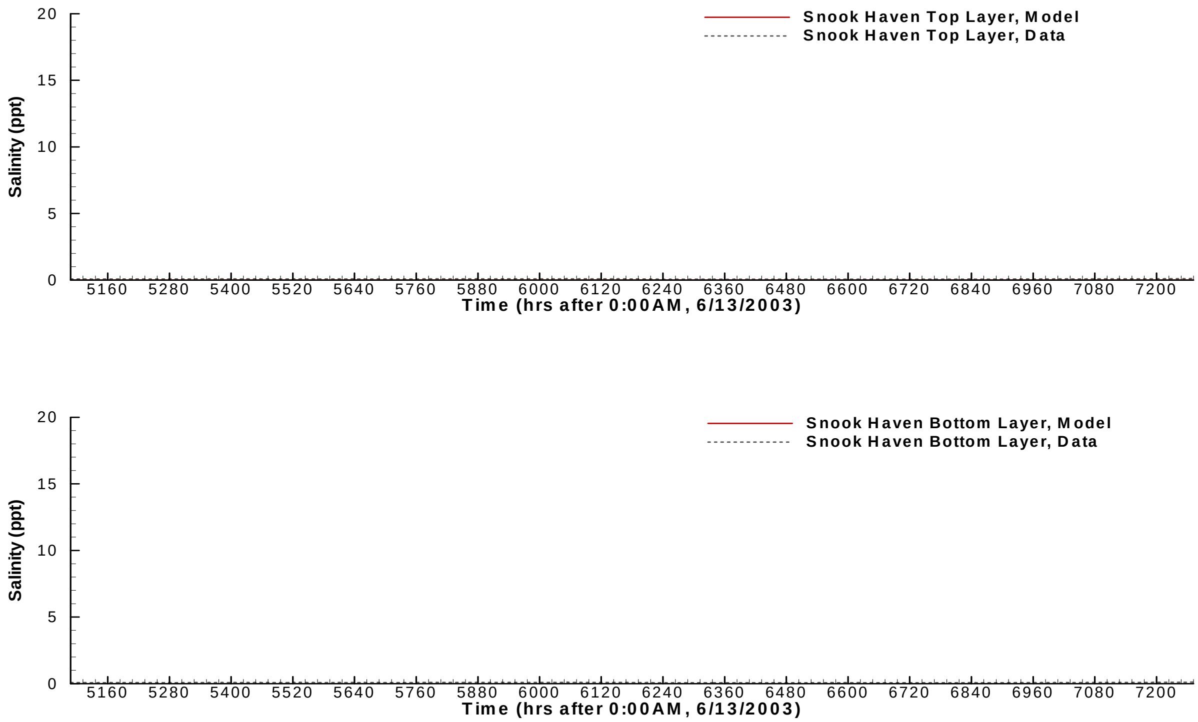

Figure 30. Comparisons of simulated and measured salinities at two depths at the Snook Haven station during January 10 – April 9, 2004.

Quantitative Assessments of the Model Performance – Skill Assessment

Comparisons shown in Figures 19 – 35 only give qualitative assessment of the performance of the model. To gain a quantitative assessment of the model performance, a skill assessment parameter introduced by Wilmott (1981) was used to judge the agreement between model results and measured data. This skill assessment parameter was used by Warner et al. (2005) to assess the performance of an estuary hydrodynamic model for the Hudson River estuary. It also was used by Chen (2005b) to examine the performance of a laterally averaged model named LAMFE for the Lower Alafia River in Florida. This skill assessment parameter takes the following form

$$\text{Skill} = 1 - \frac{\sum (y^M - y^D)^2}{\sum (|y^M - \overline{y^D}| + |y^D - \overline{y^D}|)^2} \tag{18}$$

where y^M and y^D are simulated and measured variables (surface elevation or salinity) and $\overline{y^D}$ and $\overline{y^M}$ are means of y_l^D and y_l^M, respectively. Skill in Equation (18) varies between 0 and 1: a perfect agreement between simulated results and measured data yields a skill of one and a complete disagreement yields a skill of zero.

In addition to the skill parameter, several other statistical parameters such as the R^2 value, the mean error (ME), and the mean absolute error (MAE) were also calculated to analyze the error of the model. Tables 3 - 6 list values of skill, R^2, ME, and MAE for different simulated parameters (water level, velocity, temperature, and salinity) at the eight measurement stations for both the calibration and verification periods are listed. These tables show that the coupled 3d-2DV model performs well for the LPR – LMR - UCH system.

From Table 3, one can see that skills for stage are generally greater than 0.9, except for the most upstream stations for the LPR (the Peace River Heights station) and LMR (the Snook Haven station), where the errors mainly occur during high flow conditions in the wet season when the flood plains are filled with water. Because detailed bathymetry data for flood plains are not available for all the cross sections, the 2DV portion of the coupled model simply extrapolates the river widths based on the available widths in river channel for those sections which have no flood plain bathymetry data. This practice inevitably introduces (sometimes large) errors, which could result in relatively higher deviations simulated water levels from measured data at the most upstream stations in the LPR and LMR. Similar to skill, R^2 for stage is generally greater than 0.85 except for the Peace River Heights station in LPR and the Snook Haven station in LMR. Averaged among all eight stations, the overall skill is 0l.91 and the overall R^2 is 0.82 for stage. The mean errors and the mean absolute errors of simulated water levels are small in comparison to the water level variations in the LPR – LMR - UCH system, except for the two upstream stations. The average ME and MAE for all eight stations are -5.07 cm and 11.33 cm, respectively.

Site_Name	Parameter	ME	MAE	R^2	Skill
UF	Stage (cm)	7.56	8.89	0.88	0.94
El Jobean	Stage (cm)	-3.25	6.98	0.88	0.96
Punta Gorda	Stage (cm)	5.72	8.09	0.89	0.96
North Port	Stage (cm)	-10.29	10.82	0.88	0.93
Snook Haven	Stage (cm)	-21.81	23.21	0.61	0.76
Harbor Heights	Stage (cm)	-6.47	9.89	0.80	0.92
Peace R Heights	Stage (cm)	-13.77	14.80	0.74	0.87
Shell Creek	Stage (cm)	1.78	7.97	0.85	0.95
Average	**Stage (cm)**	**-5.07**	**11.33**	**0.82**	**0.91**

Table 3. Values of skill, R^2, the mean error, and the mean absolute error of simulated water levels at the eight measurement stations during both the calibration and verification periods.

For simulated velocity components at the UF site, Table 4 shows that their skills are mostly 0.8 or better, except for the u-velocity near the surface which has a skill of 0.72 (Table 4). The mean error of the u-velocity is between -0.63 and -0.29 cm/s, while the mean error of the v-velocity varies between -0.62 and 1.55 cm/s. The mean absolute error ranges between 2.48 and 3.49 cm/s for the u-velocity and between 4.14 and 5.43 cm/s for the v-velocity. Although the model was able to simulate both the long-term and short-term velocity variations (see Figs. 21 and 22 and those in Appendix B) at the UF site, R^2 values for simulated velocities are relatively low, ranging between 0.27 and 0.58 for the u-velocity and between 0.57 and 0.63 for the v-velocity. There are several reasons for these low R^2 values. First of all, measured velocities represent localized water movement at the UF site, while simulated velocities represent overall water movement within an area with a length scale of the grid size (500 m × 500 m near the UF site). Some localized features (e.g., bathymetric variation, wind) cannot be resolved by relatively course grids used at and around the UF site. A close inspection of measured and simulated velocities reveals that the field data have many high frequency fluctuations which do not exist in model results. Also, because the UF site is close to the west bank of the Upper Charlotte Harbor, the sub-grid variation of velocity could be large. Another reason for the low R^2 values of modeled velocities appears to be related to a phase shift of roughly one hour between simulated and measured velocities during some summer months. This could be due to an error in recording the correct time during the daylight saving time. Other reasons include some sporadic peaks which cannot be simulated by the coupled model because they might be caused by some localized forces such as the boat movement, interference of the measurement platform on the velocity field, etc. As shown in Table 4, average values of ME, MAE, R2, and skill for all eight velocity sensors at the UF site are -0.04 cm/s, 3.69 cm/s, 0.53, and 0.84, respectively.

Site_Name	Parameter	ME	MAE	R^2	Skill
UF	1st_u (cm/s)	-0.63	2.48	0.58	0.86
UF	2nd_u (cm/s)	-0.53	2.49	0.54	0.85
UF	3rd_u (cm/s)	-0.29	2.73	0.42	0.80
UF	4th_u (cm/s)	-0.29	3.49	0.27	0.72
UF	1st_v (cm/s)	1.55	4.15	0.58	0.85
UF	2nd_v (cm/s)	0.61	4.14	0.63	0.89
UF	3rd_v (cm/s)	-0.13	4.61	0.63	0.88
UF	4th_v (cm/s)	-0.62	5.43	0.57	0.85
Average	**Velocity (cm/s)**	**-0.04**	**3.69**	**0.53**	**0.84**

Table 4. Values of skill, R^2, the mean error, and the mean absolute error of simulated u- and v-velocities at the UF measurement station during both the calibration and verification periods.

Site_Name	Parameter	ME	MAE	R^2	Skill
UF	Top_Sal (ppt)	0.26	1.76	0.94	0.98
UF	Mid_Sal (ppt)	0.42	1.56	0.95	0.99
UF	Bot_Sal (ppt)	-0.05	1.90	0.83	0.95
El Jobean	Top_Sal (ppt)	-1.88	2.22	0.88	0.92
El Jobean	Bot_Sal (ppt)	-1.03	1.84	0.92	0.97
Punta Gorda	Top_Sal (ppt)	0.13	1.99	0.90	0.97
Punta Gorda	Bot_Sal (ppt)	1.10	2.59	0.77	0.93
North Port	Top_Sal (ppt)	-1.07	1.21	0.88	0.93
North Port	Bot_Sal (ppt)	-1.17	1.34	0.86	0.92
Snook Haven	Top_Sal (ppt)	0.03	0.13	0.81	0.94
Snook Haven	Bot_Sal (ppt)	0.02	0.13	0.80	0.94
Harbor Heights	Top_Sal (ppt)	1.62	2.13	0.75	0.90
Harbor Heights	Bot_Sal (ppt)	1.98	2.28	0.76	0.89
Peace R Heights	Top_Sal (ppt)	0.71	0.78	0.39	0.40
Peace R Heights	Bot_Sal (ppt)	0.74	0.80	0.39	0.38

Shell Creek	Top_Sal (ppt)	0.96	1.40	0.77	0.91
Shell Creek	Bot_Sal (ppt)	1.13	1.54	0.77	0.90
Average	**Salinity (ppt)**	**0.23**	**1.51**	**0.79**	**0.87**

Table 5. Values of skill, R^2, the mean error, and the mean absolute error of simulated salinities at the eight measurement stations during both the calibration and verification periods.

From Table 5, it can be seen that the R^2 and skill values for salinity are good at most stations. Seven of the eight stations have an R^2 of 0.75 or better and a skill of 0.89 or better. The only exception is the Peace River Heights station where water is fresh most of the year. Although the mean errors and the mean absolute errors are low at this station, R^2 values for the top and bottom layers of this station are only 0.39, and salinity skills for the top and bottom layers are only 0.40 and 0.38, respectively. There were several reasons for the low salinity skills at the Peace River Heights station. First, the un-gauged flow estimates used in this study did not include any base flows, causing the model to over-predict salinity at Peace River Heights during dry seasons. Second, measured salinity was never zero (in the range of 0.01 - 0.5 ppt), even during major storm events in 2003 and 2004 when water at Peace River Heights was supposed to be fresh with zero salinity. This indicates that either the salinity sensors at this station were not correctly calibrated or runoff from the watershed might contain a certain amount of minerals. On the other hand, because we assumed that all freshwater loadings from both upstream boundaries and un-gauged areas have a salinity of 0 ppt, the couple model correctly predicted zero salinity at Peace River Heights when it is fresh there. Although an error in the range of 0.01 – 0.5 ppt is small, it lessens the R^2 and skill values, because the Peace River Heights station is fresh most of the time and this small error also occurs most of the time.

Site_Name	Parameter	ME	MAE	R^2	Skill
UF	Top_Temp (C^o)	-1.18	1.52	0.93	0.94
UF	Mid_Temp (C^o)	-0.73	0.99	0.98	0.98
UF	Bot_Temp (C^o)	-1.13	1.24	0.98	0.98
El Jobean	Top_Temp (C^o)	-1.05	1.19	0.99	0.98
El Jobean	Bot_Temp (C^o)	-1.04	1.21	0.98	0.98
Punta Gorda	Top_Temp (C^o)	-0.74	1.08	0.97	0.98
Punta Gorda	Bot_Temp (C^o)	-0.47	0.96	0.98	0.99
North Port	Top_Temp (C^o)	-2.01	2.22	0.93	0.93
North Port	Bot_Temp (C^o)	-2.05	2.25	0.92	0.93
Snook Haven	Top_Temp (C^o)	-1.80	2.12	0.90	0.93
Snook Haven	Bot_Temp (C^o)	-1.81	2.13	0.89	0.93
Harbor Heights	Top_Temp (C^o)	-1.05	1.76	0.82	0.93
Harbor Heights	Bot_Temp (C^o)	-1.02	1.69	0.82	0.93
Peace R Heights	Top_Temp (C^o)	-0.97	2.22	0.69	0.88
Peace R Heights	Bot_Temp (C^o)	-1.37	2.21	0.71	0.89
Shell Creek	Top_Temp (C^o)	-1.31	1.35	0.98	0.97
Shell Creek	Bot_Temp (C^o)	-1.22	1.28	0.98	0.97
Average	**Temperature** (C^o)	**-1.23**	**1.61**	**0.91**	**0.95**

Table 6. Values of skill, R^2, the mean error, and the mean absolute error of simulated temperatures at the eight measurement stations during both the calibration and verification periods.

Table 6 shows that temperature MEs and MAEs are generally small except for the upstream stations in both LPR and LMR (Peace River Heights, Snook Haven, and North Port). The R^2 and skill values are generally high: the lowest R^2 and skill are 0.69 and 0.88, respectively, and both occur at the top layer of the Peace River Heights station. The main reason for the relatively large errors and relatively low R^2 and skill values at these upstream stations is that tree shading is not properly considered in the model. As the Peace and Myakka rivers become narrow, tree shading can significantly affect the net heat flux at the water surface. Another cause for the relatively large errors and relatively low R^2 and skill values at these upstream stations is the lack of measured temperature for freshwater inflows, both gauged and un-gauged flows. In this study, the model used the Neumann-type temperature boundary conditions with a zero gradient for freshwater loadings, i.e.: temperature in the freshwater loading is the same as that in the grid cell where the freshwater is added to. Because temperature is not a controlling factor in determining minimum flows for the LPR, LMR, or Shell Creek, not much effort was made to calibrate the model with temperature data. Model results of temperature are considered to be good enough in this MFL modeling study.

Comparisons with Salinity Profile Data

In additional to the UF and USGS real-time data, a salinity profile data set compiled by the Mote Marine Laboratory was also available for model verification during this modeling study. These salinity profile data were collected by several government agencies and private entities, with a majority of them being collected by Mote Marine Laboratory. There were 13 salinity profile stations in the LPR, and 10 in the LMR. Locations where the salinity profiles were measured in the LPR and LMR are listed in Table 7. River KM in the table is positive in the upstream direction. Locations for River KM 0 for the LPR and LMR are denoted with red bars in Figure 1.

Salinity Profile Data Locations	Peace River	Myakka River
	River KM	River KM
1	-2.4	1.2
2	6.6	7.2
3	10.5	9.0
4	12.7	11.3
5	12.8	13.9
6	15.5	15.8
7	17.5	17.1
8	21.1	18.2
9	21.9	26.5
10	23.6	31.2
11	24.7	

12	29.5	
13	30.4	

Table 7. Locations (expressed in River Kilometers) where salinity profile data were collected in the LPR and LMR.

The profile data was normally collected monthly by driving a boat to the pre-determined stations. Although measurements were to be taken at the exact same location every time profile data were collected, errors did occur, especially at downstream stations where the Peace and Myakka Rivers are relatively wide and measurement locations for the same station could be different by as much as a few hundreds of meters for different trips. Unlike UF or USGS real-time data which represent averages of hundreds (even thousands, depending on the reading frequency) of readings during the measurement time interval (30 minutes in UF's data, and 15 minutes in USGS data), a salinity profile reading is an instantaneous reading of salinity at the moment of the measurement. As such, profile data could contain more noise than the real-time data. Also, for the same salinity profile, salinity readings for different water depths were not collected simultaneously. From the time the top layer was measured to the time the bottom layer was measured, it usually took several minutes to complete a salinity profile. Considering all these factors, one may not expect simulated salinities to match profile data very well.

Comparisons of simulated salinities at 13 stations in the LPR and 10 stations in the LMR are shown in Figures 31 and 32, respectively. In both figures, simulated results (x-axes) were plotted against measured profile data (y-axes). Comparisons were made for depth less than 1 m (top layer), greater or equal 1 m (bottom layer), and for all depths. The top left graphs in Figures 31 and 32 are comparisons for all depths (all data points), while the top right and bottom graphs are comparisons for depth < 1 m and depth ≥ 1 m, respectively. Also plotted in the figures are the linear regression lines (solid) and the 45-degree lines (dashed). Contrary to what might be expected, comparisons of model results with salinity profiles data in both the LPR and LMR are good. As shown in Figures 31 and 32, R^2 values are 0.89 – 0.91 for the LPR and 0.92 - 0.96 for the LMR. Mean errors, mean absolute errors, and skills were also calculated and listed in Table 8. It can be seen that the errors are small and the skills are quite high.

	Depth	ME	MAE	R^2	Skill
Peace River	All Depths	-0.06	1.69	0.89	0.99
	< 1m	0.28	1.51	0.91	0.98
	≥ 1m	-0.23	1.79	0.89	0.97
Myakka River	All Depths	-0.97	1.36	0.94	0.98
	< 1m	-0.95	1.50	0.92	0.97
	≥1m	-0.99	1.26	0.96	0.98

Table 8. Mean errors, mean absolute errors, q^2-values, and skills of simulated salinities in comparison with salinity profile data compiled by Mote Marine Laboratory during model calibration and verification periods in the LPR and LMR.

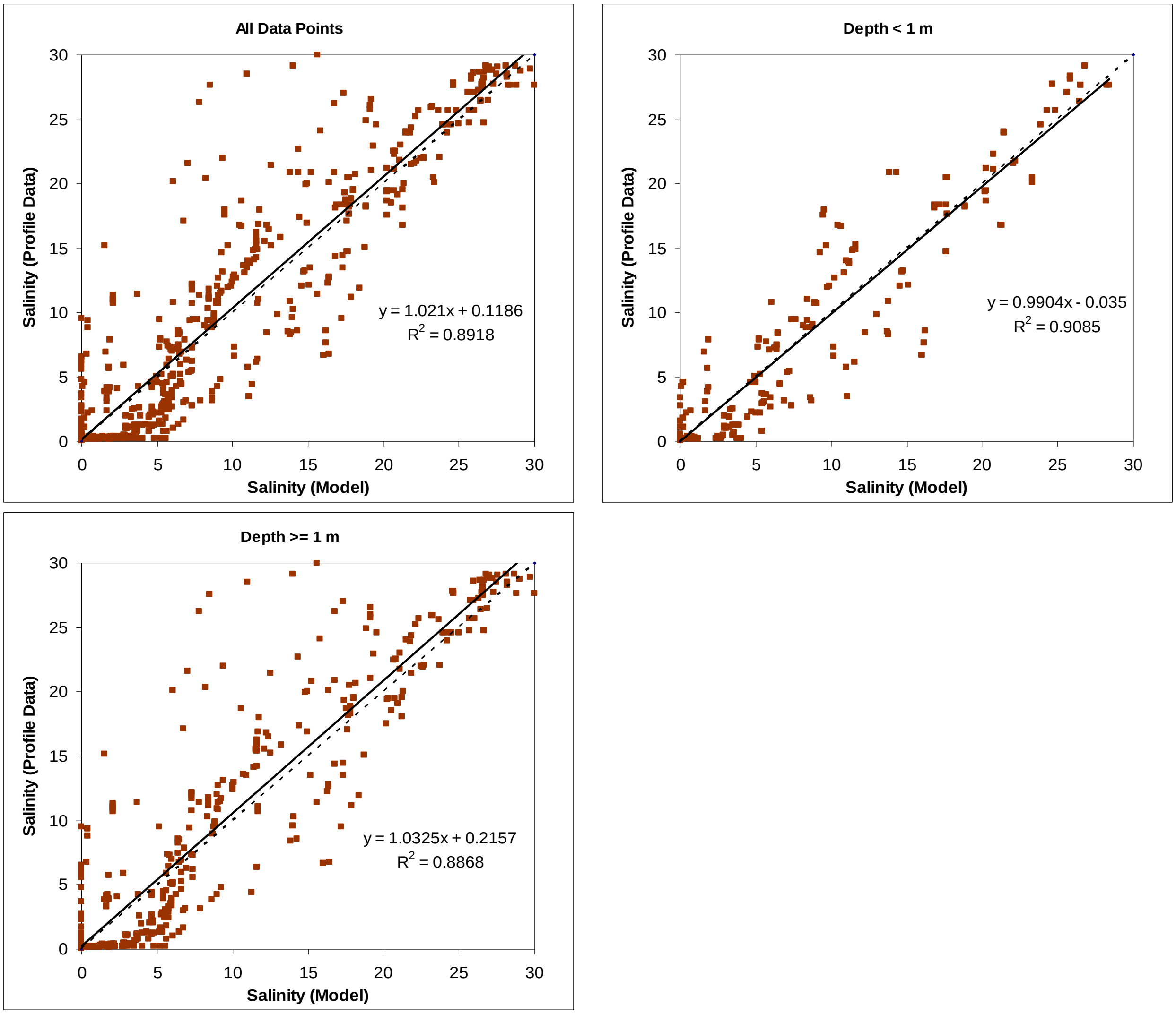

Figure 31. Comparisons of model results with salinity profile data measured at 13 stations in the Lower Peace River. The top left graph is for all data points, while the top right and bottom graphs are for depth < 1 m and depth ≥ 1 m, respectively.

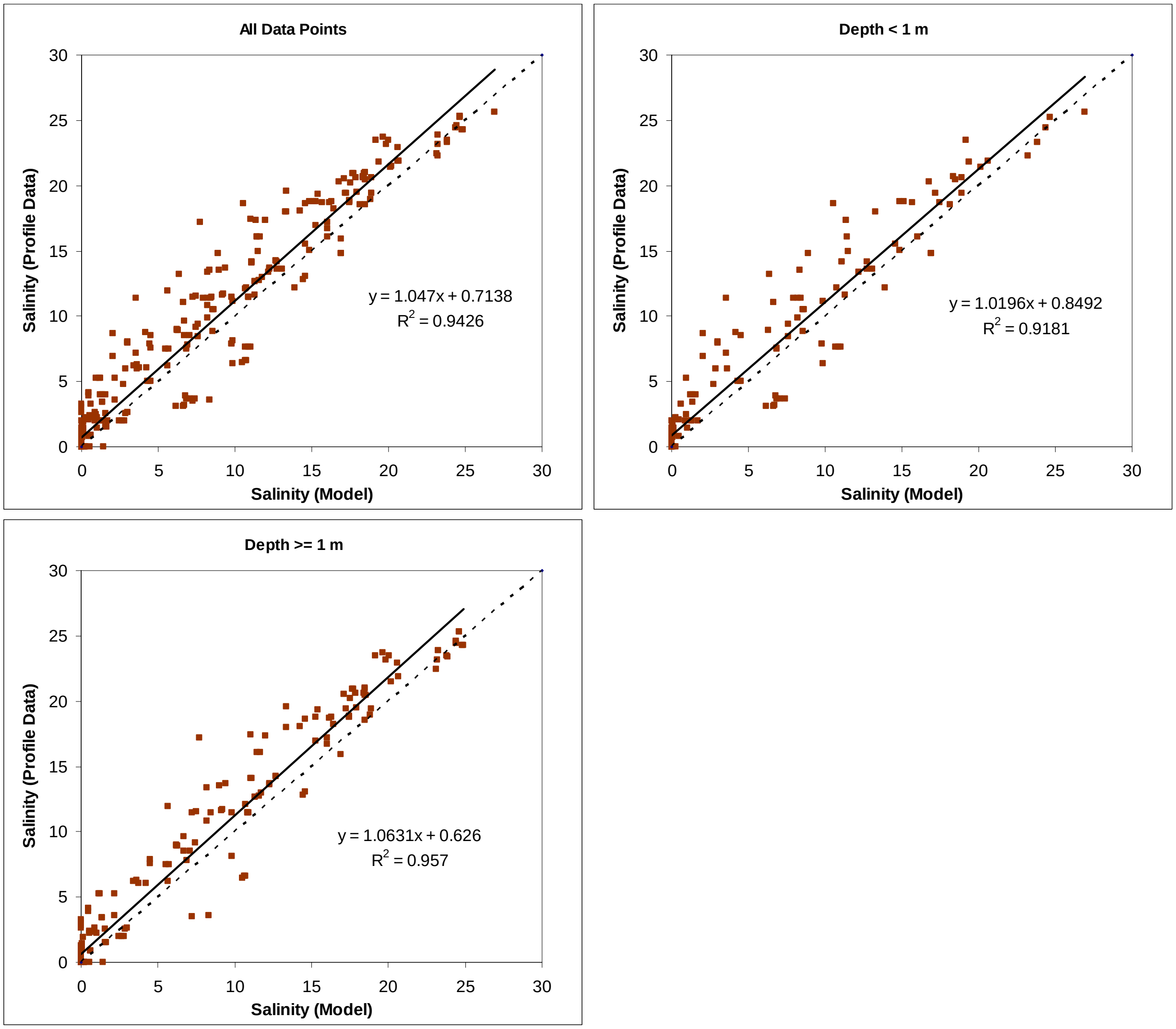

Figure 32. Comparisons of model results with salinity profile data measured at 10 stations in the Lower Myakka River. The top left graph is for all data points, while the top right and bottom graphs are for depth < 1 m and depth ≥ 1 m, respectively.

Estuarine Residence Time the LPR

During this modeling study of the LPR – LMR – UCH system, the dynamically coupled model LESS was also used to estimate the estuarine residence time (ERT) in the LPR system, even though the results of ERT for LPR was not used (also not needed) in the determination of the LPR MFL. By assuming an evenly distributed conservative tracer concentration of 10 mg L^{-1} in the main stem of the LPR only, from Arcadia to its mouth, at time = 0, the model was run for 16 combined Arcadia – Joshua - Horse flow scenarios. Table 3 lists the 16 flow rates (*Q*) used in the ERT simulations, and they are sums of gauged USGS flows in the Joshua Creek, the Horse Creek, and the Peace River at the Arcadia station. These flow rates were partitioned among Arcadia, Joshua, and Horse according to their long-term averages. Their corresponding un-gauged flows for each un-gauged sub-basins used in the ERT runs were obtained using ratios of long-term averages of un-gauged flow estimates to that of the Arcadia flow. During the 16 model runs, the total mass of the conservative tracer remained in the LPR was calculated and book-kept at each time step. Time series of the remaining conservative tracer mass were analyzed. Figures D-1 through D-16 in Appendix D are plots of these time series. Time series of the percentage of the remaining conservative mass in the LPR are also shown in Figures D-1 through D-16. It is evident that strong tidal signals are contained in these time series. To filter out the tidal signals, trend lines in the form of exponential decade can be drawn to approximate the curves:

$$L = a\exp(-Kt) \qquad (19)$$

where *L* is the percentage of the remaining conservative mass, *a* is a coefficient, *K* is the rate of the exponential decade in hour^{-1}, and *t* is time in hour. Parameters *a* and *K* for trend lines of the percentage remaining curves are listed in Table 3. As shown in the figures in Appendix D, all trend lines fit the percentage remaining curves well, with R^2 values being larger than 0.9. Some of the R^2 values are larger than 0.97.

No.	Q (cfs)	*a*	*K*
1	55	94.291	0.00119
2	106	95.316	0.00127
3	154	95.316	0.00136
4	199	86.390	0.00117
5	240	87.266	0.00256
6	281	71.633	0.00265
7	332	71.783	0.00247
8	391	83.899	0.00293
9	455	77.685	0.00301
10	544	108.858	0.00352
11	644	93.268	0.00379
12	939	78.729	0.00396
13	1443	95.558	0.00463
14	2256	63.996	0.00559
15	4036	66.788	0.00977
16	9340	100.238	0.01727

Table 3. Flow rates and values of *a* and *K* in Equation (17) for the 16 LPR ERT runs.

Equation (17) can be used to calculate the ERT for each of the flow scenarios with a given *L*:

$$t = -\frac{1}{K}\ln\left(\frac{L}{a}\right) \qquad (20)$$

One may define ERT using different *L* values. For example, if the ERT is defined as the time when 95% of the conservative mass is flushed out of the system, then *L* = 5. Therefore, for different *L* values, one can obtain different ERTs for the same flow scenario. In the table below, ERT values (in days) were calculated for 16 flow rates using *L* = 1, 2, 5, 10, 15, 20, 25, 30, 35, and 36.79.

Q (cfs)	% Remaining L									
	1	2	5	10	15	20	25	30	35	36.79
55	159.32	135.03	102.92	78.63	64.42	54.34	46.52	40.13	34.73	32.98
106	149.75	126.97	96.86	74.09	60.76	51.31	43.98	37.99	32.92	31.28
154	139.93	118.65	90.51	69.23	56.78	47.94	41.09	35.49	30.76	29.23
199	158.25	133.65	101.13	76.53	62.14	51.93	44.01	37.54	32.07	30.30
240	72.62	61.36	46.47	35.20	28.62	23.94	20.31	17.35	14.85	14.04
281	67.21	56.31	41.89	30.98	24.60	20.08	16.56	13.70	11.27	10.48
332	72.24	60.52	45.03	33.32	26.46	21.60	17.83	14.75	12.14	11.30
391	63.04	53.17	40.13	30.27	24.50	20.40	17.23	14.63	12.44	11.73
455	60.35	50.74	38.04	28.43	22.80	18.81	15.72	13.19	11.06	10.36
544	55.60	47.38	36.52	28.30	23.49	20.08	17.44	15.28	13.45	12.86
644	49.84	42.22	32.15	24.54	20.08	16.92	14.47	12.46	10.77	10.22
939	45.96	38.66	29.02	21.72	17.45	14.43	12.08	10.16	8.53	8.01
1443	41.05	34.81	26.56	20.32	16.67	14.08	12.07	10.43	9.04	8.59
2256	30.99	25.82	19.00	13.83	10.81	8.67	7.00	5.65	4.50	4.12
4036	17.92	14.96	11.05	8.10	6.37	5.14	4.19	3.41	2.76	2.54
9340	11.11	9.44	7.23	5.56	4.58	3.89	3.35	2.91	2.54	2.42

Table 4. ERT values in days for 16 flow rates using 10 different L values ranging from 1 to 36.79.

From Table 4, one can find the relationship between ERT and Q for each L. These ERT-Q relationships are illustrated in Figures 31 – 33. For any L value, the ERT – Q relationship can be fitted to a power function:

$$ERT = bQ^n \quad (21)$$

where b is a coefficient and n is the exponent. The above equation has an R^2 value varying between 0.91 and 0.94. Furthermore, the coefficient b and the exponent n in the above equation are related to L, the percentage of remaining conservative mass, with the following functions (see Figure 34):

$$b = 1747.3 - 375.53\ln(L) \quad (22)$$

$$n = -0.00088L - 0.54 \quad (23)$$

As can be seen from the R^2 values shown in Figure 34, the logarithm function in Equation (20) is a perfect fit to the b-L relationship with a R^2 of 1, while the linear relationship in Equation (21) also fit the n – L relationship very well with a R^2 of 0.987.

Replacing b and n in Equation (19) with the right hand sides of Equations (20) – (21), the final relationship among ERT, Q, and L is expressed as follows

$$ERT = [1747.3 - 375.53\ln(L)]Q^{-(0.54+0.00088L)} \quad (24)$$

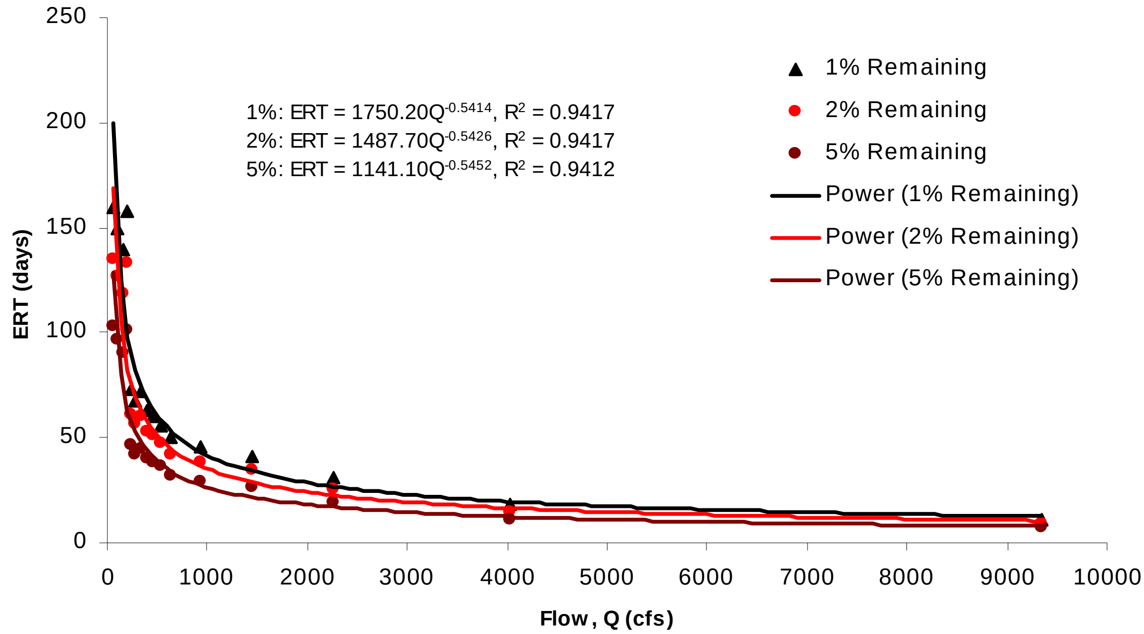

Figure 33. Relationships between ERT and Q for 1%, 2%, and 5% remaining of conservative mass in the LPR.

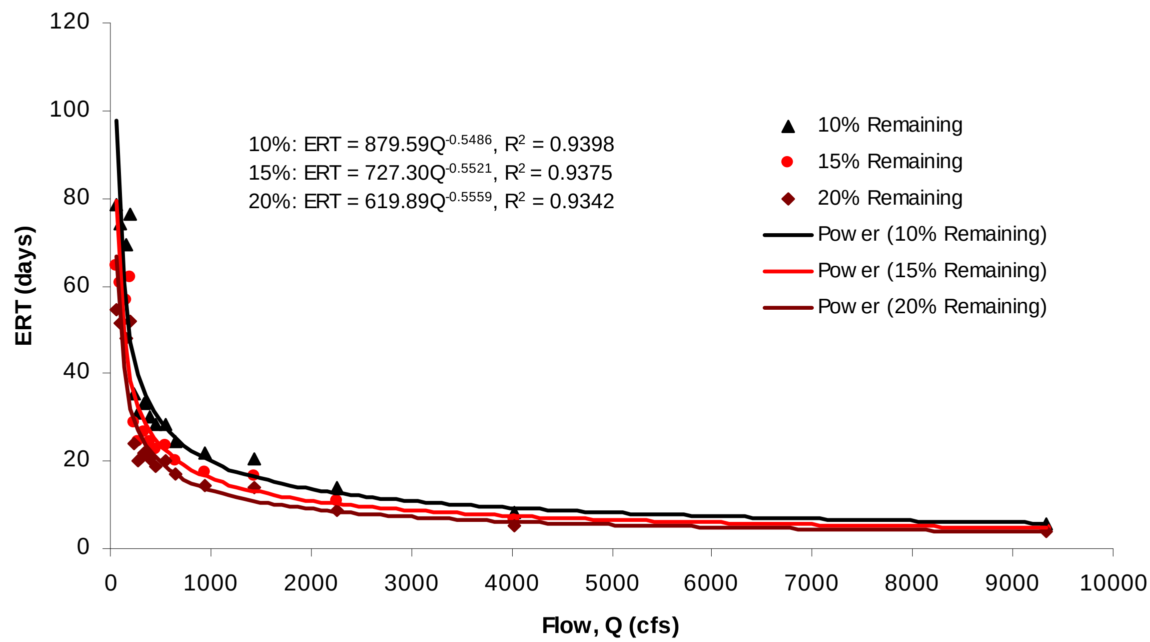

Figure 34. Relationships between ERT and Q for 10%, 15%, and 20% remaining of conservative mass in the LPR.

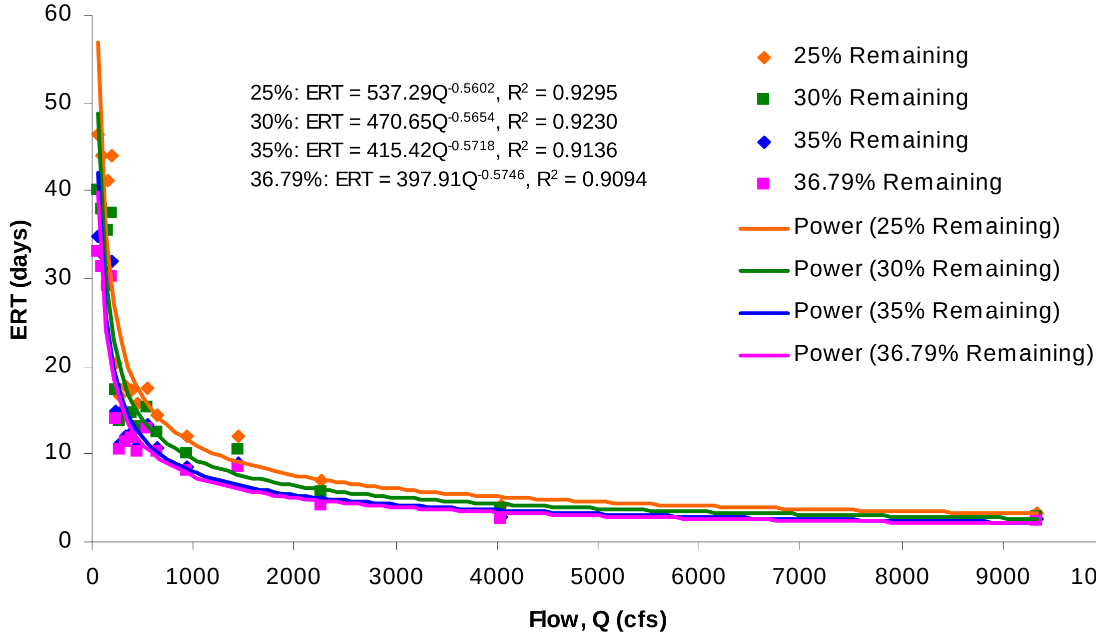

Figure 35. Relationships between ERT and Q for 25%, 30%, 35%, and 36.79% remaining of conservative mass in the LPR.

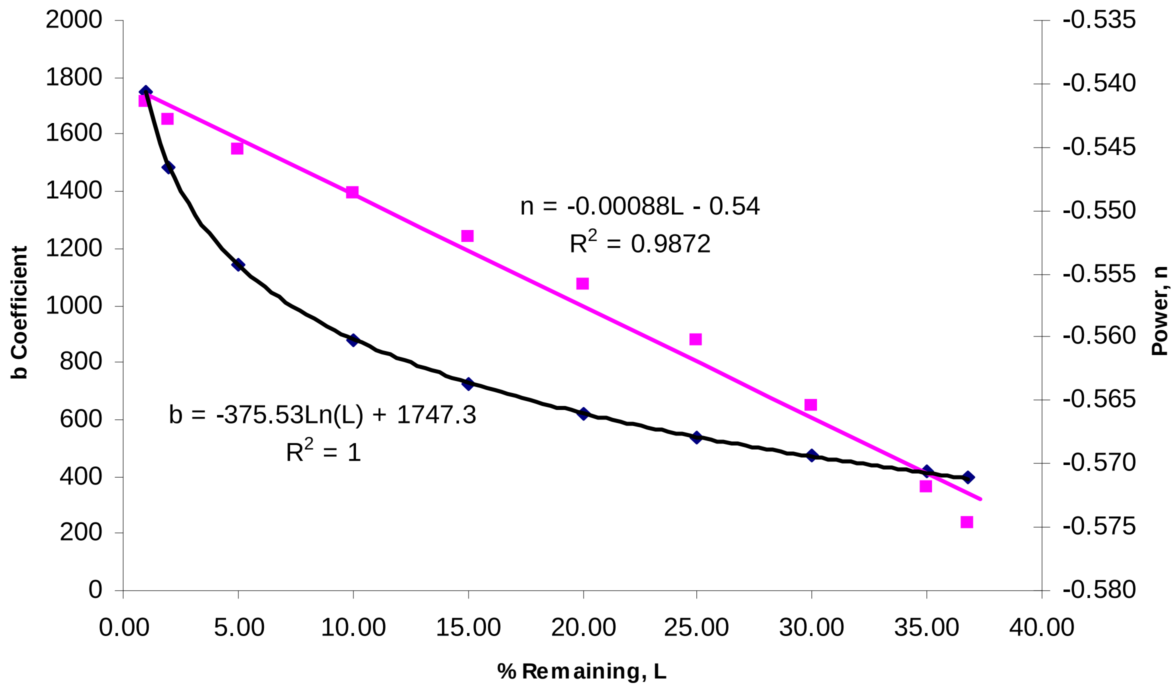

Figure 36. Relationship between *b* and *L* and relationship between *n* and *L*.

5. Conclusions

The purpose of this modeling study is to support the determinations of minimum freshwater inflows to the LPR and LMR to prevent the two rinverine estuaries from significant harms. Because of the interactions among the LPR, the LMR, and the UCH, it is logical to develop a hydrodynamic model that includes all three water bodies. To efficiently deal with the complex geometry of the LPR – LMR - UCH system, this study developed a dynamically coupled 3D-2DV model by coupling a 3D model (LESS3D) with a 2DV model (LAMFE), so that both the large downstream water body and the narrow upstream tributaries can be simulated with the same degree of resolution. The dynamically coupling of the two models is facilitated with a free-surface correction (FSC) method that is unconditionally stable with respect to gravity waves, wind and bottom shear stresses, and vertical eddy viscosity terms. The use of the FSC method allows a simultaneous solution of the free-surface elevation in both the 3D sub-domain and the 2DV sub-domain, and thus avoids any problems associated with the internal boundary. The coupled model solves laterally averaged RANS equations for the narrow open channel. For the larger water body, it solves 3D RANS equations. This kind of a coupled model is especially desirable when the narrow open channel has a large flood plain that can be submerged during a major storm event.

To apply the coupled model to the LPR - LMR - UCH system, various field data were obtained, analyzed, and graphed to evaluate their quality and availabilities and to obtain a preliminary assessment of the physical characteristics of LPR - LMR - UCH system, including freshwater inflows, rainfall, tides, salinity and temperature distributions, wind patterns, etc. Overall, the quality and availabilities of field data in the LPR - LMR - UCH system are found to be marginal with many missing data periods. One important missing piece of data is un-gauged flows, which were first estimated with the HSPF model and then adjusted based on a comparison to results generated by Janicki Environment, Inc. using the SDI method (SWFWMD, 2007).

The dynamically coupled 3D-2DV model was applied to the LPR - LMR - UCH system to simulate hydrodynamics and salinity and temperature transport processes in the three interconnected water bodies. The 3D domain includes the upper Charlotte Harbor, the downstream 1.74km of the Shell Creek, the downstream 15.5km of the LPR, and the downstream 13.8km of the LMR. The 2DV domain includes the LPR from river-km 15.5 to Arcadia, the LMR from river-km 13.8 to river-km 38.4, the Shell Creek from river-km 1.74 to the dam, and the downstream 4.16km of Myakkahatchee Creek. Model simulations were conducted for a 13-month period from June 13, 2003 to July 11, 2004, of which the first 30 days (June13 – July 11, 2003) were used for the model spin-up run. The model was calibrated against measured water levels, currents, salinities, and temperatures at a total of eight stations in the LPR - LMR - UCH system (current data are only available at one station) during a 3-month period of January 10 – April 9, 2004. It was then verified against field data measured at the same eight stations during a 6-month period before the calibration period and a 3-month period after the calibration period. Gauged freshwater flows were used for upstream boundary conditions, while adjusted un-gauged flow estimates were added to the top cells of the model at their corresponding locations. The downstream boundary conditions on the southern border of the 3D domain were specified with simulation results of another hydrodynamic model (Sheng, et al., 2007).

Although there are many uncertainties in the input data used to drive the LESS model, including measured data, un-gauged flows, boundary conditions provided by another hydrodynamic model (Sheng et al., 2007), the dynamically coupled model was successfully calibrated to measured real-time data of water levels, currents, salinities, and temperatures at eight stations during January 10 – April 9, 2004, except for salinity at the North Port station. During the two verification periods before and after the calibration period, the model generally works well in predicting water levels, velocities, and temperatures, but under-predicts salinities in wet months and slightly over-predicts salinities in the driest months. The performance of the model was assessed by calculating mean errors, mean absolute errors, coefficients of determination (R^2 values), and skills of simulated parameters in comparison with field data at eight real-time stations in the system. Overall, the performance of the coupled model is good, especially for the lower portion of the simulation domain, including the downstream segments of the LPR and LMR and the UCH. For upper portion of the simulation domain, including the upstream segments of the LPR and LMR, it didn't have as good a performance as it did in the lower portion of the simulation domain. This should not be a surprise, as there are many uncertainties in the input data (bathymetry, freshwater flows, etc.) to which the upstream segments of the LPR and LMR are more sensitive than the lower portion of the simulation domain is.

Compared to many 3D hydrodynamic simulations found in the literature with a similar complexity as that of the LPR – LMR – UCH system, the coupled model used for LPR and LMR MFL studies has been calibrated and verified against a very large data set. In most 3D hydrodynamic models found in literature, model calibration and verification were only done against limited real-time data for short time periods (days, weeks, or a couple of months). In this study, the coupled model was calibrated and verified against 13 months of real-time data collected at eight stations across the simulation domain and salinity profile data collected during a 12-month period at 23 stations. Considering the many challenges involved in calibrating and verifying a coupled 3D-2DV model in a complicated system like the LPR – LMR – UCH system, this modeling study is considered successful.

After the dynamically coupled model LESS was successfully calibrated and verified, it was used to evaluate estuarine residence times for 16 flow scenarios for the LPR. It was found that the estuarine residence time in the LPR is related to the combined flow of Arcadia, Joshua, and Horse through a power function. Based on an analysis of estimated ERT values for a total of 16 flow scenarios, the power function was found to take the form of $ERT = [1747.3 - 375.53\ln(L)]Q^{-(0.54+0.00088L)}$, where L is the percentage of conservative mass remains in the estuary after ERT days and Q is the sum of gauged USGS flows in the Joshua and Horse Creeks and in the Peace River at the Arcadia station. If the ERT is defined as the time when 95% of conservative mass is flushed out of the estuary, then L = 5 and $ERT = 1142.91Q^{-0.5444}$. It should be pointed out that the ERT calculations for the LPR are simply a by-product of this modeling effort. As a result, calculated ERT values were not used in the LPR MFL determination.

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Appendix A

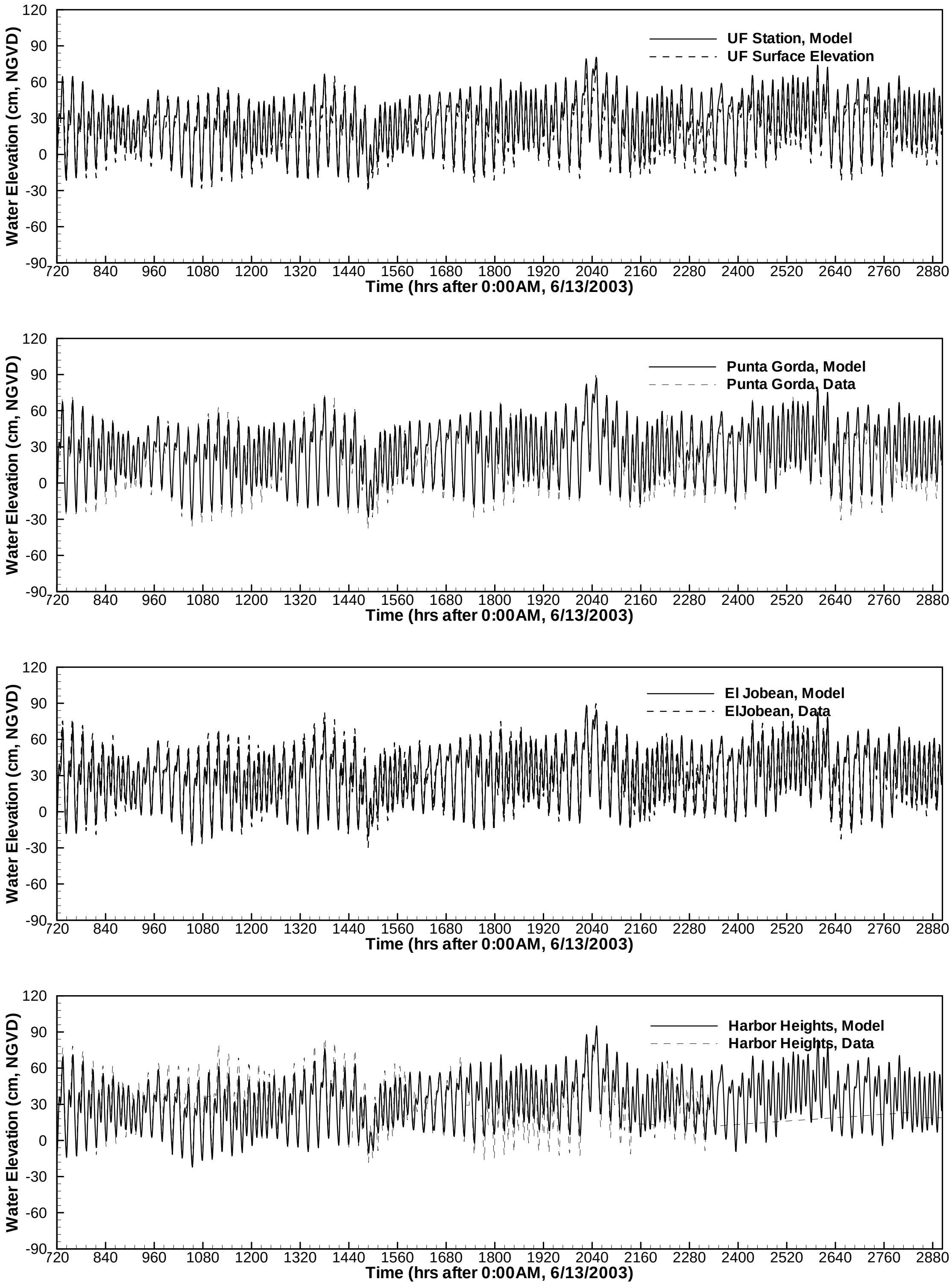

Figure A- 1. Comparisons of simulated and measured water elevations at UF, Punta Gorda, El Jobean, and Harbor Heights during July 12 – October 10, 2003.

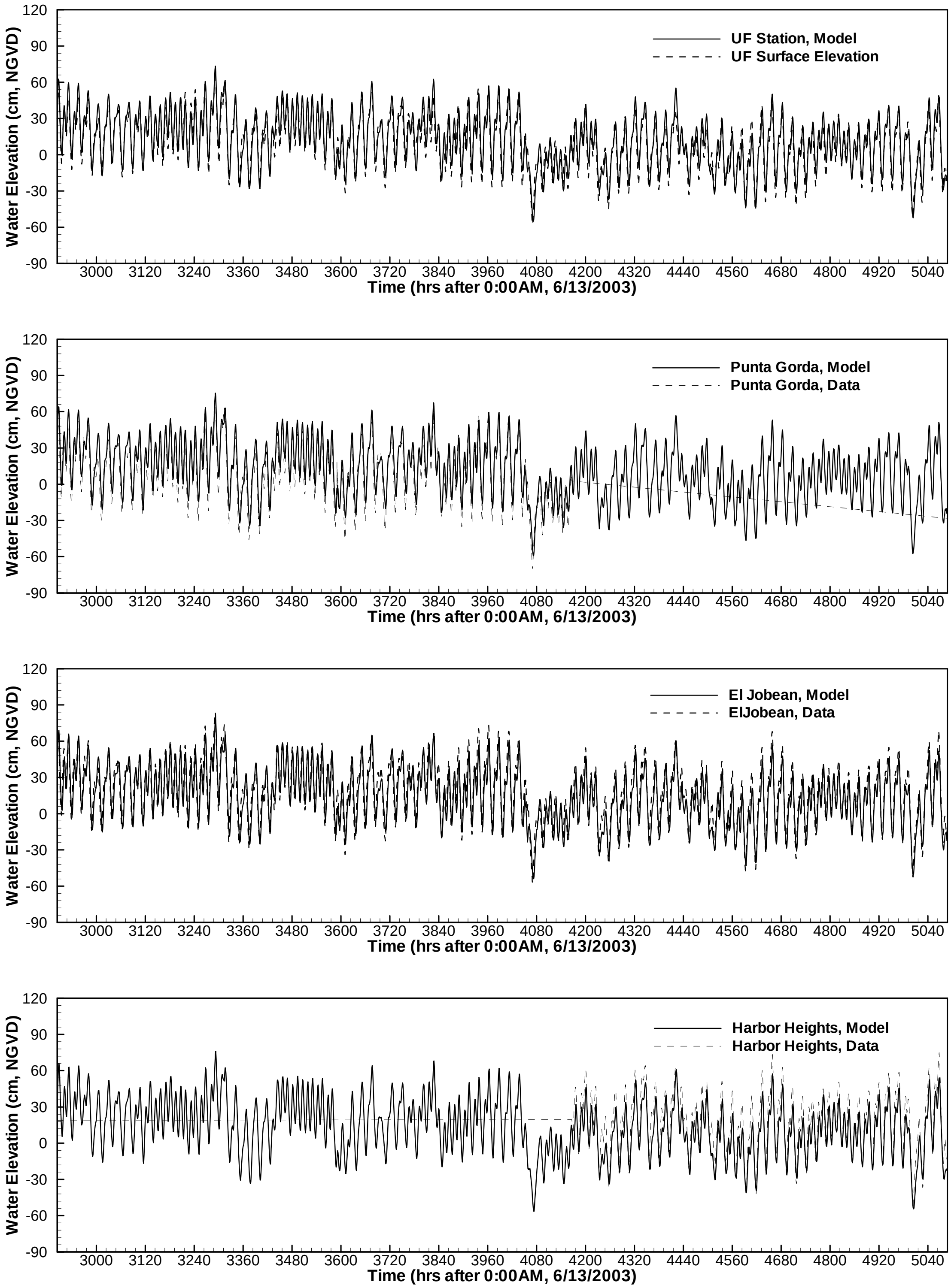

Figure A- 2. Comparisons of simulated and measured water elevations at UF, Punta Gorda, El Jobean, and Harbor Heights during October 11, 2003 – January 9, 2004.

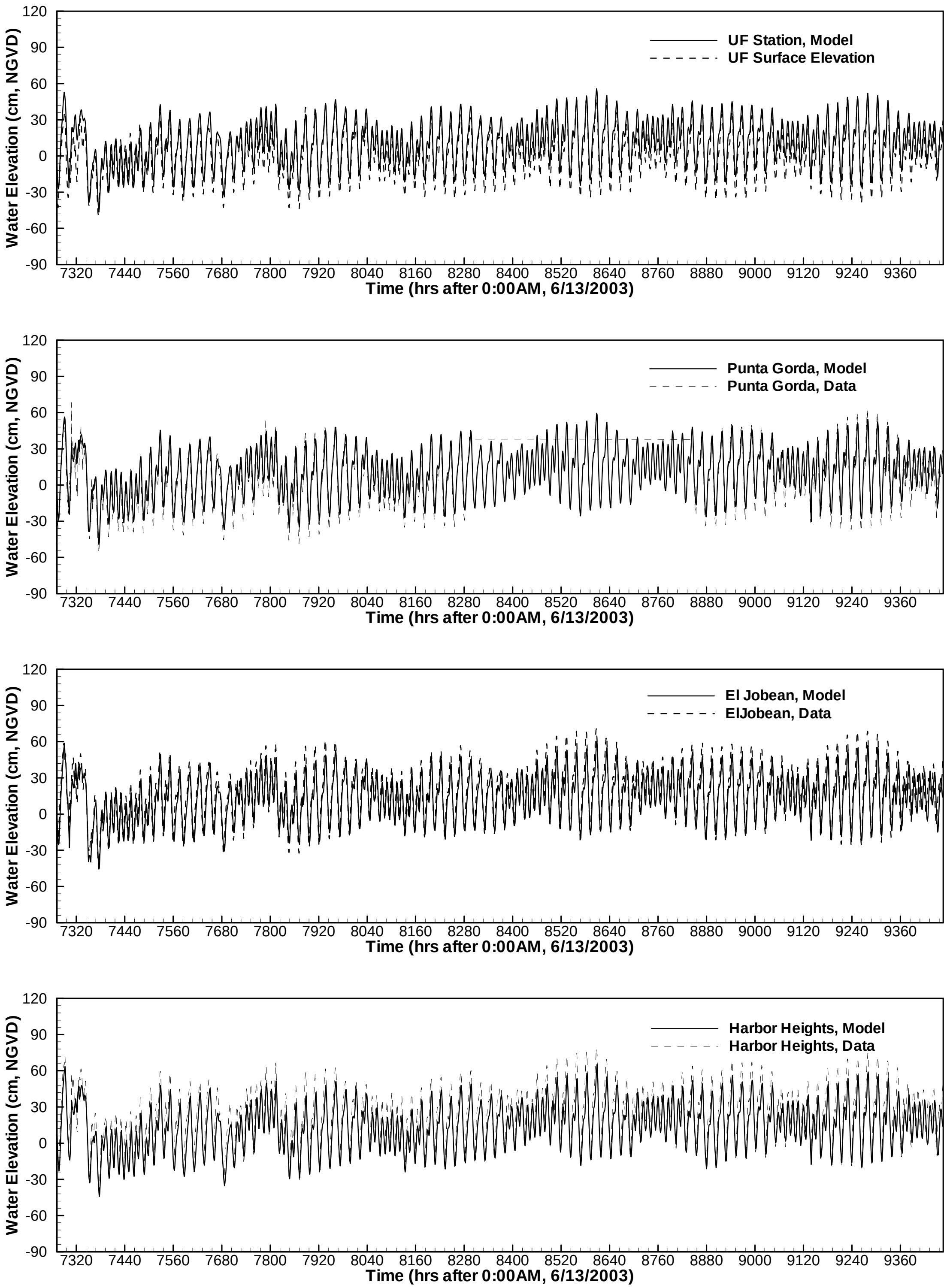

Figure A- 3. Comparisons of simulated and measured water elevations at UF, Punta Gorda, El Jobean, and Harbor Heights during April 10 – July 11, 2004.

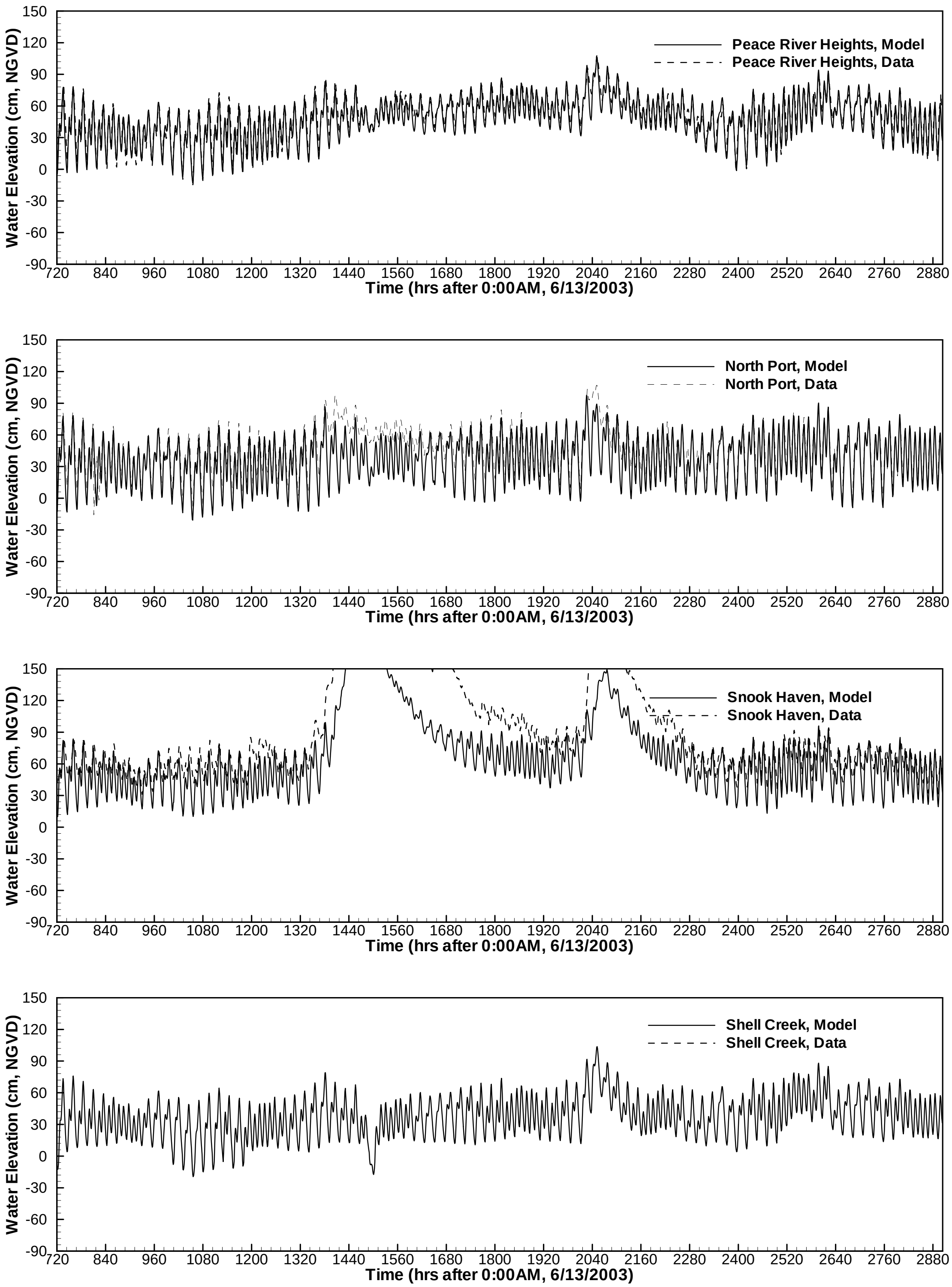

Figure A- 4. Comparisons of simulated and measured water elevations at Peace River Heights, North Port, Snook Haven, and Shell Creek during July 12 – October 10, 2003.

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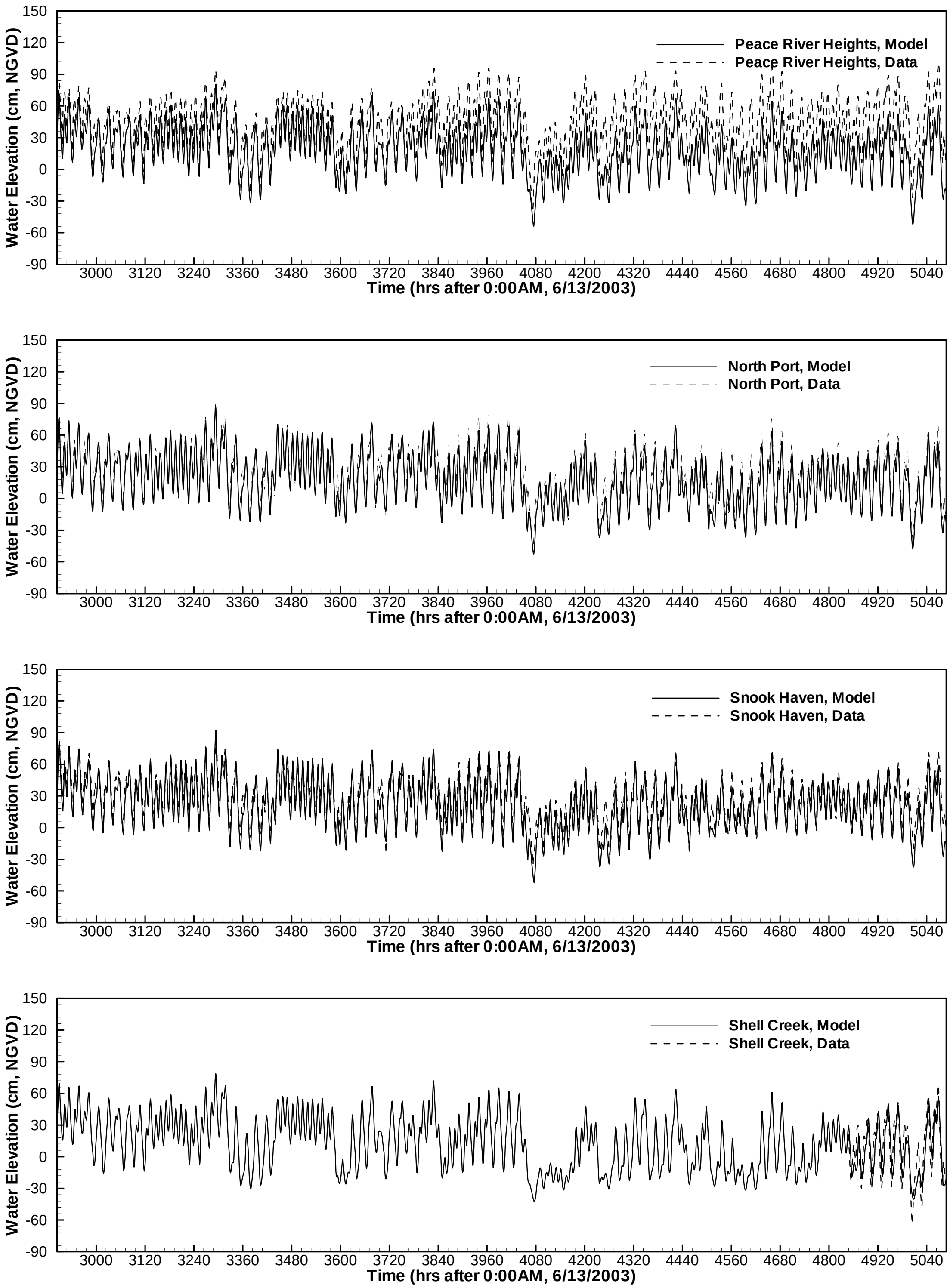

Figure A- 5. Comparisons of simulated and measured water elevations at Peace River Heights, North Port, Snook Haven, and Shell Creek during October 11, 2003 – January 9, 2004.

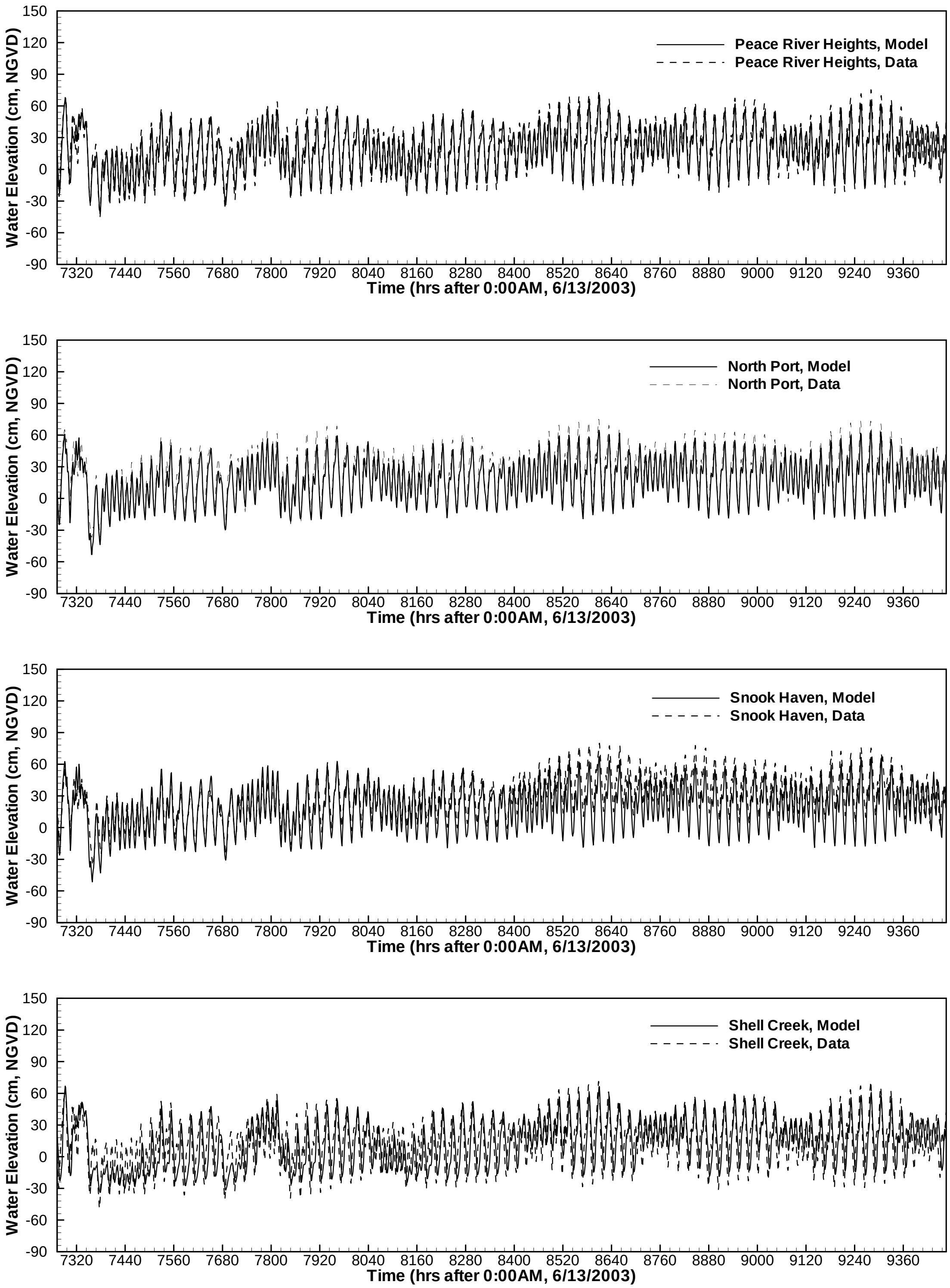

Figure A- 6. Comparisons of simulated and measured water elevations at Peace River Heights, North Port, Snook Haven, and Shell Creek during April 10 – July 11, 2004.

Appendix B

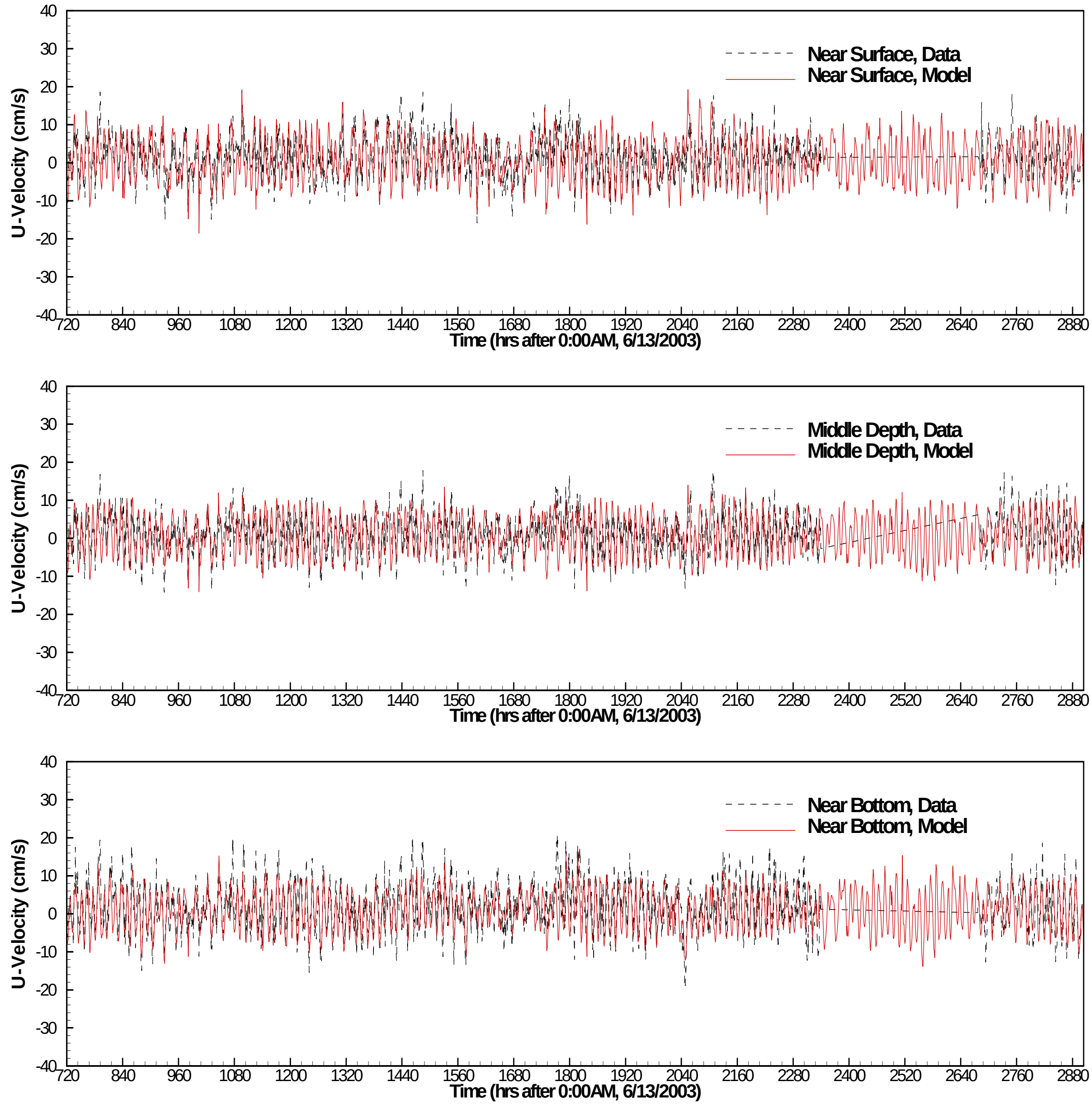

Figure B- 1. Comparisons of simulated and measured u-velocities at three depths at the UF station during July 12 – October 10, 2003.

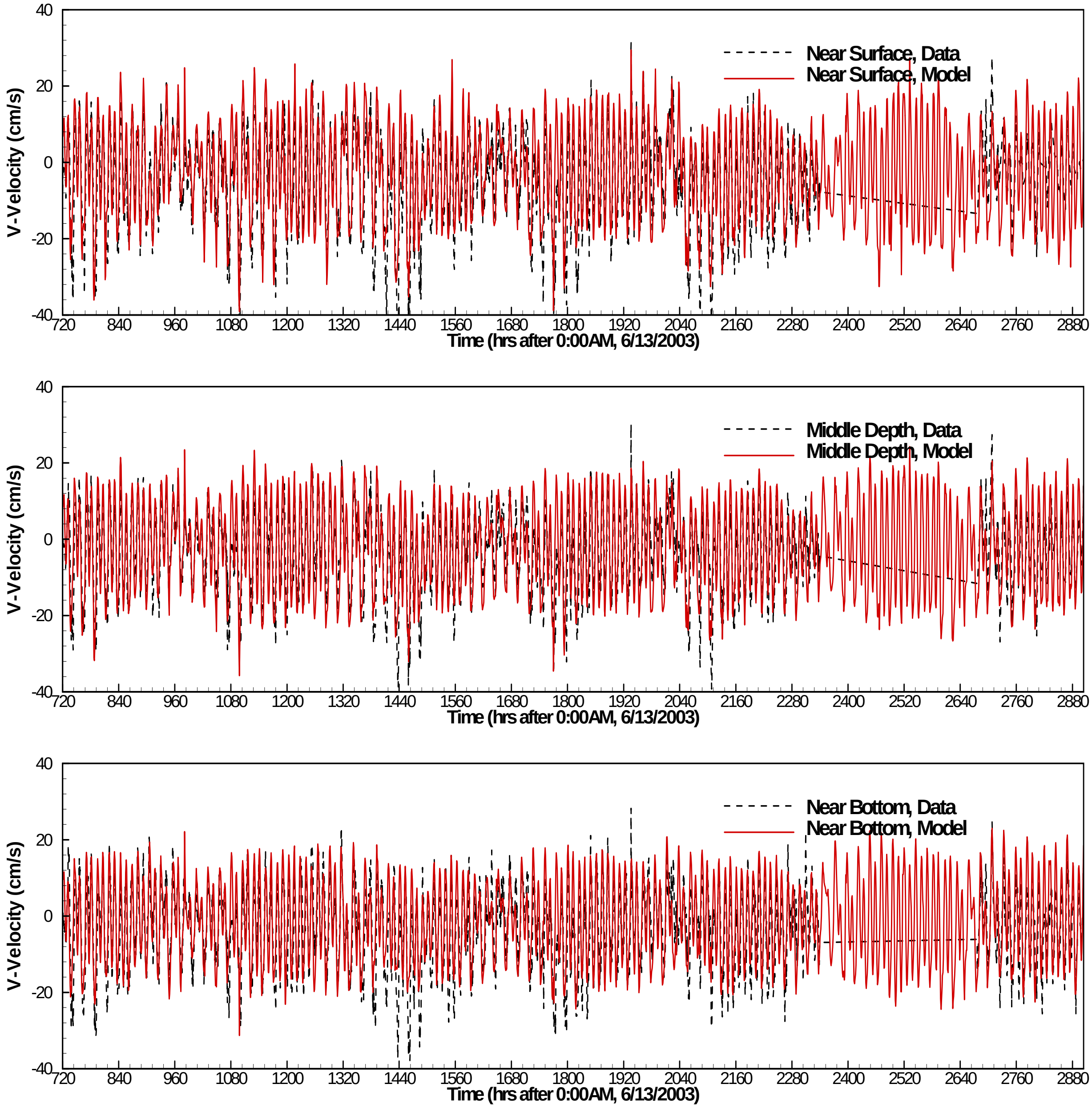

Figure B- 2. Comparisons of simulated and measured v-velocities at three depths at the UF station during July 12 – October 10, 2003.

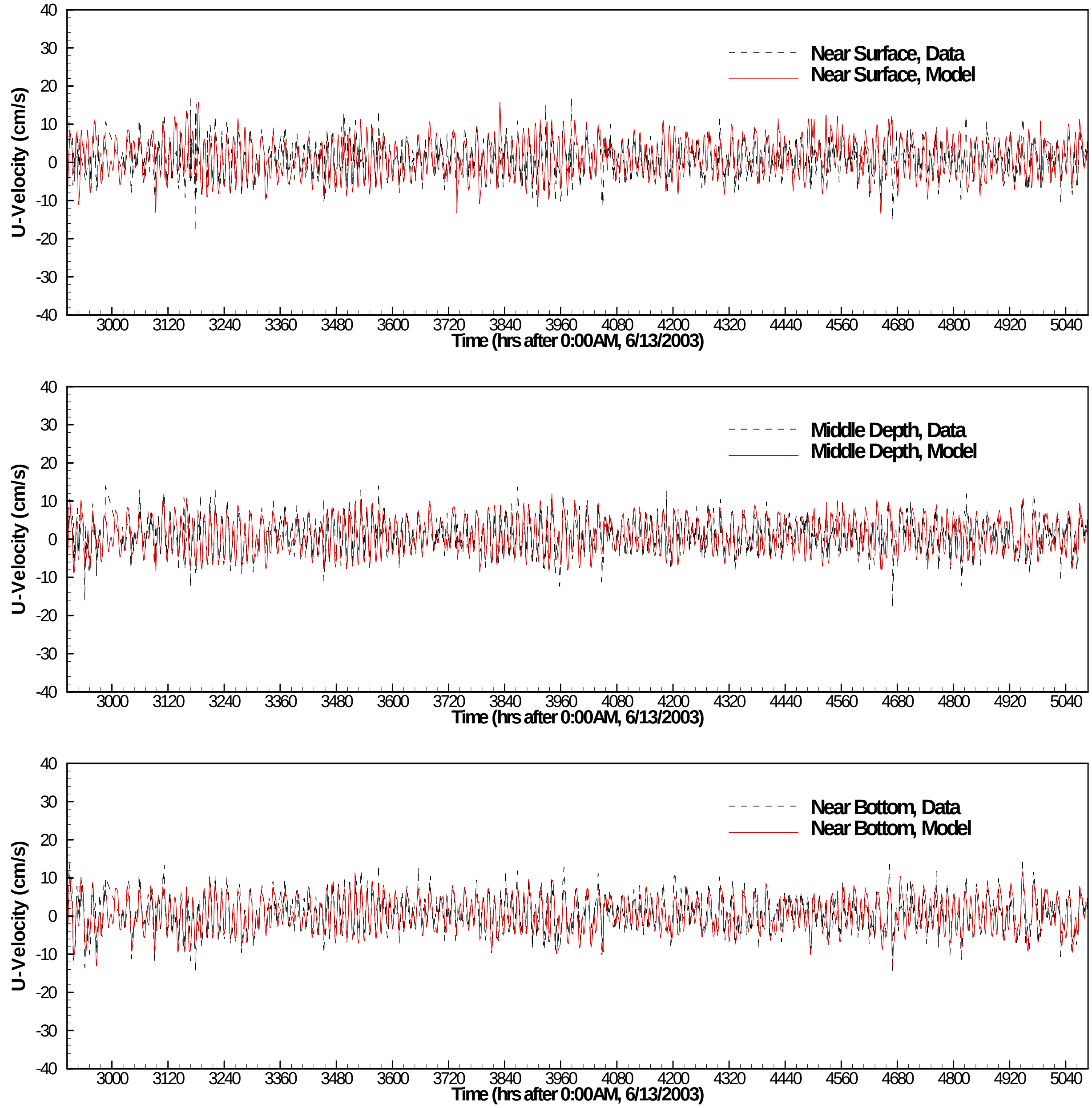

Figure B- 3. Comparisons of simulated and measured u-velocities at three depths at the UF station during October 11, 2003 – January 9, 2004.

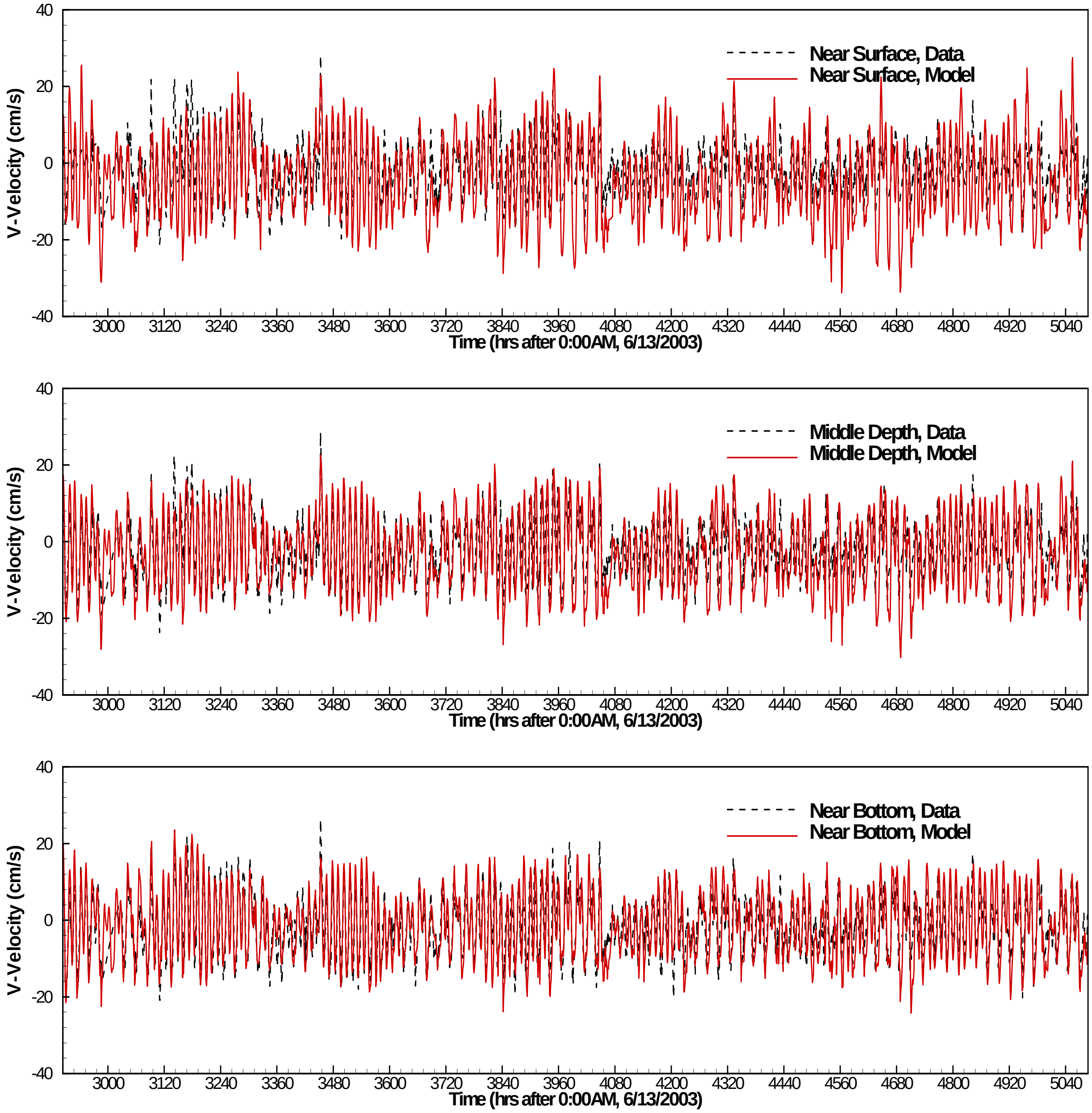

Figure B- 4. Comparisons of simulated and measured v-velocities at three depths at the UF station during October 11, 2003 – January 9, 2004.

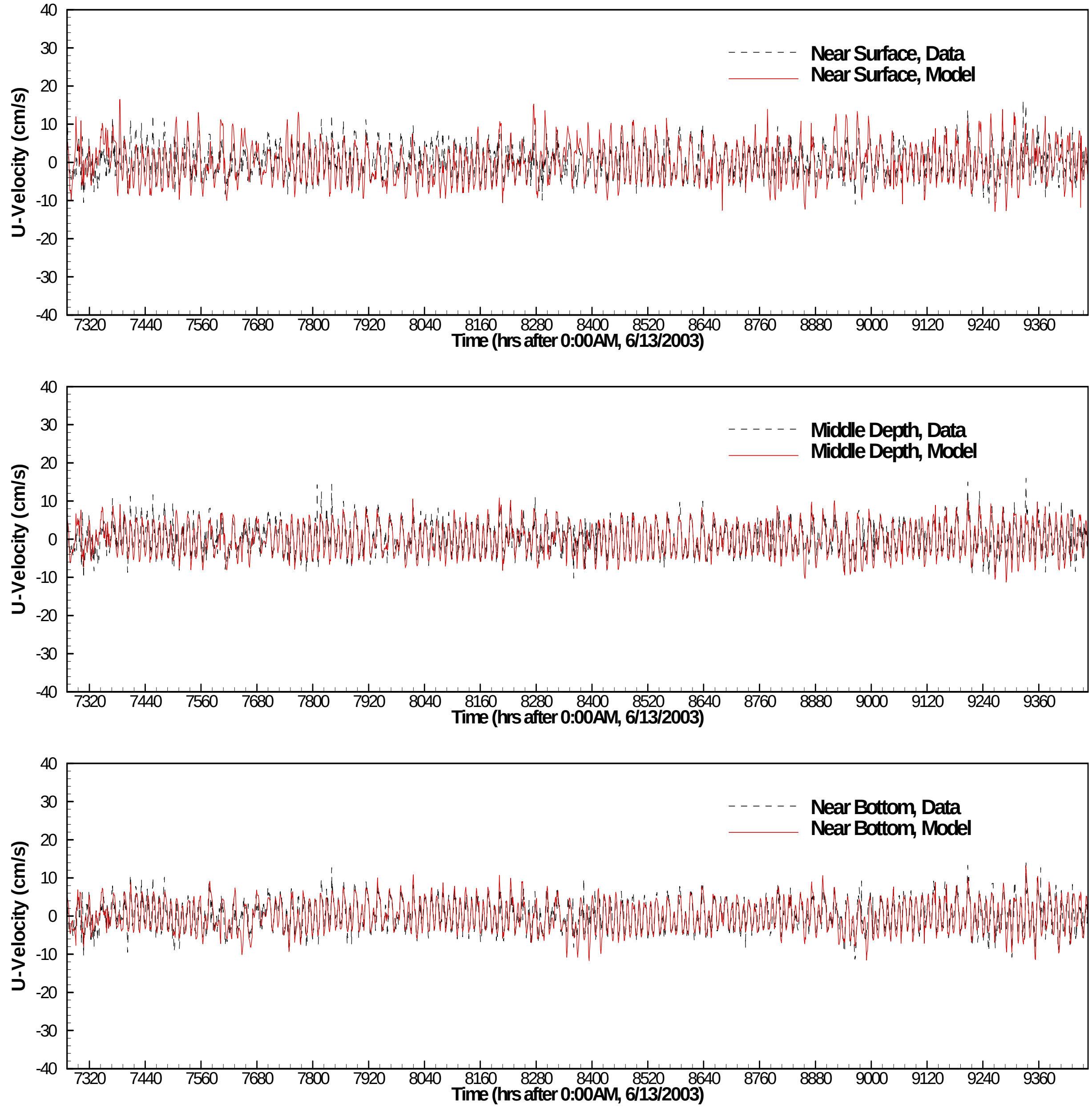

Figure B- 5. Comparisons of simulated and measured u-velocities at three depths at the UF station during April 10 – July 11, 2004.

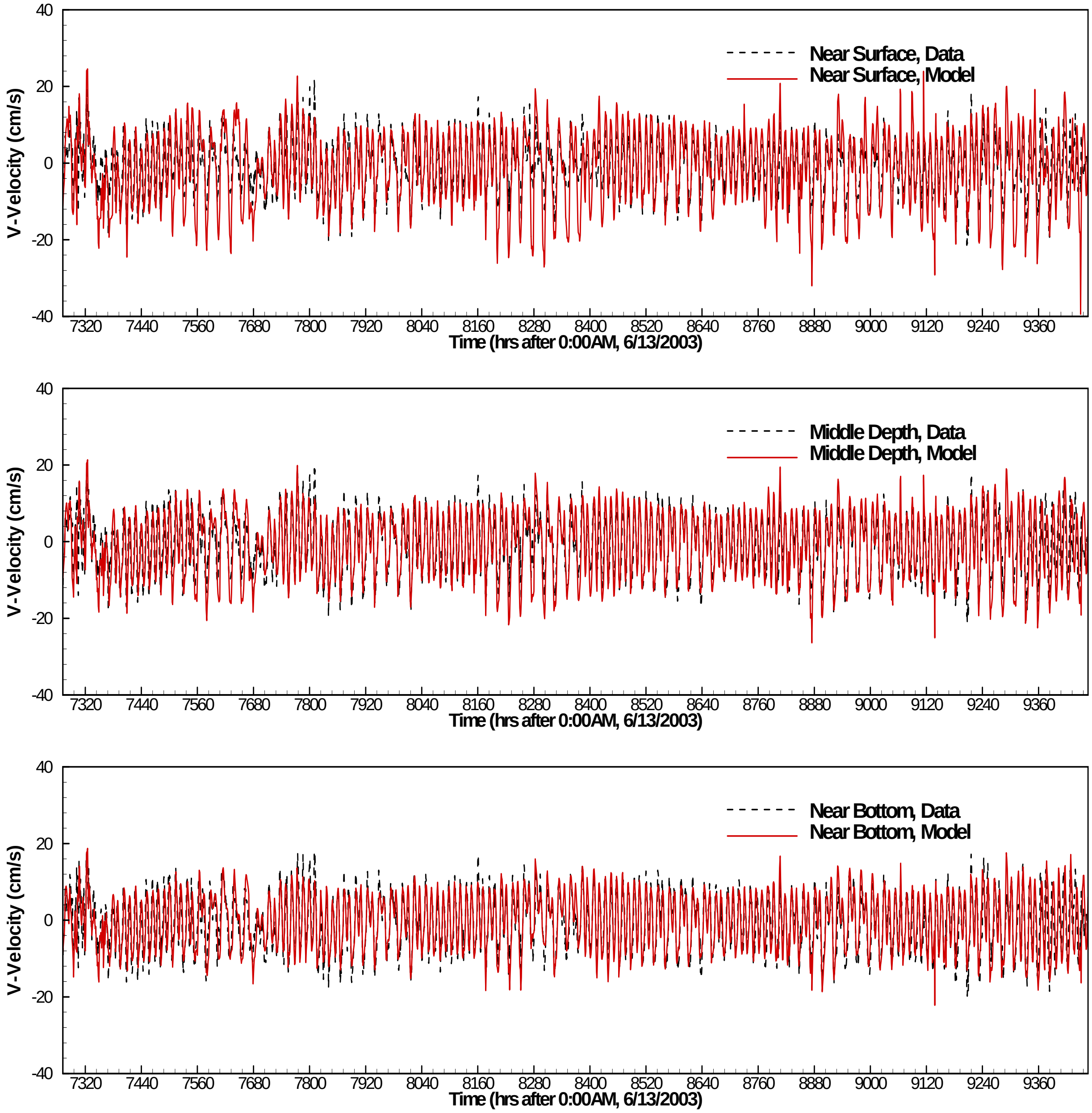

Figure B- 6. Comparisons of simulated and measured v-velocities at three depths at the UF station during April 10 – July 11, 2004.

Appendix C

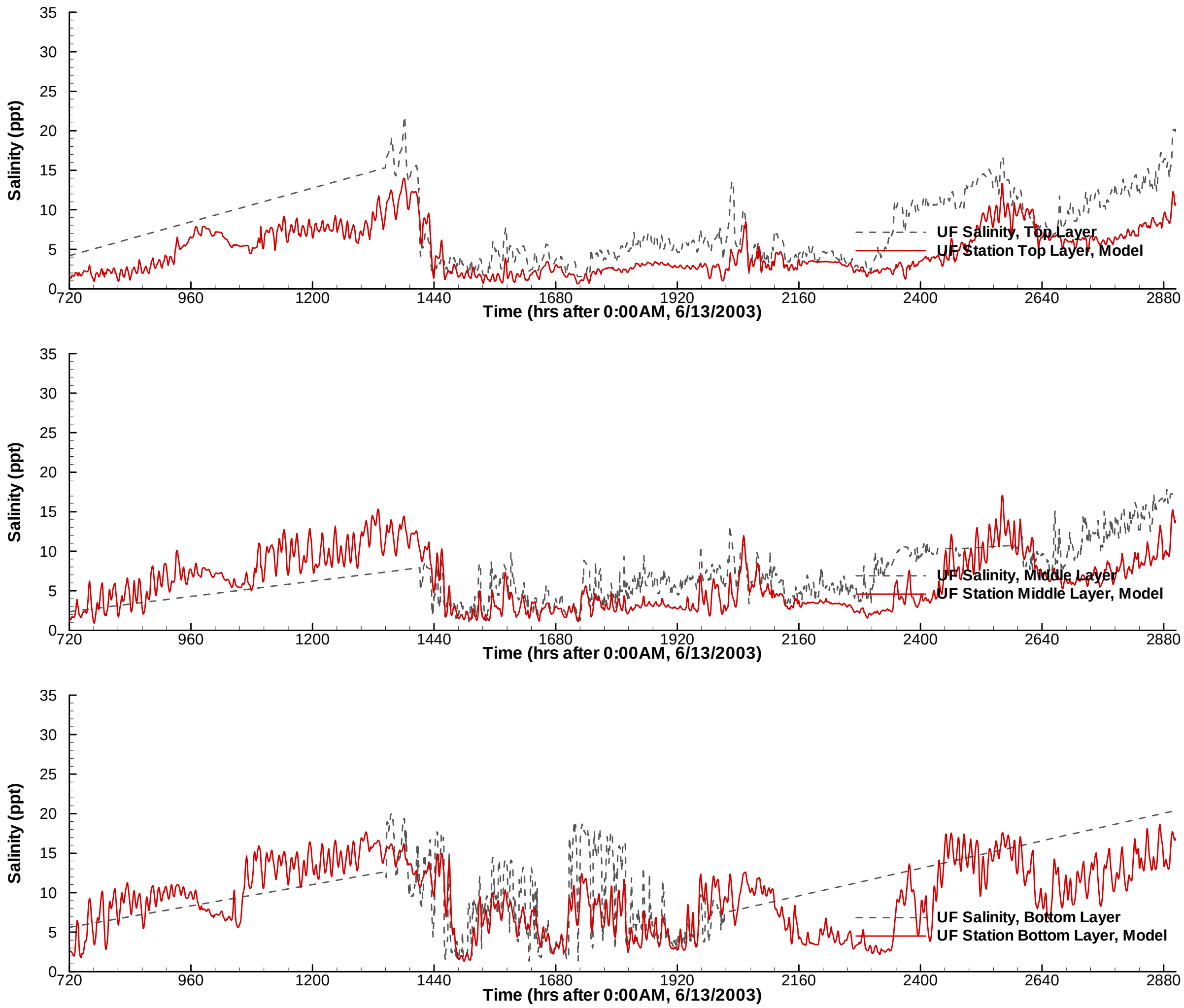

Figure C- 1. Comparisons of simulated and measured salinities at three depths at the UF station during July 12 – October 10, 2003.

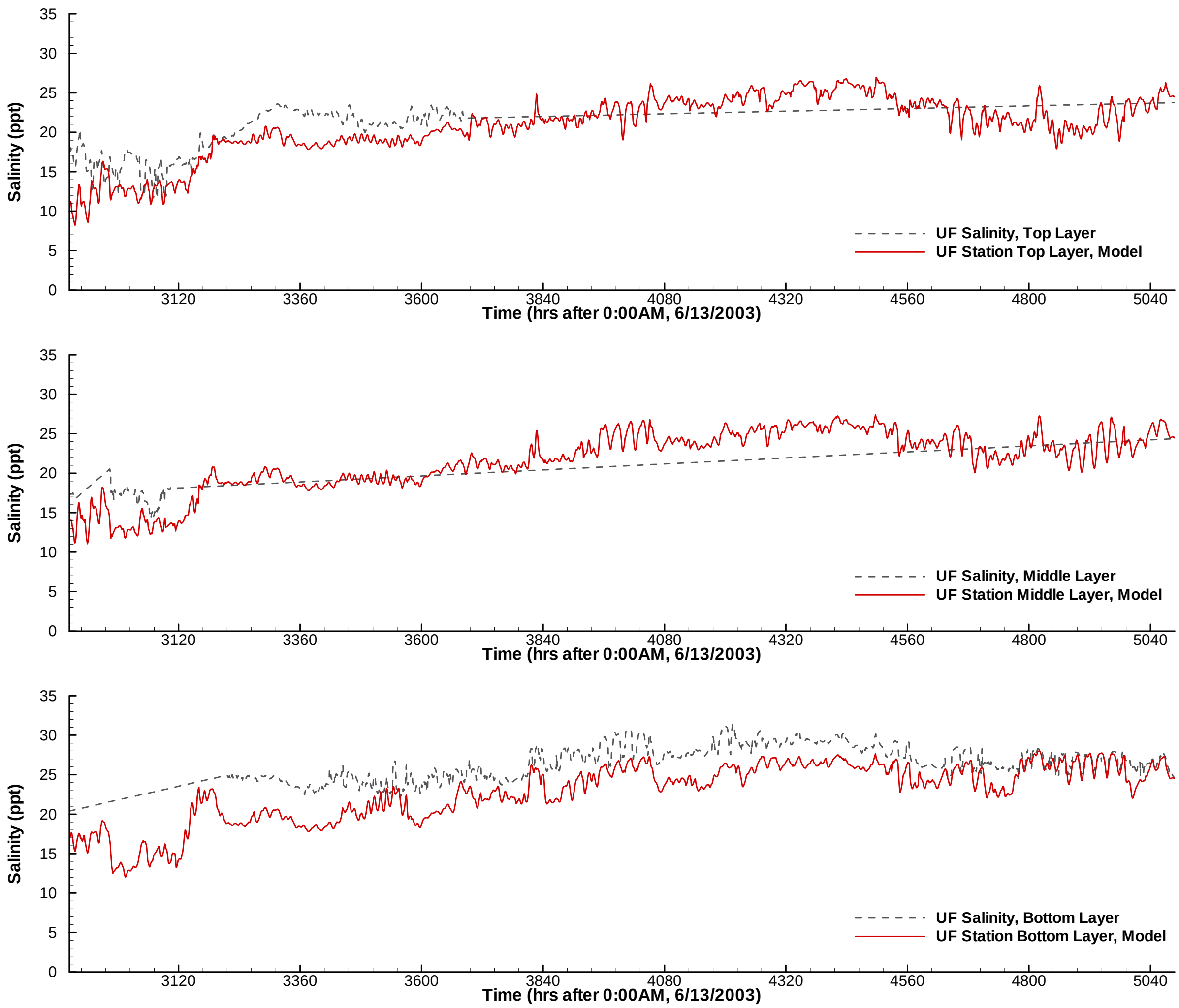

Figure C- 2. Comparisons of simulated and measured salinities at three depths at the UF station during October 11, 2003 – January 9, 2004.

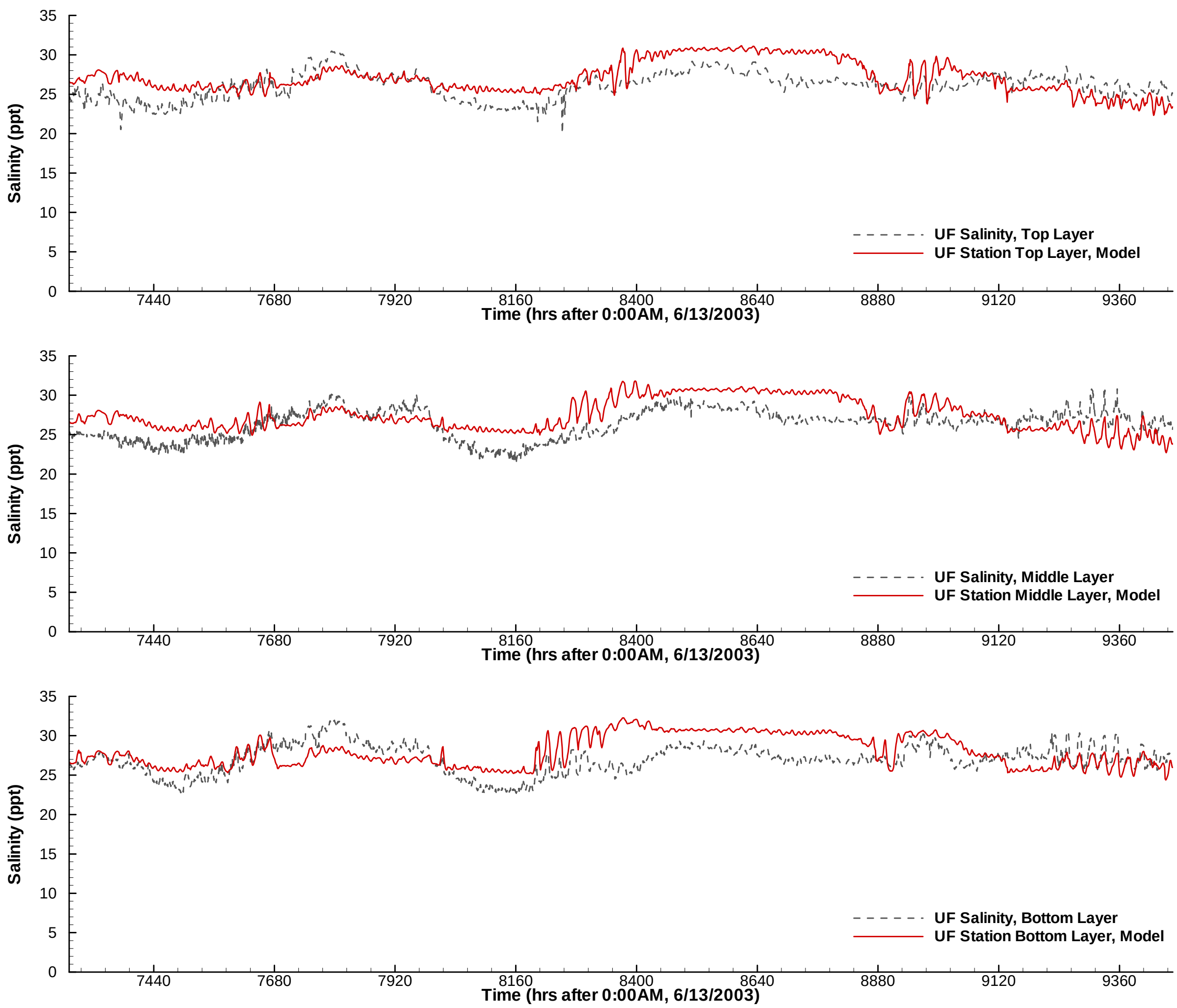

Figure C- 3. Comparisons of simulated and measured salinities at three depths at the UF station during April 10 – July 11, 2004.

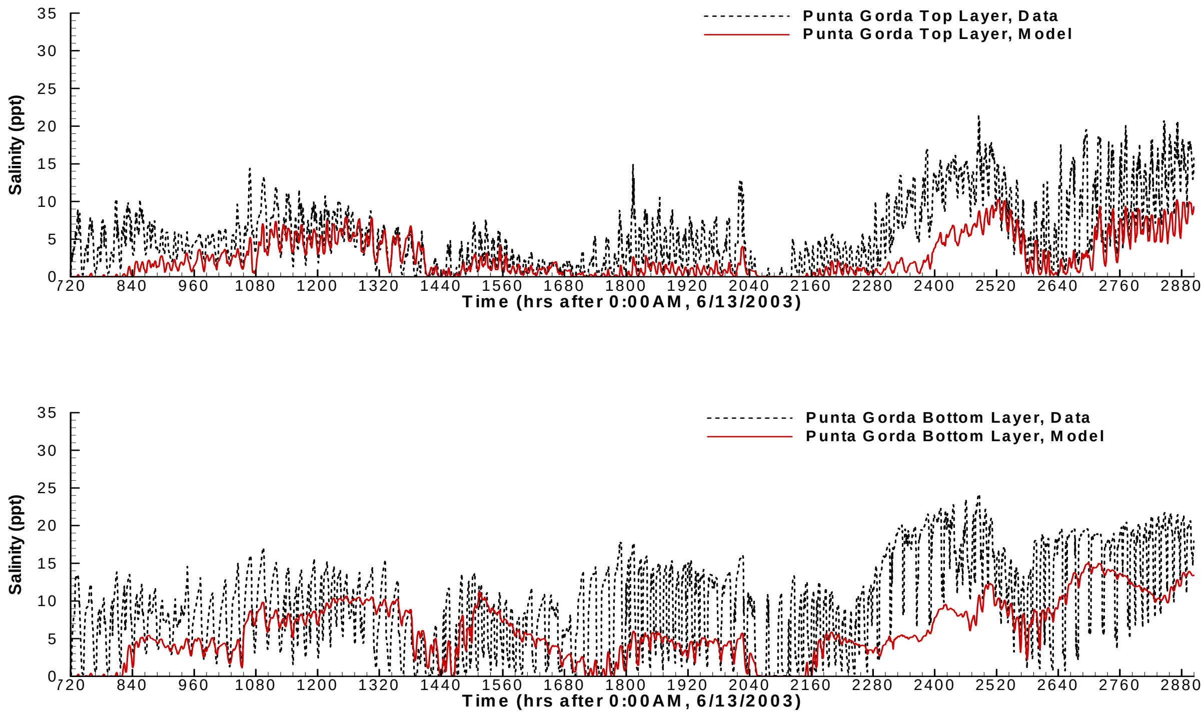

Figure C- 4. Comparisons of simulated and measured salinities at two depths at the Punta Gorda station during July 12 – October 10, 2003.

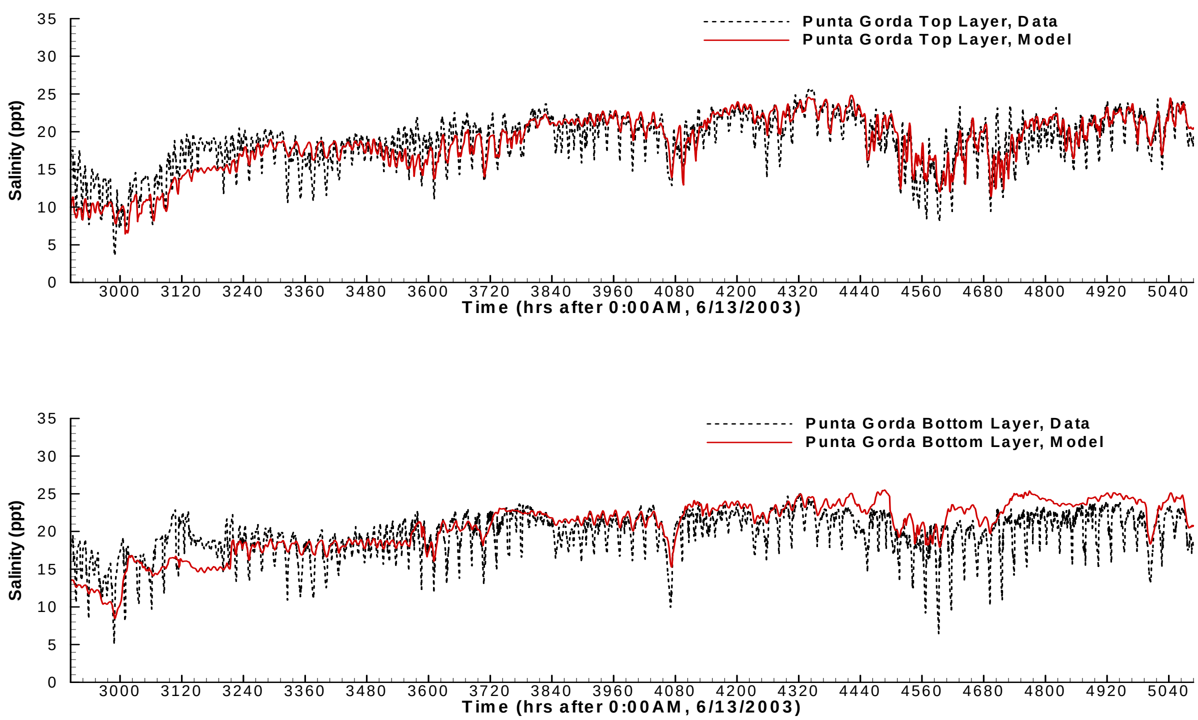

Figure C- 5. Comparisons of simulated and measured salinities at two depths at the Punta Gorda station during October 11, 2003 – January 9, 2004.

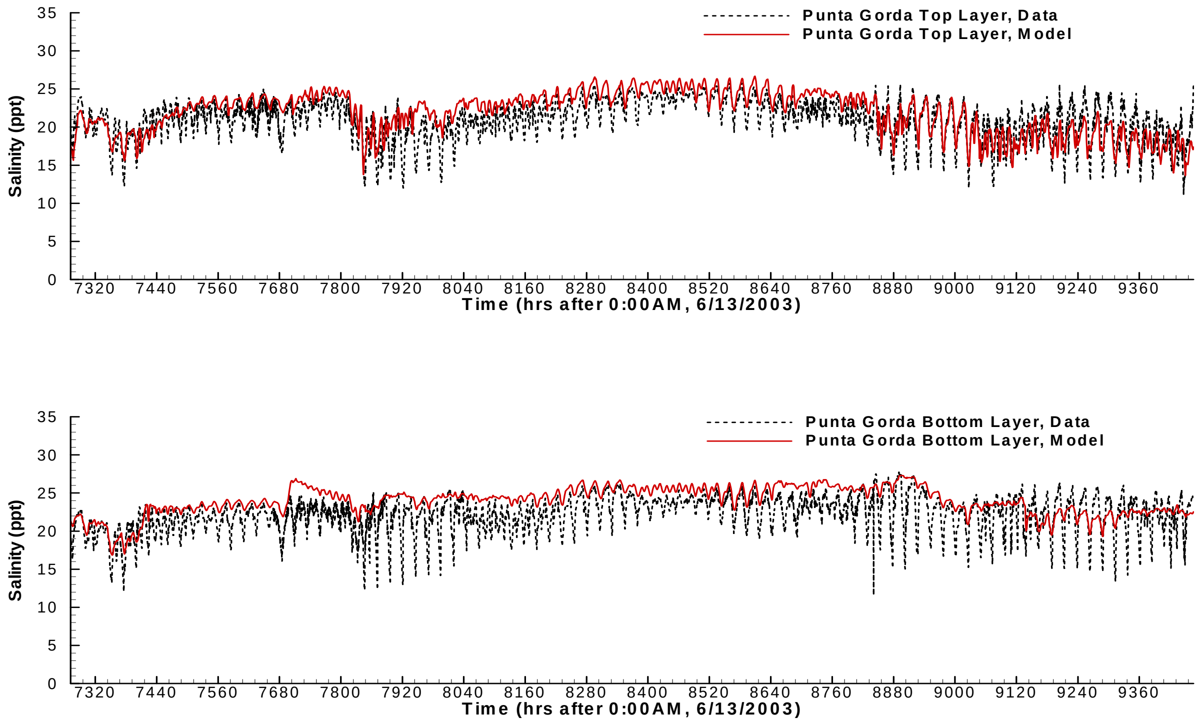

Figure C- 6. Comparisons of simulated and measured v-velocities at two depths at the Punta Gorda station during April 10 – July 11, 2004.

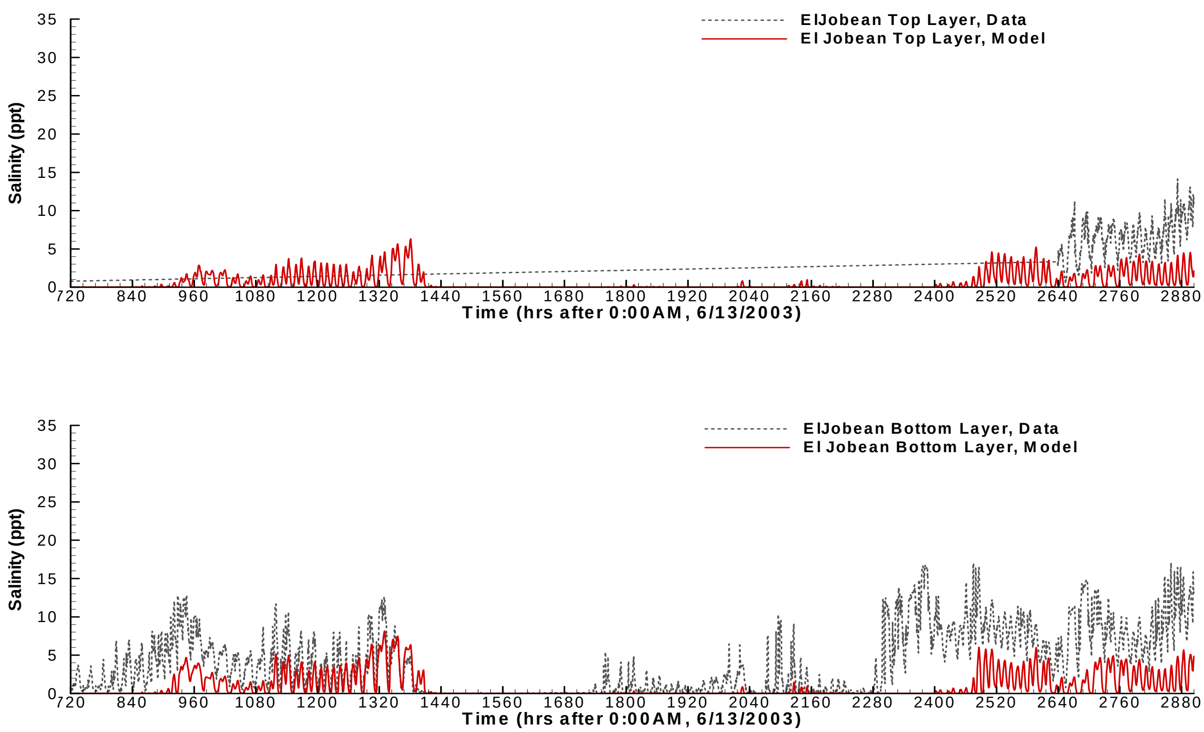

Figure C- 7. Comparisons of simulated and measured salinities at two depths at the El Jobean station during July 12 – October 10, 2003.

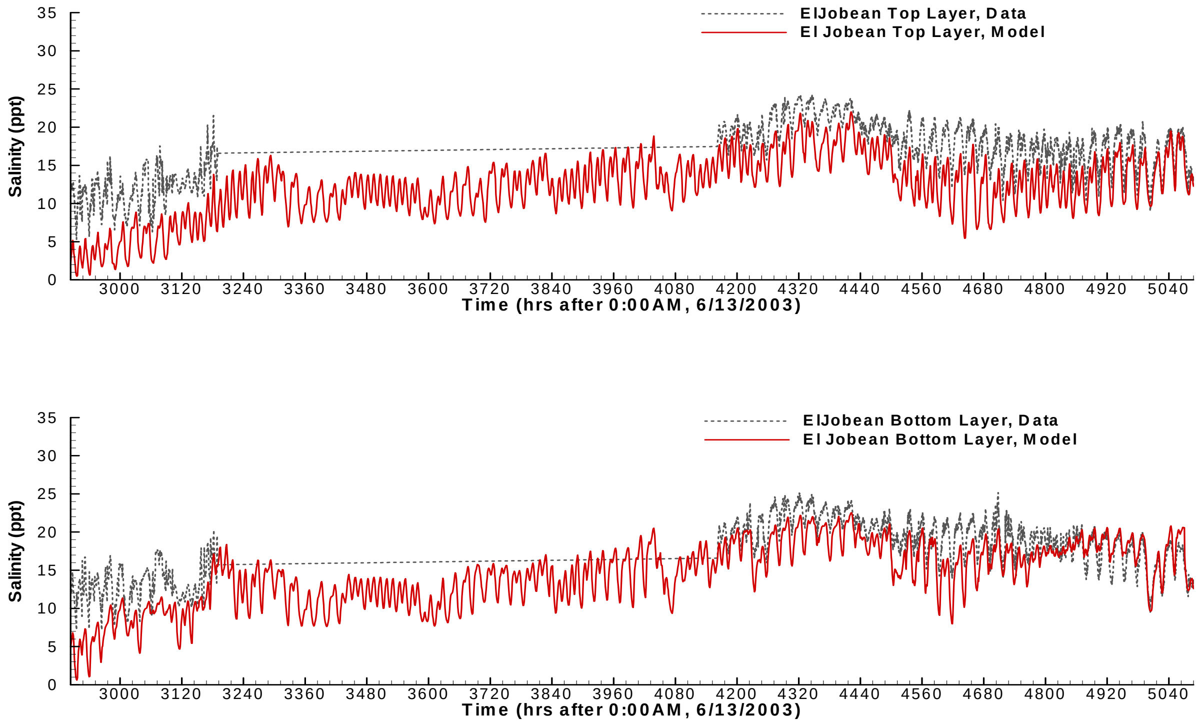

Figure C- 8. Comparisons of simulated and measured salinities at two depths at the El Jobean station during October 11, 2003 – January 9, 2004.

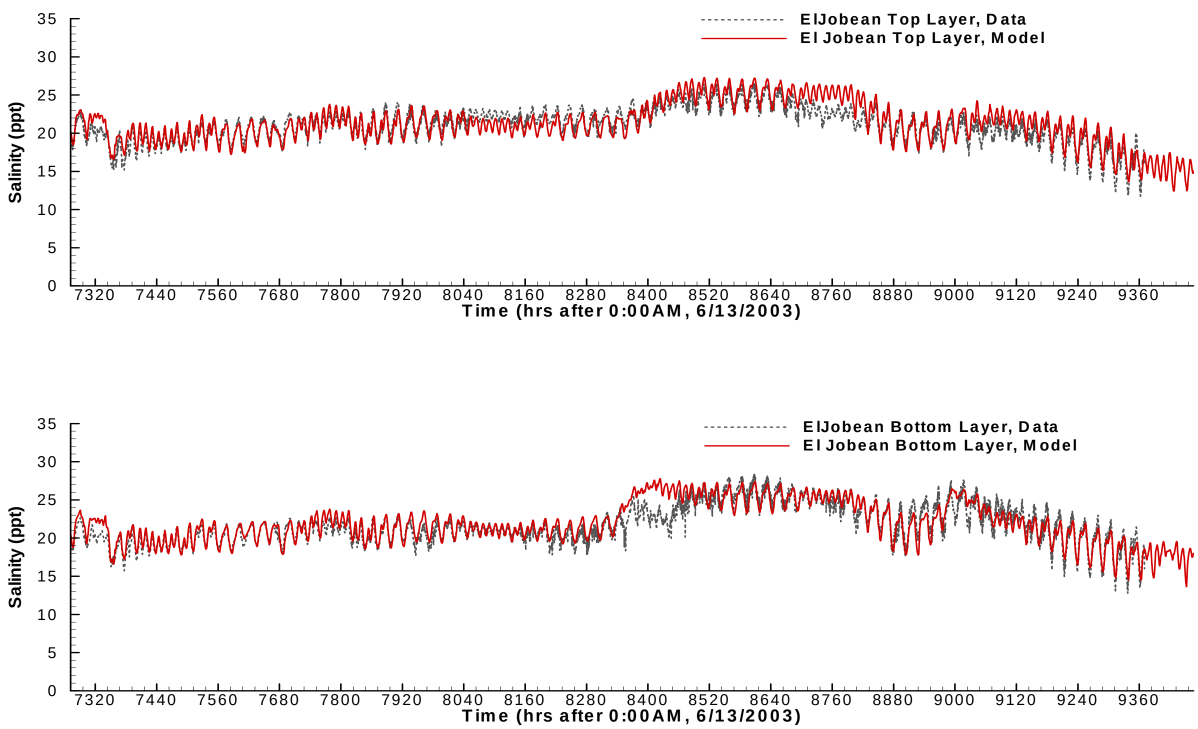

Figure C- 9. Comparisons of simulated and measured salinities at two depths at the El Jobean station during April 10 – July 11, 2004.

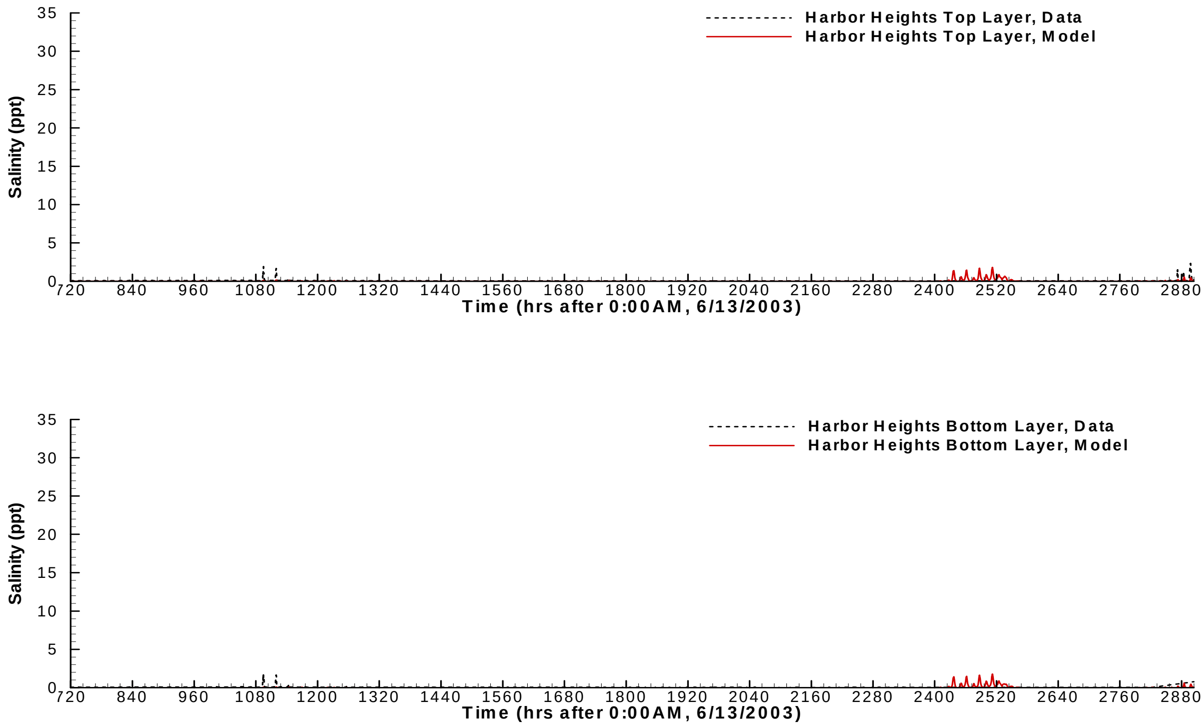

Figure C- 10. Comparisons of simulated and measured salinities at two depths at the Harbor Heights station during July 12 – October 10, 2003.

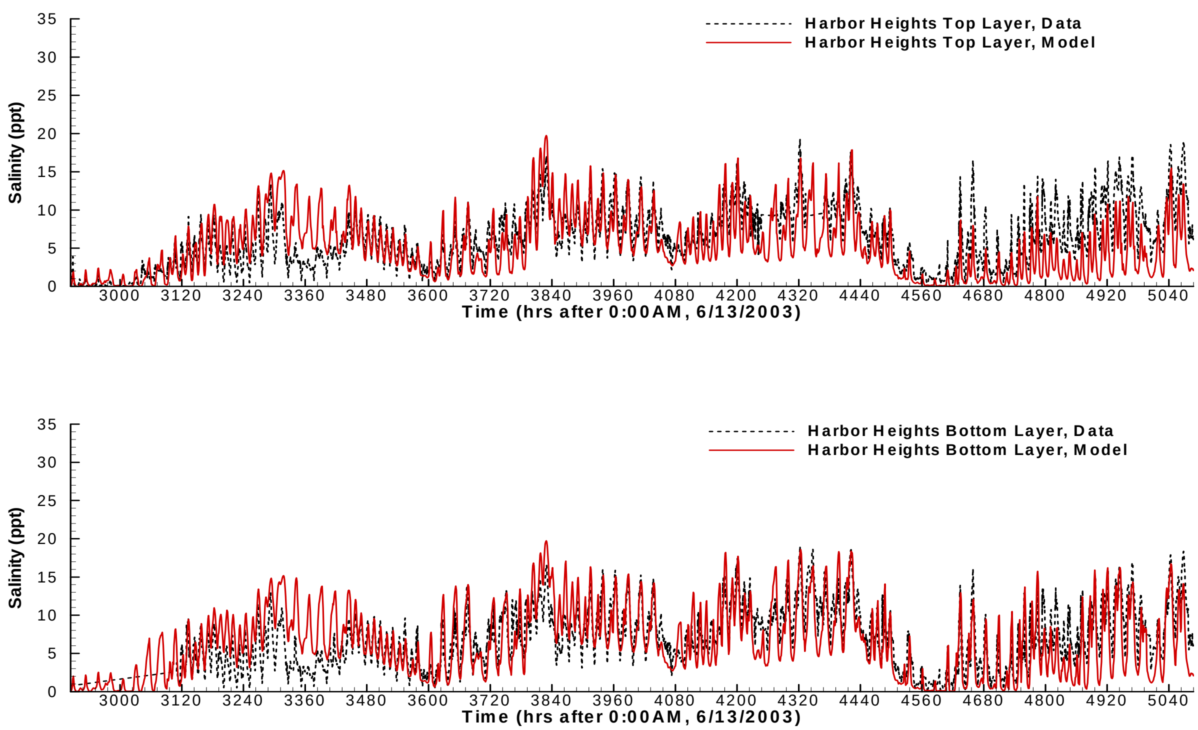

Figure C- 11. Comparisons of simulated and measured salinities at two depths at the Harbor Heights station during October 11, 2003 – January 9, 2004.

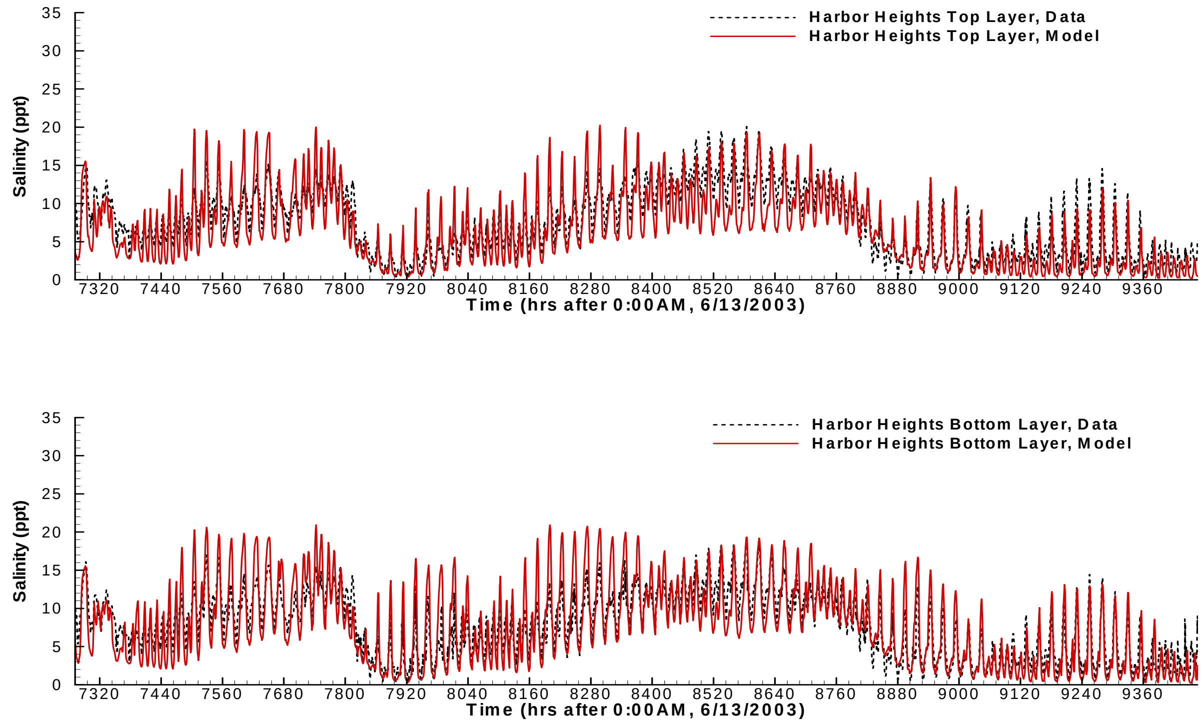

Figure C- 12. Comparisons of simulated and measured salinities at two depths at the Harbor Heights station during April 10 - July 11, 2004.

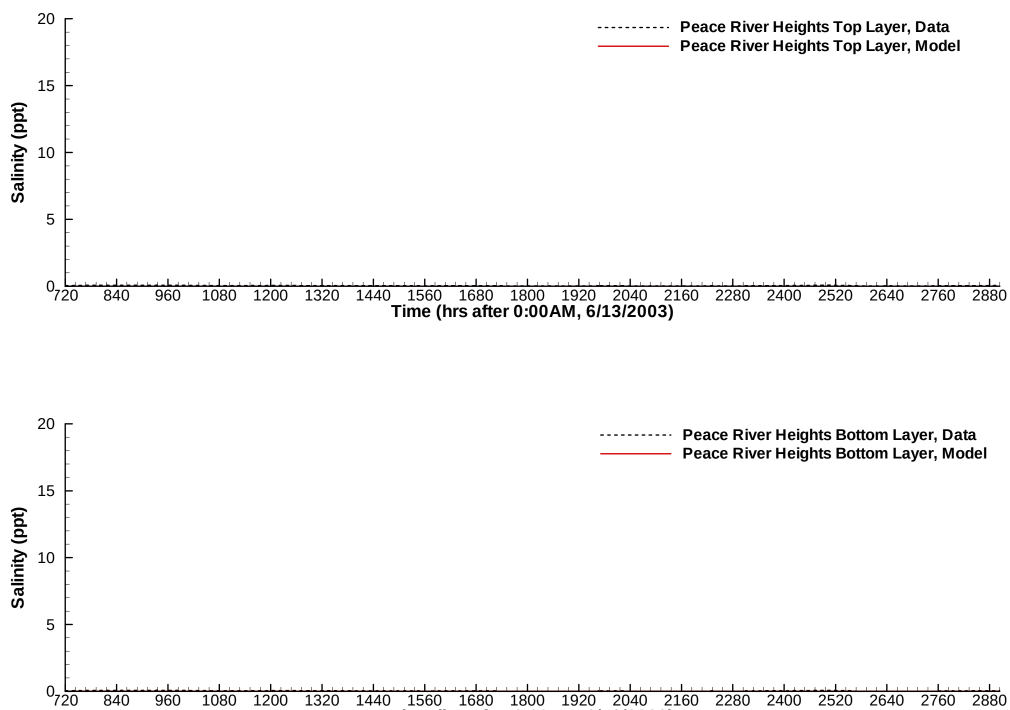

Figure C- 13. Comparisons of simulated and measured salinities at two depths at the Peace River Heights station during July 12 – October 10, 2003.

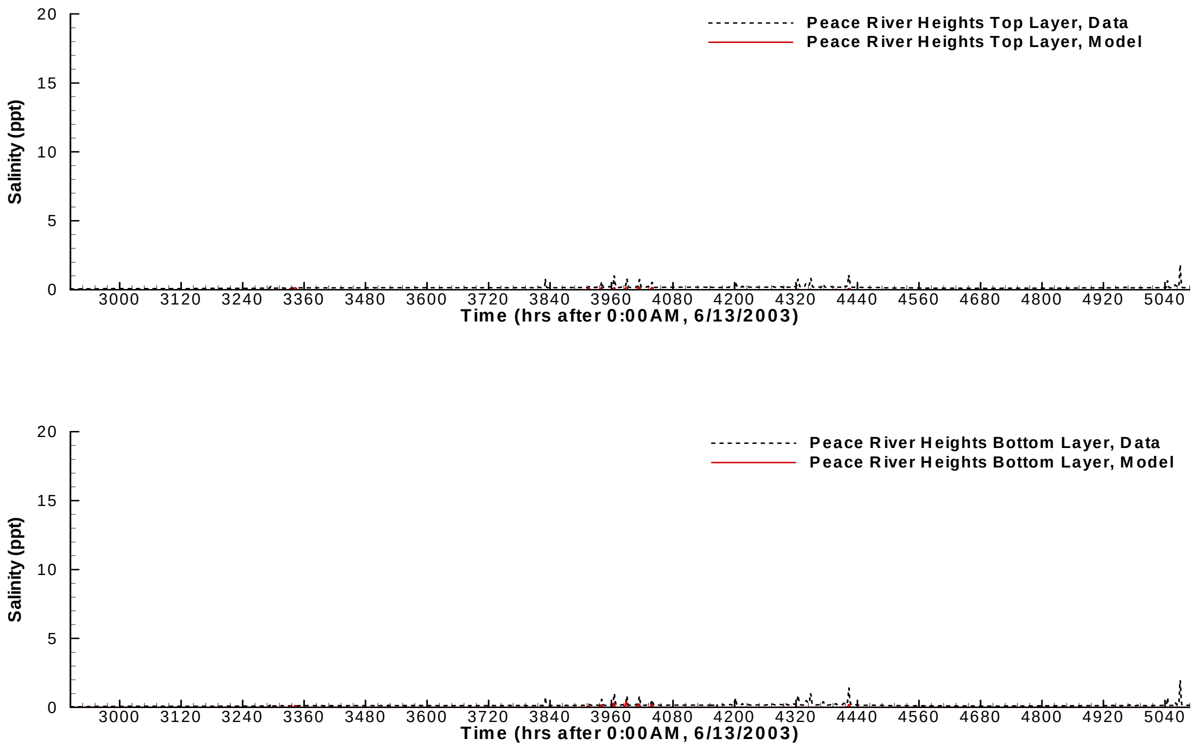

Figure C- 14. Comparisons of simulated and measured salinities at two depths at the Peace River Heights station during October 11, 2003 – January 9, 2004.

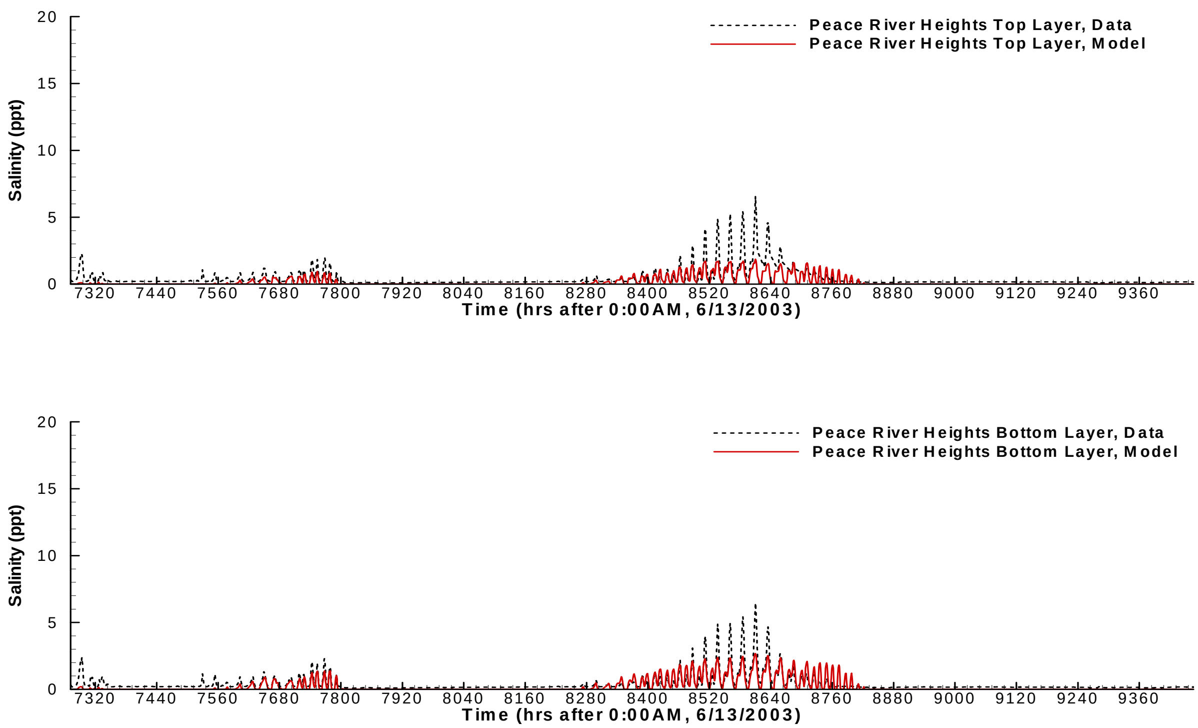

Figure C- 15. Comparisons of simulated and measured salinities at two depths at the Peace River Heights station during April 10 – July 11, 2004.

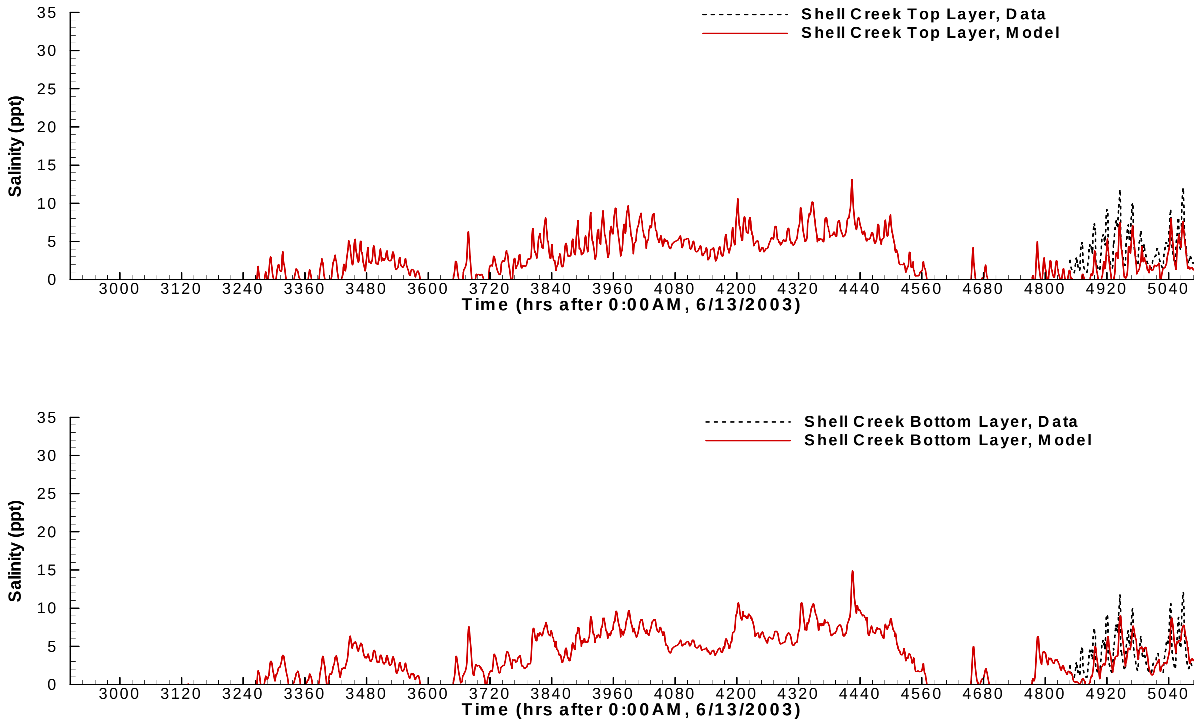

Figure C- 16. Comparisons of simulated and measured salinities at two depths at the Shell Creek station during October 11, 2003 – January 9, 2004.

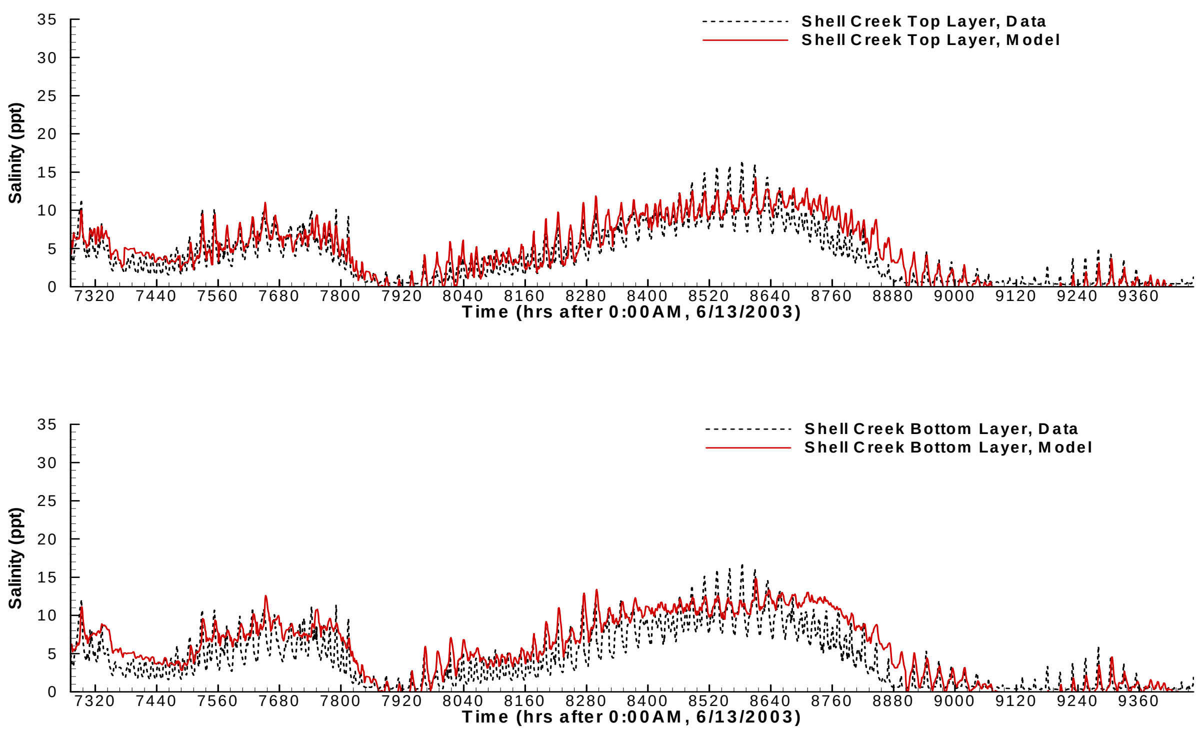

Figure C- 17. Comparisons of simulated and measured salinities at two depths at the Shell Creek station during April 10 - July 11, 2004.

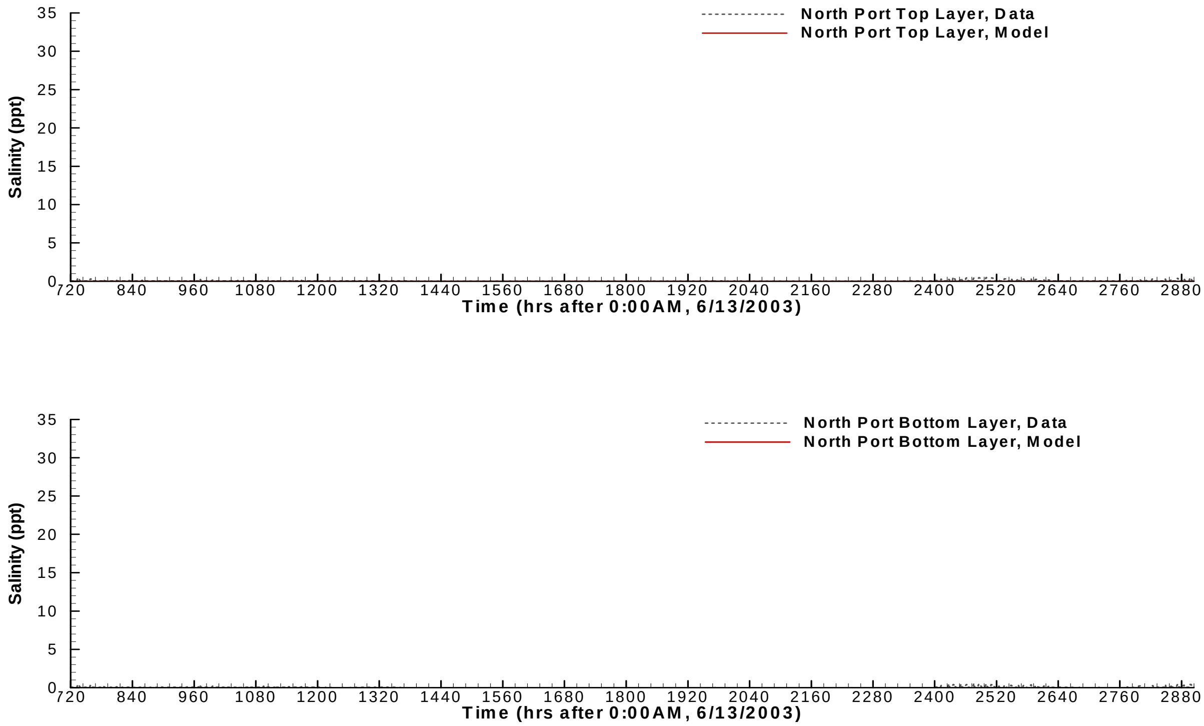

Figure C- 18. Comparisons of simulated and measured salinities at two depths at the North Port station during July 12 – October 10, 2003.

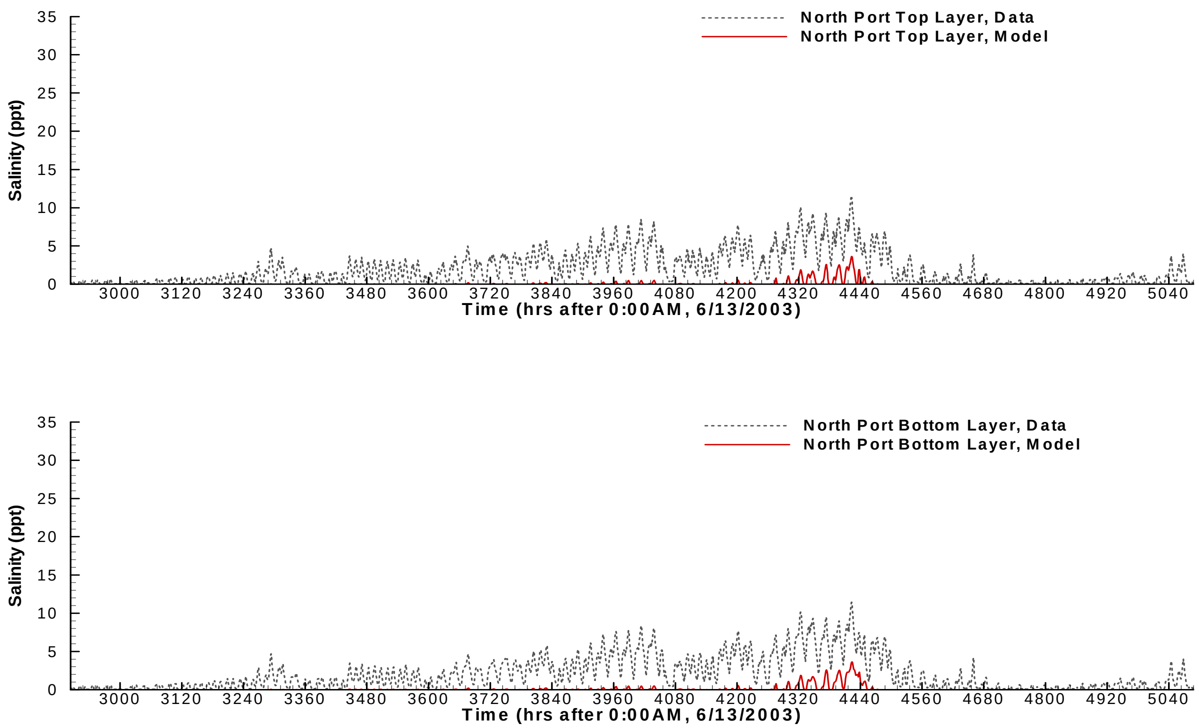

Figure C- 19. Comparisons of simulated and measured salinities at two depths at the North Port station during October 11, 2003 – January 9, 2004.

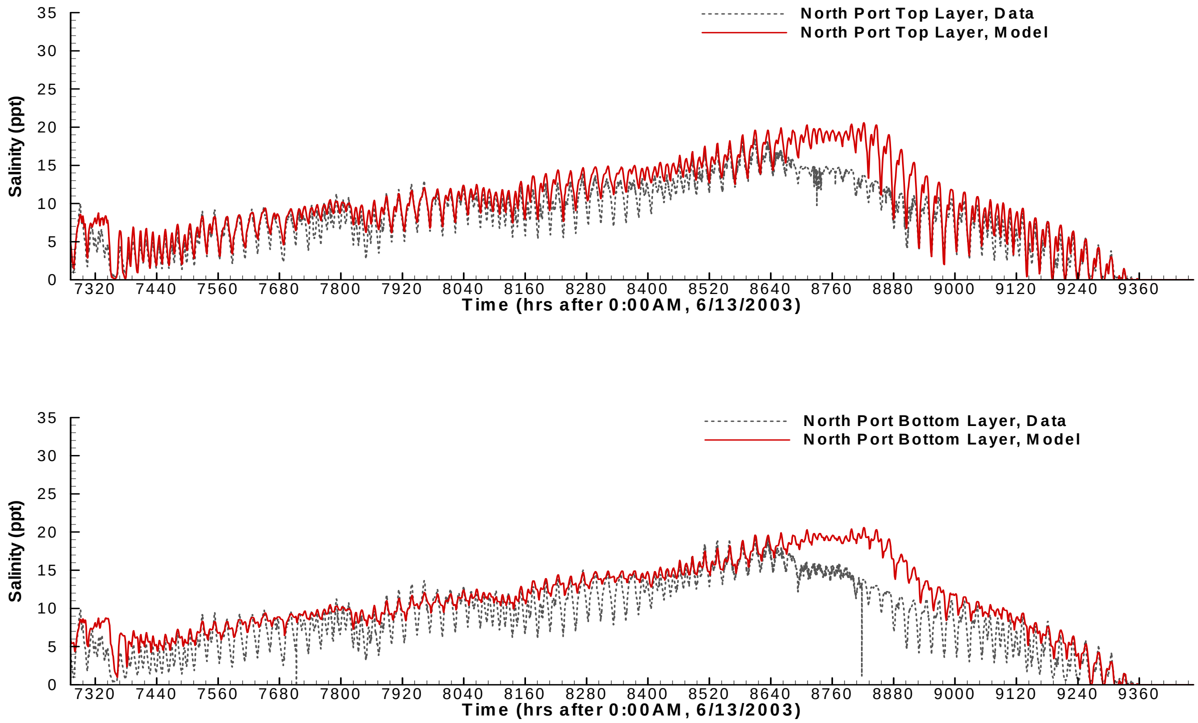

Figure C- 20. Comparisons of simulated and measured salinities at two depths at the North Port station during April 10 – July 11, 2004.

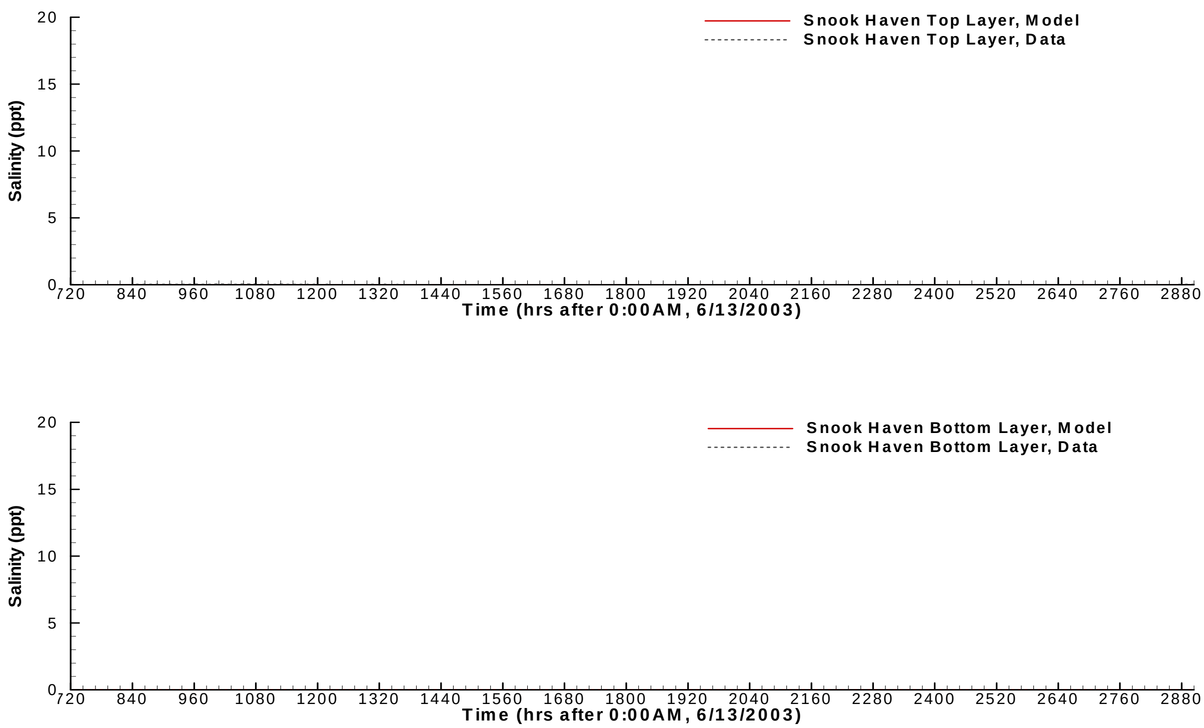

Figure C- 21. Comparisons of simulated and measured salinities at two depths at the Snook Haven station during July 12 – October 10, 2003.

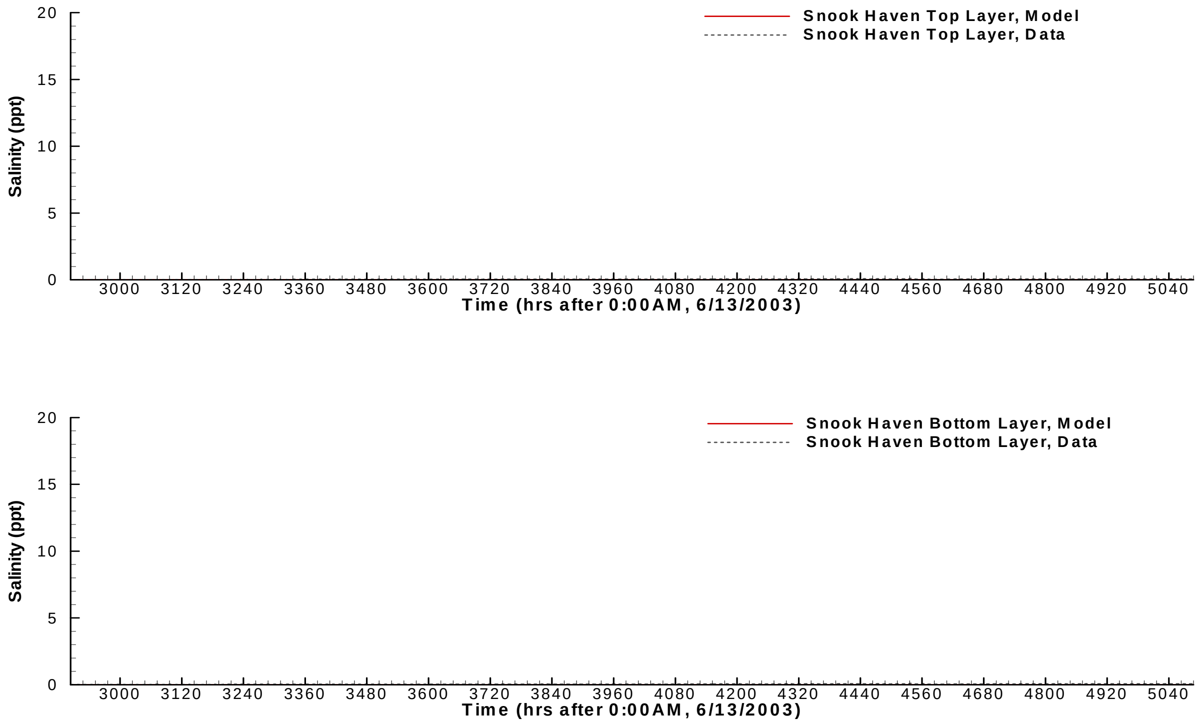

Figure C- 22. Comparisons of simulated and measured salinities at two depths at the Snook Haven station during October 11, 2003 – January 9, 2004.

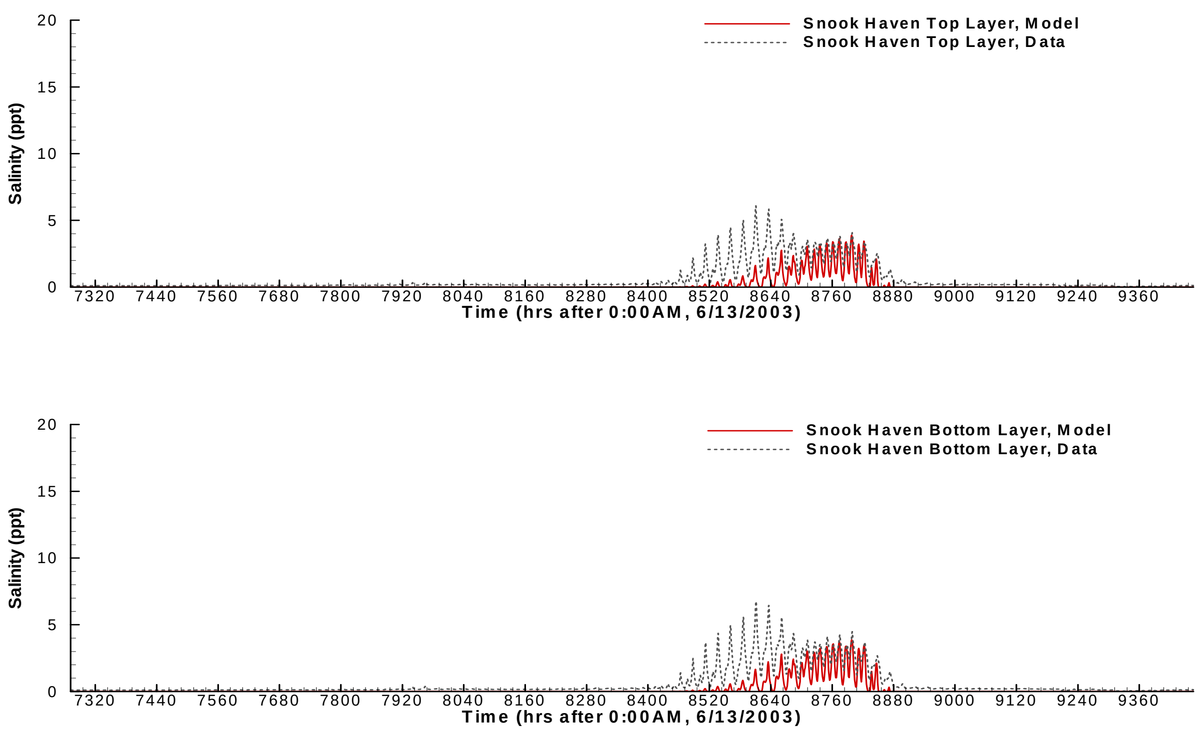

Figure C- 23. Comparisons of simulated and measured salinities at two depths at the Snook Haven station during April 10 – July 11, 2004.

Appendix D

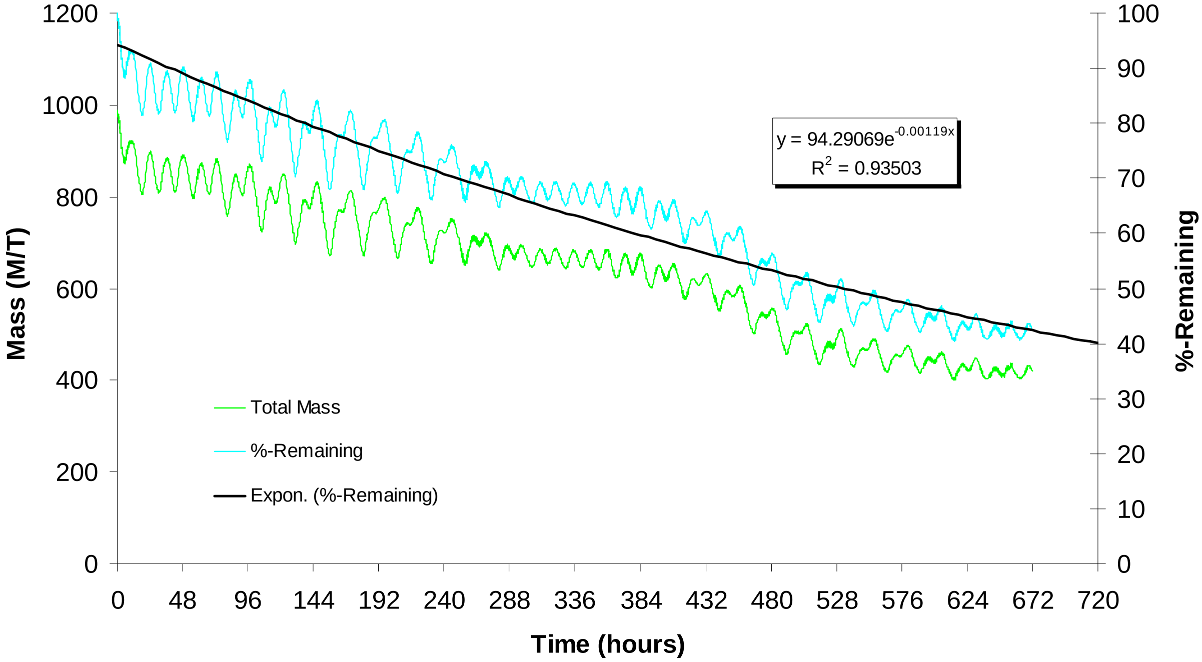

Figure D - 1. Time series of remaining conservative tracer mass in the main stem of the LPR for a combined Arcadia – Joshua - Horse flow rate of 55 cfs.

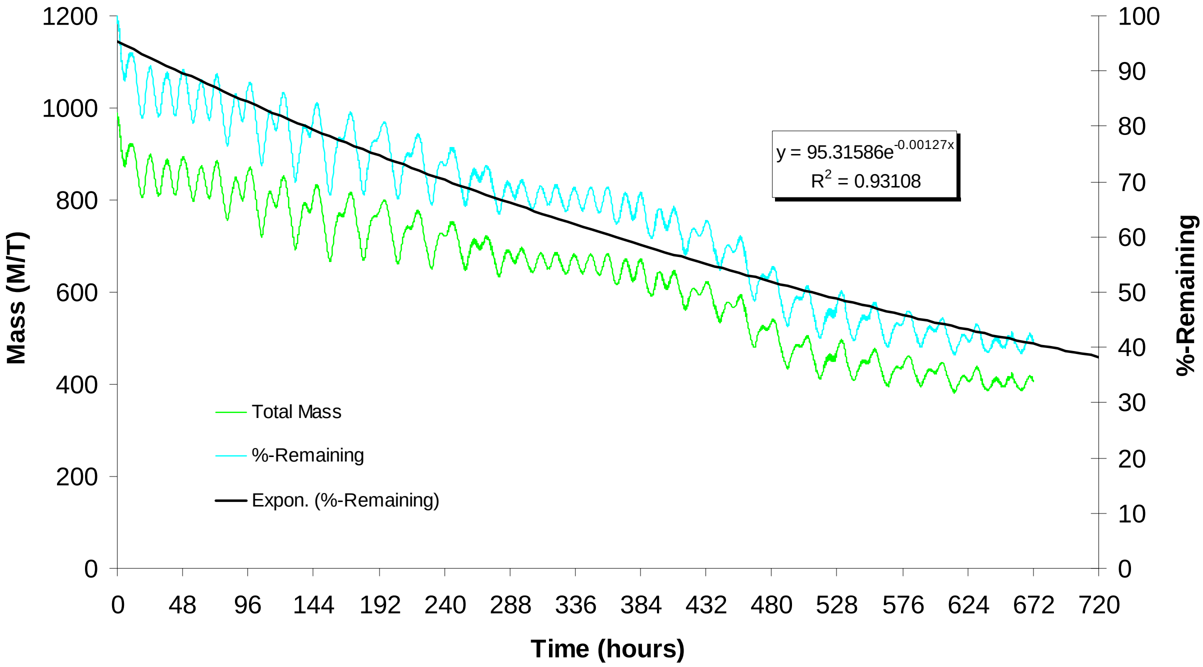

Figure D - 2. Time series of remaining conservative tracer mass in the main stem of the LPR for a combined Arcadia – Joshua - Horse flow rate of 106 cfs.

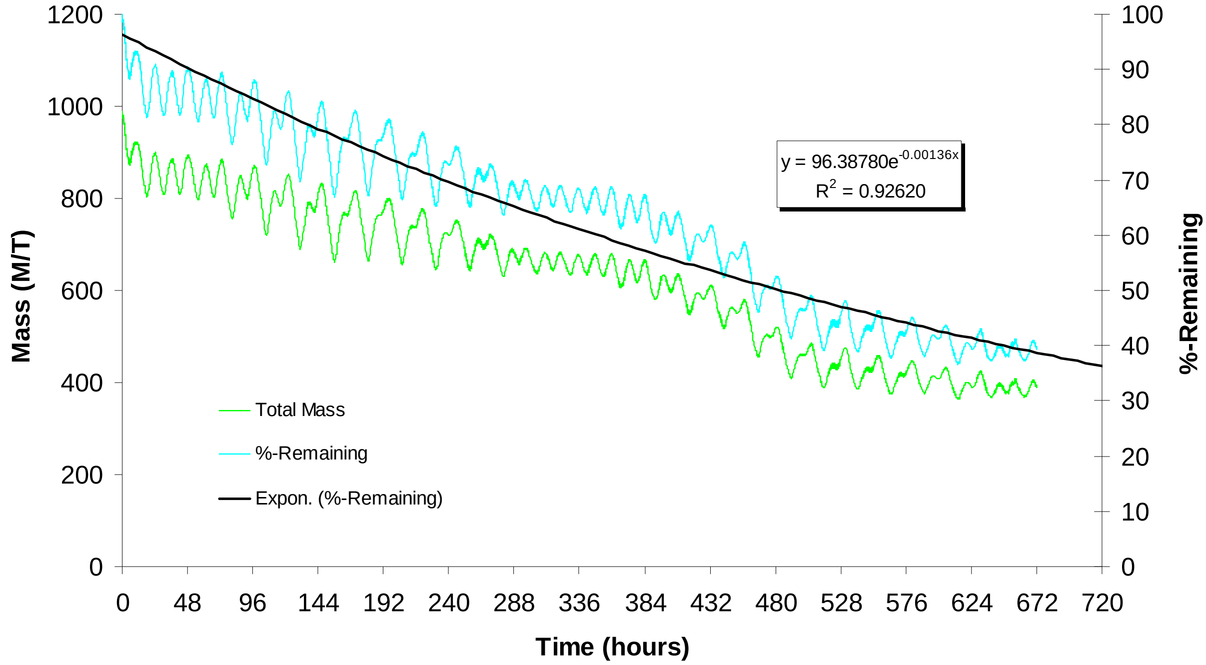

Figure D - 3. Time series of remaining conservative tracer mass in the main stem of the LPR for a combined Arcadia – Joshua - Horse flow rate of 154 cfs.

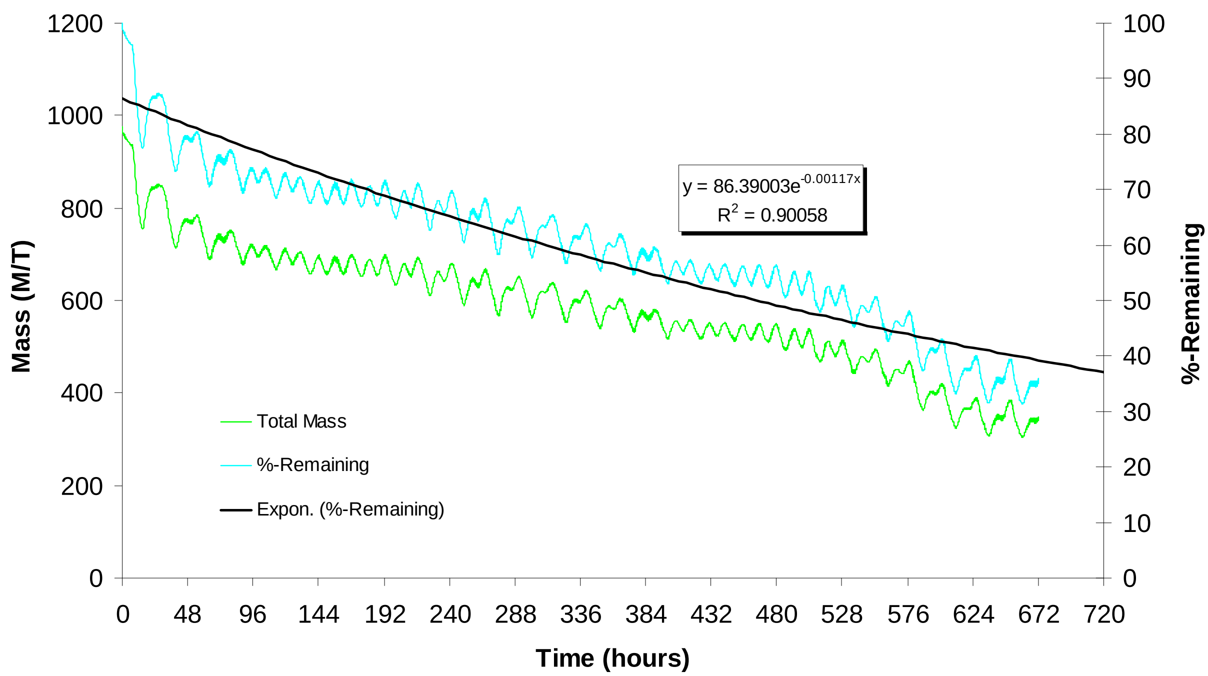

Figure D - 4. Time series of remaining conservative tracer mass in the main stem of the LPR for a combined Arcadia – Joshua - Horse flow rate of 199 cfs.

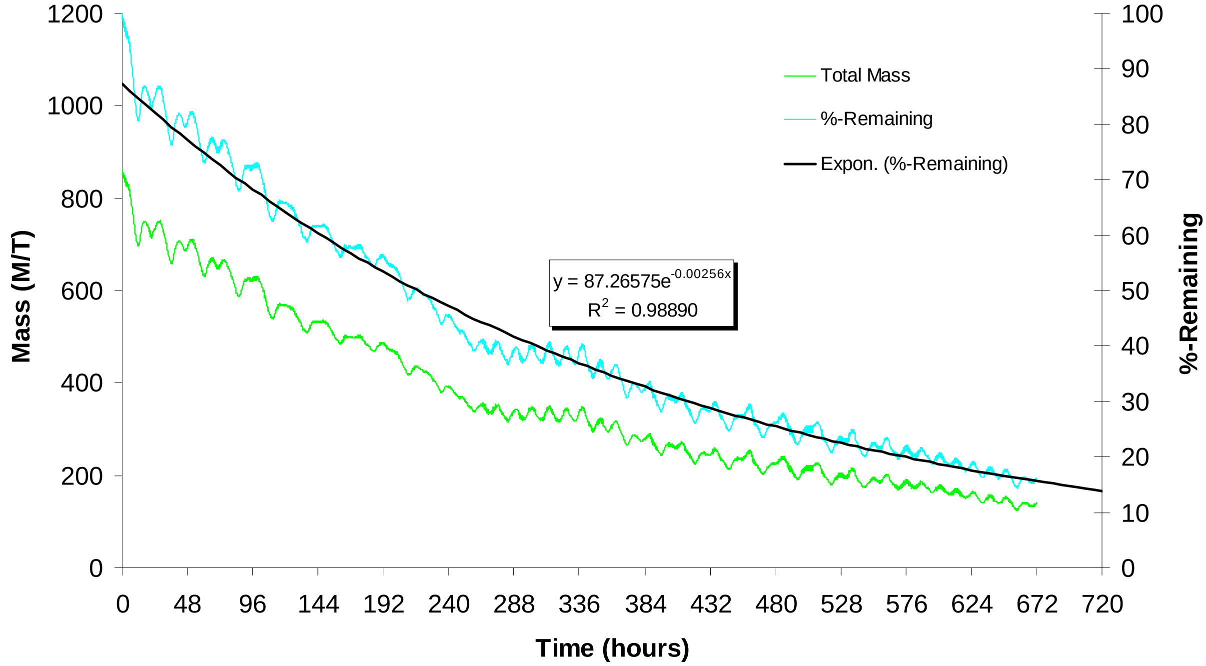

Figure D - 5. Time series of remaining conservative tracer mass in the main stem of the LPR for a combined Arcadia – Joshua - Horse flow rate of 240 cfs.

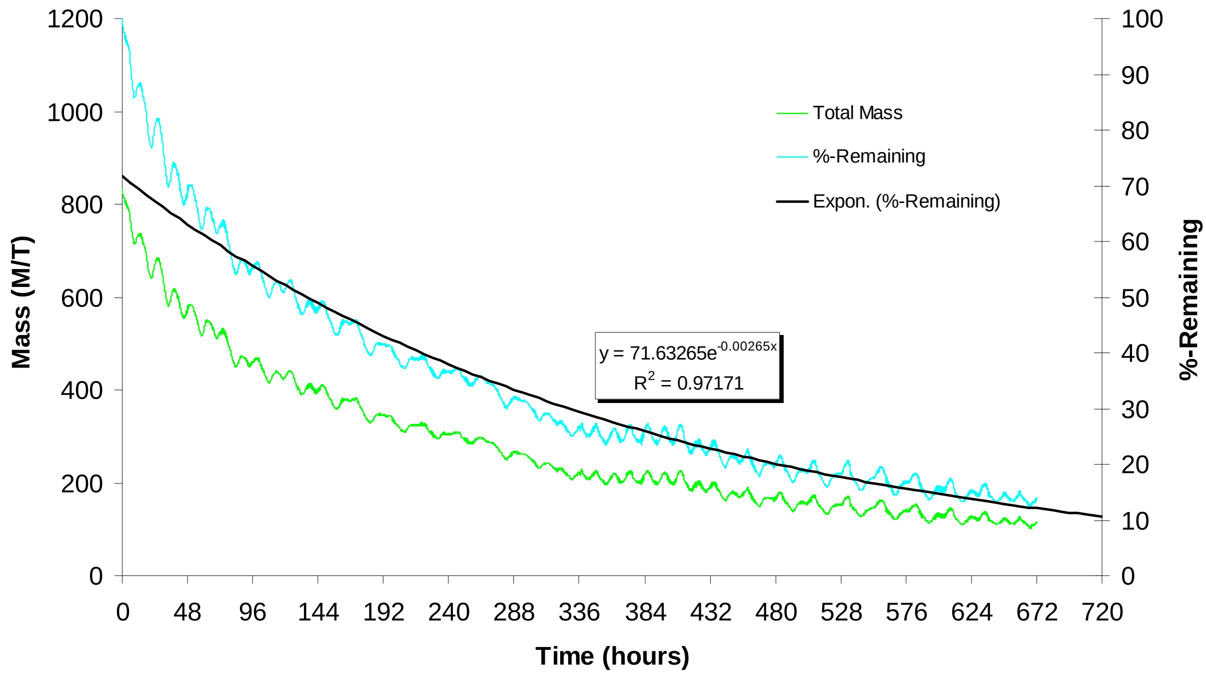

Figure D - 6. Time series of remaining conservative tracer mass in the main stem of the LPR for a combined Arcadia – Joshua - Horse flow rate of 281 cfs.

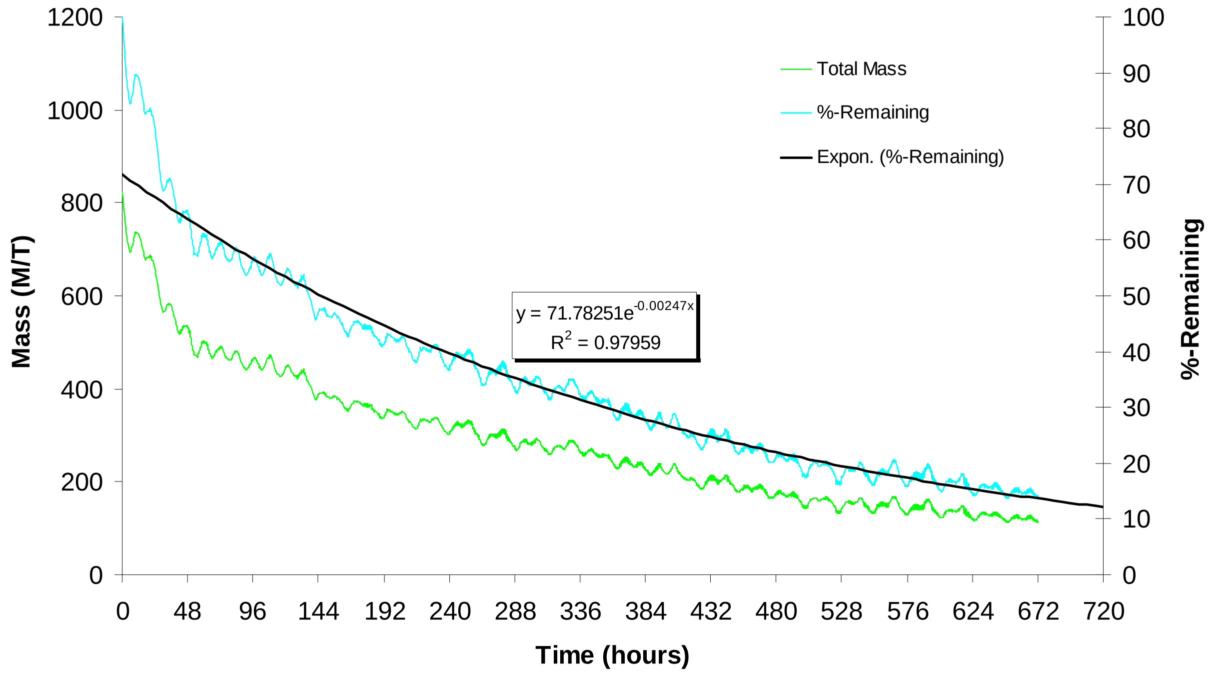

Figure D - 7. Time series of remaining conservative tracer mass in the main stem of the LPR for a combined Arcadia – Joshua - Horse flow rate of 332 cfs.

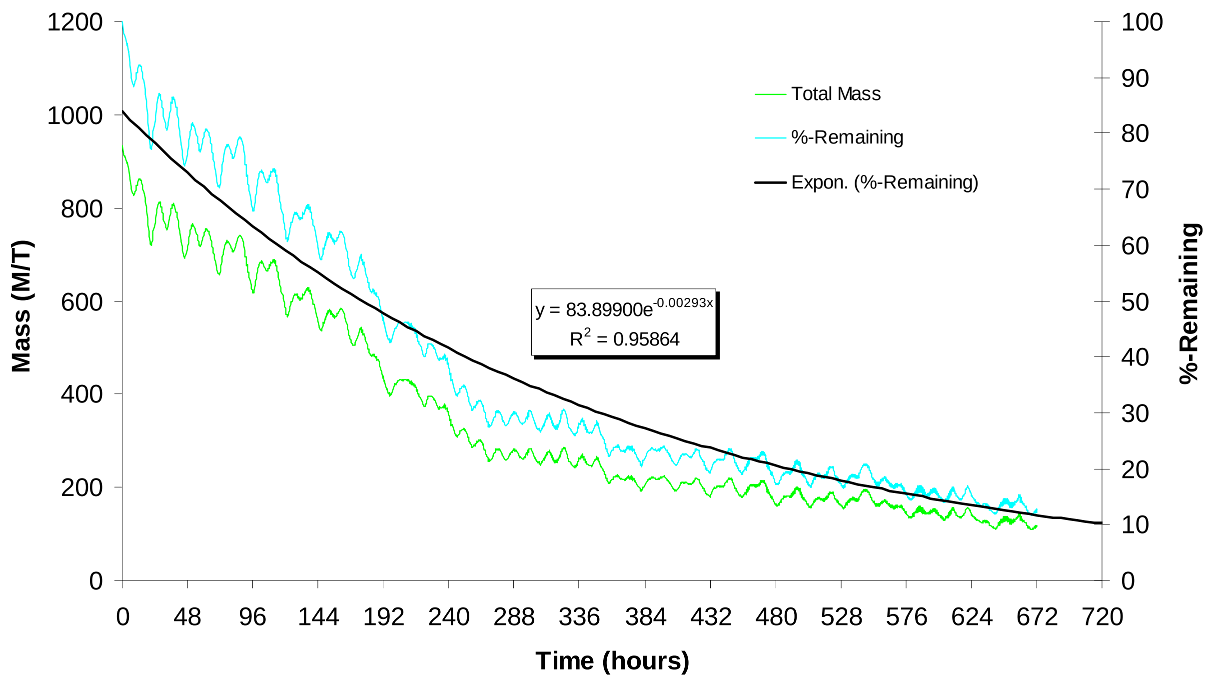

Figure D - 8. Time series of remaining conservative tracer mass in the main stem of the LPR for a combined Arcadia – Joshua - Horse flow rate of 391 cfs.

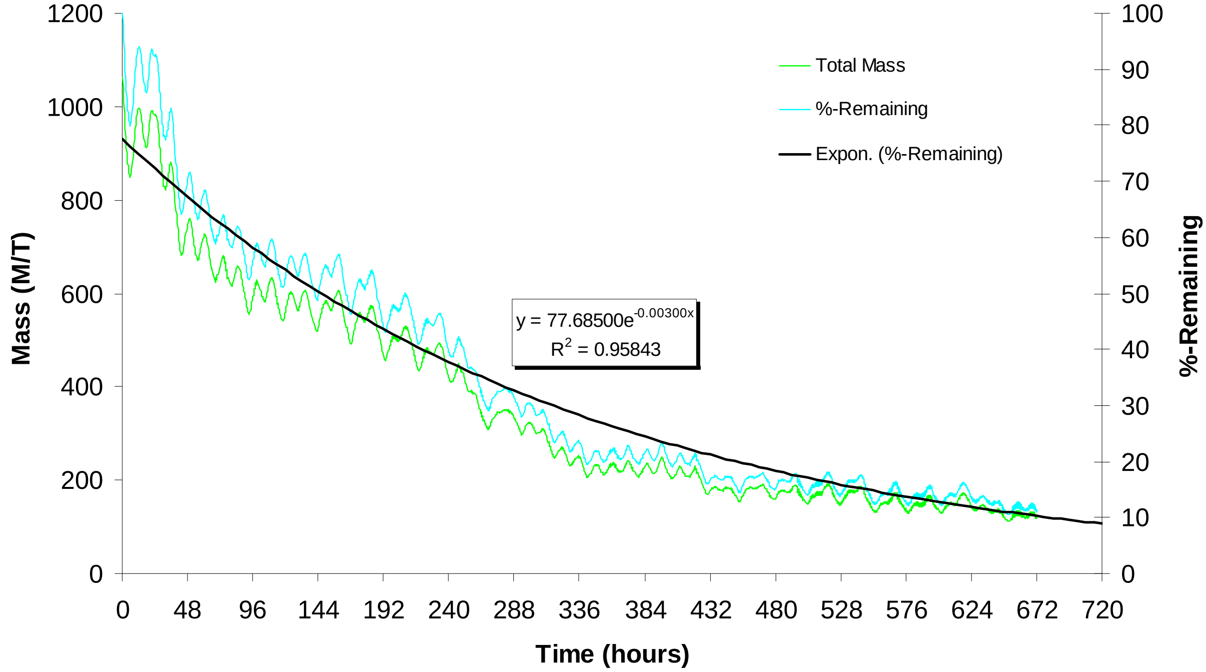

Figure D - 9. Time series of remaining conservative tracer mass in the main stem of the LPR for a combined Arcadia – Joshua - Horse flow rate of 455 cfs.

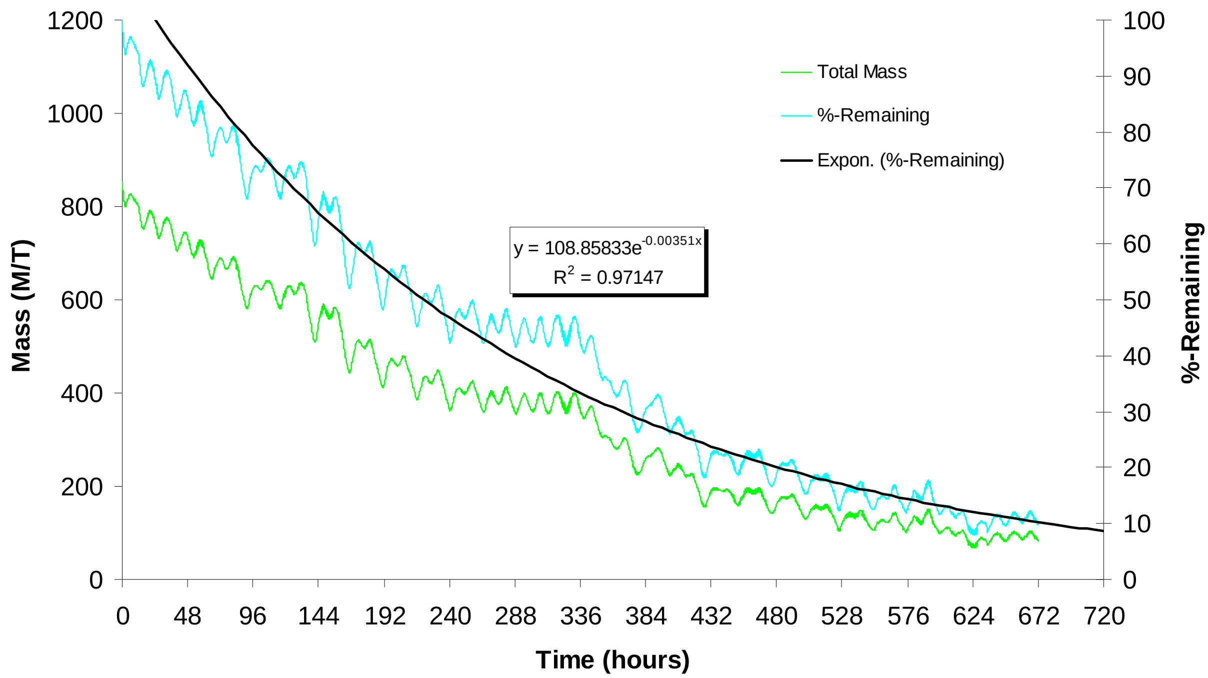

Figure D - 10. Time series of remaining conservative tracer mass in the main stem of the LPR for a combined Arcadia – Joshua - Horse flow rate of 544 cfs.

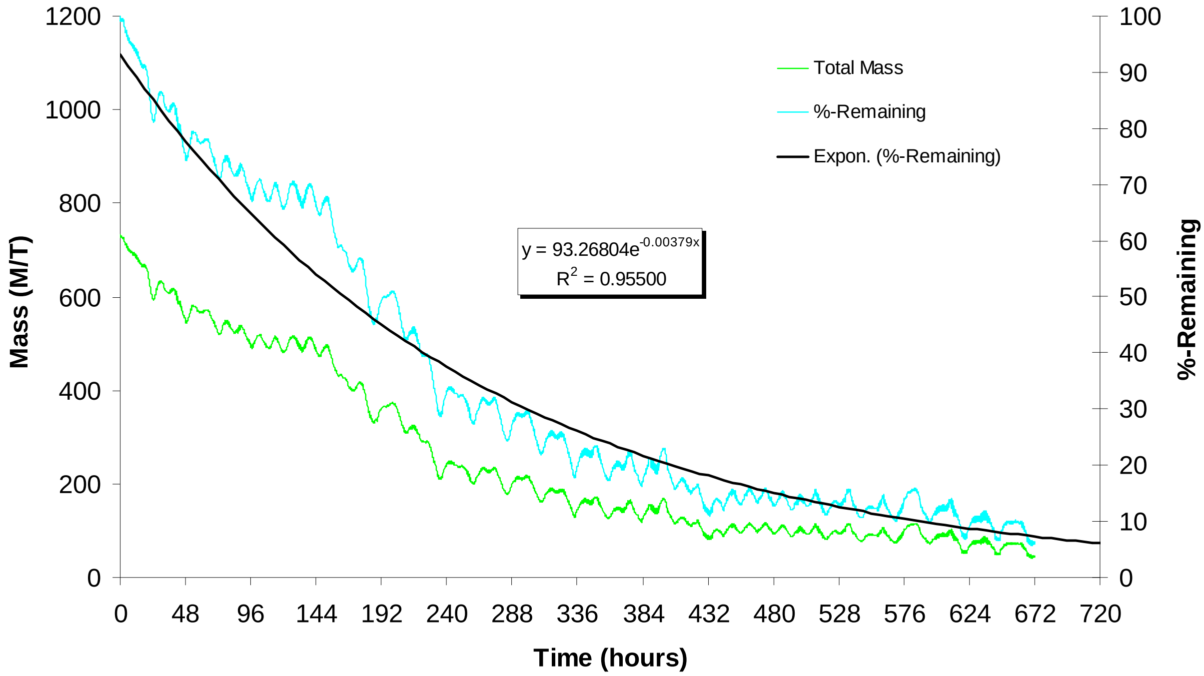

Figure D - 11. Time series of remaining conservative tracer mass in the main stem of the LPR for a combined Arcadia – Joshua - Horse flow rate of 644 cfs.

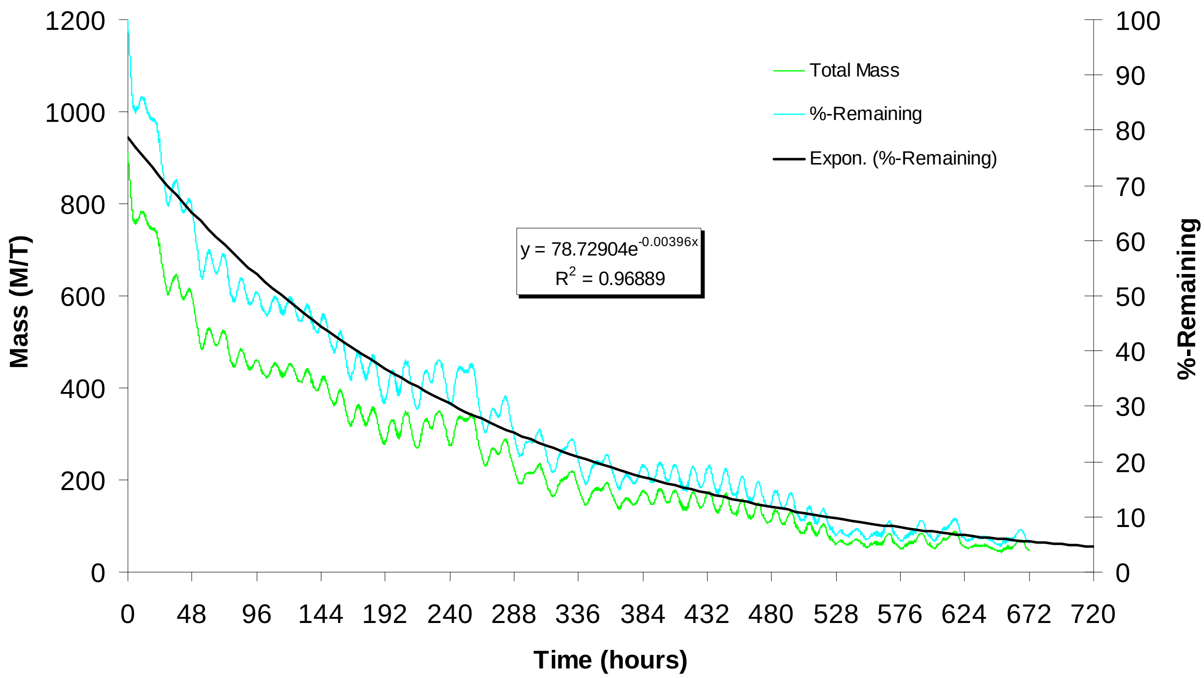

Figure D - 12. Time series of remaining conservative tracer mass in the main stem of the LPR for a combined Arcadia – Joshua - Horse flow rate of 939 cfs.

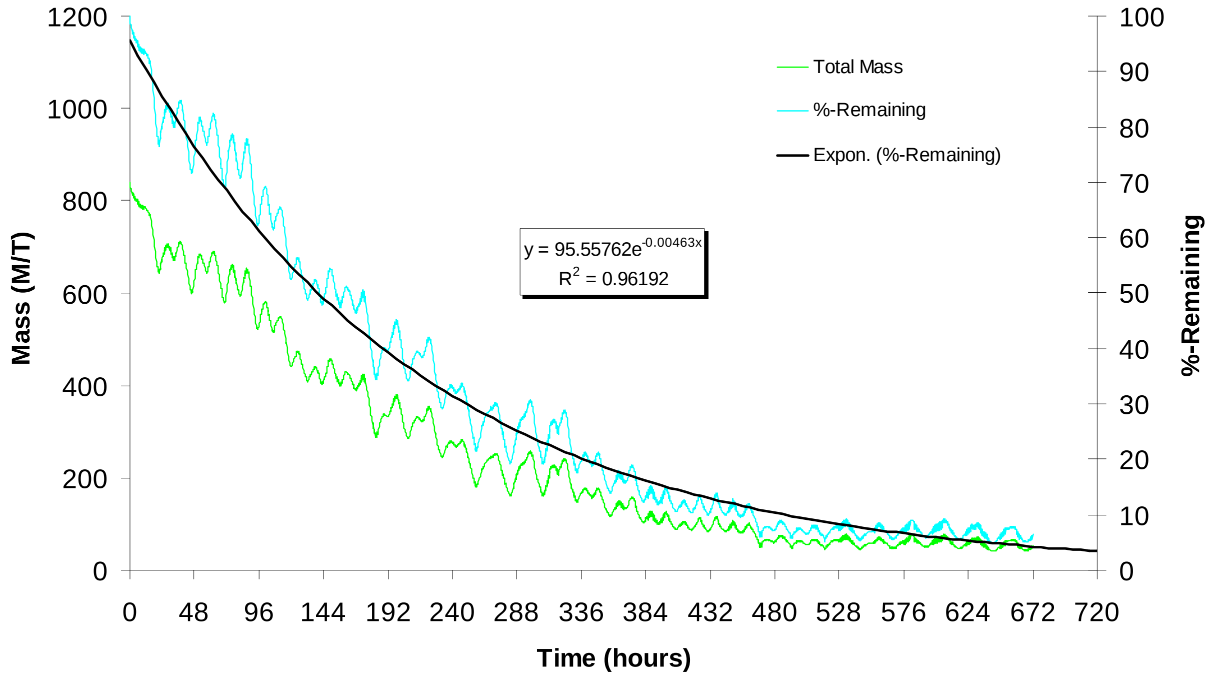

Figure D - 13. Time series of remaining conservative tracer mass in the main stem of the LPR for a combined Arcadia – Joshua - Horse flow rate of 1443 cfs.

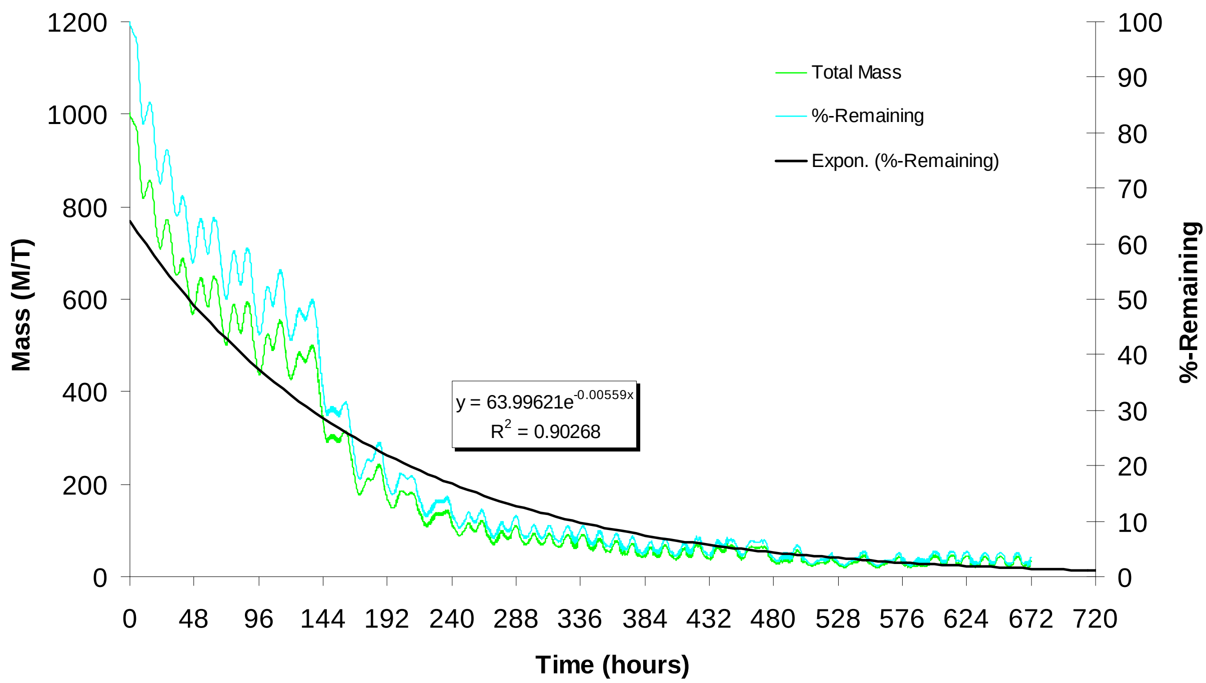

Figure D - 14. Time series of remaining conservative tracer mass in the main stem of the LPR for a combined Arcadia – Joshua - Horse flow rate of 2256 cfs.

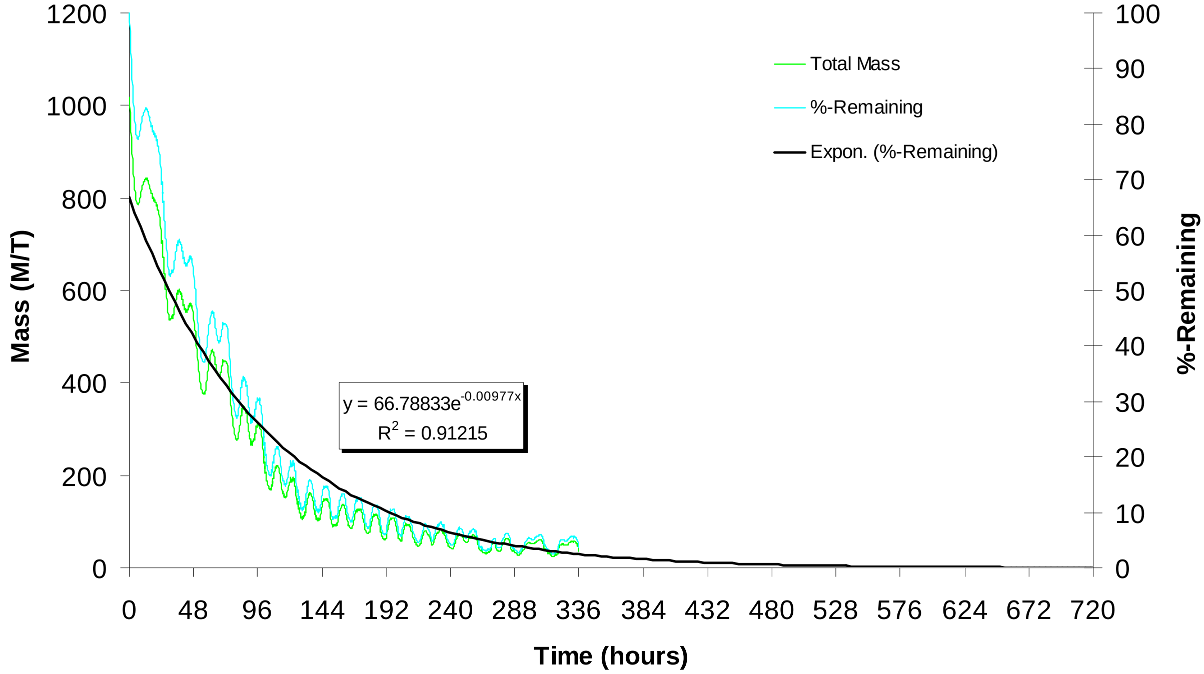

Figure D - 15. Time series of remaining conservative tracer mass in the main stem of the LPR for a combined Arcadia – Joshua - Horse flow rate of 4036 cfs.

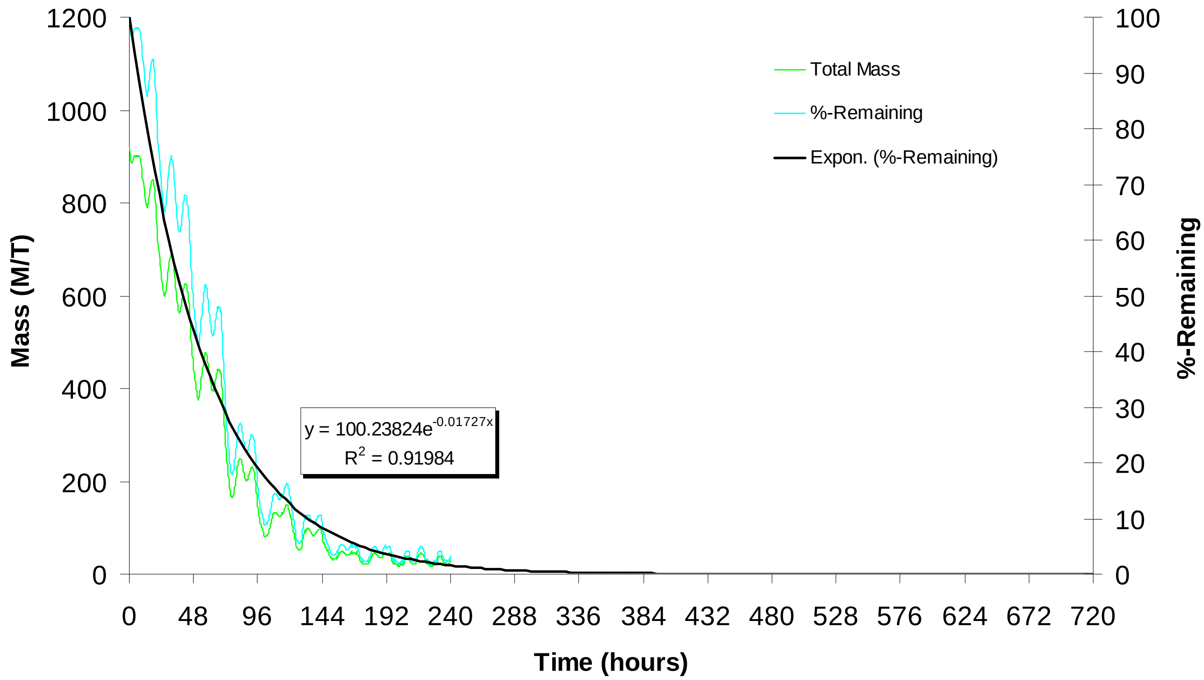

Figure D - 16. Time series of remaining conservative tracer mass in the main stem of the LPR for a combined Arcadia – Joshua - Horse flow rate of 9340 cfs.

Comments from PRMRWSA HBMP Panel

Date: December 14, 2007

To: Michael J. Flannery
Peace River Manasota Regional Water Authority

From: Joan Browder
HBMP Panel Member

Subject: Lower Peace River Minimum Flows and Levels

Thanks for the opportunity to review the Lower Peace River MFL Report, hear the presentation, and participate in discussions about it. I like the approach of integrating coverage and percent of days, by salinity-band, within each zone of the river during each designated time-block by plotting cumulative distributions . This approach is quite elegant. I especially like the plots relating specific salinity ranges to specific habitat, as was done for the 8-14 psu salinity band in river zone 3. I am very much concerned, however, with concluding on the basis of plots of this type that as much as 80% of Block 3 daily flows could be withdrawn from Shell Creek without significant harm to the ecosystem. The 10% rule seems to be working in the Peace River, and the SWFWMD and the PRMRWA should both be commended for receiving and developing the idea, making it a rule, and sticking with it. Fifteen percent might work, too. And maybe higher percentages could safely be withdrawn during high flows. But 80% from Shell Creek seems too far out to be reasonable. As we discussed at the December 4 meeting, consideration should be made of the effect of this scale of withdrawals on the adjacent and downstream sections of the Peace River. I followed the explanation that high flows in the Peace River usually occur at the same time as high flows in Shell Creek, however I also heard that, at the present time, more water is flowing from Shell Creek than through the LPR upstream from Shell Creek.

I join the recommendation of other members of the panel that the MFL process should include consideration of the potential impact on Upper Charlotte Harbor of cumulative changes in freshwater inflow from all contributing sources and that this information should be integrated and coordinated with the MFLs for the rivers and their tributaries. In this regard, the habitat suitability model developed by Dr. Peter Rubec at the Florida Fish and Wildlife Research Institute might be very useful to you. He developed the model with Charlotte Harbor data collected by FWRI. In addition, I'm sure you also would be interested in the two recent publications on Charlotte Harbor by Shannon Whaley and colleagues at FWRI, as follows:

Whaley, S. D., J. J. Burd, Jr., B. A. Robertson. 2007. Using estuarine landscape structure to model distribution patterns in nekton communities and in juveniles of fishery species. Marine Ecology Progress Series 330:83-90.

Whaley, S. D., C. W. Harnak, and B. A. Robertson. 2006. Spatial and temporal patterns of estuarine fish communities relative to habitat structure and freshwater inflow. Pp 130-136 in: Proceedings of the Second LASTED International Conference on Environmental

Modelling and Simulation. November 29-December 1, 2006, St. Thomas, U.S. Virgin Islands.

Comments on the PRMRWSA HBMP Scientific Peer Review Panel Meeting, Dec. 4-5, 2007

BY

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A. The Pump Test

Ralph Montgomery did a good job of reporting the results of this series of tests, given that the report was excessively long and tedious. There were definitively problems in carrying out and analyzing the results, but for the most part these were the result of the ambient conditions and inherent difficulties of the circumstances. Thus I was generally pleased with the results to date, although I remain committed to further tests above the plant intake and including bioindicators. I would like to see the following in the future:

1. Place several continuous recorders ABOVE the plant up until the limit of tidal influence if practical.

2. Select and monitor 5+ trophically and taxonomically representative bioindicators along with water chemistry. I would like the opportunity to participate in a debate about which organisms to choose for this purpose, and what aspects of their biology will be measured. I do NOT recommend Peebles for part of this study; he is too expensive (assuming the figure of $250k was accurate) and we need a fresh outside perspective on this problem.

3. Set up a pilot test in at least one pump on/off run in which specific chemical parameters such as Cl, Na, K, Ca, Mg, Si, etc. are measured in addition to specific conductance (note that conductivity is an inappropriate term to use after the data are corrected for cross sectional area of the test cell). This method could be restricted to the uppermost 3 stations since it is there that the effect due to mixing of fresh and salt water will be the greatest.

Some additional comments:

I am not happy that the pump test was conducted down to a flow of 90 cfs under the guise of the Panel's prior recommendations. I do not recall that there was any suggestion by the Panel that water would be removed below 130 cfs. The conduct of this revised design without any consultation with the Panel by e-mail leads one to the conclusion that the Authority may have been more interested in pumping water into their reservoir than understanding the effects of such pumping. This is an unfortunate turn of events that I hope will not be repeated. The abandonment of any effort to monitor bioindicators is equally unfortunate since there was a clear understanding that the Panel favored this approach. Indeed, after the previous meeting, I was in contact with Ralph Montgomery for some time discussing the use of fish bioindicators when suddenly the subject was dropped. I believe that the Panel members have demonstrated their good faith and devoted considerable un-paid effort to providing advice which I find very appropriate for the Authority. It is in the interest of the Authority, if it intends to maintain credibility, to keep the Panel informed of major events that impact its role. After 10 years, I feel that a true working relationship has developed that can only benefit the Authority properly if communication occurs more often. I suggest the use of e-mail to solicit occasional comments without the expense and time involved in calling a meeting.

I agreed with Tom Fraser's suggestion to compute changes in the isohalines that resulted from pump on/off conditions.

I agree that this analysis indicates that the actual changes in river estuary salinity due to pump operation seem to be consistent with previous models. I DO NOT agree that this necessarily resolves the potential impact of such changes, slight as they may seem to be, on the ecology of the estuary. The reason for this is that we still lack data for the tidal reach ABOVE THE PLANT, where one would expect the greatest ecological impacts to be felt. We also **lack a precise definition of what significant adverse harm actually is**. So any rush to absolve the plant intake from adverse ecological impacts is premature. Let us finish the logical steps in designing rigorous tests to falsify the presence of such impacts.

B. The MFL's- Lower Peace & Shell Creek

Tony Janicki defended this study report valiantly, but it has many serious flaws. I did like the basic idea of using a model to predict the effect of changes in water flow on several habitat variables. However:

1. I did not like the potentially serious statistical problem of autocorrelation among the habitat parameters. It would take some highly qualified statistical experts to decide this problem, but it appears to me that the highly correlated habitat variables should be reduced to one.

2. I did not like the choice of 15% as the level of significant harm. This has the same aura of "rule of thumb" inherent to the 10% rule of water withdrawals. For many of the same reasons it is not defensible. There needs to be some relationship, however tenuous, to real world ecology. Here again we need a connection to bioindicators of importance in this ecosystem. Is there any reason to suppose that a 15% change in habitat will result in a similar change in the biota? Indeed this 15% change might even completely remove the habitat needed for a particular life stage. Just to give one example, the shallow edge might be lost, removing the area that is used for spawning.

3. It is ridiculous to set MFL's for the watershed without simultaneously evaluating the MFL(s) for Charlotte Harbor itself. In my mind it is most logical to start at the bottom (the real top-down or holistic approach) where all water flows meet and mingle, and then work back to the top of each tributary. A perfect example of the problems caused by the present report in which Shell Creek is isolated from the estuary was given by the occurrence of important areas of SAV where manatees feed just below the Shell Creek mouth. The MFL's discussed here may or may not destroy these areas- we do not know since it was not considered. Another manatee example is the incursion of saline water into the Harbor during low flow events (likely exacerbated by MFL's set too low) which can lead to transport of highly toxic masses of red tide into the bay which have been known to kill large numbers of manatees and other organisms. We know of many examples of how the bay is controlled by water flows either high or low, and setting of MFL's in the tributaries will be crucial to manipulating such effects. These need to be evaluated all at once to balance the needs of all of the competing users, including the natural system.

4. I was shocked to hear that a lot of time was wasted in evaluating shoreline vegetation as an indicator of change in water salinity. This Panel recommended halting monitoring shoreline vegetation some time ago. Although there is a cline in vegetation species as one goes up-river, this change is very insensitive to small changes in river flow and salinity. In addition vegetation can also be strongly impacted by other factors such as freezes, rainfall, winds/hurricanes, etc. leading to an inability to separate one factor from another. Here again, the Panel should have been asked about this issue.

5. The analysis of salinity as <2, <5 and <15 ppt was criticized as causing an overlap in effects. The proper way would have been to analyze as 0-2, 2-5, and 5-15 ppt. I do not generally favor the classification of habitat salinity into such blocks since few species fall into such simplistic groups. Often one life stage will be at a different salinity than another (hog choker is a good example where the adults are at high salinities and the juveniles up-river at low salinities). I have never subscribed to the use of salinity as a surrogate for bioindicators since it would be so much more powerful and accurate to simply use a small number of representative bioindicators and their niche space requirements.

6. For these and many other reasons I recommend stopping any further separate consideration of tributary MFL's and starting first with a MFL for Charlotte Harbor and then begin working upstream to the constituent watershed flows. The setting of MFL's is an immensely complicated task and one which will have profound effects on the bays. It needs to be done with much more input from biologists (and less from abiotic modelers).

7. The upcoming MFL for the Myakka River would be especially contentious since there have been two major diversions of flow through the Blackburn Canal and Cowpens Slough. In the future "excess" groundwater added to the system at

Flatford Swamp is slated to be diverted for drinking water. The overall system is becoming more and more controlled and water is being diverted away from former drainage pathways. The adverse ecological impacts are certainly likely to be huge, yet there seems to be little concern about this for the Myakka itself and the Harbor below. The Myakka River is sometimes said to be “free-flowing” except for two low sills or dams. However the extent of diversion of water represents a significant change in the historic flow pattern.

8. I have occasionally come across some work on fish monitoring within Charlotte Harbor carried out by the DEP lab in Pt Charlotte. For example see:

   Idelberger, C. F. and M. F. D. Greenwood. 2005. Seasonal variation in fish assemblages within the estuarine portions of the Myakka and Peace Rivers, Southwest Florida. Gulf of Mexico Science 2005(2): 224-240.

   I often wonder why there is not better coordination among the scientists involved in monitoring the Harbor. It would be a more effective use of funds and would likely result in better science if all stakeholders participated in designing, analyzing and evaluating the results of biological monitoring. For example, the high cost of studying the fish near the water intake at the Ft DeSoto Plant was mentioned as one reason that it could not be done. Well- here is a group in Pt Charlotte with many years of experience that might be persuaded to help with the study of bioindicators in the pump test. What after all is the mandate of this group?

Comments for the Peace River Manasota Regional Water Supply Authority
Meeting of the Scientific Review Panel
Lower Peace River Minimum Flows and Levels Draft Report
4-5 December 2007

By

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Janicki Environmental. 2007. Proposed minimum flows and levels for the Lower Peace River and Shell Creek. Peer Review Draft, Southwest Florida Water Management District. 1-282, appendices.

Section 373.042, Florida Statutes gives the following guidance for minimum flows and levels (MFL) "...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."

The Southwest Florida Water Management District (SWFWMD) started their mandated MFL programs with the head waters of the Peace River in 2002 and the middle Peace River in 2005. For these two segments of the Peace River a methodology was accepted to protect more than just a single flow. This methodology involved defining seasons (or blocks), determining long-term median flows for each season to divide flows into higher flows and lower flows, use of benchmark periods to account for long-term oscillations in rainfall. Generally, relative water levels (gage height data and surveys) could tied biological systems to a range of heights and duration (inundation) of flows. This process lead to the use of a pre-set standard of harm above which flows could not be impacted without causing Florida Statue section 373.042 to be violated. All of this effort has a reasonable set of logic for protecting habitats and biota in the flowing river system.

The level of harm was recommended to be 15% alterations related to levels and duration of inundation for specific biological characteristics (habitats) with short and long-term standards. In section 3.1 of the Middle Peace MFL (2005) it is clear that 'bright lines" harm choices could not be made except for loss of fish passage or the wetted perimeter inflection point. SWFWMD also recognized that a range from 10-33% harm has been used in other streams (any Florida examples outside SWFWMD). The numerical choice beyond the bright line characters appear to be related to the level of comfort for alterations to natural or existing environmental conditions.

The above methodology and standards were imposed in the draft report for the tidal Peace River and tidal Shell Creek MFLs. I believe this was done for consistency and ease of lining up regulatory processes. There does not appear to be any thought or discussion about the consequences of multiple riverine management processes affecting Charlotte Harbor (Upper

Peace MFL, Middle Peace MFL, Lower Peace MFL, Shell Creek MFL, and Myakka River MFL) with no apparent consideration beyond the defined MFL boundaries. SWFWMD will be managing inflows to an estuary, perhaps the third largest in Florida, with unique national and international standings. There is an ongoing Charlotte Harbor National Estuary Program. Boca Grande Pass at the bottom of Charlotte Harbor is the pre-spawning feeding grounds for tarpon in the spring and early summer, the subject of a catch and release fishery (many millions of dollars) and internationally famous. Other important fisheries in Charlotte Harbor are sustained by fresh water inflows, but generally were not part of the analyses or possible responses to the MFL process. There is no logic or proposed processes tying these MFLs together to determine the consequences to Charlotte Harbor's biota or resulting economic impacts as the beneficiary of permitted withdrawals in the future under MFL guidance. SWFWMD and the consultant should be explicit about the choice of a harm standard and evidence from other estuaries to show that 15% harm is within a reasonable range.

The logic that demostrates protection of flows by the choice of blocks, classifying flows based on long-term median flows and its application to a tidal ecosystem was not clearly presented. For example, there was no discussion about ascending and descending arms of inflow with season and potential effects of proposed MFL guidance. There was no shortage of data on species in the tidal river which have life histories closely tied to narrow salinity levels at some or all life stages. Most were included in the early chapters but not examined in detail as part of the potential consequences (responses) to the recommended MFLs, only a comparison of predicted locations of the center of abundances for some species was presented. The behavior or reasons for such locations probable were related more to balancing sources of food and responses to predation, parasites and disease rather than to flow per se. As a reasonable assumption, the centers of abundances equate to ultimate adult populations, but we don't know if this assumption was true for any of the larval or juvenile stages given variable natural mortality rates. The broad distribution exhibited by most larval and juvenile biota in the tidal river may be more important in any given year that survive to an adult stage.

The tidal Peace River and Shell Creek have highly braided channels, a characteristic not seen in many Florida rivers. Biota distributions were used to subdivide salinity zones (but see Greenwood, 2007). These salinity zones were then used as categories of habitats. The amount of each habitat zone was predicted from a deterministic model of salinity in the tidal Peace River which included most of the braided channels. Unlike the Peace River model, a statistical model (based on monthly data) was used only for the defined main channel of Shell Creek and all of the braided channels were excluded. Shell Creek MFLs suffered from a limited areal definition of the creek's foreshortened downstream boundary with the Peace River. The proposed MFL allowing 83% of the flows higher than the median high flow not affecting more than 15% of the 2 ppt salinity habitat zone is very likely due to the location of the downstream boundary. There was no recognition of Shell Creek's flow effects downstream of its Peace River confluence on the southeastern side of a major braided channel. This region is in a larger area recognized by Greenwood et al., 2004 as having a community organization different than above the confluence of the Peace River and Shell Creek (which is a different boundary than in the MFL report) – and both were noted in section 5 of the MFL on fishes. Greenwood et al. 2004, wrote that "The dam on Shell Creek has a strong impact on the abundance of many species, but the determination of potentially positive or negative effect of this structure on the nekton community requires further study.” This is a curious statement and should be followed up with additional analyses(?) or data. SWFWMD will have to deal with serious inconsistencies when comparing and using proposed Shell Creek’s MFL guidance and then superimposing this guidance upstream on the Lower Peace River’s MFLs because of the fundamental differences in the two processes.

Shell Creek should be dropped from this MFL report until major flaws are logically examined, dealt with and re-reviewed. Because the MFL analysis for the Peace River included the ‘worst case’ for Shell Creek in making the proposed MFLs for the Lower Peace River, the proposed MFLs should be re-run without Shell Creek and the document revised. The Lower Peace River MFLs would be provisional awaiting the revisions for Shell Creek.

Normally, one might stop here, but since I cannot predict what will happen other comments are added for consideration.

Cumulative distribution functions (CDF)were used to determine temporal persistence and spacial extent of habitats. Curves were computed for one (Shell Creek) or three metrics (Lower Peace River) and each daily change of a metric output plotted against percentage occurrence per day. The baseline period (1966-2004 for Shell Creek and 1985-2004 for Peace River) for each metric was developed by adding back in water withdrawn to the existing daily flows to run either in the deterministic (run for 1996-1999) or statistical (run for 1966-2004) models for outputs associated with one (Shell Creek) or three (Peace River) salinity zones.

With the example of Figure 8-1, the percentage of days departing from the predicted baseline (similar to a duration curve?) was from all predicted fluctuations of the habitat metric at various flow reductions. These predictions were run for each block and subdivision of high and low flows. Interpretation for predicted harm to potentially rare, common and critical habitats don’t seem possible with CDFs. Perhaps there are graphic representations of the braided, tidal Peace River that can show the ‘average’ long-term 15% harm area– or harm within a grid location. Maybe other kinds of analyses are needed to complement these predictions. No discussion was presented about how SWFWMD or a permittee might do real-time monitoring to confirm the model predictions.

None of the results were analyzed for uncertainty, probability of being correct or a range of values likely for estimates, total habitat estimates or predicted changes. Such information is helpful to the policy makers and to staff when dealing with guidance issues. The MFLs were presented as if there was only one answer, its correct with no chance that there maybe numbers with a higher likelihood of being right. Do the proposed MFLs have a 50% chance of being protective for 15% harm– is the probability higher or lower? I think the answer is, we do not have a clue.

The above issues become more important because the proposed MFLs for the Lower Peace River will be based on three gaged flows: Peace River at Arcadia, Joshua Creek at Nocatee, Horse Creek near Arcadia and Shell Creek on CR 764. Previously, the only gage regulating withdrawals was the Peace River Arcadia gage. Any potential mistake in setting a 10% daily withdrawal of flow from the previous days flow at Arcadia in 1988 could be buffered by flow from Joshua and Horse Creeks. There was no estimation of what these actual withdrawals would predict for change in the habitats. The predicted 10% maximum reduction included the predicted effects of Shell Creek MFLs plus the addition of Joshua and Horse Creek so the 10% curve was not equivalent to existing conditions.

The use of the long-term median flows in each block may be more conservative when calculating proposed split MFLs than the long-term average flow would be for lower flows and may be more liberal for higher flows due to the higher average values that would re-classify flows. There were no discussions about contrasting the following with the proposed methodology: arithmetic average to split flows for MFLs, a single percent of flow across all flows for an MFL, or critical MFLs focused intense known production periods with a different strategy for other seasonal periods in a tidal, braided, riverine estuary.

Less than 75 years of flow data exists at the Arcadia gage, while there is more than 100 years of rainfall data in the basin. The Peace River Manasota Regional Water Supply Authority's (PRA) facilities may not be to deliver the water demand 95% of the time because of present physical constraints. Once those constraints engineered away in the next year or two, will the Peace River flows be 95% reliable or better in the PRA's ability to take water in the future under the proposed MFLs? There was no discussion about how the only permitted user on the entire river might be constrained or how any other potential user would be constrained. The MFLs are not very intuitive, and may never be, but there is a strong need for examples beyond here is how the math calculation would be done for a site specific MFL.

The report does not discuss the choice of doing an MFL for Shell Creek+Prairie Creek, a 330 square mile basin and not analyze Horse Creek, a 218 square mile basin (above the gage near Arcadia). Horse Creek enters the upper tidal Peace River above the PRA's water treatment plant. I suspect there may have been some reasonable logic for the choices. Nevertheless, portions of Horse Creek basin are being severed for phosphate mining, and much more activity is expected. Does hydraulic mining remove the slurry to beneficiation plant in the Payne Creek basin for processing with some loss of Horse Creek water? I assume agriculture is, and will be using groundwater in the Horse Creek basin. These issues should be made clear in the MFL report since this 100% of the creek's flow is added in to the Lower Peace River MFL. Similar, but lesser comments could be made about Joshua Creek and the SWFWMD program that would reduce groundwater irrigation flows.

The proposed combined 90 cfs threshold flows below which no water may be withdrawn was to protect the PRA's raw water quality. It was not clear what the probability of protection would be between the permitted threshold level of 130 cfs (Arcadia gage only) and 90 cfs (Arcadia+Horse+Joshua gages). The combined 90 cfs threshold may not be the same level that would be protective of biota in the upper parts of the Lower Peace River at lower flows. It was not clear why no analysis was done to determine if the seaward boundary of the hardwood swamp forest ought to receive protection from >2 psu inundations at some low flow threshold.

Questions were provided in advance through the PRA to SWFWMD and Janicki Environmental. A few questions were touched on during the panel meeting, but most were not explicitly discussed by the District or the consultant. So I attach them here for the Peer Review scientists to consider or not in their review of the draft report.

CHARLOTTE HARBOR —

1. Charlotte Harbor below the defined mouth of the tidal Peace River is left out of any consideration of freshwater inflow and the potential effects of the minimum flows and levels having been set by SWFWMD for the Upper and Middle Peace River segments and proposed for the Lower Peace River. Please combine the maximum allowable flow reductions by blocks that could be removed from all segments of the Peace River, including Shell Creek so that one can consider the potential change in flows to Charlotte Harbor (see fig 5-16 of Middle Peace; figs 8-18 and 8-19 of Lower Peace).

2. Will some overall minimum/maximum total MFL be used to protect Charlotte Harbor which is the receives the impacts of any allowable withdrawals? There is no text discussing this issue.

3. If these combined maximum allowable flows are close to or exceed 20% of the gaged inflows by block, please address the literature that shows significant biological changes for fishes and wildlife dependent on fish. There was no review of any literature about changes seen in other estuaries related to reductions of natural flows.

4. I think we need to see plots by actual year of the cumulative maximum allowable withdrawals as a percent for each day in a year so that we can see the consecutive days with high percentages of withdrawal on Charlotte Harbor. A hypothetical example is provided for a flow of 600 cfs in Shell Creek and 115 cfs for the Peace River across all blocks:

Shell Cr. Block 1	(84*0.10) =	8.40
	(600-84)*.23 =	118.68
max withdrawal =		127.08
Peace R. Block 1	(115*0.10) =	11.5
max withdrawal =		11.5

Total flow change = (127.68+11.5/715)*100 = 19.4%

Shell Cr. Block 2	(98*0.18) =	17.64
	(600-98)*.42 =	210.84
max withdrawal =		228.48
Peace R. Block 2	(115*0.14) =	16.1
max withdrawal =		16.1

Total flow change = (228.84+16.1/715)*100 = 34.2%

Shell Cr. Block 3	(424*0.35) =	148.40
	(600-424)*.83 =	146.08
max withdrawal =		294.48
Peace R. Block 3	(115*0.12) =	13.8
max withdrawal =		13.8

Total flow change = (294.48+13.8/715)*100 = 43.1%

5. Will the analysis of potential changes be extended to Charlotte Harbor before the SWFWMD allows additional users to withdraw surface waters of the Peace River and/or its tributaries?

6. Since phosphate mining severs large area of land from discharging its water naturally for long periods of time, how has the MFL process taken these existing and future changes into account?

7. The results and conclusions of various HBMP studies of phytoplankton carbon uptake, fishes, and plankton in the lower Peace River have all emphasized the importance of the initial spring freshwater inflows. Shouldn't any proposed expansion of withdrawals put a particular emphasis on minimizing any potential impacts to such biologically important flows?

MEDIAN STATISTIC - HARM - CUMULATIVE DISTRIBUTION FUNCTION—

1. What is the biological basis of using the long-term median flow as a marker for partitioning low flow and high flow?

What is the biological basis for using median long-term flow (or AMO adjusted)for the blocks instead of some other characteristic of the flow distributions delivered to estuaries?

2. Is there reason to use a series of descriptive characteristics for flows that ought to be maintained and delivered to the estuary?

3. What is the biological justification for transposing a 15% harm threshold from rivers controlled by dams to the Peace River, mostly uncontrolled?

4. How does a 15% harm threshold for dam controlled rivers be morphed into an equivalent harm threshold for a tidal estuary when there are no biological or physical equivalents?

5. Explain how the minimum flow criterion for acceptable harm (up to 15% of a change in habitat) to the tidal estuaries can be based on peer review comments for the upper Peace River?

6. Cumulative distribution functions (CDF) appear to be useful for random variables, river flow is not random, tides are not random and therefore salinity or related habitats don't have random distributions. Interpretation of any given CDF for responses by organisms to seasonal cues is not possible. There were no citations from estuarine biological literature in the three places where the following same word for word explanation was given (pp. 7-7, 7-20, 8-2):

> Habitat availability can be quantified in terms of both space and time. The tool used to evaluate temporal persistence and spatial extent of habitat meeting a biologically relevant salinity is a cumulative distribution function (CDF) plot. CDF plots are an ideal tool as they incorporate the spatial extent and the temporal persistence that a given salinity is met. Plots are drawn of the various scenarios that have been run and comparisons can be made among scenarios.

This analysis process may have merit for predicting one measure of habitat, but one cannot determine duration of any consecutive flows during relevant biological life histories and use of various habitats through life stages.

7. How and why can a 'baseline' condition (CDF) representing a long-term statistic, have relevance to the life histories, distribution, and assemblages of organisms using habitats in estuaries?

8. Why is there no partitioning of shoreline habitats or benthic habitats which are generally fixed with respect to variation in flow and salinity?

Clewell *et al.* (1999) described glycophytes as having low salinity tolerances with several species being most abundant where median yearly salinities are below 2 ppt; and the Lower Suwannee River MFL was based on "average salinities of high tide waters flooding the swamps should be kept <2 ppt, with briefer periods of higher salinity tolerable." (WRA *et al.* 2005). (report, p. 7-2)

The CDF plots of predicted habitat change provide no guidance to the zonation of major habitats (swamps, marshes, or mangrove).

9. What are the uncertainties associated with predicted habitat change using CDF plots?

10. What are the probabilities that changes will not be greater than predicted using CDF plots?

SEA LEVEL VARIATIONS—

1. Since the Lower Peace River and Charlotte Harbor tides play a role in salinity variation, do various lunar/sun cycles have roles to play in salinity modeling and regression analyses for examples or their interpretation over long periods of time? – Such as the 18 year Saros cycle, the mixed semi-diurnal and semi-diurnal tides, cycle of variation for tidal flushing as the result of multiyear differences in tidal heights over the 18 year cycle, seasonal cycle within a year in sea level. Gage height levels used in the models just get a small portion of these kinds of variations.

2. Since the intake for the Peace River water plant will likely be located in tidal waters well into the future where it has been for more than 27 years to date, should there be an examination of variations in sea level such as, the long-term trend of rising sea level (fig. 1) the average seasonal mean sea level (fig. 2)?

Fig 1. The mean sea level trend is 2.4 millimeters/year (0.79 feet/century) with a standard error of 0.18 mm/yr based on monthly mean sea level data from 1947 to 1999.The plot shows the monthly mean sea level with the average seasonal cycle removed (dashed curve), a 5-month average (solid curve), and the linear trend with its 95% confidence interval which was obtained after accounting for the average seasonal cycle. For most stations, the plotted values are relative to the 1983-2001 mean sea level datum recently established by CO-OPS (NOAA online data).

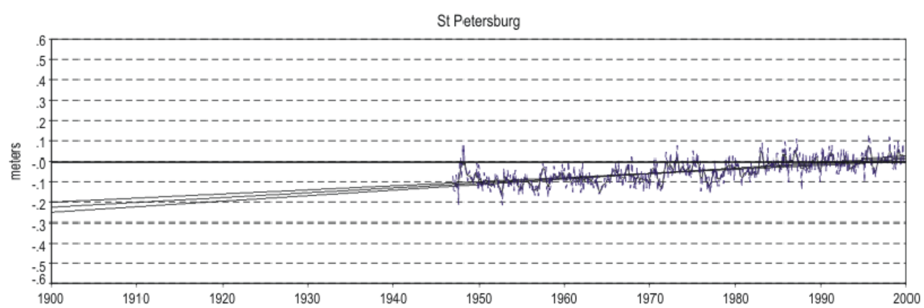
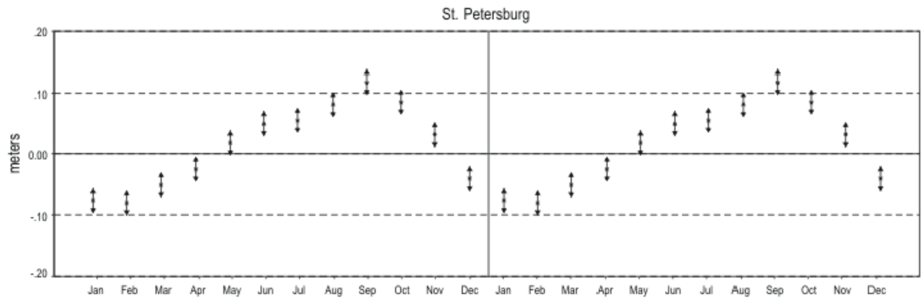


Fig 2. Average seasonal mean sea level cycle over a 2-year period with 95% confidence intervals. For most stations, the values are for the year 2000 relative to the 1983-2001 mean sea level datum recently established by CO-OPS (NOAA online data).



MODELS—

1. The LESS model data (fig. 3)are from a wet year with flows rarely less than 150 cfs. Chen states the following with my emphasis:

Comparisons of model results and measured salinities at the eight stations for the two verification periods are presented in Figures C-1 through C-23 in Appendix C. **Overall, the agreement between simulated and measured salinities at all eight stations in the LPR - LMR - UCH system is marginally.** In the wet season before the calibration period, the coupled model generally under-predicts salinities; however, in the driest months after the calibration period, the model slightly over-predicts salinities. The best agreement between simulated and measured salinities occurred in last couple weeks of the second verification period when simulated salinities in all eight stations match with data very well. Again, many factors could have caused the not-so-good agreement between simulated salinities and measured data, including the bathymetry data read to the model, un-gauged flow estimates, he boundary conditions provided by another model (Sheng et al., 2007). (Unpaginated Appendix 7.2 = pp. 186-187 of all appendices)**Although there are many uncertainties in the input data used to drive the LESS model, including measured data, un-gauged flows, boundary conditions provided by the other hydrodynamic model** (Sheng et al., 2007), the dynamically coupled model was successfully calibrated to measured real-time data of water levels, currents, salinities, and temperatures at eight stations during January 10 – April 9, 2004, except for salinity at the North Port station. During the two verification periods before and after the calibration period, the model generally works well in predicting water levels, velocities, and temperatures, but under-predicts salinities in wet months and slightly over-predicts salinities in the driest months. (Unpaginated Appendix 7.2 = pp. 196-197 of all appendices)

2. Should there be an evaluation about the model uncertainties and probabilities related to the predicted salinities before using output in the main MFL document?

3. Should there be an evaluation of using the model from one wet time period (2003-2004) and its application to 1996-1999 period in the main MFL document?

4. Should there be an evaluation of not having a station on the western side of Charlotte Harbor opposite the UF station? The HBMP reports describe about a 1‰ salinity difference between the sides There is a ‘slow spin’ in the upper harbor because higher salinity water moves up the eastern side of the upper harbor while lower salinity water moves down the western side because of the right angle physical shape of the harbor and locations of large freshwater and salt water inputs. Salinity fronts are formed as the result of interactions of tides, wind and flow. Chen noted the following:

Because of the physical configuration of the Charlotte Harbor, the magnitude of the *v*-component of the current is generally much larger than that of the *u* component at the UF station. During the dry season when the current was predominantly tidal driven, the magnitude of the *v*-component was about twice of that of the *u*-component. However, during the wet season, the magnitude of the *v*-velocity was as large as three times of that of the *u*-component because fresh water coming from the Peace and Myakka Rivers turns south when it exits the Upper Charlotte Harbor. Due to the Coriolis effect and the way the Peace River flowing to the UCH, fresh water exits the harbor mainly near the west bank, resulting in a negative, long term averaged *v*-velocity of 4 - 5 cm s-1 during the wet season and only about 1 cm s-1 during the dry season. (Unpaginated Appendix 7.2 = p. 174 of all appendices)

5. In determining the 0-2 psu zone for the various metrics used, were different portions of the water column applied?

A. Shoreline = surface salinity
B. Bottom area = bottom salinity
C. Water column = average water column?

If not, what values were used and why?

6. The maintenance of low salinity (0-2 psu) habitat was used as a criterion for establishing the lower Hillsborough River MFL. Since there isn't any dam on the Peace near the Authority intake, why was that salinity chosen as important? Hasn't the historic HBMP data shown the highest occurrences of production to occur at higher salinities along the lower Peace River?

7. Under low flows, most of the lower Peace River is stratified with saltwater moving upstream along the bottom. As flows increase, larger reaches of the lower river downstream of the Peace River Facility become fresh top to bottom, while areas further downstream become more stratified. Past some point, further increases in flows actually cause the very lower reaches of the river (downstream of the U.S. 41 Bridge) to become increasing even more stratified, so that the first approximate 6 kilometers of the lower river is characterized by a very narrow lens of freshwater flow over much higher salinity water. Was the hydrodynamic model able to accurately predict this? If not, wouldn't the model have been inaccurate in determining salinity distribution metrics in the lower river under combined gaged flows above 1000-1500 cfs?

8. Over the past 30 years, the underlying premise of the HBMP, the District's permitting, and the Facility withdrawal schedule has been that by allowing only very small changes in salinity (at any point at any time) any resulting changes in habitat and the number and distribution of organisms would also be relatively small. What are the expected maximum changes in salinity expected due the proposed withdrawals over the small temporal and spatial scales used previously?

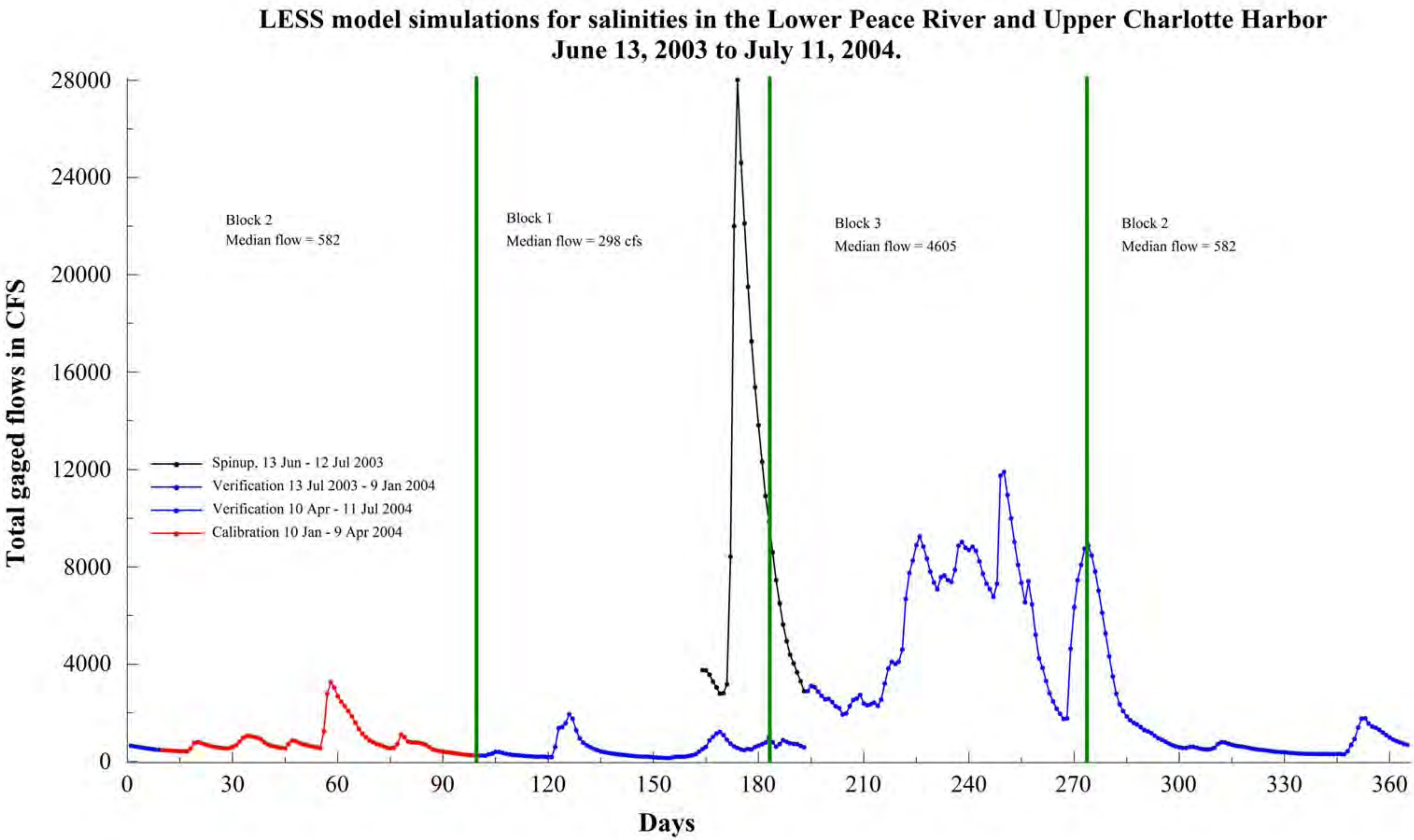


Figure 3. The hydrodynamic model for the Lower Peace River used data from a very wet period. If one splits this period into the MFL seasonal blocks for the combined flows, then the period June 26 - October 26 has a median flow of 4605 cfs, October 27 - April 19 has a median flow of 582 cfs, and April 20 - June 25 has a median flow of 298 cfs. The lowest daily flow was 140 cfs. Durations of consecutive flows less than 150 cfs were 9 days for Peace at Arcadia + Horse +Joshua and 3 day when Shell Creek is added in.

5. Shell Creek was modeled by Chen. Why was this information not used in the main MFL document? There is no explanation in Appendix 7.1 or in section 7.2 of the report.

6. The ‘whole river regression model’ for Shell Creek has a number of variables. Not all of the monthly intercepts account for variation in salinity (Unpaginated Appendix 7.1 = pp. 109-111 of all appendices). A seasonal or annual Fourier function might be enough instead of 12 variables.

7. Should there be explicit discussion of why each variable was chosen?

8. Would all of these variables be included in a step-wise regression analysis?

9. There was no table relating to the Variance Inflation Factor. Should there have been estimates of first order autocorrelated errors and a Durbin-Watson statistic?

10. Why was the choice of tide height (actual or predicted?) the Boca Grande station instead of the Harbor Heights station which is at least 20 miles closer and more likely to show the additional influences of freshwater flow and bathymetry on tide height? The Boca Grande station is inside a canal on the island.

11. Should any of the variables be lagged?

12. Why was it determined to evaluate the influences of Shell Creek flow to the limited area used, when the Shell Creek HBMP monitoring program is designed to also evaluate the influences of Shell Creek flows on the lower Peace River? Seasonally, Shell Creek can be as much as 50% of flow and over the period of record since 1965 has accounted for approximately 23% of the combined lower Peace River flow to upper Charlotte Harbor.

13. Were the maximum withdrawals for the three periods for Shell Creek determined first and then were these values used to determine what additional withdrawals could occur from the Peace River Facility?

14. If the basic assumption, for item 13 above is correct, of first withdrawing maximum amounts of water from Shell Creek then it leads to the confusing conclusion (Table 8-6) that higher amounts of water can be withdrawn from the Peace River Facility during lower flows than during higher flows (since the model assumed 200-500 cfs (see Figure 8-18)was already being withdrawn from Shell Creek?

15. Since the new expanded reservoir capacity is being sited near the Peace River Facility wouldn’t it have been more logical to approach first the Peace River withdrawals (where there is existing storage) with regard to potential impacts to the lower river/upper harbor, and then determine what additional flows beyond what is currently being utilized might be available from Shell Creek?

BUILDING BLOCKS—

1. Should the ‘three building blocks’ with fixed time definitions that are used in lotic systems, like the Peace River to partially account for ecological cycles related to seasonal flows, really work in estuarine or marine systems with much greater biological diversity, seasonal variation in assemblages and changes in abundance?

Temporal and spacial variation of physical characteristics in estuaries drive the initial responses of biological assemblages. My 50 years of experience with the Charlotte Harbor complex is that no two years have been alike. There are general multiyear, annual and seasonal patterns, but every year has been different. Perhaps, if this site were on the equator every year would be the much similar. There was no real exploration of this issue in section 7.1.3 Seasonally-Specific Assessment Periods other than it was done on the middle Peace River, so no change. Critical periods for phyoplankton blooms, seasonal rotation juvenile assemblages in nursery areas or cues related to various flows for life history cycles appear to have played no role in this process to accepting the ‘building blocks’.

Comments on the Proposed Minimum Flows and Levels for the Lower Peach River and Shell Creek Draft Report and the Associated Scientific Review Panel Meeting held on December 4-5, 2007

by

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The Southwest Florida Water Management District has been legislatively mandated to establish minimum flows and levels (MFL) for the steams and rivers (including estuaries) within its boundaries. Minimum flows are currently defined by appropriate statute 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". The proposed minimum flows and levels for the lower segment of the Peace River (from the Arcadia gauge, including Joshua Creek, Horse Creek and Shell Creek to Charlotte Harbor) were discussed in the draft report entitled "Proposed Minimum Flows and Levels for the Lower Peach River and Shell Creek". A meeting of the Scientific Review Panel, an advisory group established by the Peace River/Manasota Regional Water Supply Authority as a requirement of their permit, was held on December 4-5, 2007, to review and discuss this report and related studies (including a study conducted from December 2006-May 2007 to evaluate the impact of Authority withdrawals on short term changes in water quality given a natural estuarine background of tides and weather. The meeting was held in Bradenton, FL.

Because I have limited local knowledge and direct experience with the Peace River ecosystem and Southwestern Florida coastal ecosystems my comments are mainly related to the:

- Scientific approach and methods used for the above cited studies including implications of inherent assumptions;
- Evaluating the basis in ecological sciences for methods, findings and interpretations relative to the above studies; and
- Implications of findings and interpretations of study results to ecological processes and cumulative environmental impact of freshwater withdrawals to the Peace River ecosystem.

The percent-of-flow approach was used to ensure the natural flow regime of the river was maintained in a manner with protected ecosystem integrity with limited reduction, mainly damping, in the freshwater inflow into the downstream estuary and adjacent coastal ocean. This is a scientifically based approach which is designed to minimize stress and disturbance to natural flows and associated biota. The withdrawn water was used as a potable water supply. Establishment of the appropriate percent-of-flow withdrawal rates was based upon an understanding of climatic and anthropogenic influences on historic and current flow regimes and conditions required to maintain the ecological integrity of the source waterbody, including:

- Identification of a low flow threshold below which no withdrawals are allowed,

- Defining biologically relevant habitat strata (e.g., salinity zones) to ensure ecosystem integrity and associated processes are protected,

- Identification of ecologically appropriate metrics that quantify changes in habitat strata,

- Definition of within year (seasonal) assessment periods (i.e., seasonal "blocks") for which it was critical to maintain the " specific flows" to sustain water resources and critical ecological processes, and

- Description and application of analytical methods for quantifying habitat change including establishing: (1) study area boundaries, (2) the baseline period for minimum flow determination, (3) analysis/modeling period, and (4) appropriate and reasonable scenarios for minimum flow determination.

It was not possible to define a low flow threshold for the lower Peace River and Shell Creek using ecological criteria and the available data. The operational low flow threshold established for the lower Peace River was ultimately designated as the flow required to maintain freshwater (salinities <0.5 ppt) at the Peace River/Manasota Regional Water Supply Authority intake. The operational low flow threshold for Shell Creek was that required to maintain a 2 ppt salinity habitat strata with in the study boundaries for Shell Creek. The 2 ppt criteria for Shell Creek was assumed to be a habitat criteria appropriate for sustaining the integrity of valued ecological resources, including fish and shellfish populations in this ecosystem. I recommend that the 2 ppt criterion for Shell Creek be expanded to include some minimum amount of this habitat. The 2 ppt threshold has scientific basis in ecological science but without a specific criterion to define the amount of this critical habitat required to sustain valued ecological functions and services the value of this threshold is unclear.

The minimum flow criterion of a 15% reduction in critical habitat from baseline conditions was established as the level resulting in significant ecosystem harm. This determination was based on analyses and studies for the upper freshwater, free flowing Peace River (Gore et al. 2002). This is particularly problematic since the amount of critical habitat loss that may cause significant ecological harm in a tidal estuary is not tightly linked to changes in water level which seems to be the major basis for the 15% threshold in Gore et al. 2002. Unfortunately, no scientific justification was provided for applying the 15% habitat loss criterion to the tidal reaches of the lower Peace River and Shell Creek, and I am not aware of any studies that suggest a 15% loss in any habitat (abundant or rare) does not result in ecological harm. I am also not aware of any evidence that suggests that estuarine populations, communities, and ecosystems have adaptive processes that allow them to compensate for habitat losses in this range. A final concern with establishment of the 15% threshold value for critical habitat is that because it has no scientific basis it must include a safety factor. Even in well understood engineering systems and processes that have far less social, economic and ecological consequences than freshwater withdrawals society requires safety factors (e.g., bridge and road construction). No evidence was presented that a safety factor was incorporated into this study (e.g., uncertainty estimates were not provided). I recommend a range of threshold values be evaluated (e.g., 5%, 10%, 15% and 20%). The lower values may be more appropriate for rare habitats and include an undefined safety factor and the higher values may be more appropriate for abundant, widespread habitats and high flow periods where a safety factor may not have a great a value.

The scientific justification for the three salinity strata/habitats that are defined in the report could be expanded. It would be especially beneficial if they were specifically related to critical functions of representative important biota or ecological functions (e.g., fishery nursery and feeding/spawning grounds, productive shellfish grounds, critical mangrove habitat) in the Peace River ecosystem. In addition, it is important that the salinity thresholds established for these salinity-based habitats have both upper and lower threshold values. Establishment of upper and lower boundaries for the salinity strata has important implications in the development of estimates of the spatial extent and temporal persistence of these habitats discussed below.

Three habitat assessment metrics were defined: (1) volume of water less than a critical salinity threshold (representing the amount fish nursery habitat); (2) the bottom area less than a critical salinity threshold (representing the amount of productive feeding areas); and (3) the shoreline length less than a given salinity (representing the amount of shallow vegetated refuge habitat). It is important to note that the percent of rare habitats that provide unique ecosystem services (e.g., nursery habitat) that can be loss without ensuing impairment to ecosystem process may be much less than that the amount of abundant habitats which can be impaired without loss of critical ecosystem functions. The message here is rare habitats that may need to be evaluated using different “rules” than abundant habitats (similar to the way society has chosen to treat rare and endangered species). The value of rare habitats that have unique roles to ecosystem process far exceeds their abundance. For example, for low salinity nursery habitat (2-5 ppt), which appears to be rare in the lower Peace River, it may be desirable to maintain 50% or more of the historical amount of this habitat.

Seasonally specific assessment periods were identified by mimicking historical hydrologic cycles as closely as possible. The selected blocks correspond to periods of high (June 26-Oct 26), moderate (April 20-June 25), and low (Oct 27-April 19) flows ensuring the natural water budget of the region is mimicked in all seasons. Maintaining the natural flow regime, although somewhat damped, should sustain the ecological conditions to which the indigenous fauna and flora and ecological processes are adapted. Division of the year into flow periods is an excellent approach for ensuring natural flow cycles and the associated ecological processes are sustained for future generations of humans and organisms, while at the same time meeting some of societies potable water needs.

A regression model was used to estimate the daily salinity at any point within Shell Creek as a function of flow and other confounding variables. This model accounted for ~82% of the measured variation in salinity distributions. The boundary of the Shell Creek study area extended from the dam in the headwaters near the junction of the Peace River following the channel. Braided portions of lower Shell Creek were not included in the model. The baseline and model period for Shell Creek was from 1966-2004. Model scenarios evaluated ranged from 1-100% flow reductions at 1% increments. Cumulative frequency distribution (CDF) plots were used to evaluate the spatial extent (volume) and temporal persistence (% of days) of the biologically relevant salinity strata < 2ppt for Shell Creek.

Estimates of the maximum percent flow reduction for Shell Creek required to protect 85% of the critical habitat (only volume <2ppt) calculated using the normalized area under the curve for each modeled scenario relative to the baseline scenario by seasonal block (1,2, & 3) for low and high flow conditions are shown in Table 1. The shaded estimates represent withdrawals that are sufficiently large that they would seem to have a high probability of resulting in significant and undefined ecosystem changes. No information was present for determining if these changes would be harmful. Withdrawals at these levels approach being considered diversions in my opinion and would likely result in substantial reductions in basic system process such as primary productivity. The 85% number is of particular concern. I also have concerns about the loss of 35% of important low salinity habitat in the June to October period. If this equates to loss of 35% of the fishery production for this habitat it is simply too large without some evidence that the spawning and nursery habitat can compensate for this loss.

Table1: Estimates of allowable reductions for Shell Creek projected to result in protection of 85% of the amount of critical habitat (defined as the volume less than 2 ppt) by seasonal block for high and low flow conditions.

Block	Median Flow (cfs)	Allowable Percent Reduction in Flow	
		Low Flow Condition	High Flow Condition
Block 1 (April 20-June 25)	84	10%	23%
Block 2 (October 27-April 19)	98	18%	42%
Block 3 (June 26-October 26)	424	35%	85%

A hydrodynamic model was used to estimate the response of the lower Peace River to variation in freshwater flows and various withdrawal scenarios. The baseline model period for the lower Peace River was 1996-1999. The scenarios evaluated for the lower Peace River included the baseline period, and 10%, 20%, 24%, 28% and 30% reductions. Cumulative frequency distribution (CDF) plots were used to evaluate the spatial extent (area, volume, length) and temporal persistence (% of days) of the biologically relevant salinity strata <2 ppt, < 5 ppt, > 15 ppt and from 8-16 ppt in the lower Peace River.

Estimates of the maximum percent flow reduction for the lower Peace River required to protect 85% of the critical habitat (volume <2ppt) calculated using the normalized area under the curve for each modeled scenario relative to the baseline scenario by seasonal block (1,2, & 3) for low and high flow conditions are summarized in Table 2. These area appear to be in ranges not likely to result in substantial ecosystem changes independent of losses of the amount of critical habitat (e.g., changes in primary productivity or fish assemblage distributions. When entrainment losses from entrainment and impingement of power plants exceed 20% of the young of the year or spawning stock of a representative important fish population, regulators frequently take action to reduce losses.

Table 2: Estimates of maximum allowable flow reductions in the lower Peace River projected to result in protection of 85% of the amount of critical habitat (defined as either area, volume, and/or shoreline length less than 2ppt, 5ppt, or 15 ppt) by seasonal block for high and low flow conditions.

Block	Median Flow (cfs)	Allowable Percent Reduction in Flow	
		Low Flow Condition	High Flow Condition
Block 1 (April 20-June 25)	221	10%	26%
Block 2 (October 27-April 19)	330	14%	21%
Block 3 (June 26-October 26)	1370	12%	15%

The major concerns identified with the process used to estimate allowable flow reductions are:

- No estimates of uncertainty were associated with the calculations and results of allowable withdrawals or the habitat loss estimates. It is thus unclear what level of safety has been incorporated into the calculations.

- Estimates of the allowable withdrawals were not conducted independently for the critical habitat between 2-5ppt for the Lower Peace River. This “rare” and ecologically important habitat should be evaluated independently of other habitats. A 15% loss in this habitat may be too much to allow.

- The process used to estimate allowable withdrawal rates did not evaluate the impacts on critical habitats and ecosystem integrity in Charlotte Harbor. Under some conditions this may impact the amount of critical high salinity habitats.

Other concerns identified with the report include:

- The conceptual linkage between allowable withdrawals and MFL to water quality and ecosystem condition is not clear. Therefore it is not clear what parameters would be monitored in the future to demonstrate that significant ecological harm has not occurred? In short, how would the District or the Authority ever prove that they were not causing harm in an adjudicated proceeding in the future? Because most of the projected ecological and physical/chemical impacts of future withdrawals are based on salinity impacts, estimates of the projected impacts of various withdrawal scenarios on salinity distributions at specific places (transitional areas) and representative important biota that require specific salinities to sustain their populations would be one monitoring approach that should be evaluated. The monitoring and assessment effort that is implemented definitely needs to include some ecological/biological indicators (higher organisms). Ecological indicators will assess the impacts of interacting and additive impacts of multiple stressors (e.g., increased withdrawals plus drought plus extreme events such as a chemical spill).

- The long-term historical monitoring program and data base compiled for the lower Peace River is a legacy of the Peace River/Manasota Regional Water Supply Authority and the District. This monitoring program and data base is essential for demonstrating that significant harm to the lower Peace River ecosystem have not resulted from previous and future withdrawal regimes. Failure to make conceptual linkages between future and historical monitoring efforts would be a travesty.

- It is critical that the corporate memory of the scientific staff that have a long history of scientific studies in the Peace River ecosystem and the associated data base they have compiled be maintained. It is critical that this knowledge be transferred to future generations. This transfer has not occurred to date.

- The Peace River is a braided estuary, which is somewhat unique to Florida and the Southeast. The hydrodynamic modeling process used to estimate the influence of freshwater inflows on the braided portions of this unique ecosystem needs to be carefully evaluated. These braided sections have great value as habitat and for storage of water. It was not clear if these values were accounted for fully in the current hydrodynamic model.

- The inclusion of the Horse and Joshua creeks flows into the process used to estimate allowable withdrawal rates was confusing. This had not been discussed previously by the Scientific Panel and appears to require additional justification and explanation. This inclusion may be perfectly reasonable it just was not explained in a manner that I understood.

- In a similar manner inclusion of “worse case” and unrealistic 83% allowable withdrawal rates for Shell Creek into the analysis for the lower Peace River was difficult to understand and seem unreasonable. How can 83% of a habitat be loss without a proportional decline in productivity of biota associated with that habitat being impaired? It seems doubtful that an 83% withdrawal will ever be allowed for Shell Creek or anyplace else given the current state of knowledge. Thus, the current assessment for the lower Peace River does not reflect reality.

- I have no comments on the "pump test" that were not made orally during the meeting. These include:
    - Estimation of changes is salinity distributions at specific places with the pumps on and off,
    - Deployment of instruments and testing above the intake system to assess effects of pumps on upper reaches.

From: "Gary Powell"
To: "'Sam Stone'"
Cc: <Sid.Flannery >
Sent: Tuesday, December 18, 2007 6:41 PM
Subject: Peace River MFL

Comments on the MFL Report for Peace River and Shell Creek:

The District's MFL report on the Peace River and Shell Creek does include consideration of vegetative zonation, the abundance and distribution of benthic macro-invertebrates, as well as the standing crops of ichthyoplankton and juvenile fishes. Unfortunately, the fish studies were mostly performed during the wet period in 1997-1998, which means they are not as useful for the low-flow analysis.

The percent flow reduction method for managing water withdrawals is good because it follows the natural hydrograph. Some of the measures used in the MFL analysis (e.g., habitat water volume, bottom area, and shoreline length) are all highly correlated to each other and streamflow. However, it is still quite instructive to see the amount of habitat versus percent of time it's available. However, instead of just looking at the amount available at set at salinity points (i.e., <2 psu, <5 psu, < 15 psu), it might be even more revealing to look at the amount available between the salinity intervals (e.g., 2-5 psu, 5-15 psu, etc.), with special attention to those reductions >15%.

It is noted that less future reductions can occur in the Peace River, because the MFL report assumes that only surplus water in Shell Creek is available in the future. In practice, the Authority's maximum 90 mgd diversion at the river pump station requires 1400 cfs flow at the Arcadia streamgage. As a result, Shell Creek becomes something of a wild card in the MFL analysis, as well as in future water management, particularly if water withdrawals are potentially going to be as high as 35-83% of available flows. Clearly, the HBMP may have to be revised to concentrate on areas affected by these future diversions. Also, at least two (2) additional continuous-recording water quality meters need to be installed upstream of the Authority's Peace River pump station to compliment the three (3)existing stations below the intake facility.

Overall, the District's proposed MFL for the Peace River and Shell Creek seems to provide much needed flexibility to the Authority's water supply operations, which is itself a beneficial result.

Responses to Comments of Individual Members of PRMRWSA HBMP Scientific Peer Review Panel Members

District responses are in bold and italicized.

Specific Questions/Comments posed by Dr. Tom Fraser.

[Note: Dr. Fraser's comments were received as a pdf and were retyped verbatim into a Word file; some examples and figures were deleted as noted.]

CHARLOTTE HARBOR

1. Charlotte Harbor below the defined mouth of the tidal Peace River is left out of any consideration of freshwater inflow and the potential effects of the minimum flows and levels having been set by SWFWMD for the Upper and Middle Peace River segments and proposed for the Lower Peace River. Please combine the maximum allowable flow reductions by blocks that could be removed from all segments of the Peace River, including Shell Creek so that one can consider the potential change in flows to Charlotte Harbor (see fig. 5-16 of Middle Peace; figs 8 – 18 and 8 – 19 of Lower Peace).

The maximum allowable flow reductions by block that could be removed from the Peace River and Shell Creek combined are those that would be allowed by the proposed MFLs for the Lower Peace River (sum of flows for Arcadia gage, Horse Creek near Arcadia gage, and Joshua Creek near Nocatee gage) and Shell Creek. Stated another way, the minimum flows for Shell Creek were determined first, and the maximum withdrawals allowed by the minimum flow for Shell Creek are included in the simulations of the minimum flows for the Lower Peace River.

One would not sum the allowable reductions for the upper, middle and lower Peace Rivers to determine how much could be removed from the Peace River proper. The minimum flows for these three segments are applied independently, with cumulative water use not allowed to violate any of the minimum flows. Application of the rule to individual water users will depend on the location of that water user and the region of its potential impact. For example, the adopted MFL for the middle Peace River essentially says that the baseline or historic Arcadia gage flow can be reduced by up to 10% in Block 1 as long as the withdrawal does not cause the flow at Arcadia to drop below 67 cfs (the low flow threshold based on maintaining fish passage). Any permitted withdrawal above the Arcadia gage would be constrained by both the MFLs needed to protect the middle (freshwater) segment of the Peace River from "significant harm" and the lower (estuarine) portion of the Peace River. Because there is already a

permitted withdrawal downstream of the Arcadia gage (i.e., the PRMRWSA withdrawal), any upstream withdrawal is further constrained by the requirement to protect all existing legal users. The lower Peace River proposed MFL allows a 26% reduction in the combined flows of the three gages (Arcadia, Horse and Joshua) in Block 1 in excess of the median flow condition in addition to the 10% reduction in combined flows below the median. This restriction would apply to withdrawals below the Arcadia gage combined with any upstream withdrawals, and would generally be less restrictive than the MFL for the middle river segment.

2. Will some overall minimum/maximum total MFL be used to protect Charlotte Harbor which is the receives the impacts of any allowable withdrawals? There is no text discussing this issue.

The District's believes that by not allowing significant harm to occur in the estuarine reaches of inflow streams (e.g., Peace, Myakka), Charlotte Harbor will be protected from significant harm due to withdrawals. Stated differently, the greatest changes in flow related habitat and associated biota are believed to occur in those reaches likely to see the greatest changes in salinity, which are the tidal rivers.   The tidal rivers are also zones of concentration for juveniles of many estuarine dependent species that use the river as nursery habitat, and benthic macroinvertebrate communities characteristic of the tidal freshwater, oligohaline and mesohaline habitats. The District concurs that assessing freshwater inflows to the harbor is important, but that the tidal rivers are more sensitive to potential impacts from freshwater flow reductions, and are the first places to look for significant harm.

This comment is similar to the sometimes expressed opinion that minimum flows should first be established for the harbor then for the rivers. This topic is discussed in response to a question from Dr. Dunson below (please see response to Dr. Dunson's question/comment #6).

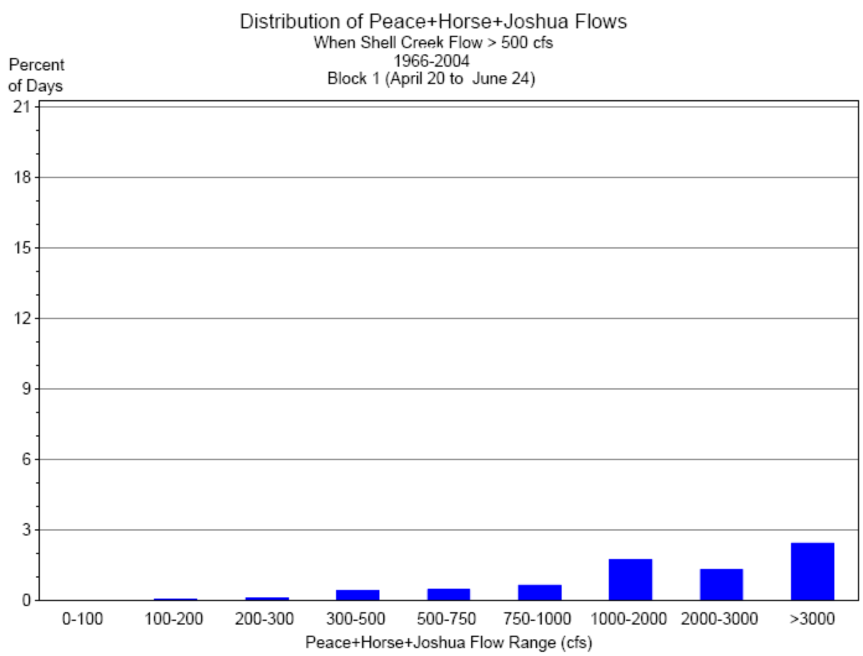
3. If these combined maximum allowable flows are close to or exceed 20% of the gaged inflows by block, please address the literature that shows significant biological changes for fishes and wildlife dependent on fish. There was no review of any literature about changes seen in other estuaries related to reductions of natural flows.

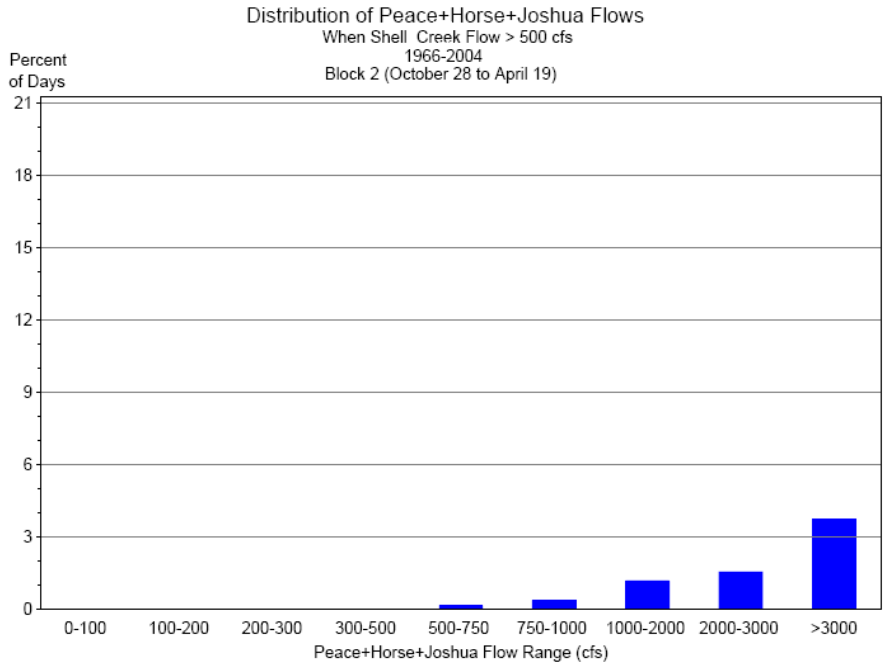
The District is unique in that it permits withdrawals on a percent-of-flow approach. However, most flow reductions reported for other systems do not mimic the natural flow regime. The literature that we are aware of typically deals with systems where the reported flow reductions are much greater than 20%. It is probably worth noting that if withdrawals were maximized to the full extent of the proposed MFLs for Shell Creek and the lower Peace River that the total mean and median flow reductions into

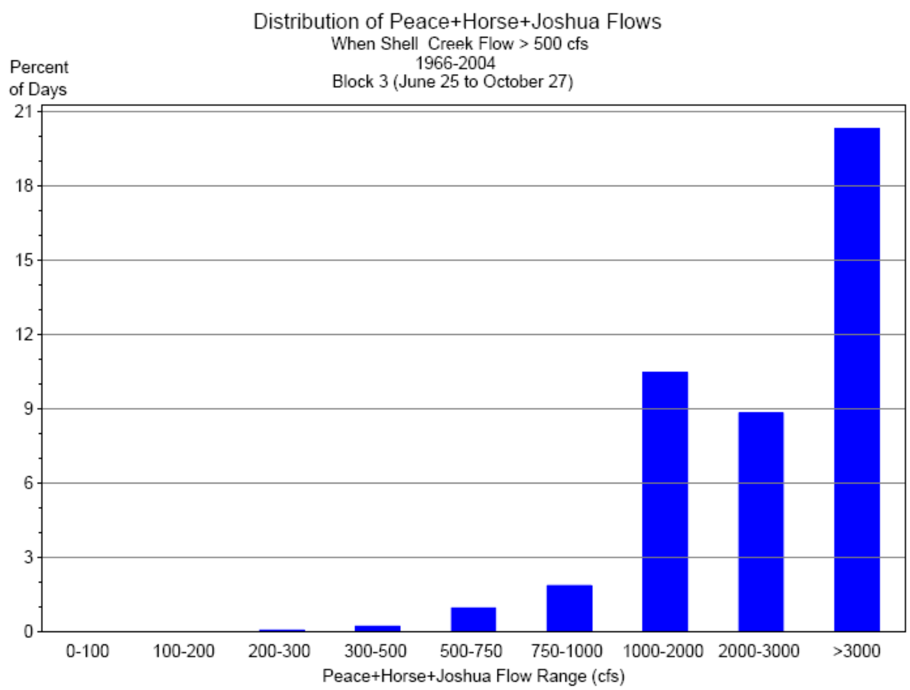
Charlotte Harbor from the combined sources of Shell Creek, Peace at Arcadia, Horse Creek, and Joshua Creek would be approximately 18% on an annual basis, 13% (mean and median) in Block 1, 17% (mean and median) in Block 2, and 22% (mean) and 20% (median) in Block].

4. I think we need to see plots by actual year of the cumulative maximum allowable withdrawals as a percent for each day in a year so that we can see the consecutive days with high percentages of withdrawal on Charlotte Harbor. A hypothetical example is provided for a flow of 600 cfs in Shell Creek and 115 cfs for the Peace River across all blocks: (Example Deleted)

The hypothetical scenario that was presented would only rarely occur, if ever. The following histograms presented below by block indicate the percent of days within a block that a given range of flows occurred for Peace River (sum of Joshua, Horse and Arcadia gage flows) when flows in Shell Creek exceeded 500 cfs.







5. Will the analysis of potential changes be extended to Charlotte Harbor before the SWFWMD allows additional users to withdraw surface waters of the Peace River and/or its tributaries?

It is anticipated that the MFLs developed for the lower Peace River will be sufficient for determining if and to what extent further withdrawals would be allowed from the Peace River.

6. Since phosphate mining severs large area of land from discharging its water naturally for long periods of time, how has the MFL process taken these existing and future changes into account?

The statutory requirement and mandate of the MFL process is to protect from significant harm due to withdrawals. This effectively determines the maximum amount of water that can be permitted for withdrawals, a responsibility of the water management districts. The comment assumes that it has been demonstrated that there have been substantial flow declines to the Lower Peace River that can be attributed to mining. The District has acknowledged and demonstrated that there have been quantifiable flow declines in the upper Peace River due to groundwater withdrawals and that historically mining activities accounted for a substantial amount of these withdrawals. The District is actively pursuing a recovery strategy aimed at restoring these flows. The District, however, has concluded that much of the flow decline (as measured at the Arcadia gage) is climatic.

> ***Based on a comparison of flows in the Peace River at Arcadia with flows from Charlie and Horse Creeks, it is concluded that most of the perceived decline in mid to high flows of the Peace River at Arcadia must be attributable to natural climatic variation. The similarity in flow trends between Charlie Creek and the Peace River at Arcadia in the median and high ranges suggests a similar causative factor is operative in both watersheds (granted that the Charlie Creek watershed is part of the larger Peace River at Arcadia watershed). Since there is no phosphate mining, little urbanization, and little surface water storage (few lakes) in the Charlie Creek watershed, it is suggested that the similar causative factor is climatic (i.e., rainfall). (fm Florida River Flows Patterns and the Atlantic Multidecadal Oscillation -- Kelly 2004)***

The same conclusion was also reached in the recently completed Peace River Cumulative Impact Study (2007) where it was stated that "[m]ost of the variation in annual total flow at the Peace River at Arcadia gage coincides with similar long-term changes at the reference Withlacoochee River at Croom USGS gaging station. This suggests that most of the variation in total annual flow at these gages is due to natural long-term variations in rainfall in southwest Florida."

7. The results and conclusions of various HBMP studies of phytoplankton carbon uptake, fishes, and plankton in the lower Peace River have all emphasized the importance of the initial spring freshwater inflows. Shouldn't any proposed expansion of withdrawals put a particular emphasis on minimizing any potential impacts to such biologically important flows?

The District operates under guiding principles articulated by Bunn and Arthington (2002) for streams, but equally relevant to tidal and estuarine areas:

> ***Principle 1: Flow is major determinant of physical habitat . . . , which in turn is a major determinant of biotic composition.***
>
> ***Principal 2: Aquatic species have evolved life history strategies primarily in direct response to the natural flow regimes.***

By linking withdrawals to the rate of streamflow, the percent-of-flow approach will ensure that withdrawals will decline during low flows in the spring. We believe that enhancing this approach with the seasonal considerations of the blocks maintains the characteristics of the natural flow regime to which the biota have adapted their life history strategies.

MEDIAN STATISTIC – HARM – CUMULATIVE DISTRIBUTION FUNCTION-

1. What is the biological basis of using the long-term median flow as a marker for partitioning low flow and high flow?

What is the biological basis for using median long-term flow (or AMO adjusted) for the blocks instead of some other characteristic of the flow distributions delivered to estuaries?

We considered the use of a median flow within a block as a further refinement of the block approach, in that it affords greater consideration to low flow conditions within each block. We consider the median (50% percentile) as more representative of conditions within a block than the mean which is skewed to the right (high flows). We would be interested in knowing what other statistic or characteristic would make better sense.

2. Is there reason to use a series of descriptive characteristics for inflows that ought to be maintained and delivered to the estuary?

Rather than focus on changes in hydrologic statistics, the District concluded in was more appropriate to base the minimum flow on the response of biologically relevant habitat metrics in the estuary to changes in freshwater inflow.

3. What is the biological justification for transposing a 15% harm threshold from rivers controlled by dams to the Peace River, mostly uncontrolled?

We do not understand the genesis of this question? It seems to imply that we have used a 15% harm threshold on impounded (dammed) rivers with

some justification, but not on unimpounded rivers. We have applied the 15% reduction in available habitat significant harm criterion on a number of unimpounded river reaches (freshwater Alafia, freshwater Braden, upper Hillsborough, upper Myakka, and middle Peace). To date, the only dammed river reach on which an MFL has been set is the lower Hillsborough River, and due to the extremely altered nature of this system, a different approach was taken.

4. How does a 15% harm threshold for dam controlled rivers be morphed into an equivalent harm threshold for a tidal estuary when there are no biological or physical equivalents?

The 15% threshold pertains to reductions in important habitats for the native biota, whether in freshwater or estuarine systems. In the Lower Peace River and Shell Creek, we concluded that reductions in the area, volume, and shoreline length of biologically relevant salinity zones would be the most relevant habitats we could assess with good predictive capability.

5. Explain how the minimum flow criterion for acceptable harm (up to 15% of a change in habitat) to the tidal estuaries can be based on peer review comments for the upper Peace River?

See the response to #4. In studies of both freshwater and estuarine systems, we have repeatedly observed that changes in available habitat due to flow reductions occur along a continuum with few inflections or breakpoints where the response dramatically shifts. We have found that loss or reduction in a given metric occurs incrementally as flows decline, and in the absence of any clear statutory guidance, believe that the use of a 15% threshold for loss of habitat is "reasonable and prudent" (Shaw et al. 2005).

6. Cumulative distribution functions (CDF) appear to be useful for random variables, river flow is not random, tides are not random and therefore salinity or related habitats don't have random distributions. Interpretation of any given CDF for responses by organisms to seasonal cues is not possible. There were no citations from estuarine biological literature in the three places where the following same word for word explanations was given (pp. 7-7, 7-20, 8-2).

This analysis process may have merit for predicting one measure of habitat, but one cannot determine duration of any consecutive flows during relevant biological life histories and use the various habitats through life stages.

Quoting from the recently completed peer review for the Braden River MFL by Cichra et al. (2007) who noted our lack of CDF plots in that report, "It is always a challenge to know how much information to include (e.g., tables

and graphs) to illustrate what is a very complex subject matter to a wide array of potential readers. The Panel notes that flow-duration curves . . ., the common currency of hydrologists, are a useful way to present information of this type and may be beneficial to the reader in that the full range of flows that can occur in any give time step can be seen."

We acknowledge that a different graphic or table would be needed to show the duration of any consecutive-day flows. However, it was concluded the use of changes in the CDF curves best represented the net changes in habitat integrated over time and space, and therefore the most appropriate method to determine the minimum flows.

7. How and why can a 'baseline' condition (CDF) representing a long-term statistic, have relevance to the life histories, distribution, and assemblages of organisms using habitats in estuaries?

CDF plots provide a particularly good mechanism for conveying a large amount of information in a single figure, and are a practical and reasonable approach for conveying the types of hydrologic data that must be considered in the development of minimum flows and levels.

It is important to note that the CDF curves were examined within seasonal blocks to ensure that unacceptable habitat loss did not occur during any season. Furthermore, the blocks were divided into low and high flows so that habitat loss would be even better linked to hydrologic conditions. We suggest that using CDF plots within this context adequately prevents unacceptable habitat loss throughout the year and will provide for use of the river by species with seasonal components to their life histories.

8. Why is there no partitioning of shoreline habitats or benthic habitats which are generally fixed with respect to variation in flow and salinity?

The CDF plots of predicted habitat change provide no guidance to the zonation of major habitats (swamps, marshes, or mangrove).

Shoreline length and benthic habitats were partitioned according to the following salinity gradients: <2 ppt, <5 ppt, and <15 ppt. We do believe these gradients would address zonation of major habitats (swamps, marshes or mangroves), as the movement of these isohalines were simulated from where they naturally occur under baseline flow conditions.

9. What are the uncertainties associated with predicted habitat change using CDF plots?

Technically, the uncertainties lie with the model predictions, not the CDF plots. The calibration and validation of the hydrodynamic model used on

the Peace River and the statistical model used on Shell Creek are discussed in some detail in the Appendix volume of the MFL report and are subject to the MFL peer review process.

10. What are the probabilities that changes will not be greater than predicted using CDF plots?

As mentioned in response 9 above, the uncertainties are associated with the hydrodynamic and regression model predictions, not the CDF plots. It is not possible to determine whether the "changes will not be greater than predicted using CDF plots" in a probabilistic sense. However, the building blocks were further divided into "low flow" (above median flow for the block) and "high flow" (above median flow for the block) in order to refine the allowable withdrawals and thus provide additional protection to the resources, especially during the "low flow" portion of the block. For example, if blocks were not subdivided into "low flow" and "high flow", the allowable withdrawal would be somewhere between the allowable withdrawals for the "low flow" and the "high flow" flow period and would not change during the block regardless of flow. By subdividing the blocks based on flow, less water can be taken during the more sensitive, low flow period, and more water can be taken during the high flow period.

SEA LEVEL VARIATIONS –

1. Since the Lower Peace River and Charlotte Harbor tides play a role in salinity variation, do various lunar/sun cycles have roles to play in salinity modeling and regression analyses for examples or their interpretation over long periods of time? - Such as the 18 year Saros cycle, the mixed semi-diurnal and semi-diurnal tides, cycle of variation for tidal flushing as the result of multiyear differences and tidal heights over the 18 year cycle, seasonal cycle within a year in sea level. Gage height levels used in the models just get a small portion of these kinds of variations.

The type of cycles mentioned (e.g., Saros cycle) were not explicitly modeled in either the hydrodynamic model or statistical model. However, the effects of tides were incorporated into both predictive models. The period chosen for the hydrodynamic model was selected because flows during the modeling period most closely mimicked long-term flows.

2. Since the intake for the Peace River water plant will likely be located in tidal waters well into the future where it has been for more than 27 years to date, should there be an examination of variations in sea level such as, the long-term trend of rising sea level (fig. 1) the average seasonal mean sea level (fig. 2)? (Figures Deleted)

The physical location of the intake for the Peace River water plant was not a consideration other than for the consideration of a low-flow threshold, which was viewed as a means of protecting an existing legal user from upstream withdrawals. It is reasonable to assume that the intake will be moved or somehow sheltered from increasing sea level rise; however, this consideration (the PRMRWSA's intake) is outside the scope of the MFL determination.

MODELS-

1. The LESS model data (fig. 3) are from a wet year with flows rarely less than 150 cfs. Chen states the following with my emphasis: (Quotation Deleted)

Comment noted.

2. Should there be an evaluation about the model uncertainties and probabilities related to the predicted salinities before using output in the main MFL document?

An assessment of the model was presented in the Appendix.

3. Should there be an evaluation of using the model from one wet time period (2003-2004) and its application to 1996-1999 period in the main MFL document?

Evaluation was presented in the Appendix. The calibration/verification period (June 2003 – July 2004) included some very wet months and some pretty dry months. Although 2003 – 2004 was overall wet, the last couple of months of the simulation period (May – July, 2004) were actually quite dry.

4. Should there be an evaluation of not having a station on the western side of Charlotte Harbor opposite the UF station? The HBMP reports describe about a 1% salinity difference between the sides. There is a 'slow spin' in the upper harbor because higher salinity water moves up the eastern side of the upper harbor while lower salinity water moves down the western side because of the right angle physical shape of the harbor and locations of large freshwater and salt water inputs. Salinity fronts are formed as the result of interactions of tides, wind and flow. Chen noted the following: (Quotation Deleted)

The model does show that there is a salinity gradient across the Upper Charlotte Harbor (UCH) in the west-east direction: water near the west bank is less salty than that near the east bank. At the time we started the MFL project, there were no real-time stations in the UCH. To better calibrate the hydrodynamic model, it was necessary to have a station in this part of Charlotte Harbor. Based on the physical characteristics of the UCH, we decided to put this station near the west bank, as most freshwater exits the estuary through the western side of the UCH.

5. In determining the 0-2 psu zone for the various metrics used, were different portions of the water column applied?

A. Shoreline = surface salinity
B. Bottom area = bottom salinity
C. Water column = average water column?

If not, what values were used and why?

For the hydrodynamic model, cells were discretized in the vertical plane. Available shoreline habitat (shoreline length) was calculated based on predicted salinities in the surface cells. Available bottom habitat (bottom area) was calculated based on the predicted salinities in the bottom cells. Available habitat (volume) was calculated based on predicted salinities in all model cells in the study area.

For the statistical model, analysis of surface, bottom, and water column average salinity by river kilometer revealed that Shell Creek was well-mixed, with a difference between average surface and bottom salinity generally less than one ppt. Therefore, water column average salinity was used for regression analysis.

6. The maintenance of low salinity (0-2 psu) habitat was used as a criterion for establishing the lower Hillsborough River MFL. Since there isn't any dam on the Peace near the Authority intake, why was that salinity chosen as important? Hasn't the historic HBMP data shown the highest occurrences of production to occur at higher salinities along the lower Peace River?

The criterion for the Lower Hillsborough River MFL was the maintenance of a salinity zone of less than 5 ppt from the dam to Sulphur Springs. The lower Peace River MFL addressed three salinity zones, which were determined from analysis of biological data from this system. These zones together account for the productive oligohaline, mesohaline and tidal freshwater zones of the river.

7. Under low flows, most of the lower Peace River is stratified with saltwater moving upstream along the bottom. As flows increase, larger reaches of the lower river downstream of the Peace River Facility become fresh top to bottom, while areas further downstream become more stratified. Past some point, further increases in flows actually cause the very lower reaches of the river (downstream of the U.S. 41 Bridge) to become increasing even more stratified, so that the first approximate 6 kilometers of the lower river is characterized by a very narrow lens of freshwater flow over much higher salinity water. Was the hydrodynamic model able to accurately predict this? If not, wouldn't the model have been inaccurate in determining salinity distribution metrics in the lower river under combined gaged flows above 1000-1500 cfs?

The hydrodynamic model accounts for the periodic occurrence of vertical stratification in the river over the range of observed flows.

8. Over the past 30 years, the underlying premise of the HBMP, the District's permitting, and the Facility withdrawal schedule has been that by allowing only very small changes in salinity (at any point at any time) any resulting changes in habitat and the number and distribution of organisms would also be relatively small. What are the expected maximum changes in salinity expected due the proposed withdrawals over the small temporal and spatial scales used previously?

It was not the objective the MFL document to evaluate the PRMRWSA's permit. Rather it was the goal of the MFL to determine at what point withdrawals would constitute significant harm. In this approach, we believed that assessing changes in salinity zone habitats, which shift dramatically in response to freshwater inflows, is more relevant than assessing changes in salinity at any given location, with the exception of salinity near the PRMRWSA intake.

[Please note that the numbering begins again with #5]

5. Shell Creek was modeled by Chen. Why was this information not used in the main MFL document? There is no explanation in Appendix 7.1 or in section 7.2 of the report.

A comparison of the two models for Shell Creek showed that the regression model gave more robust and reliable predictions.

6. The 'whole river regression model' for Shell Creek has a number of variables. Not all of the monthly intercepts account for variation in salinity (Unpaginated Appendix 7.1 = pp. 109 – 111 of all appendices). A seasonal or annual Fourier function might be enough instead of 12 variables.

As stated in Appendix 7.1 "monthly intercepts were used to capture variability in the response due to unmeasured factors such as prevailing wind direction and speed that was expressed as seasonality affecting the relationship between inflow and salinity". There was considerable internal discussion about including a seasonality term to describe the effect of the month sampled by using all levels (months) , only levels which reached statistical significance, or not including the term at all. Inclusion of the term with all levels resulted in a 2% improvement in the coefficient of determination at the cost of absorbing 11 degrees of freedom from the error term but maintained over 500 degrees of freedom for the error term.

We used an Analysis of Covariance (ANCOVA) approach to the regression modeling so that a classification variable describing a seasonality term (month) could be included in the regression model providing individual estimates of the relationship between flow and salinity for each level of the classification variable. The fact that the term was significant in the model meant that at least one level (see "month" term in ANCOVA results table below) had a statistically significant effect on the relationship between flow and salinity relative to the chosen reference group (December). The inference from this regression is that the month in which salinity - flow relationship is being modeled has a significant outcome on the prediction of salinity. We explained that this was used to capture latent aspects of the relationship between flow and salinity. Adjustments in levels with non-significant differences are statistically null (i.e., zero) as the mean is varied only within the confidence intervals of the predicted salinities. This can be seen by the coefficients in the solution of appendix 7.1 where all non – significant estimates were less than 1 ppt and often less than 0.5 ppt.

The use of the term month may or may not improve prediction of future salinities in Shell Creek relative to its omission; however, the improvement in residual plots appeared to warrant its inclusion at apparently minimal risk of prediction error associated with its inclusion according to examination of residual plots for models using: 1) all months, 2) significant months and 3) no month term.

The observed effect of seasonality does not appear to be a smooth temporal trend but rather perhaps event driven such as the passage of fronts.

Source	***DF***	***Type III SS***	***Mean Square***	***F Value***	***Pr > F***
fpower_05m	***1***	***319.265189***	***319.265189***	***73.98***	***<.0001***
rk_x	***1***	***1407.05164***	***1407.05164***	***326.06***	***<.0001***
bot_sal_blmk	***1***	***129.831788***	***129.831788***	***30.09***	***<.0001***
SHELL*rk1	***1***	***141.852246***	***141.852246***	***32.87***	***<.0001***
elev	***1***	***23.007527***	***23.007527***	***5.33***	***0.0213***
lpeace	***1***	***438.554417***	***438.554417***	***101.63***	***<.0001***
month	***11***	***325.854553***	***29.623141***	***6.86***	***<.0001***

7. Should there be explicit discussion of why each variable was chosen?

The model building exercise considered relevant driving forces where data were available for assessment using empirical regression methods.

8. Would all of these variables be included in a step-wise regression analysis?

Perhaps; however, we prefer to use our experience and professional understanding of the system under study to drive the model building process rather than let a computer algorithm chose the model. Further, stepwise regression imposes a type I sum of squares estimable function that means that the order of the variables introduced to the model building process matters in terms of partitioning the variance associated with each term. The type III sum of squares as used in the Analysis of Covariance model allows for the variables to enter in any order when partitioning the variance.

9. There was no table relating to the Variance Inflation Factor. Should there have been estimates of first order autocorrelated errors and a Durbin-Watson statistic?

The variance Inflation factor scores for the final model are given in the table below. A VIF score greater than 10 would indicate significant multicollinearity (SAS/STAT users guide 1994).

Variable	*VIF*
Fpower_05m	*3.91*
rk_x	*1.83*
bot_sal_blmk	*1.95*
shell_rk1	*2.75*
elev	*1.53*
lpeace	*4.25*
m1	*1.78*
m2	*1.71*
m3	*1.76*
m4	*1.98*
m5	*2.11*
m6	*1.92*
m7	*1.29*
m8	*1.54*
m9	*1.84*
m10	*1.91*
m11	*1.81*

Variable Definitions:
Fpower_05m = Shell Creek flow (raised to the power -0.05)
Rk_x = River Kilometer
bot_sal_blmk = Bottom salinity at black Marker (HBMP Station 9)
Shell_rk1 = Interaction term between Shell Creek and River Kilometer
elev = Tide height at Boca Grande
lpeace = natural log transform of Peace River flows
m1-m11 = Monthly intercepts using December as a reference group

Autocorrelation: The salinity stations were only sampled monthly. While autocorrelation is certain to exist in the daily flows from Shell Creek and the Peace River, the empirical data used for modeling purposes did not display significant autocorrelation as judged by residual plots provided in Appendix 7.1. The Durbin Watson statistic is 2.22 also indicating lack of autocorrelation.

10. Why was the choice of tide height (actual or predicted?) the Boca Grande station instead of the Harbor Heights station which is at least 20 miles closer and more likely to show the additional influences of freshwater flow and bathymetry on tide height? The Boca Grande station is inside a canal on the island.

A longer period of record was available for the Boca Grande Station.

11. Should any of the variables be lagged?

Lag effects were incorporated as potential explanatory variables. The reported model was formed to be the best model describing the relationship between the variables discussed given the available data.

12. Why was it determined to evaluate the influences of Shell Creek flow to the limited area used, when the Shell Creek HBMP monitoring program is designed to also evaluate the influences of Shell Creek flows on the lower Peace River? Seasonally, Shell Creek can be as much as 50% of flow and over the period of record since 1965 has accounted for approximately 23% of the combined lower Peace River flow to upper Charlotte Harbor.

The downstream section of Shell Creek has a direct connection to the Lower Peace River. Though the "Shell Creek monitoring program is designed to also evaluate the influences of Shell Creek flows on the Lower Peace River", the Shell Creek minimum flow sets a minimum flow for Shell Creek only. However, the area of the confluence of Shell Creek with the Peace River is included within the Lower Peace River hydrodynamic model. As described elsewhere, maximum flow reductions resulting from the Shell Creek MFL were included in the simulations for the MFL for the Lower Peace River, so the interaction of Shell Creek with the river was accounted for. In fact, salinity changes in a special zone near the mouth of Shell Creek (Zone 3) were evaluated as part of the MFL for the lower river.

13. Were the maximum withdrawals for the three periods for Shell Creek determined first and then were these values used to determine what additional withdrawals could occur from the Peace River Facility?

Correct.

14. If the basic assumption, for item 13 above is correct, of first withdrawing maximum amounts of water from Shell Creek then it leads to the confusing conclusion (Table 8-6) that higher amounts of water can be withdrawn from the Peace River Facility during lower flows than during higher flows (since the model assumed 200-500 cfs (see Figure 8-18) was already being withdrawn from Shell Creek?

That is correct. The simulated MFL withdrawals from Shell Creek influence the MFL that was determined for the Lower Peace River.

15. Since the new expanded reservoir capacity is being sited near the Peace River Facility wouldn't it have been more logical to approach first the Peace River withdrawals (where there is existing storage) with regard to potential impacts to the lower river/upper harbor, and then determine what additional flows beyond what is currently utilized might be available from Shell Creek?

The MFL scenarios were not planned to maximize or optimize withdrawals by the Peace River Facility. A large number of possible scenarios could be evaluated, if the objective were to maximize withdrawals.   Using the same protocols and tools employed by the minimum flow process, the District's Regulatory Department could evaluate other potential percentage flow reductions from Shell Creek and the Lower Peace River, if they do not violate the thresholds for significant harm as determined by the MFLs.

BUILDING BLOCKS

1. Should the 'three building blocks' with fixed time definitions that are used in lotic systems, like the Peace River to partially account for ecological cycles related to seasonal flows, really work in estuarine or marine systems with much greater biological diversity, seasonal variation in assemblages and changes in abundance?

We believe it should, since the blocks represent the three distinct seasons of flows in west-central Florida. We believe the biology has evolved or adapted to this flow regime over time, and not the other way around.

Temporal and spatial variation of physical characteristics in estuaries drive the initial responses of biological assemblages. My 50 years of experience with the Charlotte Harbor complex is that no two years have been alike. There are general multiyear, annual and seasonal patterns, but every year has been different. Perhaps, if this site were on the equator ever year would be the much similar. There was no real exploration of this issue in section 7.1.3 Seasonally-Specific Assessment Periods other than it was done on the middle Peace River, so no change. Critical periods for phytoplankton blooms, seasonal rotation juvenile assemblages in nursery areas or cues related to various flows for life history cycles appear to have played no role in this process to accepting the 'building blocks'.

See response above.

Questions/Comments from Dr. W.A. Dunson

A. The MFL's- Lower Peace & Shell Creek

1. I did not like the potentially serious statistical problem of autocorrelation among the habitat parameters. It would take some highly qualified statistical experts to decide this problem, but it appears to me that the highly correlated habitat variables should be reduced to one.

This comment seems to suggest that a statistical model was developed for MFL prediction purposes that used a number of habitat variables as independent variables to predict changes in some dependent variable; however, no such statistical models were used to develop the proposed MFLs that included multiple habitat variables. There was, however, a salinity model used for Shell Creek that relied on a number of physical variables including flow.

2. I did not like the choice of 15% as the level of significant harm. This has the same aura of "rule of thumb" inherent to the 10% rule of water withdrawals. For many of the same reasons it is not defensible. There needs to be some relationship, however tenuous, to real world ecology. Here again we need a connection to bioindicators of importance in this ecosystem. Is there any reason to suppose that a 15% change in habitat will result in a similar change in the biota? Indeed this 15% change might even completely remove the habitat needed for a particular life stage. Just to give one example, the shallow edge might be lost, removing the area that is used for spawning.

As previously described, we have repeatedly observed that changes in available habitat due to flow reductions occur along a continuum with few inflections or breakpoints where the response dramatically shifts. We have found that loss or reduction in a given metric occurs incrementally as flows decline, and in the absence of any clear statutory guidance, believe that the use of a 15% threshold for loss of habitat is "reasonable and prudent" (Shaw et al. 2005).

With respect to the so called 10% rule, a couple of points should be made. Currently the PRMRWSA is permitted to withdraw, within certain

constraints, a volume of water equivalent to 10% of the flow as measured at the Peace River at Arcadia gage. This withdrawal does not constitute 10% of the flow that would enter Charlotte Harbor from the Peace River since this gage captures none of the flow contributed by Horse, Joshua Creek, and Shell Creek nor any of the flow that originates off the ungaged area upstream of the PRMRWSA intake. As you are aware the 10% rule was part of a rule challenge with the hearing officer eventually ruling that a withdrawal of 10% of a river's flow would not have the same ecological effect from river to river due to inherent differences in hydrographic and ecological differences between rivers. This is why the current approach is preferable. We are now determining the amount of flow in each system that results in an equivalent ecological impact (reductions in available habitat), which we believe is keeping with what the hearing officer suggested.

Although it is presented only as a hypothetical example, it is not apparent how shallow edge habitat would be lost. This comment suggests that a habitat once inundated would no longer be inundated. We suggest that the application of the models in these tidal systems do not exclude any physical habitats.

3. It is ridiculous to set MFL's for the watershed without simultaneously evaluating the MFL(s) for Charlotte Harbor itself. In my mind it is most logical to start at the bottom (the real top-down or holistic approach) where all water flows meet and mingle, and then work back to the top of each tributary. A perfect example of the problems caused by the present report in which Shell Creek is isolated from the estuary was given by the occurrence of important areas of SAV where manatees feed just below the Shell Creek mouth. The MFL's discussed here may or may not destroy these areas- we do not know since it was not considered. Another manatee example is the incursion of saline water into the Harbor during low flow events (likely exacerbated by MFL's set too low) which can lead to transport of highly toxic masses of red tide into the bay which have been known to kill large numbers of manatees and other organisms. We know of many examples of how the bay is controlled by water flows either high or low, and setting of MFL's in the tributaries will be crucial to manipulating such effects. These need to be evaluated all at once to balance the needs of all of the competing users, including the natural system.

This comment raises several points. Please keep in mind that the peer review panel to which these comments are being forwarded was charged with evaluating the proposed MFLs for the lower Peace River and Shell Creek. It is also important to remember that when MFLs are used for regulatory purposes (permitting), withdrawals can not cause a violation of established minimum flows and levels for any waterbody that would be affected. For example, should someone propose a withdrawal on the

middle segment of the Peace River upstream of Arcadia, their withdrawal could not cause the minimum flow for the middle Peace River (segment between Zolfo Springs and Arcadia) or for the lower Peace River to be violated. It is conceivable that the MFL for the middle Peace River could limit such a withdrawal without causing a violation of the MFL for the lower river. The District chose to address the upper Peace MFL first for several reasons, but a primary reason was the acknowledged fact that groundwater withdrawals had caused significant flow declines during the naturally low flow time of the year, and it would be necessary to develop a recovery strategy to address this condition. Since the purpose of MFLs is to protect from "significant harm" <u>due to withdrawals</u>, the District has prioritized the development of MFLs to those waterbodies directly affected or likely to be affected by withdrawals in the near future. Unless specifically targeted or likely to be affected by groundwater withdrawals, tributary MFL development would be given a lower priority in MFL development. Having said this, it should be noted that the District has included both Horse and Charlie Creeks (significant tributaries to the Peace River) for MFL development by 2012. It is also anticipated that the MFL for the lower Myakka River will be completed in 2008. As previously described In the Shell Creek was not isolated from the determination of minimum flows for the Lower Peace River, and the region of the river near the Shell Creek confluence is included in the hydrodynamic model. The approach for setting an MFL for the lower Peace was conservative for the lower Peace River in that it was assumed that the maximum allowable withdrawals possible (under the proposed MFL) from Shell Creek would be taken before the MFL for the lower Peace River was determined.

4. I was shocked to hear that a lot of time was wasted in evaluating shoreline vegetation as an indicator of change in water salinity. This Panel recommended halting monitoring shoreline vegetation some time ago. Although there is a cline in vegetation species as one goes up-river, this change is very insensitive to small changes in river flow and salinity. In addition vegetation can also be strongly impacted by other factors such as freezes, rainfall, winds/hurricanes, etc. leading to an inability to separate one factor from another. Here again, the Panel should have been asked about this issue.

The District and its consultant evaluated habitat a number of ways: as shoreline length exposed to a given salinity, as volume of water of a given salinity, and as bottom area exposed to a given salinity. Once the hydrodynamic was constructed and model runs made, not a lot of additional time was needed to evaluate changes in the resultant salinity gradient against shoreline length. All that was really needed was some forethought given to this variable before model runs were made, since the bathymetry from which shoreline length was determined was a necessary component of the hydrodynamic model and was needed to determine

volume and bottom area exposed. Separate model runs were not needed to evaluate shoreline length, water volume and bottom area exposed; for a given scenario, this could all be evaluated with a single run. It is our opinion that it is worth evaluating shoreline length (and at least one of the PRMRWSA's panel members appears to agree; see Dr. Fraser's comments above), since we were not willing to make the a priori assumption that if volume and area changes met our constraint that shoreline length would necessarily do so. A major difficulty in setting MFLs is that many factors affect the biology and water quality of the system. The argument made above regarding the possibility of the vegetation being strongly impacted by a number of factors unrelated to flow could just as easily be made with respect to any bioindicator proposed.

5. The analysis of salinity as <2, <5 and <15 ppt was criticized as causing an overlap in effects. The proper way would have been to analyze as 0-2, 2-5, and 5-15 ppt. I do not generally favor the classification of habitat salinity into such blocks since few species fall into such simplistic groups. Often one life stage will be at a different salinity than another (hog choker is a good example where the adults are at high salinities and the juveniles up-river at low salinities). I have never subscribed to the use of salinity as a surrogate for bioindicators since it would be so much more powerful and accurate to simply use a small number of representative bioindicators and their niche space requirements.

Several reviewers have noted their interest in seeing the effect of flow reductions on individual salinity blocks (e.g., 2-5 ppt), and we will evaluate these, although we do not expect this would significantly alter the results. We also acknowledge that there is considerable overlap in such groups as is implied by the PCA analysis presented in the report. We also acknowledge that there are differences in salinity tolerances/preferences in some species dependent on life stage. We do, however, believe that "salinity distribution is a strong driver of the biological components in estuarine ecosystems, including the plankton, benthos and fishes" (Montagna et. al. 2007).

6. For these and many other reasons I recommend stopping any further separate consideration of tributary MFL’s and starting first with a MFL for Charlotte Harbor and then begin working upstream to the constituent watershed flows. The setting of MFL’s is an immensely complicated task and one which will have profound effects on the bays. It needs to be done with much more input from biologists (and less from abiotic modelers).

Comment noted; however, this is an estuarine centric position, and essentially ignores the value of MFLs for protecting in-stream freshwater habitats, some of which may be more sensitive to flow changes than their estuarine counterparts.

Also, the District maintains it makes sense to first establish minimum flows for the tidal estuarine portions of Shell Creek and the Peace and Myakka Rivers before considering minimum flows for Charlotte Harbor. We suggest that this approach is a more sensitive method for evaluating the potential for significant harm to critical parts of the estuary. It is well documented, including extensive studies from Charlotte Harbor and the Peace and Myakka Rivers, that low salinity zones in the tidal rivers serve as critical nursery habitat for the early life stages of many important fish and shellfish species. Many estuarine dependent species migrate to these low salinity areas as juveniles to utilize the habitats and rich food resources found there. Analyses of benthic and planktonic invertebrate communities also show the tidal rivers maintain distinct communities comprised of many taxa that are important prey items for juvenile fishes. Due in part to the much smaller volume of the rivers compared to the harbor and differences in their mixing characteristics, the relative effect of freshwater withdrawals on salinity, nutrients, sediments, and primary productivity will generally be greater within the tidal rivers than in the harbor.

Rivers contain many species and communities characteristic of oligohaline and mesohaline waters, as opposed to organisms with more marine affinities that are common in the harbor. Granted, large scale changes in freshwater inflow are important to ecological processes in the harbor, However, due to the hydrographic and physical-chemical characteristics of the system, we conclude that unacceptable ecological changes (significant harm) from a given rate of freshwater withdrawal will likely be first manifested within the rivers before unacceptable changes occur in the harbor.

This approach was considered by the HBMP panel for the PRMWRSA permit, who concluded that monitoring for that program should be focused in the river to evaluate any effects of freshwater withdrawals. The topic of bay vs. tributary minimum flows was also considered at a workshop sponsored by the Tampa Bay National Estuary Program. Although it was pointed out that bays are priority water bodies for minimum flows establishment, the summary document for that workshop stated - "Several participants indicated that the rivers are more sensitive than the bay to changes in freshwater inflow, and that if the MFLs set for the rivers were adequate to protect resources in the rivers from significant harm, they should also protect the Bay's resources. There also appeared to be general agreement of the workshop participants with Janet Llewellyn's recommendation to complete the MFLs for the rivers, then analyze cumulative effects on the Bay and revise the river MFLs if necessary" (Tampa Bay National Estuary Program. 2001. Proceedings of a Water

Budget Workshop for Tampa Bay). We suggest that this approach is also appropriate for Charlotte Harbor.

7. The upcoming MFL for the Myakka River would be especially contentious since there have been two major diversions of flow through the Blackburn Canal and Cowpens Slough. In the future "excess" groundwater added to the system at Flatford Swamp is slated to be diverted for drinking water. The overall system is becoming more and more controlled and water is being diverted away from former drainage pathways. The adverse ecological impacts are certainly likely to be huge, yet there seems to be little concern about this for the Myakka itself and the Harbor below. The Myakka River is sometimes said to be "free-flowing" except for two low sills or dams. However the extent of diversion of water represents a significant change in the historic flow pattern.

We understand the comments made with respect to the Myakka River; but, the Myakka River is outside of the review of the current MFL. It should be noted, however, that the District has adopted MFLs for the upper Myakka River which explicitly addressed the excess groundwater added to the system (Kelly et. al. 2005), and we expect to set an MFL on the lower Myakka in 2008. We concur that historic diversions have significantly altered the pre-development flow patterns by routing flows out of the lower Myakka River watershed into Dona / Roberts Bay watershed. The District is currently evaluating Cow Pen Slough, and also expects to set MFLs for the Cow Pen Slough and Dona / Roberts Bay complex in 2008.

8. I have occasionally come across some work on fish monitoring within Charlotte Harbor carried out by the DEP lab in Pt Charlotte. For example see:

   Idelberger, C. F. and M. F. D. Greenwood. 2005. Seasonal variation in fish assemblages within the estuarine portions of the Myakka and Peace Rivers, Southwest Florida. Gulf of Mexico Science 2005(2): 224-240.

   I often wonder why there is not better coordination among the scientists involved in monitoring the Harbor. It would be a more effective use of funds and would likely result in better science if all stakeholders participated in designing, analyzing and evaluating the results of biological monitoring. For example, the high cost of studying the fish near the water intake at the Ft DeSoto Plant was mentioned as one reason that it could not be done. Well- here is a group in Pt Charlotte with many years of experience that might be persuaded to help with the study of bioindicators in the pump test. What after all is the mandate of this group?

The fish study of the Myakka River and Shell Creek by Greenwood et al (2004) that is discussed in the MFL report was conducted by the same

agency (FWRI) that is referred to above. The sampling program for the District funded MFL project was expanded to coincide with the existing FWRI sampling program that had been conducted in the rivers and Charlotte Harbor.

Comments noted; some appear directed to fellow members of the PRMRWSA peer review panel and the pump test.

Comments on the Proposed Minimum Flows and Levels for the Lower Peach River and Shell Creek Draft Report and the Associated Scientific Review Panel Meeting held on December 4-5, 2007

by

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Charleston, SC 29412

The Southwest Florida Water Management District has been legislatively mandated to establish minimum flows and levels (MFL) for the steams and rivers (including estuaries) within its boundaries. Minimum flows are currently defined by appropriate statute 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". The proposed minimum flows and levels for the lower segment of the Peace River (from the Arcadia gauge, including Joshua Creek, Horse Creek and Shell Creek to Charlotte Harbor) were discussed in the draft report entitled "Proposed Minimum Flows and Levels for the Lower Peach River and Shell Creek". A meeting of the Scientific Review Panel, an advisory group established by the Peace River/Manasota Regional Water Supply Authority as a requirement of their permit, was held on December 4-5, 2007, to review and discuss this report and related studies (including a study conducted from December 2006-May 2007 to evaluate the impact of Authority withdrawals on short term changes in water quality given a natural estuarine background of tides and weather. The meeting was held in Bradenton, FL.

Because I have limited local knowledge and direct experience with the Peace River ecosystem and Southwestern Florida coastal ecosystems my comments are mainly related to the:

- Scientific approach and methods used for the above cited studies including implications of inherent assumptions;

- Evaluating the basis in ecological sciences for methods, findings and interpretations relative to the above studies; and

- Implications of findings and interpretations of study results to ecological processes and cumulative environmental impact of freshwater withdrawals to the Peace River ecosystem.

The percent-of-flow approach was used to ensure the natural flow regime of the river was maintained in a manner with protected ecosystem integrity with limited reduction, mainly damping, in the freshwater inflow into the downstream estuary and adjacent coastal ocean. This is a scientifically based approach which is designed to minimize stress and disturbance to natural flows and associated biota. The withdrawn water was used as a potable water supply. Establishment of the appropriate percent-of-flow withdrawal rates was based upon an understanding of climatic and anthropogenic influences on historic and current flow regimes and conditions required to maintain the ecological integrity of the source waterbody, including:

- Identification of a low flow threshold below which no withdrawals are allowed,

- Defining biologically relevant habitat strata (e.g., salinity zones) to ensure ecosystem integrity and associated processes are protected,

- Identification of ecologically appropriate metrics that quantify changes in habitat strata,

- Definition of within year (seasonal) assessment periods (i.e., seasonal "blocks") for which it was critical to maintain the " specific flows" to sustain water resources and critical ecological processes, and

- Description and application of analytical methods for quantifying habitat change including establishing: (1) study area boundaries, (2) the baseline period for minimum flow determination, (3) analysis/modeling period, and (4) appropriate and reasonable scenarios for minimum flow determination.

It was not possible to define a low flow threshold for the lower Peace River and Shell Creek using ecological criteria and the available data. The operational low flow threshold established for the lower Peace River was ultimately designated as the flow required to maintain freshwater (salinities <0.5 ppt) at the Peace River/Manasota Regional Water Supply Authority intake. The operational low flow threshold for Shell Creek was that required to maintain a 2 ppt salinity habitat strata with in the study boundaries for Shell Creek. The 2 ppt criteria for Shell Creek was assumed to be a habitat criteria appropriate for sustaining the integrity of valued ecological resources, including fish and shellfish populations in this ecosystem. I recommend that the 2 ppt criterion for Shell Creek be expanded to include some minimum amount of this habitat. The 2 ppt threshold has scientific basis in ecological science but without a specific criterion to define the amount of this critical habitat required to sustain valued ecological functions and services the value of this threshold is unclear.

The minimum flow criterion of a 15% reduction in critical habitat from baseline conditions was established as the level resulting in significant ecosystem harm. This determination was based on analyses and studies for the upper freshwater, free flowing Peace River (Gore et al. 2002). This is particularly problematic since the amount of critical habitat loss that may cause significant ecological harm in a tidal estuary is not tightly linked to changes in water level which seems to be the major basis for the 15% threshold in Gore et al. 2002. Unfortunately, no scientific justification was provided for applying the 15% habitat loss criterion to the tidal reaches of the lower Peace River and Shell Creek, and I am not aware of any studies that suggest a 15% loss in any habitat (abundant or rare) does not result in ecological harm. I am also not aware of any evidence that suggests that estuarine populations, communities, and ecosystems have adaptive processes that allow them to compensate for habitat losses in this range. A final concern with establishment of the 15% threshold value for critical habitat is that because it has no scientific basis it must include a safety factor. Even in well understood engineering systems and processes that have far less social, economic and ecological consequences than freshwater withdrawals society requires safety factors (e.g., bridge and road construction). No evidence was presented that a safety factor was incorporated into this study (e.g., uncertainty estimates were not provided). I recommend a range of threshold values be evaluated (e.g., 5%, 10%, 15% and 20%). The lower values may be more appropriate for rare habitats and include an undefined safety factor and the higher values may be more appropriate for abundant, widespread habitats and high flow periods where a safety factor may not have a great a value.

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." What constitutes "significant harm" was not defined. The District, after consideration of a recommendation by the peer review panel for the upper Peace River MFLs (Gore et al. 2002), has defined significant harm 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."

While the initial recommendation by Gore et al. (2002) was made in consideration of their experience with PHABSIM, a logical extension of this position is a 15% reduction in available habitat as long as it can be quantified. Compared to freshwater reaches, the total volume of water in most estuarine areas changes comparatively little as inflows rise,, since the inflow volume is small relative to the total water volume and the tidal exchange in the estuary. However, what changes measurably and quantifiably is the salinity in a particular area.

It is suggested above that "a range of threshold values be evaluated (e.g., 5%, 10%, 15% and 20%). The lower values may be more appropriate for rare habitats and include an undefined safety factor and the higher values may be more appropriate for abundant, widespread habitats and high flow periods where a safety factor may not have a great a value."

A range of threshold value was examined as expressed in the Normalized Area Under the Curve plots in Chapter 8 of the report. Essentially, a plot is provided that identifies the percent of a given habitat available as a function of incremental decreases in flow from the baseline condition. On each of these plots (e.g., Figure 8-3 in the report) a horizontal reference line is drawn at the 0.85 NAUC point on vertical axis. This line represents the flow decrease that results in a 15% reduction in this habitat. As noted, no clear breakpoints can be discerned in these plots, but the amount of available habitat steadily decreases as flows decrease. In some cases, there is a fairly linear decrease with percent flow reduction (e.g., lower panel in Figure 8.4), and in other cases the reduction is curvilinear (e.g., upper panel in Figure 8.4), but in all cases there are no clear breakpoints. This is entirely consistent with Montagna et al. (2002) who noted, "One of the strategies for choosing an indicator is looking for clear break points in

ecosystem response to salinity or flow regimes to use as decision goals. While this is sometimes easy, in many instances there is simply a linear response to freshwater inflows".

To suggest that the "lower values may be more appropriate for rare habitats" invites the same criticisms just applied to the 15% criterion.

The scientific justification for the three salinity strata/habitats that are defined in the report could be expanded. It would be especially beneficial if they were specifically related to critical functions of representative important biota or ecological functions (e.g., fishery nursery and feeding/spawning grounds, productive shellfish grounds, critical mangrove habitat) in the Peace River ecosystem. In addition, it is important that the salinity thresholds established for these salinity-based habitats have both upper and lower threshold values. Establishment of upper and lower boundaries for the salinity strata has important implications in the development of estimates of the spatial extent and temporal persistence of these habitats discussed below.

Three habitat assessment metrics were defined: (1) volume of water less than a critical salinity threshold (representing the amount fish nursery habitat); (2) the bottom area less than a critical salinity threshold (representing the amount of productive feeding areas); and (3) the shoreline length less than a given salinity (representing the amount of shallow vegetated refuge habitat). It is important to note that the percent of rare habitats that provide unique ecosystem services (e.g., nursery habitat) that can be loss without ensuing impairment to ecosystem process may be much less than that the amount of abundant habitats which can be impaired without loss of critical ecosystem functions. The message here is rare habitats that may need to be evaluated using different “rules” than abundant habitats (similar to the way society has chosen to treat rare and endangered species). The value of rare habitats that have unique roles to ecosystem process far exceeds their abundance. For example, for low salinity nursery habitat (2-5 ppt), which appears to be rare in the lower Peace River, it may be desirable to maintain 50% or more of the historical amount of this habitat.

There appears to be some confusion between allowable flow reductions (expressed as percentages) and reductions in available habitat. We hold that a greater than 15% reduction in available habitat constitutes significant harm, and then determine the amount of flow that can be taken as a percentage of the baseline that maintains 85% of the habitat available (15% loss of available habitat). In the example given above, if the desirable habitat to be maintained is the volume of water with a salinity in the range of 2-5 ppt, we would determine the volume of water in this salinity range during the baseline condition, and then remove a percent of the flow until the volume is reduced by 15%, and in this example, would maintain 85% of the historical amount.

Seasonally specific assessment periods were identified by mimicking historical hydrologic cycles as closely as possible. The selected blocks correspond to periods of high (June 26-Oct 26), moderate (April 20-June 25), and low (Oct 27-April 19) flows ensuring the natural water budget of the region is mimicked in all seasons. Maintaining the natural flow regime, although somewhat damped, should sustain the ecological conditions to which the indigenous fauna and flora and ecological processes are adapted. Division of the year into flow periods is an excellent approach for ensuring natural flow cycles and the associated ecological processes are sustained for future generations of humans and organisms, while at the same time meeting some of societies potable water needs.

We, of course, concur with this assessment.

A regression model was used to estimate the daily salinity at any point within Shell Creek as a function of flow and other confounding variables. This model accounted for ~82% of the measured variation in salinity distributions. The boundary of the Shell Creek study area extended from the dam in the headwaters near the junction of the Peace River following the channel. Braided portions of lower Shell Creek were not included in the model. The baseline and model period for Shell Creek was from 1966-2004. Model scenarios evaluated ranged from 1-100% flow reductions at 1% increments. Cumulative frequency distribution (CDF) plots were used to evaluate the spatial extent (volume) and temporal persistence (% of days) of the biologically relevant salinity strata < 2ppt for Shell Creek.

Estimates of the maximum percent flow reduction for Shell Creek required to protect 85% of the critical habitat (only volume <2ppt) calculated using the normalized area under the curve for each modeled scenario relative to the baseline scenario by seasonal block (1,2, & 3) for low and high flow conditions are shown in Table 1. The shaded estimates represent withdrawals that are sufficiently large that they would seem to have a high probability of resulting in significant and undefined ecosystem changes. No information was present for determining if these changes would be harmful. Withdrawals at these levels approach being considered diversions in my opinion and would likely result in substantial reductions in basic system process such as primary productivity. The 85% number is of particular concern. I also have concerns about the loss of 35% of important low salinity habitat in the June to October period. If this equates to loss of 35% of the fishery production for this habitat it is simply too large without some evidence that the spawning and nursery habitat can compensate for this loss.

We do appreciate this comment, and District staff and our consultant considered limiting percent withdrawals to no more than 50%, because we felt that most would intuitively assume that a >50% withdrawal would constitute significant harm even if one had no clear idea of how significant

harm should be defined; however, we decided to present the results based on the criteria that were applied. The primary reason why such a large withdrawal (or diversion) could occur in the wet season is that once you exceed the median flow, almost the entire reach of Shell Creek has a salinity of less than 2 ppt. The NAUC plot (Figure 8-5) suggests that you could remove 50% of the flow above the median in Block 3 (wet season) and maintain >96% of the <2ppt habitat volume. Again, there appears to be some confusion regarding allowable habitat loss and the percent flow reduction that would lead to a 15% reduction in available habitat. We are not proposing to allow a 35% reduction in important low salinity habitat in the June to October period, but have determined that 35% of the flow could be removed and still maintain 85% of the habitat.

Table1: Estimates of allowable reductions for Shell Creek projected to result in protection of 85% of the amount of critical habitat (defined as the volume less than 2 ppt) by seasonal block for high and low flow conditions.

Block	Median Flow (cfs)	Allowable Percent Reduction in Flow	
		Low Flow Condition	High Flow Condition
Block 1 (April 20-June 25)	84	10%	23%
Block 2 (October 27-April 19)	98	18%	42%
Block 3 (June 26-October 26)	424	35%	85%

A hydrodynamic model was used to estimate the response of the lower Peace River to variation in freshwater flows and various withdrawal scenarios. The baseline model period for the lower Peace River was 1996-1999. The scenarios evaluated for the lower Peace River included the baseline period, and 10%, 20%, 24%, 28% and 30% reductions. Cumulative frequency distribution (CDF) plots were used to evaluate the spatial extent (area, volume, length) and temporal persistence (% of days) of the biologically relevant salinity strata <2 ppt, < 5 ppt, > 15 ppt and from 8-16 ppt in the lower Peace River.

Estimates of the maximum percent flow reduction for the lower Peace River required to protect 85% of the critical habitat (volume <2ppt) calculated using the normalized area under the curve for each modeled scenario relative to the baseline scenario by seasonal block (1,2, & 3) for low and high flow conditions are summarized in Table 2. These area appear to be in ranges not likely to result in substantial ecosystem changes independent of losses of the amount of critical habitat (e.g., changes in primary productivity or fish assemblage distributions. When entrainment losses from entrainment and impingement of power plants exceed 20% of the young of the year or spawning stock of a representative important fish population, regulators frequently take action to reduce losses.

Table 2: Estimates of maximum allowable flow reductions in the lower Peace River projected to result in protection of 85% of the amount of critical habitat (defined as either area, volume, and/or shoreline length less than 2ppt, 5ppt, or 15 ppt) by seasonal block for high and low flow conditions.

Block	Median Flow (cfs)	Allowable Percent Reduction in Flow	
		Low Flow Condition	High Flow Condition
Block 1 (April 20-June 25)	221	10%	26%
Block 2 (October 27-April 19)	330	14%	21%
Block 3 (June 26-October 26)	1370	12%	15%

The major concerns identified with the process used to estimate allowable flow reductions are:

- No estimates of uncertainty were associated with the calculations and results of allowable withdrawals or the habitat loss estimates. It is thus unclear what level of safety has been incorporated into the calculations.

No explicit "level of safety" was incorporated into the calculations.

- Estimates of the allowable withdrawals were not conducted independently for the critical habitat between 2-5ppt for the Lower Peace River. This “rare” and ecologically important habitat should be evaluated independently of other habitats. A 15% loss in this habitat may be too much to allow.

We believe the model output already generated should allow us to make this determination, and we will pursue this recommendation. However, experience on the Lower Alafia River indicates that reductions in salinity zone intervals (e.g., 2-5 ppt) may not be as conservative a criterion and represent as predicable response to reductions in freshwater inflow as changes in total areas and volumes less than the same concentrations (< 2 and < 5 ppt.

- The process used to estimate allowable withdrawal rates did not evaluate the impacts on critical habitats and ecosystem integrity in Charlotte Harbor. Under some conditions this may impact the amount of critical high salinity habitats.

Please see above responses concerning Charlotte Harbor proper.

Other concerns identified with the report include:

- The conceptual linkage between allowable withdrawals and MFL to water quality and ecosystem condition is not clear. Therefore it is not clear what parameters would be monitored in the future to demonstrate that significant ecological harm has not occurred? In short, how would the District or the Authority ever prove that they were not causing harm in an adjudicated proceeding in the future? Because most of the projected ecological and physical/chemical impacts of future withdrawals are based on salinity impacts, estimates of the projected impacts of various withdrawal scenarios on salinity distributions at specific places (transitional areas) and representative important biota that require specific salinities to sustain their populations would be one monitoring approach that should be evaluated. The monitoring and assessment effort that is implemented definitely needs to include some ecological/biological indicators (higher organisms). Ecological indicators will assess the impacts of interacting and additive impacts of multiple stressors (e.g., increased withdrawals plus drought plus extreme events such as a chemical spill).

While this is an important consideration, it was not the intent of the MFL document to develop a monitoring plan. As exemplified by the HBMP monitoring program implemented by the PRWRWSA, a monitoring program/protocol would be required as a permit condition.

- The long-term historical monitoring program and data base compiled for the lower Peace River is a legacy of the Peace River/Manasota Regional Water Supply Authority and the District. This monitoring program and data base is essential for demonstrating that significant harm to the lower Peace River ecosystem have not resulted from previous and future withdrawal regimes. Failure to make conceptual linkages between future and historical monitoring efforts would be a travesty.

Comment noted.

- It is critical that the corporate memory of the scientific staff that have a long history of scientific studies in the Peace River ecosystem and the associated data base they have compiled be maintained. It is critical that this knowledge be transferred to future generations. This transfer has not occurred to date.

Comment noted.

- The Peace River is a braided estuary, which is somewhat unique to Florida and the Southeast. The hydrodynamic modeling process used to estimate the influence of freshwater inflows on the braided portions of this unique ecosystem needs to be carefully evaluated. These braided sections have great value as habitat and for storage of water.

It was not clear if these values were accounted for fully in the current hydrodynamic model.

The hydrodynamic model was based on fairly detailed bathymetry and included the large majority of the braided channels. The braided nature of the estuary would be captured by the habitat metrics assessed, but would likely weigh most heavily in the calculation of shoreline length.

- The inclusion of the Horse and Joshua creeks flows into the process used to estimate allowable withdrawal rates was confusing. This had not been discussed previously by the Scientific Panel and appears to require additional justification and explanation. This inclusion may be perfectly reasonable it just was not explained in a manner that I understood.

The MFL determination for the lower Peace River was not based on the location of nor in direct consideration (with the exception of the low-flow cutoff) of the permit issued to the PRMRWSA, but based on the flows that essentially contribute to the lower Peace River, which upstream of Shell Creek are best represented as the sum of the flow from Horse Creek, Joshua Creek, and the river upstream of Arcadia.

- In a similar manner inclusion of "worse case" and unrealistic 83% allowable withdrawal rates for Shell Creek into the analysis for the lower Peace River was difficult to understand and seem unreasonable. How can 83% of a habitat be loss without a proportional decline in productivity of biota associated with that habitat being impaired? It seems doubtful that an 83% withdrawal will ever be allowed for Shell Creek or anyplace else given the current state of knowledge. Thus, the current assessment for the lower Peace River does not reflect reality.

Based on the analysis presented and the habitat metrics that were quantified and assessed, it was concluded that an <u>83% withdrawal of flows above the median in the wet season</u> flow block (Block 3) would be necessary to cause a 15% reduction in the volume of water with a salinity less than 2 ppt. Inspection of the NAUC plot for the 83% reduction scenario (Figure 8-5) suggests that if all the flow (100%) above the median was removed, approximately 42-44% of the less than 2 ppt habitat volume would be retained.

Date: December 14, 2007

To: Michael J. Flannery

Peace River Manasota Regional Water Authority

From: Joan Browder
HBMP Panel Member

Subject: Lower Peace River Minimum Flows and Levels

Thanks for the opportunity to review the Lower Peace River MFL Report, hear the presentation, and participate in discussions about it. I like the approach of integrating coverage and percent of days, by salinity-band, within each zone of the river during each designated time-block by plotting cumulative distributions . This approach is quite elegant. I especially like the plots relating specific salinity ranges to specific habitat, as was done for the 8-14 psu salinity band in river zone 3. I am very much concerned, however, with concluding on the basis of plots of this type that as much as 80% of Block 3 daily flows could be withdrawn from Shell Creek without significant harm to the ecosystem. The 10% rule seems to be working in the Peace River, and the SWFWMD and the PRMRWA should both be commended for receiving and developing the idea, making it a rule, and sticking with it. Fifteen percent might work, too. And maybe higher percentages could safely be withdrawn during high flows. But 80% from Shell Creek seems too far out to be reasonable. As we discussed at the December 4 meeting, consideration should be made of the effect of this scale of withdrawals on the adjacent and downstream sections of the Peace River. I followed the explanation that high flows in the Peace River usually occur at the same time as high flows in Shell Creek, however I also heard that, at the present time, more water is flowing from Shell Creek than through the LPR upstream from Shell Creek.

Please see response to Dr. Holland's and Dr. Fraser's comments.

I join the recommendation of other members of the panel that the MFL process should include consideration of the potential impact on Upper Charlotte Harbor of cumulative changes in freshwater inflow from all contributing sources and that this information should be integrated and coordinated with the MFLs for the rivers and their tributaries. In this regard, the habitat suitability model developed by Dr. Peter Rubec at the Florida Fish and Wildlife Research Institute might be very useful to you. He developed the model with Charlotte Harbor data collected by FWRI. In addition, I'm sure you also would be interested in the two recent publications on Charlotte Harbor by Shannon Whaley and colleagues at FWRI, as follows:

Whaley, S. D., J. J. Burd, Jr., B. A. Robertson. 2007. Using estuarine landscape structure to model distribution patterns in nekton communities and in juveniles of fishery species. Marine Ecology Progress Series 330:83-90.

Whaley, S. D., C. W. Harnak, and B. A. Robertson. 2006. Spatial and temporal patterns of estuarine fish communities relative to habitat structure and freshwater inflow. Pp 130-136 in: Proceedings of the Second LASTED International Conference on Environmental Modelling and Simulation. November 29-December 1, 2006, St. Thomas, U.S. Virgin Islands.

From: "Gary Powell"
To: "'Sam Stone'"
Cc: <Sid.Flannery >
Sent: Tuesday, December 18, 2007 6:41 PM
Subject: Peace River MFL

Comments on the MFL Report for Peace River and Shell Creek:

The District's MFL report on the Peace River and Shell Creek does include consideration of vegetative zonation, the abundance and distribution of benthic macro-invertebrates, as well as the standing crops of ichthyoplankton and juvenile fishes. Unfortunately, the fish studies were mostly performed during the wet period in 1997-1998, which means they are not as useful for the low-flow analysis.

The percent flow reduction method for managing water withdrawals is good because it follows the natural hydrograph. Some of the measures used in the MFL analysis (e.g., habitat water volume, bottom area, and shoreline length) are all highly correlated to each other and streamflow. However, it is still quite instructive to see the amount of habitat versus percent of time it's available. However, instead of just looking at the amount available at set at salinity points (i.e., <2 psu, <5 psu, < 15 psu), it might be even more revealing to look at the amount available between the salinity intervals (e.g., 2-5 psu, 5-15 psu, etc.), with special attention to those reductions >15%.

Several reviewers have noted their interest in seeing the effect of flow reductions on individual salinity blocks (e.g., 2-5 ppt), and we will evaluate these. However, experience on the Lower Alafia River indicates that reductions in salinity zone intervals (e.g., 2-5 ppt) may not be as conservative a criterion and represent as predicable response to reductions in freshwater inflow as changes in total areas and volumes less than the same concentrations (< 2 and < 5 ppt).

It is noted that less future reductions can occur in the Peace River, because the MFL report assumes that only surplus water in Shell Creek is available in the future. In practice, the Authority's maximum 90 mgd diversion at the river pump station requires 1400 cfs flow at the Arcadia streamgage. As a result, Shell Creek becomes something of a wild card in the MFL analysis, as well as in future water management, particularly if water withdrawals are potentially going to be as high as 35-83% of available flows. Clearly, the HBMP may have to be revised to concentrate on areas affected by these future diversions. Also, at least two (2) additional continuous-recording water quality meters need to be installed upstream of the Authority's Peace River pump station to compliment the three (3)existing stations below the intake facility.

We concur with the above comments, and as noted elsewhere by applying Shell Creek "worse case" withdrawals under the proposed MFL for Shell Creek, allowable withdrawals above Shell Creek (i.e., combined flows of Peace at Arcadia, Horse and Joshua Creeks) are more constrained than if a different scenario would have been used.

Overall, the District's proposed MFL for the Peace River and Shell Creek seems to provide much needed flexibility to the Authority's water supply operations, which is itself a beneficial result.

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CHARLOTTE HARBOR NATIONAL ESTUARY PROGRAM
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December 28, 2007

To: Michael Flannery and Marty Kelly
Southwest Florida Water Management District

From: Catherine Corbett
Senior Scientist, Charlotte Harbor National Estuary Program (NEP)

RE: Comments on the Proposed Minimum Flows and Levels (MFLs) for the Lower Peace River and Shell Creek

Thanks for the opportunity to review and provide comments on the Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek. We also greatly appreciate the presentation to the Charlotte Harbor scientific community on September 12, 2007 and keeping the Charlotte Harbor NEP informed of your progress on establishing MFLs for the tributaries to Charlotte Harbor. The comments herein were prepared by myself on behalf of the Charlotte Harbor NEP.

We have reviewed the document and proposed MFLs for the lower Peace River and Shell Creek along with comments from members of the Peace River Manasota Regional Water Supply Authority's HBMP Panel. We understand that these comments will be provided to the Lower Peace River and Shell Creek MFL Peer Review Panel members for their consideration and appreciate the opportunity to provide such comments. We concur with the concerns of the HBMP Panel members and provide the following additional comments regarding the proposed MFLs:

1. We reiterate the panel members' request to evaluate the cumulative impacts of the established MFLs and those proposed for Charlotte Harbor before finalizing these MFL rules. A thorough investigation of the impacts to the 3 major Charlotte Harbor tributaries (Peace, Myakka and Caloosahatchee River) as well as Charlotte Harbor as a whole should be completed before these MFLs are codified. MFL rules have been established for the tidal Caloosahatchee River; the upper and middle Peace River and the upper Myakka River. MFLs have been or will be proposed for the lower Peace River and Shell Creek and the lower Myakka River (2008). These rules will not only alter the freshwater inflows for the respective tidal tributary but also impact the entire Charlotte Harbor estuary.
   Changes in freshwater inflows to Charlotte Harbor have tremendous influence to this riverine estuarine system and will impact sedimentation; residence time; nutrient and other pollutant loading; water clarity; benthic habitat extent and quality; planktonic community density and composition, and fish communities. As is noted in Stoker (1992) and described in the MFL document, seasonal fluctuations in salinity in Charlotte Harbor occur primarily in response to changes in freshwater inflow from the Peace, Myakka and Caloosahatchee Rivers. Daily minimum, maximum and mean salinities were documented to be inversely related to discharge from the rivers, and the daily range was directly

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related to stream discharge (see page 6-2 of MFL document for text). Salinity in turn impacts benthic invertebrate and fish species presence/absence, abundance and community composition. Residence time and sedimentation are also related to freshwater inflows from the tributaries. Longer residence times from reduced inflows favors phytoplankton blooms, while changes in sedimentation can alter the benthic macroinvertebrate community. Thus, it follows that significant inflow changes to the 3 major tributaries will impact the harbor's benthic, fish and planktonic communities, and an agency propagating rules allowing such changes should thoroughly investigate cumulative impacts to the receiving waterbody before codifying such rules. As such an effort would cross Water Management District boundaries, we offer to help the SWFWMD coordinate with SFWMD to undertake a cumulative impact assessment of the MFLs proposed and established for the 3 major tributaries to the harbor and are open to other suggestions of aiding in this effort.

2. Keeping the above in mind, it is important that the metrics used for the MFL methods are relative to the Charlotte Harbor system, specifically the Peace River. Hence, we question the salinity criteria (i.e., <2 ppt, <5 ppt, 15 ppt) and the defense of these salinity criteria within the document. Much of the defense of these criteria are not germane to the Peace River (e.g., references of similar criteria in the Suwannee River MFL, lower Hillsborough River and Sulphur Springs MFL) or of documented importance to the protection of Peace River-specific habitat [e.g. reference to loss of oligohaline habitat gulf-wide cited in Beck et al. (2000)]. Interpretation of Figures 5-11 and 5-12 is highly subjective, and therefore a reviewer could choose a wide range of criteria from these figures. Many previous fish and benthic invertebrate community analyses used the Mote Marine Laboratory (2002) river zonation by salinity as described in the document as mean salinities <0.5 ppt (Zone 1), 0.5 – 8 ppt (Zone 2), 8 – 16 ppt (Zone 3) and >16 ppt (Zone 4). Described in the MFL document, Janicki Environmental (2006) developed a salinity classification scheme based upon benthic community structure (<8 ppt, 8 -15 ppt, 16 – 28 ppt, and >28 ppt). The MFL effort also developed Peace River-specific salinity criteria for analyses of FWRI FIM seine and trawl catches listed on page 5-31. The salinity criteria in these efforts do not match the resulting MFL salinity criteria listed in the MFL document. One could also use the well-established Venice System (0-0.5, 0.5-5, 5-18, 18-30, 30-40 and >40 ppt). Finally, Greenwood (2007) analyzed FWRI data from Tampa Bay (n = 10,192) and Charlotte Harbor (n = 6,200) to develop salinity zones for the 2 systems. The author found accelerated rates of change in nekton community change in low salinity ranges of 0.5 – 1 ppt in Tampa Bay and 1-2 ppt in Charlotte Harbor and high salinity ranges of > 30 ppt in Tampa Bay and >34-35 in Charlotte Harbor. Between 0 to 10-15 ppt, the rate of change was small and fairly constant, and the author found that clearly defined end points between salinity zones did not exist except at the marine freshwater interface (Greenwood 2007). Greenwood (2007) discusses a number of past efforts to define salinity zones in various estuaries and greatly implies that salinity zones are river-specific, noting that the salinity zones found elsewhere were not found in Tampa Bay nor Charlotte Harbor and that biologically relevant salinity zones in these 2 regions differ. Hence, the salinity zones used in the lower Hillsborough and Suwannee River MFLs are

not readably transferable to the lower Peace River, and SWFWMD staff should use Peace River-specific salinity criteria in establishing MFLs. In addition, why are salinities above 15 ppt not included as criteria in this document?

3. We reiterate the concerns of the HBMP Panel members for the allowable percent flow reduction of 83% of high flows from June 26-October 26 (Block 3) in Shell Creek. We also are concerned with the reduction of the low flow threshold in the main stem of the Peace River from 130 cfs at the USGS gage at Arcadia (excluding Horse and Joshua Creek flows) to 90 cfs (including Horse and Joshua Creeks). These reductions are based upon the fact that no statistically significant relationship could be found between those environmental variables analyzed and modeled flow levels. Many studies described in the MFL document found distinct differences in benthic and fish community structures using differing salinity gradients and/or zones in both the main stem of the river and Shell Creek. Why could not these zones and the potential to alter them be used as criteria for the MFLs? Using the Mote Marine Laboratory zonation scheme, the benthic community differed between each zone and between Shell Creek and Zone 3 (the zone in which Shell Creek primarily joins the Peace River). Fish communities also changed between zones; this was thought to be in part influenced by habitat (channel versus shoreline) within these zones. Browder and Moore (1981) describe how estuarine productivity can be maximized when species' preferred stationary habitat (e.g., vegetation and structure) overlap with preferred dynamic habitat (e.g., salinity). We found no evaluation of how salinity "zones" might migrate upstream with the proposed flow reductions and if the benthic and fish communities' preferred stationary habitats are coincident with the locations of this upstream migration. FWRI has identified the area of the Peace River near the confluence of Shell Creek as an area of particularly high productivity, and perhaps this region could be used as a key habitat region zone/metric for such an evaluation.

   We find the proposed flow reductions high and counter-intuitive with keeping with the precautionary principle "first: do no harm" and the current SWFWMD practice of allowing only small changes in salinity with the PRMRWSA withdrawal schedule. In light that the MFL document authors and previous researchers have had problems predicting/modeling salinity, nutrient loads, chlorophyll *a* concentrations, dissolved oxygen and other environmental variables in the Peace River and upper Charlotte Harbor, the lack of significant relationships between these factors and flow is not surprising. Tides, winds, residence time, sampling methods and other factors confound environmental data analyses and results. A *lack* of statistic evidence does not provide a scientific basis for a significant deviation from current protection efforts (i.e., low threshold flow level of 130 cfs at Arcadia gage alone) and a significant increase in flow reductions in these systems. The burden of proof to significantly increase the flow reductions allowable by MFL rules should be much more difficult to meet than that which is described in the proposed MFL document.

4. There is little to no scientific justification of the 15% reduction in critical habitat threshold value as a "significant harm" definition. The 15% reduction threshold was proposed arbitrarily during the peer review of the upper Peace River MFL by Gore et al.

(2002), notably a freshwater system. The document does little to provide background information on this threshold value in a tidally influenced system or provide a scientific basis for this number. This number should be evaluated by the Peer Review Panel and if deemed defensible, SWFWMD should provide scientific justification of this value for the final document. At a very minimum, a margin of safety should be incorporated into the 15% threshold value.

5. This work would be greatly strengthened by a more rigorous review of literature related to freshwater inflow management. There are few seminal studies cited in this work and a general lack of references throughout. For instance, there is a multitude of previous research on salinity zones, but the authors of this document only review Jassby (1995) (see Greenwood 2007 for more thorough discussion of other efforts).

As in the middle Peace River and upper Myakka River MFLs, we applaud the SWFWMD's use of a percent-of-flow approach in flow reductions to allow the natural hydrograph to be maintained and the seasonal block approach to protect the natural flow cycle. We endorse your incorporation and expansion of local research by FWRI FIM's and Dr. Ernst Peebles' data and research; the benthic invertebrate work by Mote Marine Laboratory and Janicki Environmental Inc; and Tom Fraser's fisheries analyses.

We have attached the Greenwood (2007) journal article cited above for your review. Please copy this article to the Peer Review Panel along with this letter. Thanks again for allowing us to provide comments on the Proposed Minimum Flows and Levels (MFLs) for the Lower Peace River and Shell Creek. If you have questions or if I can provide additional information, please feel free to contact me at (239) 338-2556 ext 241 or email: ccorbett@swfrpc.org.

Enclosure (1)

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Nekton Community Change Along Estuarine Salinity Gradients: Can Salinity Zones be Defined?

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ABSTRACT: Organisms tend to inhabit predictable portions of estuaries along salinity gradients between the ocean inlets (salinity > 35 psu) and the freshwater tributaries (salinity = 0). Previous studies have suggested that the continuous change in biological community structure along this gradient is relatively rapid at certain salinities. This is the basis for estuarine salinity zonation schemes similar to the classic Venice System (i.e., 0–0.5, 0.5–5, 5–18, 18–30, 30–40, > 40). An extensive database (n > 16,000 samples) of frequency of occurrence of nekton was used to assess evidence for estuarine salinity zones in two southwest Florida estuaries: Tampa Bay and Charlotte Harbor. Rapid change in nekton community structure occurred at each end of the estuarine salinity gradient, with comparatively slow (but steady) change in between. There was little strong evidence for estuarine salinity zones at anything other than low salinities (0.1–1). As previously suggested by other authors, estuaries may be regarded as ecoclines, because they form areas of relatively slow but progressive ecological change. The ends of the estuarine salinity gradient appear to be ecotones (areas of rapid change) at the interfaces with adjacent freshwater and marine habitats. This study highlights the rapid change that occurs in nekton community structure at low salinities, which is of relevance to those managing freshwater inflow to estuaries.

Introduction

The major environmental gradient in many estuaries consists of a change in salinity from marine to freshwater conditions. Organisms tend to inhabit fairly predictable portions of the salinity gradient; this may be due either to their own salinity tolerances or else the coincidence of particular salinity ranges with ecological features (habitat, food) that they find beneficial. Remane and Schlieper (1971, p. 4) stated ''It is certain that biologically the salinity range from sea to fresh water is not continuous, but capable of subdivision into distinct stages.'' Many salinity classification schemes have been proposed to address this observation (see Remane and Schlieper 1971, p. 4–7), but perhaps the most widely used is the Venice System (0–0.5, 0.5–5, 5–18, 18–30, 30–40, > 40; Anonymous 1958). Bulger et al. (1993) noted that the criteria underlying the salinity zones of the Venice system were not made explicit. To produce a classification based on explicit criteria, they analyzed salinity-range data from fishes and invertebrates of mid-Atlantic U.S.A. estuaries and defined five biologically based salinity zones (0–4, 2–14, 11–18, 16–27, 24–marine).

Bulger et al. (1993) suggested that it would be of interest to repeat their analysis using data from other estuaries. This has been done on at least two occasions (Christensen et al. [1997] in several northern Gulf of Mexico estuaries and Farrell et al. [2005] in the Suwannee River watershed, Florida), with somewhat similar results to those of Bulger et al. (1993). In the present study, a large database (n > 16,000 seine samples) compiled from nekton sampling in two southwest Florida estuaries (Tampa Bay and Charlotte Harbor) was used to make further comparisons of estuarine salinity zonations. Nekton community change along the salinity gradient was assessed with the goal of examining the evidence for salinity-zone end points, i.e., the boundaries between salinity zones, which can be thought of as regions ''of accelerated change superimposed on a gradient of continuous change'' (Boesch 1977, p. 259).

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Materials and Methods

STUDY AREAS AND SAMPLING METHODS

This study is derived from data collected in Tampa Bay and Charlotte Harbor (southwest Florida, U.S.A.; Fig. 1 in Greenwood et al. 2006) by the Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute's Fisheries-Independent Monitoring Program from January 1996 to December 2005. Further details of this sampling program can be obtained from representative publications (e.g., Poulakis et al. 2003; Idelberger and Greenwood 2005; Greenwood et al. 2006). Tampa Bay (1,030 km^2) and Charlotte Harbor (700 km^2) are the two largest estuaries in Florida; detailed descriptions of them are available from Lewis and Estevez (1988) and McPherson et al.

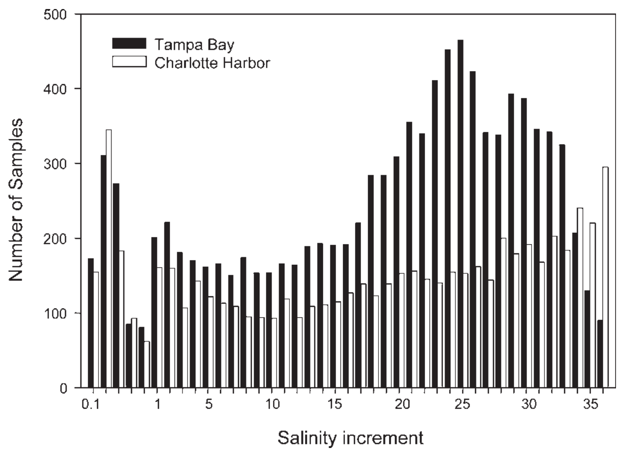

Fig. 1. Sampling effort grouped by salinity increment (0.1 = 0–0.1, 0.2 = >0.1–0.2, etc., 36 = >35).

(1996). The nekton used in this study were collected in 21.3-m center-bag seines of 3.2-mm stretched mesh, via the deployment technique appropriate to the habitat sampled (Tsou and Matheson 2002). This gear collects principally small-bodied animals, i.e., juveniles of larger species and juveniles and adults of smaller species. Habitats that were sampled included shorelines of the two estuaries and their major tributaries (Tampa Bay: Hillsborough, Palm, Alafia, Little Manatee, and Manatee Rivers; Charlotte Harbor: Peace, Myakka, and Caloosahatchee Rivers), as well as open-estuary (i.e., nonriverine) areas away from shore. Sampling was limited to waters ≤ 1.8 m deep in tributaries and ≤ 1.5 m deep in the open estuaries. The area covered in each estuary ranged from the upper limits of salt penetration, in the tidal freshwater reaches of the major tributaries, to full-strength seawater (salinity > 35; Fig. 1 in Greenwood et al. 2006). In total, 10,192 samples from Tampa Bay and 6200 samples from Charlotte Harbor were included in this study (Fig. 1).

At each sampling site, nekton (principally fish, but also selected macroinvertebrates) were identified (generally to species), enumerated, and a subsample (≤ 40 individuals of each species) was measured (standard length for teleosts, disk width for rays, precaudal length for sharks, carapace width for crabs, and postorbital head length for shrimps). Only taxa identified to the species level were included in this study. Certain taxa (e.g., caridean shrimp) were not included in the study because their biological data were recorded in only some of the tributaries in the study areas. Various environmental variables were also recorded concurrent with each sample, salinity being the one pertinent to this study. Salinity was recorded with a Hydrolab or YSI multiprobe at the water's surface (0.15 m) and bottom. Salinity was also recorded at 1-m increments between surface and bottom when water depth was > 1 m, whereas only surface readings were taken when water depth was < 0.4 m. This study used values based on water-column-averaged salinities at each site. Stratification was generally absent because of the shallow depths (difference between surface and bottom salinities: mean = 0.32; SE = 0.01; minimum = 0; 25% quantile = 0; median = 0; 75% quantile = 0.1; 95% quantile = 1.6; 99% quantile = 6.9; maximum = 23.4).

Data Analysis

Each of the 16,192 seine samples was assigned to one of 41 salinity increments (Fig. 1). The 0–0.5 range was subdivided into five increments because of the relatively large number of samples in this range and the potential ecological importance of this range (Anonymous 1958); 0 was not assigned its own increment because there were relatively few samples with a water-column-averaged salinity of 0, as a result of sampling being limited to the upper limits of saline penetration. Each species was subdivided into size classes to reflect the potential for shifts in salinity preference through ontogeny (Livingston 1988; Peebles et al. 1991; Able et al. 2001). To this end, an approach was adopted similar to that of Baltz and Jones (2003) and Farrell et al. (2005): animals were subdivided into 0–30-mm, 31–50-mm, 51–100-mm, and > 100-mm size classes (except for pink shrimp, *Farfantepenaeus duorarum*, which were divided into 0–15-mm and > 15-mm size classes). This process yielded a total of 558 species-size class combinations, which for the purposes of this paper are termed pseudospecies.

I originally intended to analyze the data following the method of Bulger et al. (1993). They conducted a factor analysis of nekton salinity ranges (presence or absence over a defined salinity range) followed by interpretation of statistically significant varimax-rotated factors. I also wished to refine the analysis by incorporating semiquantitative information (frequency of occurrence of nekton by salinity increment) into a correspondence analysis to provide a solution that could be rotated in an analogous manner to the factor analysis method of Bulger et al. (1993). Initial findings suggested that the data were unlike those of Bulger et al. (1993) in that the solution of the factor analysis exhibited a prominent arch effect, suggesting a single very strong environmental gradient (the first factor explained ca. 60% of the variability in the data). The same was true of the correspondence analysis solution: the data were not suitable for rotation (van de Velden and Kiers 2005) and it was most appropriate to simply examine the relation of salinity increments in what was basically a one-dimensional solution (van de Velden personal communication).

In this study, a relatively simple nonparametric examination was undertaken of estuarine salinity zones as determined by nekton community change along the salinity gradient. For each estuary separately, the frequency of occurrence of each pseudospecies by salinity increment, i.e., the percentage of samples at a particular salinity increment that a pseudospecies was collected, was square-root transformed in order to lessen the influence of very common species. Matrices of pairwise Bray-Curtis similarities (Bray and Curtis 1957) between all salinity increments were calculated. Nonmetric multidimensional scaling (MDS; Clarke 1993; Clarke and Warwick 2001) was conducted on each estuary's Bray-Curtis similarity matrix to produce ordination plots depicting the similarity in community structure between all salinity increments. These ordination plots were based on ranked similarities in community structure between salinity increments, i.e., they were nonmetric, and so the salinity increments were plotted on unitless axes. The only important information from the MDS ordination plots was the proximity of the increment labels to each other, as an indication of community-structure similarity over the salinity gradient. The ordination plots were visually inspected in order to assess the evidence for estuarine salinity zones, based on regions of accelerated change (salinity-zone end points). To allow comparison with previous studies (principally Bulger et al. [1993] and Christensen et al. [1997]), the analysis was repeated with salinity-range data. In this case, the data were not transformed because they consisted of presence or absence by salinity increment over a given salinity range. The salinity range was calculated by the maximum and minimum salinities at which a pseudospecies had occurred, with these and all intermediate salinities being assigned a value of 1, indicating presence (assumed or actual). For brevity, the individual pseudospecies' identities are not discussed, with the focus instead being on multivariate community patterns.

The unusually large database allowed treatment of each salinity increment as a separate sample and incorporation of frequency-of-occurrence information. Deployment techniques differed according to habitat and so precluded the possibility of relative abundance data being used in the analysis, but given the correlation between frequency of occurrence and relative abundance (Wright 1991), the results are likely to be similar whether using frequency or abundance data. Analyses included data from all months of the year, which in some cases has been shown to change observed relationships due to the marked seasonality of estuarine nekton (Wagner and Austin 1999). Conducting the same analyses separately for each season gave similar results.

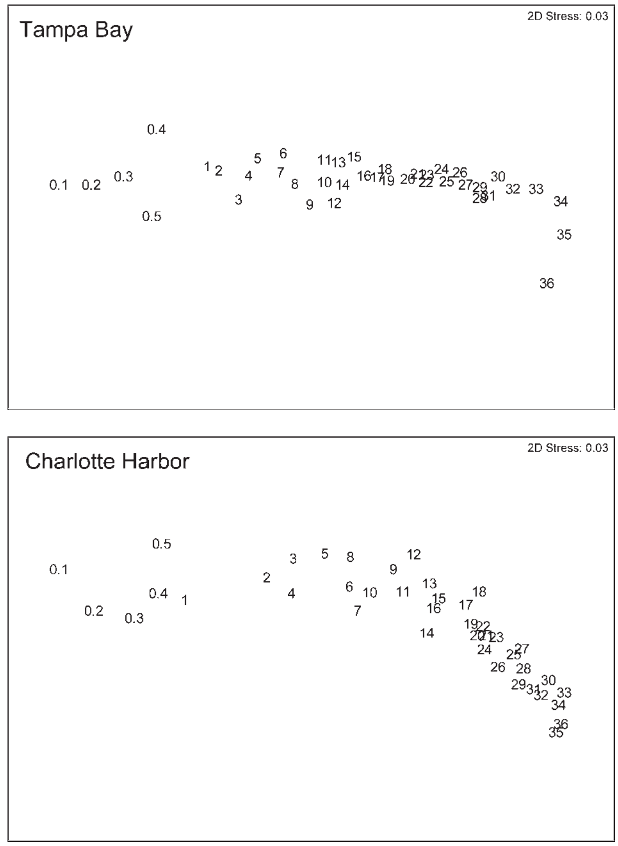

Fig. 2. Nekton community change along the estuarine salinity gradients of Tampa Bay and Charlotte Harbor, based on frequency of occurrence (%) at each salinity increment. In the MDS ordinations, each label represents the community at that salinity increment (0.1 = 0–0.1, 0.2 = > 0.1–0.2, . . ., 36 = > 35), with the proximity of labels indicating the relative similarity of the nekton community along the salinity gradient.

Results

The rate of change in nekton community structure was very rapid as salinity increased from 0 (Figs. 2 and 3). It was apparent that the rate of change was generally decreasing from 0 to 10–15, after which the rate of change was small and fairly constant. In Tampa Bay, the rate of change subsequently increased again above salinities of 30; in Charlotte Harbor, there was evidence of the rate of change increasing at somewhat higher levels, 34–35, although the rate was much lower than that of Tampa Bay. The results did little to support the concept of salinity-zone end points as being ''regions of accelerated change superimposed on a gradient of continuous change'' (Boesch 1977, p. 259). By examining proximities of sequential

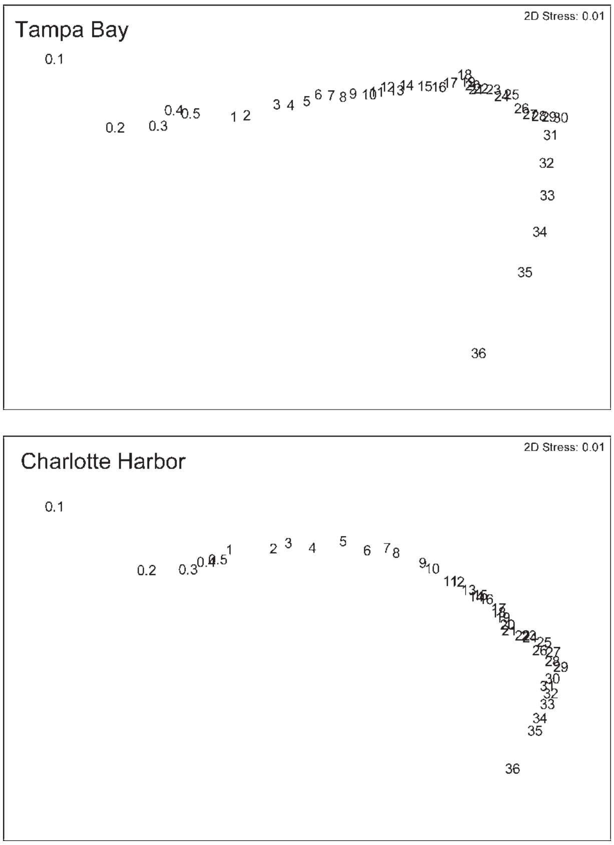

Fig. 3. Nekton community change along the estuarine salinity gradients of Tampa Bay and Charlotte Harbor, based on species' salinity ranges. In the MDS ordinations, each label represents the community at that salinity increment (0.1 = 0–0.1, 0.2 = > 0.1–0.2, . . ., 36 = > 35), with the proximity of labels indicating the relative similarity of the nekton community along the salinity gradient.

salinity increments for frequency-of-occurrence data, one could suggest that accelerated change occurred between 0.5 and 1 (in Tampa Bay) or 1 and 2 (in Charlotte Harbor; Fig. 2), although this is somewhat subjective. Clearly defined end points between salinity zones did not exist anywhere other than near the interfaces with marine and freshwater. All MDS ordinations had stress values below 0.05, indicating ''excellent representation with no prospect of misinterpretation'' (Clarke and Warwick 2001, p. 5–6). The arch effect was present to varying degrees in all plots, indicating the considerable change in community structure along the estuarine salinity gradient (Figs. 2 and 3).

Discussion

There was no firm evidence for the existence of salinity zones that are based on end points defined by ''regions of accelerated change superimposed on a gradient of continuous change'' (Boesch 1977, p. 259), with the possible exception of very low salinity regions (i.e., 0.1–1). Boesch (1977) determined that benthic macrofauna showed rapid changes at salinities of 5–8 and 18–21 along the York River-Chesapeake Bay salinity gradient, i.e., in two of the regions defined as end points by the Venice System. Bulger et al.'s (1993) analysis suggested rapid change at 2–4, 11–14, 16–18, and 24–27. This was not true of the present study. Rapid change in nekton community structure occurred at each end of the estuarine salinity gradient, with comparatively slow (but steady) change in between; e.g., the community in Tampa Bay changed as much over the range 0–2 as it did between 2 and 17 or between 17 and 33 (Fig. 2). Croghan (1983, p. 39) noted that ''the physiologist must inevitably suspect the division of what is obviously a continuum into specific named salinity zones;'' results from this study tend to support this comment. Reasons for the lack of distinct salinity zones in the present study compared to the most recent comprehensive treatment of the subject (Bulger et al. 1993) are unclear but may be due to differences in community composition or water chemistry. The present study was based on small-bodied nekton data, whereas Bulger et al. (1993) and a subsequent similar study (Christensen et al. 1997) included information on organisms ranging from eggs and larvae to large-bodied adults, which may also have influenced the results.

The rapid change in community structure at the lower end of the salinity range is largely attributable to the stenohaline nature of primary freshwater fishes (Bulger et al. 1993). Ion ratios of estuarine water decrease exponentially as salinity increases (Deaton and Greenberg 1986), and this change is reflected in the plots of community change (Figs. 2 and 3). The region of accelerated change at the upper limit of the salinity range was somewhat different for the two estuaries: in Tampa Bay, great differences began at about 30–31, whereas in Charlotte Harbor, rapid change occurred only over the last two salinity increments. Reasons for the difference are unclear but could include a decline in sample size above 33 in Tampa Bay (Fig. 1) or the greater length of the study area in Tampa Bay. Regarding the latter possibility, differences in community structure are to be expected because of distance to the sea (Kupschus and Tremain 2001) or to fresh water (Wagner and Austin 1999), irrespective of salinity. Stenohaline marine species would be expected to have limited penetration into lower salinities because of their limited osmoregulatory capacity (Bulger et al. 1993), so rapid change in community structure with decreasing salinity is not unexpected. The coincidence of salinity change with habitat change may also be important (Bulger et al. 1993) but was not considered explicitly in this study. As salinity decreases and one moves upstream, the dominant shoreline vegetation changes from mangrove to salt marsh to freshwater marsh to forested wetlands (Estevez et al. 1991). Whether it is the change in salinity or the change in habitat that is most important in determining nekton community structure is difficult to establish, but it is likely that both components are critical, at least for some species. Estuarine productivity may be maximized when species' preferred stationary (e.g., vegetation or structure) and dynamic (e.g., salinity) habitats overlap optimally (Browder and Moore 1981).

From a theoretical viewpoint, the present study provides further information on the nature of ecological boundaries in estuaries. A recent detailed analysis of the subject by Attrill and Rundle (2002) concluded that the estuary represents two ecoclines, which correspond to declines in freshwater and marine taxa with movement from favored habitats to the mid estuary. The analyses in the present study support this conclusion. There appears to be evidence to support the notion of two ecotones (regions of relatively rapid ecological change), one at either end of the estuarine salinity gradient. These ecotones result because of the transition from fresh water to estuary and the transition from estuary to the sea. The estuary as a whole cannot be thought of as an ecotone because of the constant change in nekton community structure along its length.

The results of the present study have potential to aid estuarine management. Extraction of fresh water from rivers for human consumption may alter salinity regimes and organism distribution (Drinkwater and Frank 1994). The nonlinear change in river volume as one moves from river mouth upstream means that the salinity in areas in the tidal freshwater reaches (0–2; Wagner and Austin 1999) can change drastically if flow is altered (Estevez 2002). The rapid change in community structure at lower salinities compounds the potential for change in the oligohaline or limnetic areas. Management options include limiting withdrawals to fixed percentages of total flow, above a minimum total-flow threshold for withdrawal (Flannery et al. 2002). Given knowledge of salinity regimes within an estuary, the MDS plots produced in this study could be examined in order to ascertain salinities where the rate of change in nekton community structure becomes unacceptably rapid. Flow targets could then be set in order to maintain relevant isohalines at particular regions of the estuary. Isohaline-based management has been used in the San Francisco estuary (Kimmerer 2002). Maintenance of appropriate freshwater inflow is assumed to influence not only the distribution of organisms but also other important processes such as nutrient supply and estuarine flushing (Alber 2002).

This study expanded the knowledge gained in previous studies by apparently being the first to examine evidence for biologically based estuarine salinity zones by using semiquantitative incidence information grouped by salinity instead of site. The results suggested that well-defined estuarine salinity zones based on nekton frequency of occurrence (or salinity ranges) were not evident in two southwest Florida estuaries. There was a clear community change along the estuarine salinity gradient, with accelerated change near the freshwater or marine interfaces with the estuarine water. Future research should include analyses of other large databases of estuarine biotic sampling to validate this study's observations.

Acknowledgments

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SOURCE OF UNPUBLISHED MATERIALS

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SHELL CREEK PROPOSED MINIMUM FLOW AND LEVEL TECHNICAL REVIEW

FINAL
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SHELL CREEK PROPOSED MFL TECHNICAL REVIEW

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1.1 INTRODUCTION

The City of Punta Gorda (City) requested that Carollo Engineers and a hydrobiological subconsultant, HSW Engineering, complete a technical review of the "Peer Review Draft - Proposed Minimum Flow and Levels for the Lower Peace River and Shell Creek" that was published by the Southwest Florida Water Management District (SWFWMD) on August 24, 2007. The review includes an analysis of the scientific methodologies, data, and assumptions utilized in developing the draft rule, as well as comments on the proposed rule. Specifically, the technical review consists of:

- A summary of the proposed minimum flow and level (MFL).
- Evaluation of how the proposed MFL would affect the City's current water use permit and future withdrawal schedule, i.e., an analysis of the MFL impacts on past and future withdrawals under several interpretations of the MFL.
- Technical review of the "Proposed MFL for the Lower Peace River and Shell Creek Peer Review Draft" and its basis of development. This includes an evaluation of the technical methodologies, data, and assumptions made in developing the rule, including an evaluation of the appropriateness of the 2 part per thousand (ppt) isohaline as a critical metric, and other assumptions related to the biology of Shell Creek. This review includes an investigation of how the MFL links its assumptions and recommendations to the definition of "significant harm" in State of Florida rules.

1.2 MINIMUM FLOWS AND LEVELS BACKGROUND

The MFL program within the State of Florida is based on the requirements of Chapter 373.042 of Florida Statutes (F.S.). This statute requires that either a Water Management District (WMD) or the Department of Environmental Protection (DEP) establish minimum flows for surface watercourses and minimum levels for groundwaters and surface waters. The statutory description of a minimum flow is "the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area" (Ch. 373.042 (1)(a), F.S.).

The statute provides additional guidance to the WMDs and DEP on how to establish MFLs, including how they may be calculated, using the "best information available," to reflect "seasonal variations," when appropriate. Protection of non-consumptive uses also are to be considered as part of the process, but the decision on whether to provide for protection of non-consumptive uses is to be made by the Governing Board of the WMD or DEP (Ch. 373.042 (1) (b), F.S.).

The statue also states, “When establishing minimum flows and levels pursuant to s. 373.042, the department or governing board shall consider 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 an affected watershed, surface water, or aquifer, provided that nothing in this paragraph shall allow significant harm as provided by s. 373.042(1) caused by withdrawals.”

WMDs are to develop priority lists of watercourses and water bodies for which to establish MFLs and the proposed schedules to do so. These lists are to be updated yearly and sent to DEP for review and approval. In developing these lists, the WMDs are to examine the importance of the watercourse or water body to the State or region and the potential for significant harm to the water resources or ecology.

Chapter 62-40.473 F.A.C lists ten water resource values (WRVs) that may be considered when developing MFLs. These include:

- 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
- Sediment loads
- Water quality
- Navigation

1.3 SUMMARY OF PEER REVIEW DRAFT MFL

The area of analysis for Shell Creek extends from Hendrickson Dam downstream to the confluence of Shell Creek with the lower Peace River. The “Peer Review Draft” uses seasonal blocks corresponding to periods of low, medium, and high flow. The goal of this method is to maintain the appropriate amount of flow at the right time. Additionally, to account for variability within seasonal blocks, salinity response under high and low flow conditions (above and below the median flow) was examined and incorporated into the proposed MFL. The critical criterion for analysis in the “Peer Review Draft” was habitat with 2 ppt salinity or lower. According to the analysis in the “Peer Review Draft,” the flow regime outlined in the MFL results in no more than a 15 percent reduction in habitat with 2 ppt salinity or lower during each of the blocks used in the MFL. There is no low flow cutoff in the MFL, as this report discovered no clear defensible low flow threshold when examining the relationship of several habitat variables to flow.

Table 1.1 outlines the allowed percentage withdrawals during each block. The percent withdrawal is calculated based on the time of year, amount of flow in Shell Creek, and whether the flow is above or below the median value. For example, if the flow on October 30 (Block 2) is 75 cfs (below the median for Block 2), the maximum withdrawal allowed is 75 cfs x 18% = 13.5 cfs. However if the flow on the same day is 150 cfs (above the median for Block 2), the maximum withdrawal is 98 cfs x 18% + (150 cfs - 98 cfs) x 42% = 39.5 cfs.

Table 1.1 Proposed Shell Creek MFL Allowable Percent Reduction in Flow

Block	Dates	Low Flow Condition (Below Median) (% of Flow)	High Flow Condition (Above Median) (% of Flow)	Median Flow (cfs)
1	April 20 to June 25	10%	23%	84 cfs
2	October 27 to April 19	18%	42%	98 cfs
3	June 26 to October 26	35%	83%	424 cfs

1.4 IMPACT OF PROPOSED MFL ON HISTORICAL FLOWS

The impact of the proposed MFL on the City’s potable water supply was evaluated as part of the review of the “Peer Review Draft.” To analyze the effect of the proposed MFL on the City’s historical withdrawals, several interpretations of the MFL were selected for analysis. These interpretations were then used to determine the number of days that the City’s water treatment plant (WTP) would not have been able to meet the City’s water demand if the MFL had been implemented during the period 1996 to 2006.

1.4.1 City of Punta Gorda Water Supply

The City currently withdraws raw water from Shell Creek Reservoir for treatment and distribution to its customers. Raw water is withdrawn from Shell Creek Reservoir through two horizontal, open-ended intake pipes (30-inch) located adjacent to the Hendrickson Dam. The dam essentially acts as a rectangular, sharp-crested weir with free overflow. Water entering the reservoir from the Shell and Prairie Creeks is retained up to the crest elevation of the dam. Excess flow spills over the dam into the lower portion of Shell Creek, which combines with the lower Peace River and flows into Charlotte Harbor. The crest of the dam is approximately 1.25 feet above the maximum high tide elevation in Charlotte Harbor (3.75 ft MSL). However, if the reservoir level falls below the crest of the dam during periods of low flow, this simple type of dam is not capable of serving as an outlet control device to augment downstream flow.

The City has used a 95 percent reliability criterion for water supply planning in previous master planning efforts. However, the City may wish to increase this criterion in the future to provide a more reliable water supply.

1.4.2 Interpretations of Proposed MFL for the City's Water Supply

The proposed MFL does not address withdrawals from water storage created by Hendrickson Dam. This water could be considered a part of Shell Creek addressed by the MFL, and thus subject to the restrictions of the MFL, or it could be considered a raw water storage reservoir for the Punta Gorda WTP and therefore not restricted by the MFL. This is an important distinction, as the WTP's intake is below the level of the dam. Thus, to withdraw from the stream, the WTP in actuality withdraws water from the reservoir.

For completeness of analysis, three interpretations of the proposed MFL were examined:

1. The MFL applies to Shell Creek reservoir as well as to the stream, e.g., if there is a no flow event, withdrawals from the reservoir are not allowed since a percentage of no flow is zero flow.

2. The MFL applies only when water is flowing over the dam, i.e., when flow over the dam ceases, the WTP can withdraw water from the reservoir.

3. The in-stream reservoir is treated as a stand-alone reservoir and water can be withdrawn regardless of the presence or absence of flow going over the dam. In this case, the reservoir is considered a separate water body “underneath” the streamflow.

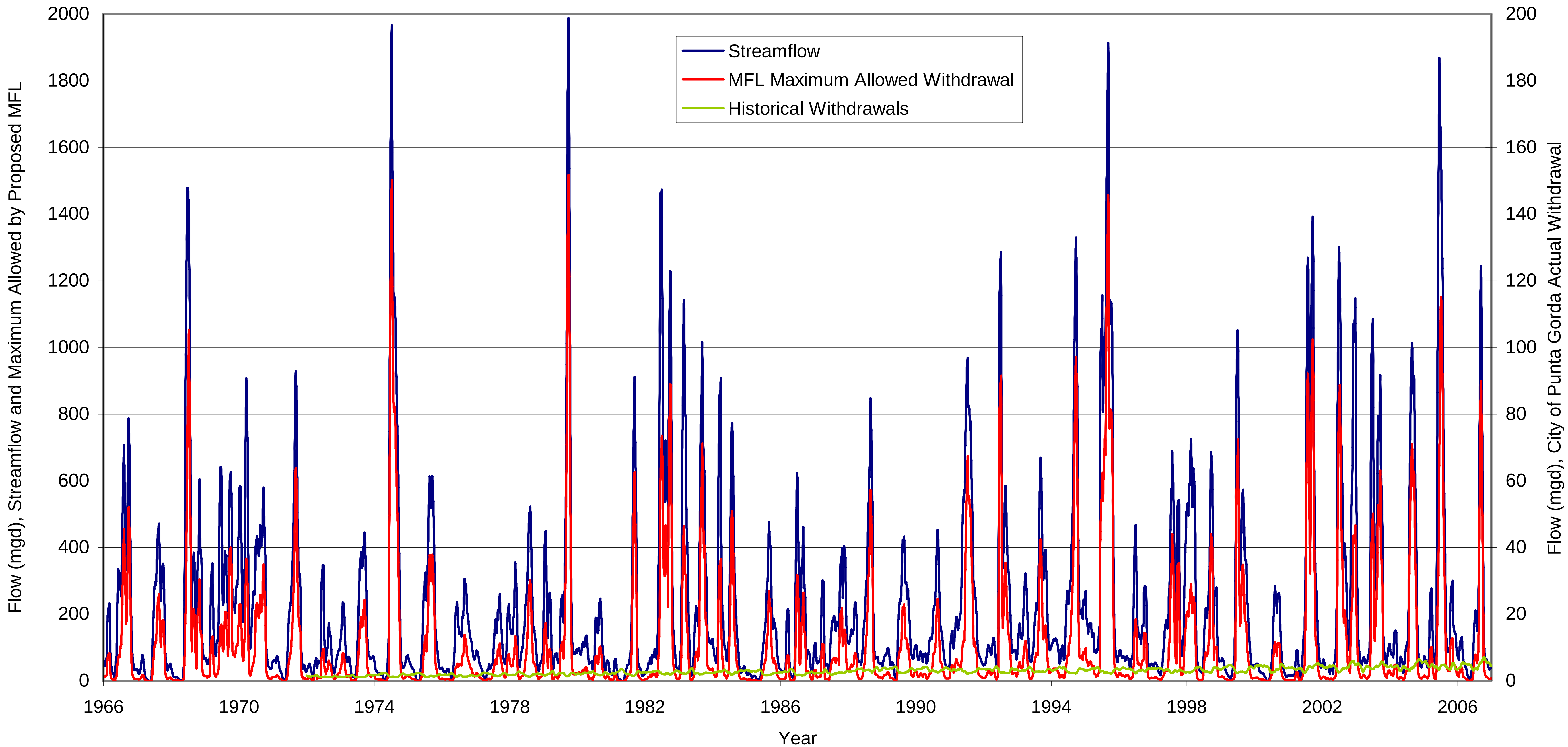
A mass balance model developed during the City's previous master planning efforts (Carollo, 2006) was used to evaluate the proposed MFL with the three interpretations listed above. The model is a spreadsheet mass balance of water sources, treatment, and storage facilities at the WTP, including the in-stream reservoir created by the dam. Historical withdrawal data, the restrictions of the proposed MFL, and the in-stream reservoir were incorporated into the model. The viable storage in the in-stream reservoir is 320 million gallons (MG) based on water quality limitations.

1.4.3 Historical Data Analysis

Historical withdrawal and streamflow data were compared to the allowed withdrawal quantities using the proposed Shell Creek MFL. Like the proposed MFL, the historical streamflow was estimated by adding the flow at the Punta Gorda Gage (USGS 022298202) to the withdrawals made by the City of Punta Gorda WTP. Zero flow days at the gage were recorded as zero, despite any withdrawals made by the WTP. Figure 1.1 illustrates historical streamflow, historical withdrawals made by the City for water supply, and the quantity of water that could have been withdrawn if the proposed MFL were in effect during the period of record. It should be noted that data were missing from the USGS record for several days in 2006. Because no flow was recorded, the analysis assumed that flow on these days was zero. In Figure 1.1, the City withdrawal data scale on the y-axis is exaggerated by a factor of 10 to facilitate comparison of gross trends across all data. Figure 1.2 illustrates the same data with identical scales, but the maximum scale value was set at 8 million gallons per day (mgd) to better compare the City's withdrawal data to the flow that would have been allowed by the proposed MFL. Figures 1.1 and 1.2 illustrate 30-day rolling averages of the flow data.

Shell Creek flow is highly variable. Flow ranged from zero flow to a 30-day average of nearly 2,000 mgd during the period of record. During much of the year (especially during Block 3), very large quantities of water are available to the WTP. Nevertheless, there are several time periods when the City's actual withdrawal would have been restricted during the period of record. The City's withdrawals would have been limited when the green line is shown above the red line in Figure 1.2. It should be noted that since the data are plotted as 30-day averages, the MFL may have restricted withdrawals outside of points where the green line is shown above the red line. Figure 1.2 demonstrates the frequency and duration of periods when the City's WTP would have been restricted in meeting its historical demand if the proposed MFL were in place at that time.

The number of days that the City's actual withdrawals would have been restricted by the proposed MFL if it were in place from 1996 to 2006 is presented in Figure 1.3 for all three interpretations of the proposed MFL. The period 1996-2006 had slightly higher flows than the baseline period (1966-2004) used in the MFL; the average flow for the baseline period was 357 cfs, during the period 1996-2006 it was 394 cfs. Restricted days were determined by comparing the maximum withdrawal allowed by each interpretation of the MFL to the actual withdrawal for each day from 1996 to 2006.

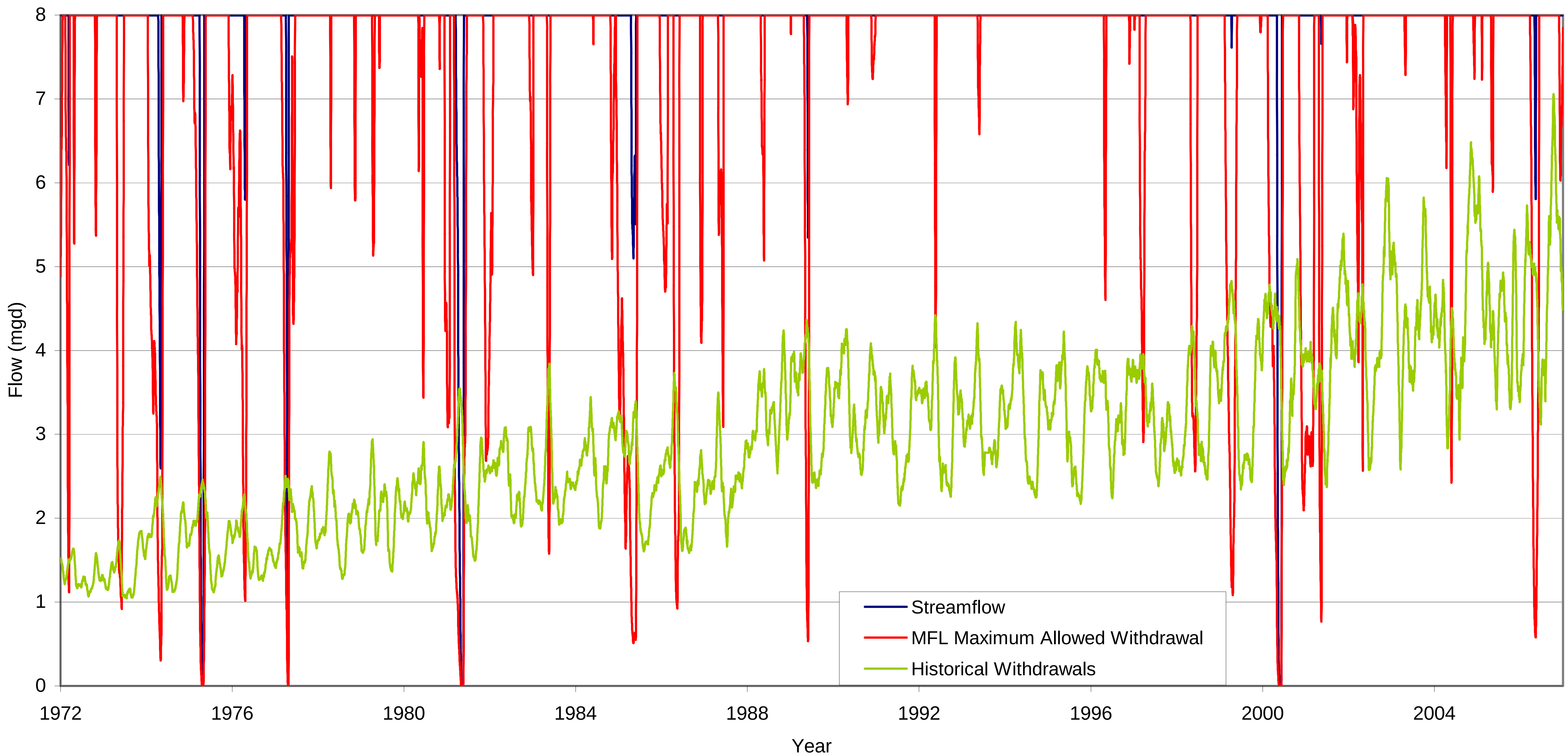


Notes: All plots are 30-day rolling averages. Y-axis for historical withdrawals is exaggerated 10 times.

Shell Creek Proposed Minimum Flow and Level Technical Review - FINAL

Shell Creek Streamflow, MFL Maximum Allowed Withdrawal, and Historical Withdrawals, Scale Exaggerated for Historical Withdrawals (1966-2006)

FIGURE 1.1



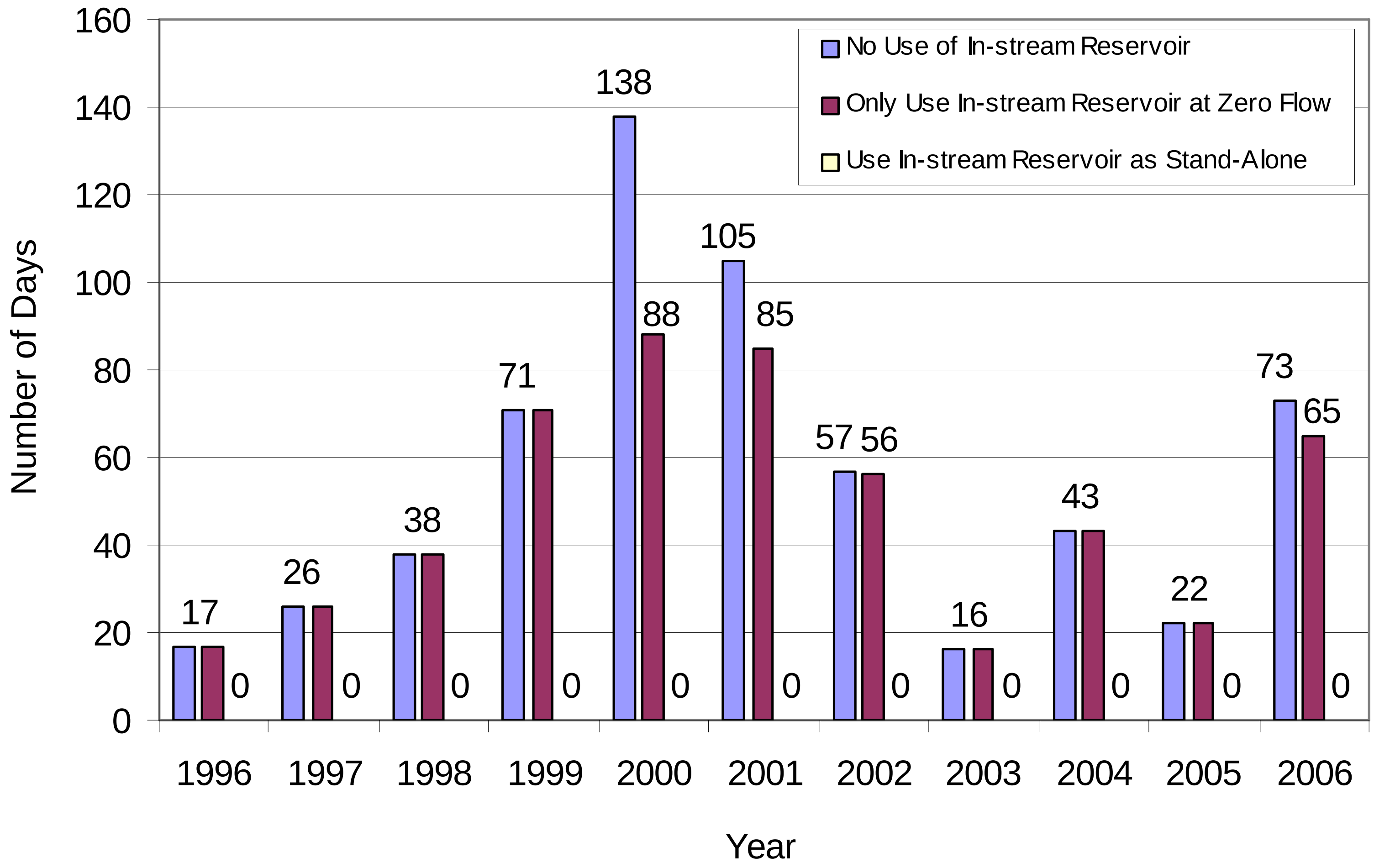
Notes: All plots are 30-day rolling averages. All data values greater than 8 mgd are represented as 8 mgd.

Shell Creek Streamflow, MFL Maximum Allowed Withdrawal, and Historical Withdrawals (1972-2006)

FIGURE 1.2

Number Of Days Historical Withdrawal Limited Under Proposed MFL

FIGURE 1.3



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If the MFL would have been imposed with the strictest interpretation (the reservoir is considered a portion of the stream, and no withdrawals are allowed when the flow over the dam is zero), the number of days the flow would have been restricted ranges from 16 to 138 days per year. The flow would have been restricted (and the entire demand not met) during each of the past 10 years. During years of drought, 2000, 2001, and 2006, the flow would have been restricted for 138, 105, and 73 days during those years, respectively. If the proposed MFL would have been in place in 2000 with this interpretation, the City would have been unable to meet their demand for more than 35 percent of the days during that year.

If the MFL would have been imposed with the second interpretation (the MFL applies only when water is flowing over the dam, i.e., when flow over the dam ceases, the WTP can withdraw water from the reservoir), the number of days the flow would have been restricted ranges from 16 to 88 days per year. The City's full demand would not have been met for at least 16 days during each of the past 10 years. During years of drought, 2000, 2001, and 2006, the flow would have been restricted for 88, 85, and 65 days during those years, respectively. If the proposed MFL would have been in place in 2000 with this interpretation, the City would have been unable to meet their demand for approximately 24 percent of the days during that year.

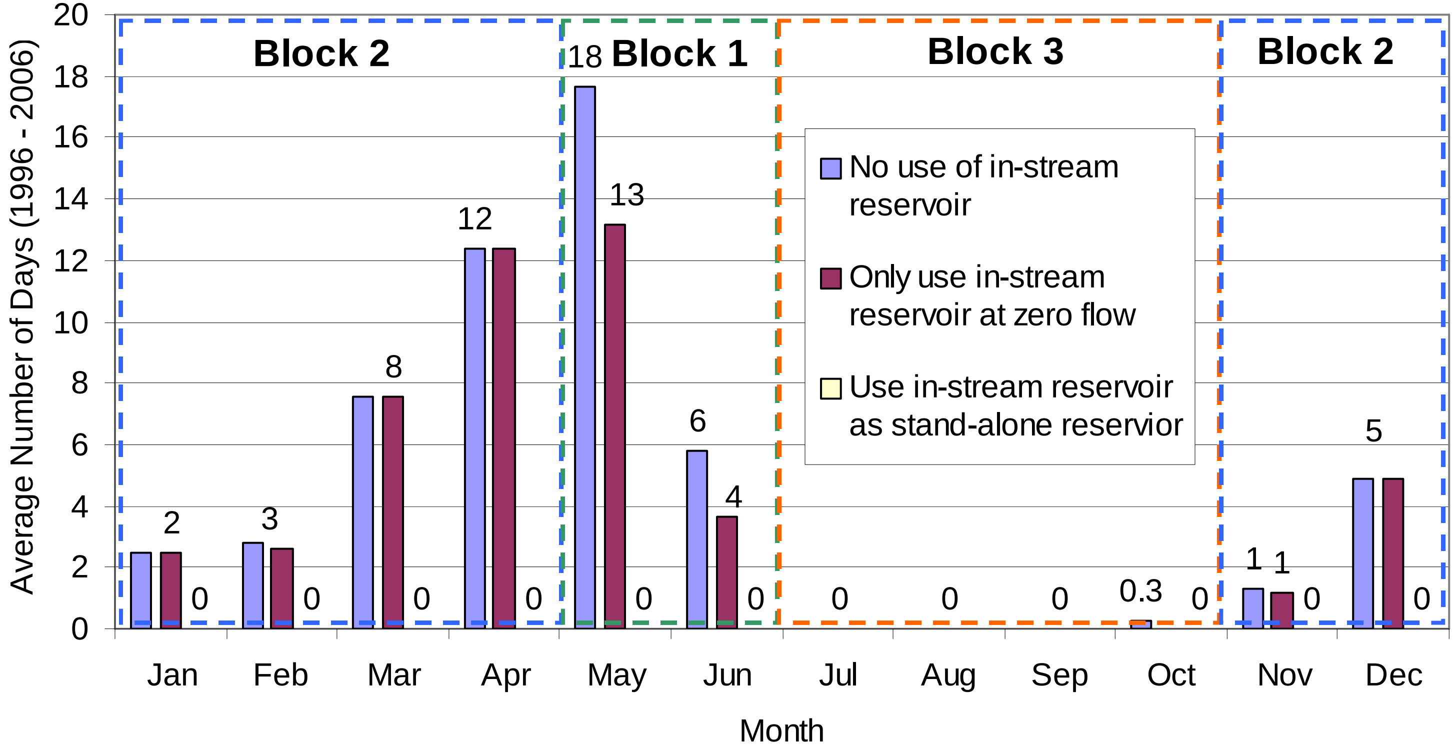
When comparing the first two interpretations of the MFL, the data suggests that for years of severe drought, using the reservoir after the flow after the dam has ceased is critical. For other, more normal flow years, the difference between the first two interpretations of the MFL is not as great.

If the MFL would have been imposed with the third interpretation (in-stream reservoir is treated as a stand-alone reservoir and water can be withdrawn regardless of the presence or absence of flow going over the dam), the proposed MFL does not limit the City's withdrawals. In essence, this interpretation treats the reservoir as a separate water body "underneath" the flow of the stream. This interpretation of the MFL would require the City to maintain a record of flow withdrawn from the stream versus the reservoir.

Figure 1.4 presents the average number of days withdrawals would have been restricted during each month of the year for all interpretations of the proposed MFL. March through June are the most impacted months, with an average of 4 to 18 days of restricted flow per month depending on the month and how the MFL is interpreted. Block 3 is the least impacted, with only a few restrictions during the month of October and no restrictions for other months during that block.

FIGURE 1.4

Number Of Days Historical Withdrawal Limited Per Month Under Proposed MFL



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1.4.4 Summary of Impact of Proposed MFL on Historical Withdrawals

The MFL would have had an impact on the withdrawals of the Punta Gorda WTP during the period of 1996 to 2006. In 2000, an extremely dry year, the WTP would not have been able to meet demand more than one-third of the time. Even if the WTP would have been allowed to withdraw after flow over the dam ceased, the plant could have met demand during only 75 percent of days in 2000.

Blocks 1 and 2 are the most restrictive for the Punta Gorda WTP, with almost all restricted withdrawal days occurring within those blocks. April and May are the most restrictive months, with over half of restricted withdrawal days occurring in those two months.

Allowing the WTP to withdraw from the existing reservoir as a stand-alone reservoir yields 100 percent reliability, even if downstream flow is somehow augmented by constructing a bypass around the dam. However, this understanding of the MFL rule would require modifications to the existing dam as the current dam is not capable of serving as an outlet control device to augment downstream flow.

1.5 IMPACT OF PROPOSED MFL ON FUTURE WITHDRAWALS

Punta Gorda is a growing city, currently serving a population of approximately 34,034 with an annual average water demand of 4.58 mgd. The population is poised to grow to a build-out population of 58,905 with a corresponding increase in water demand to 9.05 mgd by build-out conditions (Carollo, 2007). To give a context for future withdrawals, this section provides a summary of the current water use permit and future water demand projections. An analysis of the effects of the proposed MFL on the future reliability of water supply is also presented. To evaluate the impact of the MFL on future withdrawals, the mass balance model was used to analyze reliability using historical stream flow data as a baseline.

1.5.1 Current Water Use Permit Quantities

The City's current water use permit (WUP) allows withdrawals of 8,088,000 gallons per day (gpd) from Shell Creek on an average annual basis. This WUP may be modified to address compliance with the MFL requirement. The City may withdraw up to 11,728,000 gpd during the peak month. The WUP was issued on July 31, 2007 and expires on July 31, 2027. This permit will serve the City for the next 20 years. This WUP replaced the WUP documented in the proposed MFL. The previous MFL allowed an average withdrawal of 5.38 mgd and a peak monthly withdrawal of 6.9 mgd.

At this time, the City is permitted to withdraw regardless of the flow over the dam. Additionally, there are no conditions requiring a minimum downstream flow in Shell Creek.

Therefore, the City is allowed to use the impounded water below the crest of the dam during dry periods when the WTP withdrawals exceed the streamflow. This provision provides a usable storage volume below the dam (an in-stream reservoir), which provides raw water storage during the dry season.

1.5.2 Future Water Demand Projections

Based on the ongoing Water System Master Plan (Carollo, 2007), the City is expected to reach an annual average demand of 9.05 mgd at build-out conditions (approximately 2027). Water demand projections were developed using 5-year and build-out percentages of land parcels for several types of land use and historical unit water demand factors. A graphical presentation of water demand projections through 2027 is presented in Figure 1.5.

1.5.3 Model Description

To analyze the effects of the MFL on future withdrawals, a spreadsheet mass balance model was used. The model was modified from a previous version used during master planning efforts for the City in 2006. The modified model incorporates the proposed Shell Creek MFL, including all three interpretations discussed in Section 1.4.2. The model calculates the mass balance of water sources, treatment, and storage facilities at the WTP as well as the existing in-stream and potential future off-stream reservoirs. The model predicts water supply reliability based on the demand of the service area and the diversion restriction imposed on withdrawals. Reliability is defined as the percent of days that the City could supply water to meet the entire demand of the service area. The projected demands were adjusted using historical average monthly peaking factors, which ranged from 0.83 to 1.18. Flow data were obtained from USGS and the Punta Gorda WTP.

1.5.4 Model Analysis

Several factors were accounted for in the model: the use or absence of aquifer storage and recovery (ASR) wells, water quality requirements, and the interpretation of the MFL. The future of ASR wells in Florida is somewhat in question, as mobilization of heavy metals such as arsenic has been observed in several systems. Ongoing studies and discussion regarding regulations for ASR wells and underground aquifers may impose stringent regulations that could affect the use of ASR systems in the future. Thus, the model was run both with and without the use of ASR wells for all interpretations.

Shell Creek currently experiences elevated levels of chlorides and other dissolved solids, which creates water quality limitations in the raw water source. The monthly raw water total dissolved solids (TDS) concentration from January 1985 to June 2006 ranged from 78 to 978 milligrams per liter (mg/L) and averaged 469 mg/L during this time.

Future Water Demand Projections

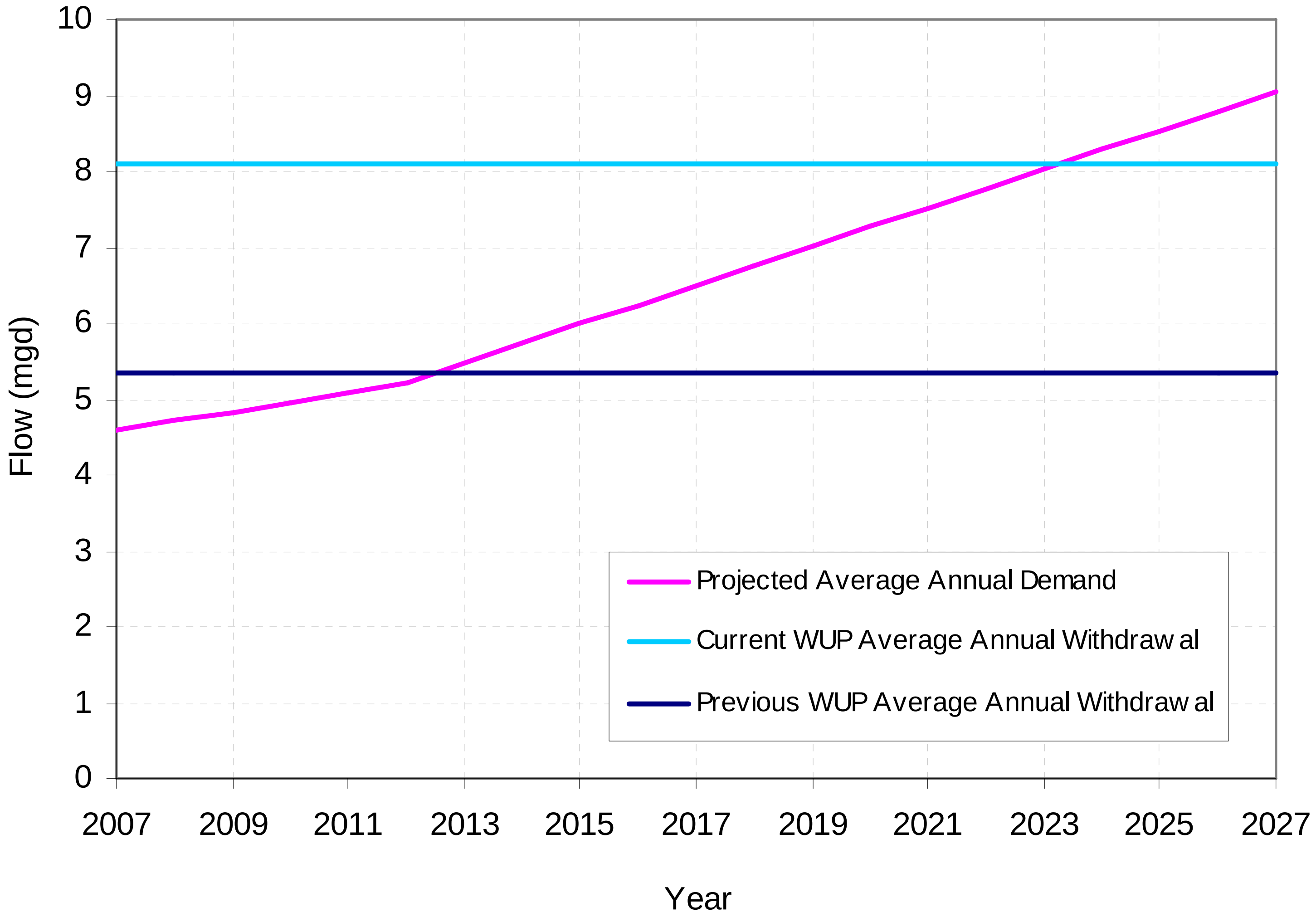

FIGURE 1.5

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The City has experienced difficulties in meeting the secondary maximum contaminant level (MCL) of 500 mg/L in the finished water during dry times due to the increased TDS concentrations in the raw water supply and the inability of treatment processes to remove these compounds. As such, the reliable supply of both water quantity alone and the reliable supply of water meeting the secondary TDS standard was determined. To meet the TDS standard, the off-stream reservoir is used to store higher quality (low TDS) water during times of high flow, typically during summer months. This water is then used to blend with the flow from Shell Creek during times of lower quality to meet a desired TDS concentration. For this analysis, the TDS water quality target was set at 450 mg/L when sizing the off-stream reservoir to meet water quality reliability.

1.5.4.1 First Interpretation of MFL - No Use of In-stream Reservoir

For the first interpretation of the MFL (the MFL applies to the reservoir as well as to the stream, e.g., if there is a no flow event, withdrawals from the reservoir are not allowed since a percentage of no flow is zero), a future off-stream reservoir is needed to store water for use during times of low or zero flow. Several parameter combinations were used to predict reliability under this interpretation of the MFL to reflect multiple regulatory scenarios:

1. Use ASR wells and include a TDS goal of 450 mg/L
2. No use of ASR wells but include a TDS goal of 450 mg/L
3. Use ASR wells and no water quality goal
4. No use of ASR wells and no water quality goal

The required off-stream reservoir size to obtain a daily reliability between 90 and 100 percent was calculated using the mass balance model. Figure 1.6 presents results for conditions when use of the in-stream reservoir is not allowed. When assuming a future annual average water demand of 9.05 mgd, a sizeable off-stream reservoir is required to provide reasonable reliability. To achieve high (99 to 100 percent) reliability, more than 1 billion gallons (BG) of storage is needed under most scenarios evaluated. To achieve a more modest reliability (95 to 96 percent), approximately 600 MG to 1 BG of storage capacity is needed. The slope of Figure 1.6 increases with increasing reliability, showing diminishing increases in reliability as the reservoir increases in size. The largest reservoir is needed when ASR wells are not utilized and when sizing the reservoir to meet both water quantity and water quality requirements. If ASR wells are utilized and if another mechanism can be used to decrease the TDS to meet water quality requirements, a smaller reservoir is required.

Required Off-Stream Reservoir Size Without Use of In-Stream Reservoir

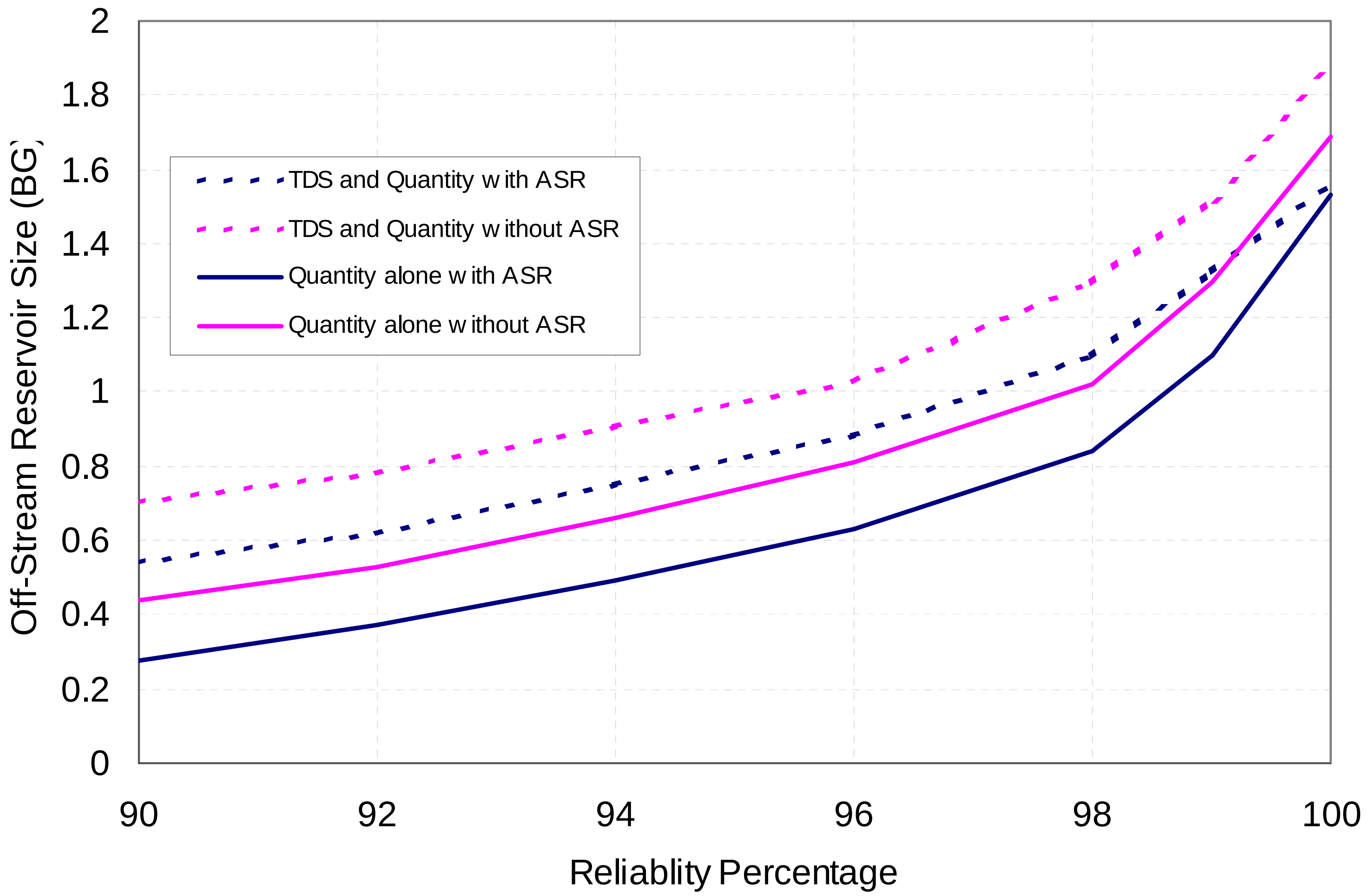

FIGURE 1.6

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1.5.4.2 Second Interpretation of MFL - Use In-stream Reservoir At Zero Flow

For the second interpretation of the MFL (the MFL applies to flow going over the dam, i.e., when flow over the dam ceases, the WTP can withdraw from the in-stream reservoir), the same mass balance model was used to determine the size of an additional off-stream reservoir needed to meet various reliability conditions. Because the in-stream reservoir TDS cannot be controlled, no TDS requirements were used as parameters in the model. In this scenario, another mechanism must be used to meet water quality requirements. The following scenarios were analyzed:

1. Using ASR wells, the in-stream reservoir, and no water quality goal
2. Using the in-stream reservoir, no use of ASR wells, and no water quality goal

The required off-stream reservoir size to obtain reliability between 90 and 100 percent was determined for this interpretation of the MFL. Figure 1.7 presents the results as compared to the corresponding quantity only parameter combinations for the first interpretation of the model. Use of the in-stream reservoir decreases the size of off-stream reservoir needed to meet selected reliability. The use of ASR wells also decreases the size of off-stream reservoir need to meet the selected reliability.

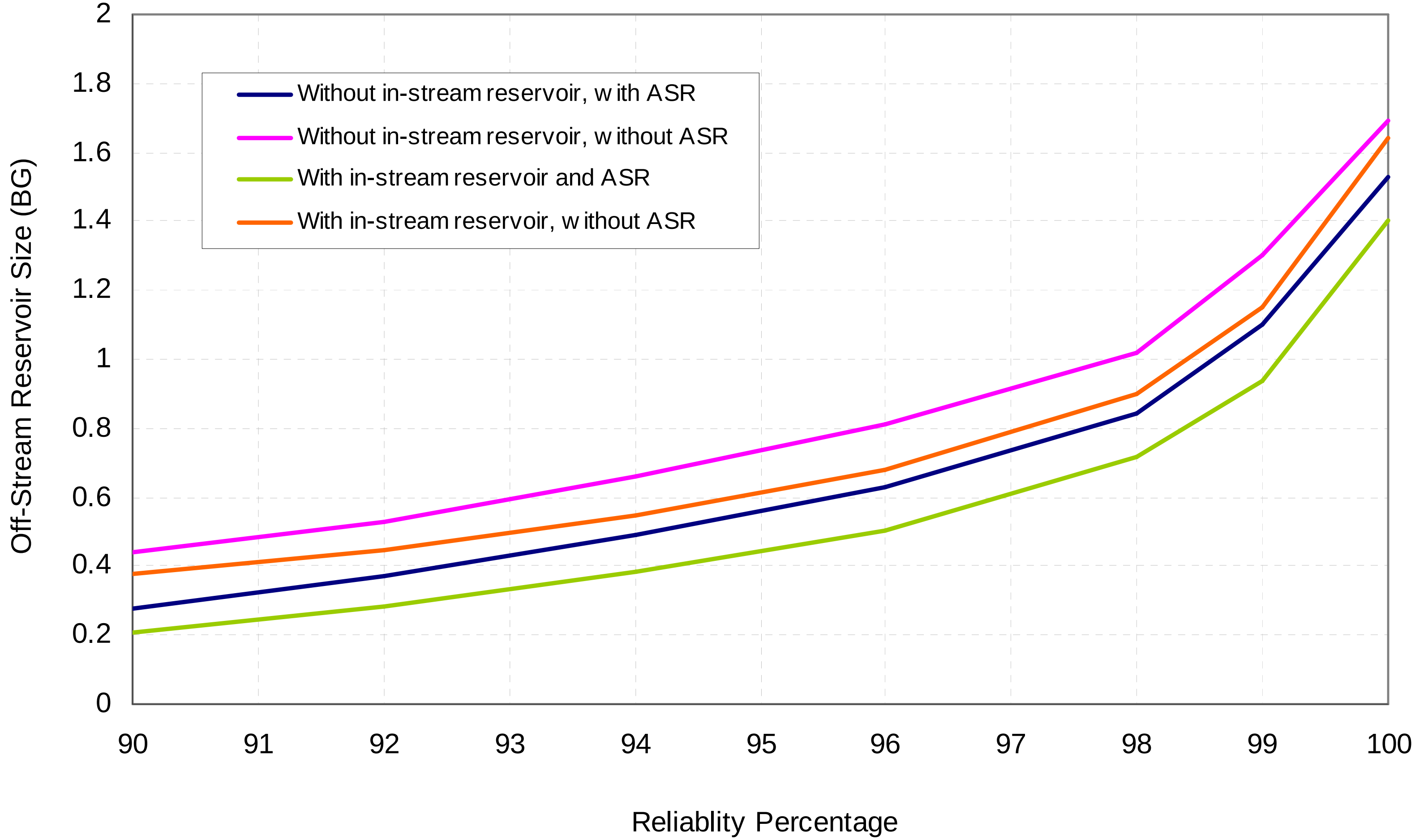
Use of the in-stream reservoir when the flow over the dam reaches zero reduces the required off-stream reservoir size by between 50 and 160 MG, depending on the desired reliability and ASR regulatory scenario. Table 1.2 presents the size reduction for each reliability percentage.

Table 1.2 Size Reduction in Off-stream Reservoir if In-stream Reservoir is Used at Zero Flow

Reliability	With ASR (MG)	Without ASR (MG)
90	65	64
92	90	85
94	105	110
96	125	130
98	120	120
99	160	150
100	130	50

Required Off-Stream Reservoir Size to Meet Water Quantity for Future Demand

FIGURE 1.7



Note: Reservoir size reflects capacity needed to meet only quantity reliability, with no provision for using the off-stream reservoir for blending to meet water quality requirements.

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1.5.4.3 Third Interpretation of MFL - Use In-stream Reservoir As Stand-Alone

The third interpretation of the MFL, (the in-stream reservoir can be treated as a stand-alone reservoir and water can be withdrawn by the WTP regardless of the presence or absence of flow going over the dam) provides the most reliable interpretation of the MFL for the City's water supply. The required off-stream reservoir size for this interpretation is presented in Figure 1.8. Because TDS cannot be controlled in the in-stream reservoir, the TDS requirement of 450 mg/L was not incorporated into this interpretation. In this case, another mechanism would be needed to meet the TDS requirement. Figure 1.8 compares the reservoir size necessary with and without the use of the in-stream reservoir when acting as a stand-alone water body. This scenario still requires an off-stream reservoir to meet projected drought conditions. For 98 to 99 percent reliability, the size of the reservoir ranges from 0.5 to 1 BG depending on if the ASR wells are utilized.

1.5.5 Reliability of Existing Water Supply System With and Without MFL

Table 1.3 presents the reliability of the existing system with and without the restrictions of the proposed MFL, under several future scenarios that utilize combinations of the City's ASR wells, in-stream reservoir, and WTP to meet projected build-out conditions, i.e., 9.05 mgd by approximately 2027. Under the proposed MFL, none of the potential scenarios provides a reliability that meets the City's 95 percent reliability criterion. Even if the City were able to utilize the existing reservoir as a stand-alone water body dedicated to storage for the City's potable water supply (third interpretation of model), the City would be able to meet their projected demand on only approximately 91 percent of days when ASR wells are utilized and 87 percent of days when the ASR wells are not utilized, under the proposed MFL. This suggests that an off-stream reservoir is needed regardless of the interpretation of the MFL to meet reasonable reliability criteria. However, if the existing in-stream reservoir can be utilized as a portion of the City's storage, the size of the off-stream reservoir needed is substantially reduced.

With no MFL restriction on withdrawals, the reliability of the existing system increases substantially. With the use of the in-stream reservoir as a stand-alone reservoir, the reliability increases substantially without an MFL, to above 98 percent. Using the in-stream reservoir as a stand-alone reservoir without ASR wells yields a reliability of 98.6 percent; the use of ASR wells increases the reliability to 99.2 percent.

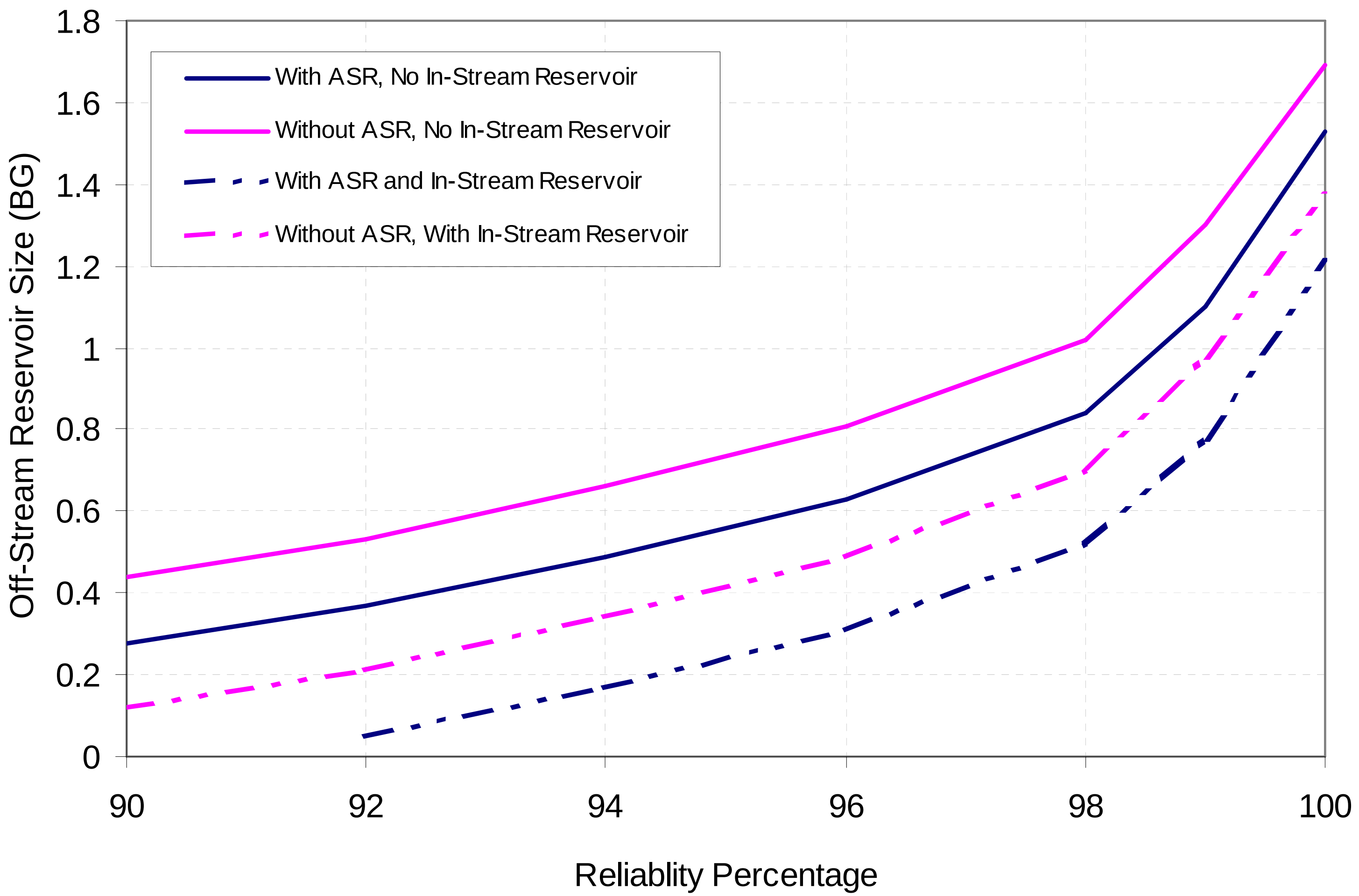
For future scenarios without the restrictions of the MFL, no off-stream storage is required unless the desired reliability is above 98 percent. Because 98 percent reliability is higher than other typical planning reliabilities utilized in the region, the need for building an off-stream reservoir for the City of Punta Gorda water system is solely based on the restrictions of the MFL.

Table 1.3 Reliability of Existing System at Build-Out Demand		
Condition	**Reliability under Proposed MFL**	**Reliability with no MFL**
With ASR, no use of reservoir	73.4 %	94.6 %
With ASR, only use reservoir after no flow	75.5 %	96.5 %
With ASR, use reservoir as stand-alone reservoir	90.8 %	99.2 %
No ASR, no use of reservoir	68.5%	93.5 %
No ASR, only reservoir use after no flow	70.5 %	95.4 %
No ASR, use reservoir as stand-alone reservoir	86.9 %	98.6 %

Figure 1.9 graphically compares the required off-stream reservoir size to meet a range of reliability criteria for future scenarios with and without ASR and with and without the MFL. It is unlikely that without an MFL, withdrawals from the reservoir would be restricted. Thus, all scenarios illustrated in Figure 1.9 include the use of the in-stream reservoir as a stand-alone reservoir (both with and without an MFL) for the sake of comparison. No off-stream storage is required below a 98 percent reliability criterion without the restrictions of the proposed MFL.

Required Off-Stream Reservoir Size With Use of In-Stream Reservoir as Stand-Alone

FIGURE 1.8



Note: Reservoir size reflects capacity needed to meet only quantity reliability, with no provision for using the off-stream reservoir for blending to meet water quality requirements.

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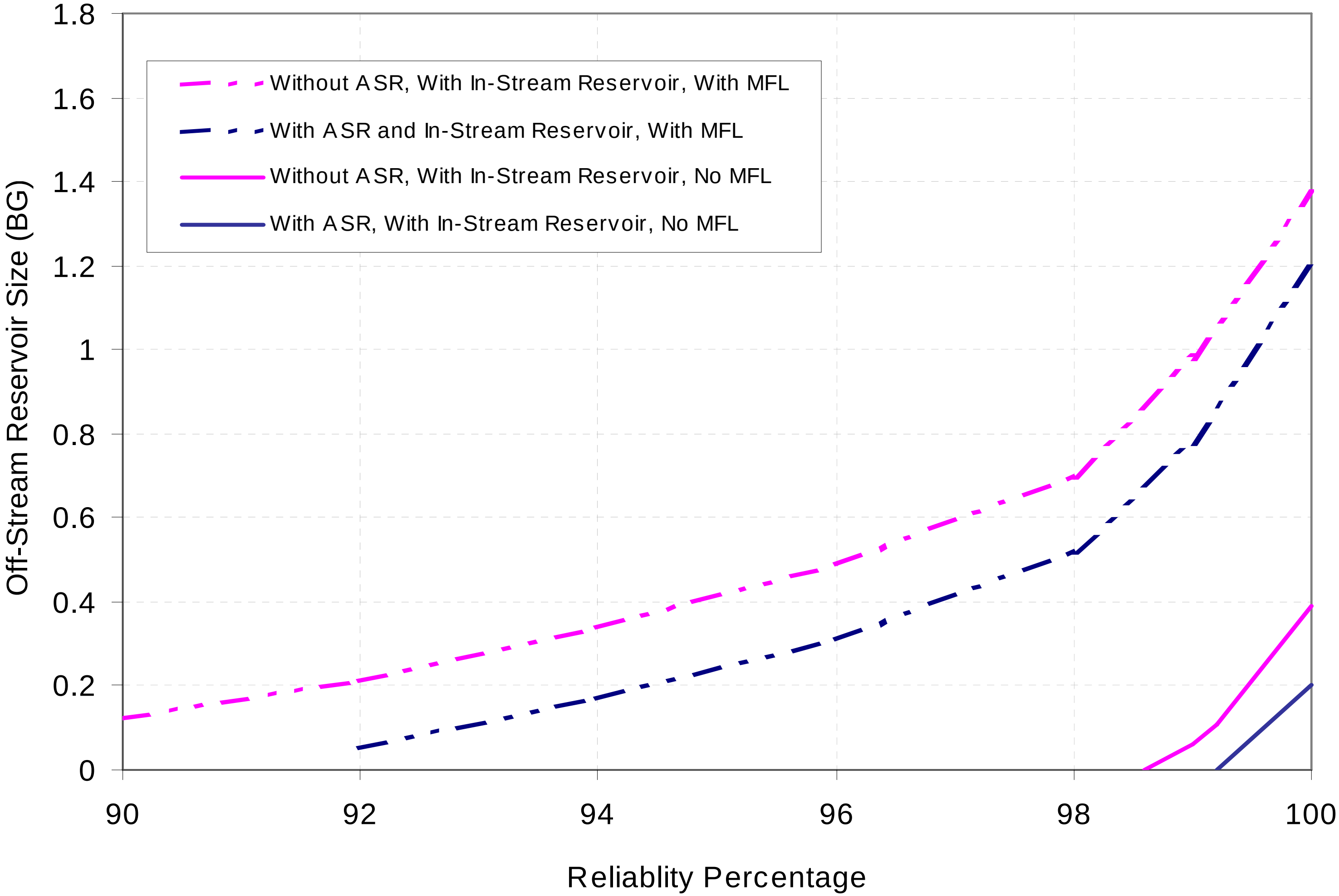
Required Off-Stream Reservoir Size With and Without MFL



Note: Reservoir size reflects capacity needed to meet only quantity reliability, with no provision for using the off-stream reservoir for blending to meet water quality requirements.

FIGURE 1.9

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1.6 TECHNICAL REVIEW OF MFL DEVELOPMENT

The technical review of the “Peer Review Draft MFL” includes brief summaries of the various chapters, but ultimately focuses on Chapters 7 and 8, in which the MFL is developed. Questions and comments on the “Peer Review Draft” are interspersed in this section, and additional comments and questions are provided in Section 1.6.2.

1.6.1 MFL Report Summary and Comments

Chapter 1 - Purpose and Background of Minimum Flows and Levels provides background on the legislative aspects, conceptual approach, and introduction to the chapters contained in the MFL report. Relevant language is in the conceptual approach whereby it is stated that “the District applied the percent of flow method to determine minimum flows for the LPR and the SC.” In addition, it is stated that “the method is oriented for use on unimpounded rivers that still retain a largely natural flow regime” (Flannery et al. 2002).

It should be noted that Shell Creek (SC) is impounded although it is not clear how the section of Shell Creek below the impoundment (the section for which an MFL is proposed) has been impacted by the impoundment. At the very least, the dam is the upper limit of tidal influence.

It is further stated that the goal of the percent of flow method is that the natural flow regime of the river be maintained, albeit with some flow reduction for water supply. It is also stated that natural flow regimes have short-term and seasonal variations. For reasons discussed later in the summary of Chapter 7, it is not clear to what extent the proposed block-flow MFL flow-reduction schedule maintains this goal.

Chapter 2 - Description of the Lower Peace River and Shell Creek provides information on the physical characteristics of the watershed including sources of flow, geography, land use, soil types, bathymetry and morphology, vegetation, rainfall, freshwater flows, and sediment characteristics. The general format of the report is to present information on the Peace River first and then Shell Creek. Because of the comparative sizes and information available, there generally is more information available for Peace River than Shell Creek.

There is a USGS gage (02298202) at Shell Creek on the control structure, i.e., the Hendrickson Dam. As discussed previously, the reservoir behind the dam provides water supply for the City. Peak streamflow occurs from June through October with August having the maximum flow. Various notes and comments on Chapter 2 include the following:

- Captions for Figures 2-20, 2-21, and 2-22 on pages 2-20 and 20-21 should be corrected to reference withdrawals by the Peace River Manasota Regional Water Supply Authority (PRMRWSA) instead of flows. Figure 2-20 shows an increasing trend of withdrawals by PRMRWSA averaging about 0.8 cubic feet per second (cfs) per year since 1982. What quantifiable effect, if any, this has had on the Lower PR (LPR) salinity regime in the vicinity of SC is not addressed.

- On page 2-27, Section 2.2.4, the City of Punta Gorda water use permit quantities are incorrect. The City received a new permit (#20000871.008) on June 26, 2007, which allows an average permitted withdrawal of 8.088 mgd and a peak month withdrawal of 11.728 mgd.

- Additional characterization of historic flows is needed on page 2-29 to describe the context for reviewing various periods such as the SC MFL flow baseline (calendar years 1966 through 2004), water quality monitoring data (1996 to 2004), benthos surveys (1999 and 2003), and fish / zooplankton survey (2002).

- Graphs summarizing withdrawals from SC reservoir, similar to those prepared for the LPR, would be informative. The long-term flow hydrograph for Shell Creek (Figure 2-33) appears to illustrate a trend of increasing flow. A double-mass curve analysis of rainfall and SC flow or simple regression between annual flow and annual rainfall could be used to detrend the historic data for variations in rainfall which may, or may not, make a trend more evident. In summary, later in Chapter 7 it appears that water quality and biological data indicative of more recent conditions are being associated with “block” flow statistics based on a much longer period of record that does not appear to be stationary.

Chapter 3 - Water Quality Characteristics of Shell Creek contains a historical review of studies completed on Shell Creek followed by discussions of salinity, temperature, chlorophyll a, and spatial and temporal variations of these parameters. Of particular interest, because it plays a defining role in the MFL, is the distribution of salinity in SC. Various notes, comments, and questions on Chapter 3 include the following:

- The last paragraph on page 3-32 states that salinity was observed to increase by 6.6 percent of the median value for bottom measurements and 5.5 percent of the median value per year for the surface measurements from 1991 to 2001. Matching conductivity trends also were reported. Comparatively large increases in chloride and conductivity were also reported for Shell Creek Reservoir. Based on this information, and perhaps other lines of data, has the contribution of agricultural runoff to flow been evaluated? A concern is that a portion of the historical flow record represents a contribution from agriculture and this flow may change as agricultural water use changes.

- Referring to page 3-32: Were the water-quality trend tests performed on flow-adjusted concentrations or on the measured concentrations? Where are Stations No. 1 and 2 located? They are not shown in Figure 2-26.

- Superposition of a flow-duration plot for the period 1996 to 2005 onto the baseline period flow duration in Figure 2-35 would be an informative graphic for comparing recent hydrologic conditions with long-term conditions (page 3-33).

- Referring to page 3-53, longitudinal salinity plots similar to Figure 3-75 are needed for the seasonal blocks of time discussed later in Chapter 7. In addition to box-and-whisker plots, longitudinal plots of the discrete salinity measurements at the location of observation (similar to Figure 2a by Jassby, et.al. 1994 and to longitudinal plots of median salinity illustrated in SC / LPR Report Figure 4-5) are needed to better illustrate the spatial interval within which a particular salinity occurs.

Chapter 4 - Benthic Macroinvertebrate Community provides a discussion of the benthic communities and their relation to the salinity regime in an estuarine system. Some species are limited in extent because of osmotic limitations while others can tolerate a wide range of salinities. Likewise, the benthic communities are impacted by sediment transport and nutrient and organics transport.

SC had salinity/abiotic characteristics similar to river kilometer (RKM) 16 to 34 of the Lower Peace River. Salinities were oligohaline (0.7 to 2.7 ppt) in a study by Mote Marine in 2003. On page 4-17, the community structure of SC is reported to be similar to Zone 2 of the Peace River, i.e., a lower salinity habitat than where the SC enters the LPR. The following questions and comments are presented regarding Chapter 4:

- On page 4-17, the explanation of the relationship between salinity and benthics is not entirely clear. Does the relationship support a critical salinity metric of 2 ppt?

- On page 4-24, Figure 4-5 (a salinity plot) does not match the discussion of dissolved oxygen (DO) in this section.

- Figure 4-5 on page 4-25 seems out of place and could be moved to Chapter 3. Comparison of the long-term (1976 to 1999) plot with the more recent (1996 to 1999) plot indicates the more recent period is associated with somewhat lower salinities. The mouth of SC is at PR kilometer 15, the border between Zones 2 and 3, which has a distinctly lower median salinity more recently than compared to the long-term median. This would seem to imply that the biological community sampling performed relatively recently in SC may be indicative of a lower salinity environment than has historically existed.

- On pages 4-37 and 4-38, it appears that the dominant taxa in the SC have a relatively wide salinity tolerance range. Does this conclusion support a conservative metric (e.g., 15 percent reduction 2 ppt habitat- see Chapter 8)?

Chapter 5 - Fish Communities of the Lower Peace River and Shell Creek includes information on the distribution of fish species and the relationship between the distribution and abundance as a function of water quality and flow. A number of studies including recent work (EQL, FWRI, USF/DEM (Peebles 2002), FWC/FWRI (Greenwood et al. 2004).

Results and discussion on pages 5-23 and 5-24 provide the most relevant summary information of the abundance and distribution of fish in relation to flow. The following questions and comments are presented regarding Chapter 5:

- On pages 5-27 and 5-28 (Figures 5-9 and 5-10), the y-axis label should be changed to "# of Organisms / Sample." The current label implies a population count.

- An illustration of the linkage between a biological resource metric, salinity, and location (similar to Figure 5 by Jassby et. al, 1994) is needed to more clearly substantiate the selection of a specific salinity target. This would seem important because the development of the MFL is based on the reduction in an isohaline-specific estuary volume (a distance-related characteristic). The plot of abundance by four zones (Figure 5-10) does not illustrate much spatial variation (perhaps because it is a plot of individuals per trawl sample, instead of overall number of individuals within the zone). The principal components analysis and plots (such as Figures 5-11 and 5-12) illustrate the influence of salinity, but not of location and season. The report identifies a salinity range for class 1 of 1-3 ppt based on a score of 0.60 used as a criterion (Figure 5-11). However, it could be argued that salinities out to 4-5 ppt still load heavily (>0.5) on this component.

Chapter 6 - Relationship between Flow and Water Quality Constituents includes a review of historical studies of the relationships between flow and water quality constituents and a review observed empirical relationships that describe how freshwater inflow affects responses salinity and other WQ parameters. The following questions and comments are presented for Chapter 6:

- The natural log function is missing from the generic fixed station regression equation developed for the LPR on page 6-5. Similarly, the coefficients listed in Table 6-2 on page 6-10 and equation listed on page 6-5 for the LPR isohaline model do not seem to match well with the plots (Figures 6-5, 6-6 and 6-7). For example, the calculated RKM associated with 12 ppt and a flow of 500 cfs is 4.385 rkm, but the data plotted in Figure 6-7 would seem to indicate a value of seven is more appropriate.

- Referring to Figure 6-3, what are the zero ppt data associated with flows between 0 and 350 cfs attributable to? This situation is not apparent in the plots for the more upstream USGS gage (Figure 6-4) or the plots based on HBMP data (Figures 6-1 and 6-2).
- A figure illustrating longitudinal distribution of the HBMP data (i.e. discrete salinity measurements versus LPR kilometer) would be useful.

Chapter 7 - Applications of Modeling Tools that Relate freshwater Inflows to Salinity in Shell Creek and the lower Peace River provides a discussion of the following for Shell Creek:

- Biologically-relevant salinities
- Habitat assessment metrics
- Seasonally-specific assessment periods
- Modeling tools that relate salinity to flows (in Shell Creek)
- Study area definition
- Baseline period
- Modeling period
- Baseline scenario
- Habitat availability as a function of inflow

In essence, Chapter 7 forms the basis for the MFL on Shell Creek.

The development of the tools for setting MFLs begins in Chapter 7. For Shell Creek, SWFWMD uses the volume of water in Shell Creek with salinities below 2 ppt as the key metric. The volume of water is determined between RKM 2.35 and 9.9 (i.e., the dam).

Biologically relevant salinities of 2, 5, and 15 ppt are discussed with reference to articles/reports by Jassby et al. (1995), Clewell et al. (1999), and WRA et al. (2005) for the 2 ppt regime. Principal component analysis results (Figures 5-11 and 5-12) are used to support the importance of salinity classes. Characterizations are by abundance, distribution, and dominance. An estimate of overall population, i.e. number of organisms, determined from sampling area-weighted counts (Jassby et.al., 1994) does not appear to have been considered.

Jassby et al. (1994) cites literature indicating the location of the 2 ppt isohaline approximates the upstream boundary of the estuarine turbidity maximum (ETM) which is defined as follows: Strong tidal forces push salinity upriver beneath the outflowing river water. The turbulence caused by this tidal forcing results in re-suspension of sediment and other particulate material present on the river bed. Concurrently, dissolved material in the river water flocculates when it comes into contact with the salt wedge pushing its way upriver. The combination of these two processes results in elevated levels of suspended particulate material: the ETM. Within the region of the ETM, material in the water column, and on the bed of the estuary, is trapped, re-suspended, and advected. ETMs vary in strength and distance they move with the tides depending on the strength of the tide and the flow of the river. The median top and bottom salinity profiles (Figure 4-5 on page 4-25) are generally supportive of this being the case in the LPR Zone 3.

Three habitat assessment metrics are discussed: volume of water, bottom area, and shoreline length related to a specific salinity regime. For SC, only the volume of water is used as a metric.

Seasonally-specific (i.e., flow specific) assessment periods are then discussed, and the building block approach is presented. An important discussion is presented on page 7-3 that summarizes the logic in the setting of the MFL on SC.

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."

The report goes on to say that "although 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 of ensuring the maintenance of similar, although dampened, natural hydrographic conditions (SWFWMD 2005a)." – The MFL Report for Middle Peace River segment.

Flow records are summarized and three flow time segments are identified – Block 1, 2, and 3, each representing a time of year and set of flow statistics.

The procedure for developing the MFL is then as follows:

1. A salinity regression equation is developed using average water column salinity and time (month), Shell Creek flow, salinity in Charlotte Harbor, tide, Peace River Flow, River kilometer, and River kilometer*Shell Creek flow interaction term.

2. Baseline flow conditions are defined as discharge at the gage (dam) plus City of Punta Gorda withdrawals.

3. Cumulative distribution functions (cdfs) are developed for salinity volumes at critical isohalines (2 and 5 ppt) for baseline flow conditions and baseline minus various flows. These cdfs are developed for 3 flow blocks and 2 flows within each block (above and below median) for a total of 6 sets of functions. The volume of water with salinity less than 2 ppt is determined between RKM 2.35 and 9.9. This volume is calculated for each building block and for each flow condition generating a series of cdfs.
   – Note importantly that RKM 9.9 is at the dam so this location in fact sets the upstream limit of the volume of water with a salinity less than 2 ppt

4. Significant harm is defined as a flow reduction that causes a 15 percent loss of habitat as measured by water volume less than 2 ppt. This is covered in Chapter 8.

The following questions and comments are presented regarding Chapter 7:

- On page 7-5, it is not clear why salinity data collected prior to 1997 were excluded from the regression analysis because the time of data collected was not recorded. If it assumed that field work is commonly done between about 8 a.m. and 4 p.m., the benefits of using data that span a longer time frame may outweigh the uncertainty with an estimated tide. In addition, the tide gage at Boca Grande is quite distant from SC. Were other closer tide gages evaluated? Missing periods of monthly measurements of Upper Charlotte Harbor at Black Marker and median tide were estimated for the modeling period (section 7.2.4, page 7-6).
  – As an alternative, tide could be omitted from the equation altogether to limit the amount of data that must be synthesized. Similar to the variable “Month,” tide cannot be “managed.” The r^2 may decrease slightly, but the overall standard error of prediction may not change.

- Referring to page 7-5, section 7.2.2: why is the lower 2.3 km of SC omitted from consideration? LPR Station 10 at LPR 7 km experiences 2 psu on occasion (Figure 3-1), as does LPR Station 12 at LPR 16 km (about 3 km upstream from mouth of SC).

- Referring to page 7-7, section 7.2.6, a figure illustrating longitudinal profiles of morphologic characteristics (cumulative volume, bottom area, shoreline length, and thalweg) are needed to illustrate how "highly correlated" the characteristics are. For the LPR, these metrics are not highly correlated. It would be beneficial to present seasonal or block analyses of the SC and LPR water quality and biology data that support the delineation of the blocks selected for these water bodies.
  - It is not entirely clear what the sentence "If the variability in flow within a block is appreciable, then it is prudent to refine the recommended MFL within a block by accounting for this variability" means. What calculations or statistics have been developed to characterize variability and by what standard is "appreciable" gauged? Block 1, the low-flow block, is likely to have the least variability as characterized by the coefficient of variation for daily flows during this 66 day period.
  - In Chapter 1, it is stated that the goal of the percent of flow method is that the natural flow regime of the river be maintained, albeit with some flow reduction for water supply. It is furthermore stated that natural flow regimes have short-term and seasonal variations. It is not clear to what extent the proposed block-flow MFL flow-reduction schedule maintains this goal.

- There is no mention of how the dam is considered in the analysis, which is in contrast to how the District treated the Lower Hillsborough River. It is understood that the structures are different but the dam still impacts the analysis.

Chapter 8 - District Recommendations for Shell Creek and Lower Peace River Minimum Flows presents the specific criterion for setting MFLs. The MFL criterion for SC is the flow that results in no more than a 15 percent reduction in available habitat relative to the baseline condition.

- Note importantly that the baseline condition is the historical flow record from 1966 through 2004, or after the reservoir was constructed. It is computed by adding the historical withdrawals back into the flow record.

The normalized area under the curve (NAUC) is calculated by taking the ratio of the area under the cdfs for the baseline and a series of cdfs that represent various flow reductions from baseline. This NAUC value is then plotted versus the flow reduction scenarios and where the value crosses 0.85 (i.e., a 15 percent habitat reduction) defines the flow reduction scenario for the MFL. This process is repeated for each building block and flow condition (above and below the median of each block).

- Note that 2 ppt is used over 5 ppt because it is more conservative. That is, by protecting the 2 ppt regime, the 5 ppt regime is protected but not visa versa.

The definition of NAUC is: The volume of water in SC with a salinity < 2 ppt under a flow reduction divided by the volume of water with a salinity < 2 ppt under baseline conditions. Under low flow conditions, both volumes are relatively quite small as the dam provides the physical upper boundary for the volume calculation.

- Note that the breakdown of the MFL by three “blocks” of time lacks specific analyses of biological and water quality data to substantiate the periods selected. In addition, it is not clear in the report how much the historic flow duration characteristics of SC below the dam would change in response to the proposed above- and below-block-median constraints on withdrawals.

1.6.2 Summary of Comments on Proposed MFL

The following comments are proposed on the “Peer Review Draft” of the proposed MFL for Shell Creek:

1. It seems problematic to use a method designed for uncontrolled rivers with a habitat volume formula that is constrained by a control structure.
2. Is it consistent with MFL objectives to try to return a segment of a river to a fictitious near historical condition while at the same time recognizing that the control structure will remain in place? The current habitat exists to some extent as a result of the control structure. Likewise, the relationship between salinity and flow is affected by the control structure or, at least, the extent is limited by the control structure. The baseline condition that is calculated is in fact simply a salinity regime that would exist with the control structure but without withdrawals. In addition, the MFL regime is an attempt to recreate or nearly recreate a condition that has never existed.
3. Because the control structure is the upstream boundary for the habitat volume calculation, a larger volume < 2ppt would be obtained by simply moving the control structure further upstream. For example, if one were to double the baseline volume by moving the control structure upstream, and the 2 ppt isohaline moved the same distance under the flow reduction scenarios, then the percent habitat reduction would be half. The point is that the control structure is controlling the habitat volume.

4. The measured flow regime also should be adjusted for agricultural contributions to flow. For example, if agricultural contributions to flow are reduced over time, it will reduce river flow and the allowable withdrawal.

5. In Figure 7-3, it appears that the salinity regime of 2 ppt does not exist at all for 92 percent of the Block 1 low flow time (it exists above a volume of 0.0 about 2.64 (.08 * .5 * 66) days out of the year), and while the volume difference may be 15 percent it really is a small reduction in volume. By reducing flow by 10 percent, the 2 ppt salinity regime exists about 2.31 days per year and 1.98 days per year at a 20 percent reduction in flow. Perhaps 15 percent "habitat loss" as defined by the 2 ppt volume criterion is not so critical at this low flow. It would be much more useful if the x-axis in the CDF plots was changed from percent of days to the actual number of days. This would more clearly indicate the significance of a potential harm, presuming that a condition like 15 percent habitat reduction expected to occur for a longer period of time is potentially more harmful than the same reduction for a short period. Given the importance of maintaining the water supply, it might be appropriate to compare the absolute loss of a salinity regime (both volume and number of days) instead of the relative loss.

6. It is surprising that Figures 7-3 and 7-4 are so different when the medians are so similar.

7. It should be noted that "maintenance of freshwater storage and supply" is a WRV to be considered. It might be worthwhile to compare the loss of supply against the expected impact to the estuarine resource, particularly for Block 1 and low flow condition.

8. The allowable flow reduction when flow is "above the median" seems counter-intuitive to the reduction allowable when flow is "below the median." The discussion given for Block 1 is used as an example.
   - When flow (Q) is below the median (M), the allowable withdrawal is 10 percent of the flow or 0.1Q. This indicates that the regulatory threshold is independent of the median, other than the median being a "hinge" point at which the allowable percentage of flow changes. Furthermore, the allowable withdrawal would decrease if the median flow decreases with time. When flow is above the median, the allowable withdrawal is described as 10 percent of the median plus 23 percent of the flow above the median, which expressed mathematically equals 0.1M + 0.23(Q-M) or 0.23Q - 0.13M.
   - The "above the median" rule implies that greater withdrawals can be made if the median decreases over time, and vice versa. This also prompts the question regarding how long a baseline median should be retained as a regulatory threshold.

9. On page 8-3, it is stated that the selection of 2 ppt in lieu of 5 ppt is because "… 2 ppt in SC requires a higher flow ….than 5 ppt." It is not clear from this statement whether the 2 ppt is any more protective of water resource values 2 and 3 (fish and wildlife habitats and the passage of fish and estuarine resources) than 5 ppt.

10. The proposed MFL for the 7.55 km stretch of Shell Creek below the dam is based upon no more than a 15 percent reduction in habitat less than 2 ppt. What is not examined in the report is the question of how much of the entire amount of less than 2 ppt habitat within the Lower Peace River system is the portion that Shell Creek represents. With respect to the < 2 ppt salinity value, the Jassby et al. (1995) publication was reviewed. The 2 ppt isocline clearly applied to San Francisco Bay ("the utility of this value may be peculiar to this estuary," p. 275) and was chosen 1) "because it is a useful length-scale for parameterizing the salt field of the estuary" and 2) it describes the boundary between downstream and upstream reaches characterized by vertical stratification and little to no stratification, respectively.

11. Although SWFWMD does cite several reasons in support of the < 2 ppt value used, the metric is not clearly well justified with regard to SC, although it does not appear to be unreasonable as a placeholder. It might be useful to determine the allowable flow reductions associated with, for example, 3 or 4 ppt.

12. The 15 percent threshold of loss in habitat (i.e., volume) although somewhat arbitrary does not appear unreasonable. Significant harm is inherently a value-based decision. However, it is not clearly evident from the "Peer Review Draft" that, for Shell Creek, the reduction level for the 2 ppt metric would definitely constitute "significant harm." Dr. Emery notes, "The proposed MFL for the 7.55 Km stretch of Shell Creek below the dam is based upon no more than a 15% reduction in habitat less than 2 ppt. What is not examined in the report is the question of how much of the entire amount of less than 2 ppt habitat within the Lower Peace River system is the portion that Shell Creek represents" (see comment 10). This is a very important point. It is not very clear from the report how Shell Creek interacts with the LPR ecologically or how important the 2 ppt habitat within Shell Creek is to the LPR system as a whole.

13. Volume was selected for use in flow reduction scenario impact calculations for Shell Creek because the other two habitat metrics (bottom area, shoreline length) were highly correlated with volume. The main body of the report in Section 7.2.6 does not detail these correlations. It could be instructive to consider these other metrics. For the LPR, these metrics were not highly correlated. Tables 8-2, 8-3, and 8-4 report the allowable percent reductions in flow based on volume, bottom area, and shoreline length for the LPR. The tables show that percent reductions in flow increase as bottom area and

shoreline are considered. The volume metric provides the most conservative allowable flow reduction values.

14. The statute requires "structural alterations" to be taken into account by the water management districts in the establishment of MFLs. The District has done this in a different MFL involving a dam and a water supply withdrawal upstream of the dam (Lower Hillsborough River MFL). It is not clear that the District has treated the City of Punta Gorda's situation in a similar fashion.

15. Based on the current Draft MFL Report, it appears that Shell Creek would be in recovery. Is it the District's position that significant harm has occurred and that a recovery plan is needed? This appears to be a unique assertion, i.e., since it is assumed that significant harm will occur with a 15 percent loss of habitat, and since it can be demonstrated that a 15 percent loss of a narrowly defined habitat has occurred, then one can conclude that significant harm has occurred. Again, it poses the question - does the District believe that significant harm has actually occurred?

1.7 CONCLUSIONS AND RECOMENDATIONS

If the proposed MFL had been in place during the period of 1996 to 2006, the City's withdrawals would have been limited if the in-stream reservoir could not be used, as well as if it could be used only when the flow over the dam was zero. All years during this period have days when the City would not have been able to meet its full demand, and during some years the City would not have been able to meet its demand during one-third of the year. Blocks 1 and 2 prove to be the most restrictive, with almost all restricted withdrawal days occurring in those blocks. If the in-stream reservoir were treated as a stand-alone water body, the MFL would have resulted in no restricted flow days, but would have required significant modifications to the dam so that it could augment downstream flow.

To achieve reliability above 95 percent in meeting future demands, an off-stream reservoir is required. If the off-stream reservoir is the only water storage utilized, an 800 MG reservoir is needed to meet 95 percent reliability for both water quality and quantity reliability (meet entire projected demand and TDS concentration of 450 mg/L on 95 out of 100 days). A reservoir size of 740 MG is required for 95 percent reliability when considering quantity alone assuming ASR wells are not utilized.

If the in-stream reservoir can be used when the flow over the dam reaches zero flow, 95 percent reliability requires an off-stream reservoir size of 620 MG if ASR wells are not utilized.

It should be noted that although the City has used 95 percent reliability as a baseline during previous water master planning efforts, the City may choose to increase the reliability percentage when considering the size of an off-stream reservoir needed. A reliability of 95 percent correlates to 18 days per year of not meeting the City's entire demand. A reliability of 98 or 99 percent decreases this number of days to 7 and 4, respectively.

When considering the overall impact of the proposed MFL on the City, it is important to note that with no MFL restriction on withdrawals, the reliability of the existing system is well above the 95 percent criteria. When utilizing the in-stream reservoir and under no MFL restrictions, the reliability of the existing system to meet build-out water demands is above 98 percent. The existing system without ASR wells yields a reliability of 98.6 percent; the use of ASR wells increases the reliability to 99.2 percent. Because 98 percent reliability is higher than other typical planning reliabilities utilized in the region, the need for building an off-stream reservoir for the City of Punta Gorda water system is solely based on the restrictions of the MFL.

In the review of the proposed MFL with SWFWMD, it would be useful to generate a flow duration curve for baseline, MFL, and the City's current withdrawal schedule (either by permit or actual). There may be very little difference between the MFL scenario and the "City" scenario. Parsed into blocks, there may be some noticeable difference in Block 1. Given the lack of demonstrated significant harm, and the impact to City, some adjustment to the MFL could be appropriate.

This approach makes provisions for the limited data available, the lack of a clear indication of real significant harm, and the application of the procedure to a controlled river with an in-stream reservoir.

What really appears to be limited by the proposed MFL is the movement of the 2 ppt isohaline to about 85 percent of its baseline position (i.e., position without withdrawal) relative to the dam. Evidence that the movement of the 2 ppt isohaline has caused significant harm is questionable. It may be more appropriate to evaluate the habitat volume between two isohalines that exist under baseline conditions and that are unaffected by the physical footprint of the dam (e.g., the change in the volume of habitat between 5 and 7 ppt under baseline versus the MFL condition).

The City should document their projected water demands over the next permit cycle, and discuss with the SWFWMD how the District may be able to utilize the "structural alteration" component of the statute to allow the City some adjustments to the MFL. The City of Punta Gorda could point to the "seasonal adjustment" scale provided to the City of Tampa by the District as an example.

1.8 REFRENCES

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HSW ENGINEERING DECEMBER 14, 2007 MEMORANDUM: TECHNICAL REVIEW

MEMORANDUM

To: Ms. Laura Baumberger, P.E.

From: Ken Watson, Ph.D. and Dean Mades and consultation with Brian Ormiston, Ph.D. and Scott Emery, Ph.D.

Date: December 14, 2007

Re: Draft Technical Review of the Report

Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek, SWFWMD, August 24, 2007 Peer Review Draft.

HSW Engineering, Inc. (HSW) was retained by Carollo Engineers to complete a technical review of the referenced report. Included in the review is an evaluation of the technical methodologies, data and assumptions made in developing the rule, including an **evaluation of the appropriateness of the 2 ppt isohaline as a critical metric**, and other assumptions related to biology of Shell Creek. An investigation of how the Minimum Flows and Levels (MFL) report links its assumptions and recommendations to the **definition of "significant harm"** in State rules.

This review includes brief summaries of the report sections but ultimately focuses on sections 7 and 8 in which the MFLs are developed. Questions and comments are interspersed in this review document and some additional comments and questions are provided at the end.

Introduction

The MFL Program within the State of Florida is based on the requirements of Chapter 373.042 Florida Statutes. This statute requires that either a Water Management District (WMD) or the Department of Environmental Protection (DEP) establish minimum flows for surface watercourses and minimum levels for groundwaters and surface waters. The statutory description of a minimum flow is "the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area" (Ch. 373.042 (1)(a), F.S.).

The statute provides additional guidance to the WMDs and DEP on how to establish MFLs, including how they may be calculated, using the "best information available," to reflect "seasonal variations," when appropriate. Protection of non-consumptive uses also are to be considered as part of the process, but the decision on whether to provide for protection of non-consumptive uses is to be made by the Governing Board of the WMD or the DEP (Ch. 373.042 (1) (b), F.S.).

The statue also states that “When establishing minimum flows and levels pursuant to s. 373.042, the department or governing board shall consider 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 an affected watershed, surface water, or aquifer, provided that nothing in this paragraph shall allow significant harm as provided by s. 373.042(1) caused by withdrawals.”

WMDs are to develop priority lists of water courses and water bodies for which to establish MFLs and the proposed schedules to do so. These lists are to be updated yearly and sent to DEP for review and approval. In developing these lists, the WMDs are to examine the importance of the watercourse or water body to the State or region and the potential for significant harm to the water resources or ecology.

As discussed, Chapter 62-40.473 F.A.C lists ten water resource values (WRVs) that may be considered when developing MFLs. These include:

1. recreation in and on the water
2. fish and wildlife habitats and the passage of fish
3. estuarine resources
4. transfer of detrital material
5. maintenance of freshwater storage and supply
6. aesthetic and scenic attributes
7. filtration and absorption of nutrients and other pollutants
8. sediment loads
9. water quality
10. navigation

MFL Report Summary

Section 1 Purpose and Background of Minimum Flows and Levels provides back ground on the legislative aspects, conceptual approach and introduction to the chapters contained in the MFL report. For this review the relevant language is in the conceptual approach whereby it is stated that “the District applied the percent of flow method to determine minimum flows for the LPR and the SC.” In addition it is stated that “the method is oriented for use on unimpounded rivers that still retain a largely natural flow regime (Flannery et al. 2002).

- HSW points out that Shell Creek (SC) is impounded although it is not clear how the section of Shell Creek below the impoundment (the section for which an MFL is proposed) has been impacted by the impoundment. At the very least, the dam is the upper limit of tidal influence.

It is further stated that the goal of the percent of flow method is that the natural flow regime of the river be maintained, albeit with some flow reduction for water supply. It is also stated that natural flow regimes have short-term and seasonal variations. For reasons discussed later in

Section 7, it is not clear to what extent the proposed block-flow MFL flow-reduction schedule maintains this goal.

Section 2 Description of the Lower Peace River and Shell Creek provides information on the physical characteristics of the watershed including sources of flow, geography, land use, soil types, bathymetry and morphology, vegetation, rainfall, freshwater flows, and sediment characteristics. The format of the report generally is to present information on the Peace River first and the Shell Creek. Because of the comparative sizes and information available, there generally is more information available for the Peace River than Shell Creek.

There is a USGS gage (02298202) at Shell Creek on the control structure or SC dam. The reservoir behind the dam provides the water supply for the city of Punta Gorda. Peak flows occur from June through October with August having the maximum flow. The current water use permit allows for 8.3 cfs average and 10.7 maximum monthly withdrawals.

- **Pages 2-20 and 2-21.** The captions on Figures 2-20, 2-21, and 2-22 should reference withdrawals by PRMRWSA instead of flows. Figure 2-20 shows an increasing trend of withdrawals by PRMRWSA averaging about 0.8 cfs/yr since 1982. What quantifiable affect, if any, this has had on the LPR salinity regime in the vicinity of SC is not addressed.

- **Page 2-29.** Additional characterization of historic flows is needed to describe the context for reviewing various periods such as the SC MFL flow baseline (calendar years 1966 through 2004), water quality monitoring data (1996 - 2004), benthos surveys (1999 and 2003), and fish / zooplankton survey (2002).

- Graphs summarizing withdrawals from SC reservoir, similar to those prepared for the LPR, would be informative. The long-term flow hydrograph for Shell Creek (figure 2-33) appears to illustrate a trend of increasing flow. A double-mass curve analysis of rainfall and SC flow or simple regression between annual flow and annual rainfall could be used to detrend the historic data for variations in rainfall which may, or may not, make a trend more evident. In summary, later in Chapter 7 it appears that water quality and biological data indicative of more recent conditions are being associated with "block" flow statistics based on a much longer period of record that does not appear to be stationary.

Chapter 3 Water Quality Characteristics of Shell Creek contains a historical review of studies completed on Shell Creek followed by discussions of salinity, temperature, chlorophyll a, and spatial and temporal variations of these parameters.

Of particular interest because it plays a defining role in the MFL is the distribution of salinity in SC.

- Page 3-32 last paragraph states that salinity was observed to increase by 6.6% of the median value for bottom measurements and 5.5% of the median value per year for the surface measurements from 1991 to 2001. Matching conductivity trends also were reported. Comparatively large increases in chloride and conductivity were also reported for the SC reservoir. Based on this information and perhaps other lines of data, has the contribution of agricultural runoff to flow been evaluated? A concern is that a portion of the historical flow record represents a contribution from agriculture and this flow may change as agricultural water use changes.

- Page 3-32. Were the water-quality trend tests performed on flow-adjusted concentrations or on the measured concentrations? Where are stations No. 1 and 2 located? They are not shown in Figure 2-26.

- Page 3-33, Section 3.2.2. Superposition of a flow-duration plot for the period 1996 to 2005 onto the baseline period flow duration (Figure 2-35) would be an informative graphic for comparing recent hydrologic conditions with long-term conditions.

- Page 3-53, Section 3.2.2.3. Longitudinal salinity plots similar to Figure 3-75 are needed for the seasonal blocks of time discussed later in Section 7. In addition to box-and-whisker plots, longitudinal plots of the discrete salinity measurements at the location of observation (similar to Figure 2a by Jassby, et.al. 1994 and to longitudinal plots of median salinity illustrated in SC / LPR report Figure 4-5) are needed to better illustrate the spatial interval within which a particular salinity occurs.

Chapter 4 Benthic Macroinvertebrate Community provides a discussion of the benthic communities and their relation to the salinity regime in an estuarine system. Some species are limited in extend because of osmotic limitations while others can tolerate a wide range of salinities. Likewise the benthic communities are impacted by sediment transport and nutrient and organics transport.

SC had salinity/abiotic characteristics similar to river kilometer (RKM) 16 to 34 of the Lower Peace River. Salinities were oligohaline (0.7 to 2.7 ppt) in a study by Mote Marine in 2003. On page 4-17, the community structure of SC is reported to be similar to Zone 2 of the Peace River, i.e., a lower salinity habitat than where the SC enters the LPR.

- Page 4-17. The explanation of the relationship between salinity and benthics is not entirely clear. **Does the relationship support a critical salinity metric of 2 ppt?**
- Page 4-24, Section 4.4.5.2. Figure 4-5 (a salinity plot) does not match the discussion of DO in this section.
- Figure 4-5 on page 4-25 seems out of place and could be moved to section 3. Comparison of the long term (1976 – 1999) plot with the more recent (1996 – 1999) indicates the more recent period is associated with somewhat lower salinities. The mouth of SC is at PR kilometer 15, the border between zones 2 and 3, which has a distinctly lower median salinity more recently than compared to the long-term median. This would seem to imply that the biological community sampling performed relatively recently in SC may be indicative of a lower salinity environment than has historically existed.

- Page 4-37, 38. It appears that the dominant taxa in the SC have a relatively wide salinity tolerance range. **Does this conclusion support a conservative metric (e.g., 15 % reduction 2 ppt habitat- see section 8)?**

Chapter 5 Fish Communities of the Lower Peace River and Shell Creek. This section includes information on the distribution of fish species and the relationship between the distribution and abundance as a function of water quality and flow. A number of studies including recent work (EQL, FWRI, USF/DEM (Peebles 2002), FWC/FWRI (Greenwood et al. 2004).

Results and discussion on page 5-23, 24 provides the most relevant summary information of the abundance and distribution of fish in relation to flow.

- Pages 5-27, 28 (Figures 5-9 and 5-10): Y-axis label should be changed to "# of Organisms / Sample". The current label implies a population count.

- An illustration of the linkage between a biological resource metric, salinity, and location (similar to Figure 5 by Jassby et. al, 1994) is needed to more clearly substantiate the selection of a specific salinity target. This would seem important because the development of the MFL is based on the reduction in an isohaline-specific estuary volume (a distance-related characteristic). The plot of abundance by four zones (Figure 5-10) does not illustrate much spatial variation (perhaps because it is a plot of individuals per trawl sample, instead of overall number of individuals within the zone). The principal components analysis and plots (such as Figures 5-11 and 5-12) illustrate the influence of salinity, but not of location and season. The report identifies a salinity range for class 1 of 1-3 ppt based on a score of 0.60 used as a criterion (Figure 5-11). However, it could be argued that salinities out to 4-5 ppt still load heavily (>0.5) on this component.

Chapter 6 Relationship between Flow and Water Quality Constituents. This section includes a review of historical studies of the relationships between flow and water quality constituents and a review observed empirical relationships that describe how freshwater inflow affects responses salinity and other WQ parameters.

- Page 6-5. The natural log function is missing from the generic fixed station regression equation developed for the LPR. Similarly, the coefficients listed in Table 6-2 on page 6-10 and equation listed on page 6-5 for the LPR isohaline model do not seem to match well with the plots (Figures 6-5, 6-6 and 6-7). For example, the calculated RKM associated with 12 ppt and a flow of 500 cfs is 4.385 rkm, but the data plotted in Figure 6-7 would seem to indicate a value of 7 is more appropriate.

- Page 6-8, Figure 6-3. What are the zero ppt data associated with flows between 0 and 350 cfs attributable to? This situation is not apparent in the plots for the more upstream USGS gage (Figure 6-4) or the plots based on HBMP data (figures 6-1 and 6-2).

- A figure illustrating longitudinal distribution of the HBMP data (i.e. discrete salinity measurements versus LPR kilometer) would be useful.

Chapter 7 Applications of Modeling Tools that Relate freshwater Inflows to Salinity in Shell Creek and the lower Peace River Provides a discussion of the following for Shell Creek:

- biologically-relevant salinities,
- habitat assessment metrics
- seasonally-specific assessment periods,
- modeling tools that relate salinity to flows (in Shell Creek)
- study area definition
- baseline period
- modeling period
- baseline scenario
- habitat availability as a function of inflow

When all is said and done, this chapter forms the basis for the MFL on Shell Creek.

The development of the tools for setting MFLs begins. For Shell Creek the District uses the volume of water in Shell Creek with salinities below 2 ppt as the key metric. The volume of water is determined between RKM 2.35 and 9.9 (i.e., the dam).

Biologically relevant salinities of 2, 5, and 15 ppt are discussed with reference to articles/reports by Jassby et al. (1995), Clewell et al. (1999), and WRA et al. (2005) for the 2 ppt regime. Principal component analysis results (Figures 5-11 and 5-12) are used to support the importance of salinity classes. Characterizations are by abundance, distribution, and dominance. An estimate of overall population, i.e. number of organisms, determined from sampling area-weighted counts (Jassby et.al., 1994) does not appear to have been considered.

Jassby et al. (1994) cites literature indicating the location of the 2 ppt isohaline approximates the upstream boundary of the estuarine turbidity maximum (ETM) which is defined as follows (http://wiki.answers.com/Q/Estuarine_turbidity_maximum): Strong tidal forces push salinity upriver beneath the outflowing river water. The turbulence caused by this tidal forcing results in resuspension of sediment and other particulate material present on the river bed. Concurrently, dissolved material in the river water flocculates when it comes into contact with the salt wedge pushing its way upriver. The combination of these two processes results in elevated levels of suspended particulate material: the ETM. Within the region of the ETM, material in the water column, and on the bed of the estuary, is trapped, resuspended and advected. ETMs vary in strength and distance they move with the tides depending on the strength of the tide and the flow of the river. The median top and bottom salinity profiles (Figure 4-5 on page 4-25) are generally supportive of this being the case in the LPR zone 3.

Three habitat assessment metrics are discussed; volume of water, bottom area, and shoreline length related to a specific salinity regime. For SC, only the volume of water is used as a metric.

Seasonally-specific (i.e., flow specific) assessment periods are then discussed and the building block approach is presented. An important discussion is presented on page 7-3 that summarizes the logic in the setting of the MFL on SC.

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."

The report goes on to say that "Although 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 of ensuring the maintenance of similar, although dampened, natural hydrographic conditions (SWFWMD 2005a)." – The MFL Report for Middle Peace River segment.

Flow records are summarized and three flow time segments are identified – Block 1, 2, and 3, each representing a time of year and set of flow statistics.

The procedure for developing the MFL is then as follows:

1. A salinity regression equation is developed using average water column salinity and time (month), Shell Creek flow, salinity in Charlotte Harbor, tide, Peace River Flow, River kilometer, and River kilometer*Shell Creek flow interaction term.

2. Baseline flow conditions are defined as discharge at the gage (dam) plus City of Punta Gorda withdrawals.

3. Cumulative distribution functions (cdfs) are developed for salinity volumes at critical isohalines (2 and 5 ppt) for baseline flow conditions and baseline minus various flows. These cdfs are developed for 3 flow blocks and 2 flows within each block (above and below median) for a total of 6 sets of functions. The volume of water with salinity less than 2 ppt is determined between RKM 2.35 and 9.9. This volume is calculated for each building block and for each flow condition generating a series of cdfs.

    - **Note importantly that RKM 9.9 is at the dam so this location in fact sets the upstream limit of the volume of water with a salinity less than 2 ppt**

4. Significant harm is defined as a flow reduction that causes a 15% loss of habitat as measured by water volume less than 2 ppt. This is covered in Chapter 8.

- **Page 7-5, section 7.2.1.** It is not clear why salinity data collected prior to 1997 were excluded from the regression analysis because the time of data collected was not recorded. If it assumed that field work is commonly done between about 8 a.m. and 4 p.m., the benefits of using data that span a longer time frame may outweigh the uncertainty with an estimated tide. In addition, the tide gage at Boca Grande is quite distant from SC. Were other closer tide gages evaluated? Missing periods of monthly measurements of Upper Charlotte Harbor at Black Marker and median tide were estimated for the modeling period (section 7.2.4, page 7-6).

  As an alternative, tide could be omitted from the equation altogether to limit the amount of data that must be synthesized. Similar to the variable "Month", tide can not be "managed." The r^2 may decrease a bit, but the overall standard error of prediction may not change.

- **Page 7-5, section 7.2.2.** Why is the lower 2.3 km of SC omitted from consideration? LPR station 10 at LPR 7 km experiences 2 psu on occasion (Figure 3-1) as does LPR station 12 at LPR 16 km (about 3 km upstream from mouth of SC).

- **Page 7-7, section 7.2.6.** A figure illustrating longitudinal profiles of morphologic characteristics (cumulative volume, bottom area, shoreline length, and thalweg) are needed to illustrate how "highly correlated" the characteristics are. For the LPR, these metrics are not highly correlated. It would be beneficial to present seasonal or block analyses of the SC and LPR water quality and biology data that support the delineation of the blocks selected for these water bodies.

  It is not entirely clear what the sentence "If the variability in flow within a block is appreciable, then it is prudent to refine the recommended MFL within a block by accounting for this variability" means. What calculations or statistics have been developed to characterize variability and by what standard is "appreciable" gaged? Block 1, the low-flow block is likely to have the least variability as characterized by the coefficient of variation for daily flows during this 66 day period.

  In Section 1, it is stated that the goal of the percent of flow method is that the natural flow regime of the river be maintained, albeit with some flow reduction for water supply. It is furthermore stated that natural flow regimes have short-term and seasonal variations. It is not clear to what extent the proposed block-flow MFL flow-reduction schedule maintains this goal.

- There is no mention of how the dam is considered in the analysis, which is in contrast to how the District treated the Lower Hillsborough River. It is understood that the structures are different but the dam still impacts the analysis.

Chapter 8 District Recommendations for Shell Creek and Lower Peace River Minimum Flows presents the specific criterion for setting MFLs.

The MFL criterion for SC is the flow that results in no more than a 15% reduction in available habitat relative to the baseline condition.

- **Note importantly that the baseline condition is the historical flow record between 1966 through 2004 or after the reservoir was constructed. It is computed by adding the historical withdrawals back into the flow record.**

A normalized area under the curve (NAUC) is calculated by taking the ratio of the area under the cdfs for the baseline and a series of cdfs that represent various flow reductions from baseline. This NAUC value is then plotted versus the flow reduction scenarios and where the value crosses 0.85 (i.e., a 15% habitat reduction) defines the flow reduction scenario for the MFL. This process is repeated for each building block and flow condition (above and below the median of each block).

- **Note that 2 ppt is used over 5 ppt because it is more conservative. That is, by protecting the 2 ppt regime the 5 ppt regime is protected but not visa versa.**

The definition of NAUC is:

The volume of water in SC with a salinity < 2 ppt under a flow reduction divided by the volume of water with a salinity < 2 ppt under baseline conditions. Under low flow conditions, both volumes are relatively quite small as the dam provides the physical upper boundary for the volume calculation.

- Note that the breakdown of the MFL by three "blocks" of time lacks specific analyses of biological and water quality data to substantiate the periods selected. In addition, it is not clear in the report how much the historic flow duration characteristics of SC below the dam would change in response to the proposed above- and below-block-median constraints on withdrawals.

General Comments

1. It seems problematic to use a method designed for uncontrolled rivers with a habitat volume formula that is constrained by a control structure.

2. Is it consistent with MFL objectives to try to return a segment of a river to a fictitious near historical condition while at the same time recognizing that the control structure will remain in place? The current habitat exists to some extent as a result of the control structure. Likewise, the relationship between salinity and flow is affected by the control structure or, at least, the extent is limited by the control structure. The baseline condition that is calculated is in fact simply a salinity regime that would exist with the control

structure but without withdrawals. And the MFL regime is an attempt to recreate or nearly recreate a condition that has never existed.

3. Because the control structure is the upstream boundary for the habitat volume calculation, a larger volume < 2ppt would be obtained by simply moving the control structure further upstream. For example, if one were to double the baseline volume by moving the control structure upstream, and the 2 ppt isohaline moved the same distance under the flow reduction scenarios, then the percent habitat reduction would be half. The point is that the control structure is controlling the habitat volume.

4. The measured flow regime also should be adjusted for agricultural contributions to flow. For example, if agricultural contributions to flow are reduced over time, it will reduce river flow and the allowable withdrawal.

5. Figure 7-3 low flow (bottom graph). It appears that the salinity regime of 2 ppt does not exist at all for 92% of the Block 1 low flow time (it exists above a volume of 0.0 about 2.64 (.08 * .5 * 66) days out of the year) and while the volume difference may be 15% it really is a small reduction in volume. By reducing flow by 10%, the 2 ppt salinity regime exists about 2.31 days per year and 1.98 days per year at a 20% reduction in flow. Perhaps 15% "habitat loss" as defined by the 2 ppt volume criterion is not so critical at this low flow. It would be much more useful if the x-axis in the CDF plots was changed from percent of day to the actual number of days. This would more clearly indicate the significance of a potential harm, presuming that a condition like 15% habitat reduction expected to occur for a longer period of time is potentially more harmful than the same reduction for a short period.

   Given the importance of maintaining the water supply, it might be appropriate to compare the absolute loss of a salinity regime (both volume and number of days) instead of the relative loss.

6. It is surprising that Figures 7-3 and 7-4 are so different when the medians are so similar.

7. We note that "maintenance of freshwater storage and supply" is a WRV to be considered. It might be worthwhile to compare the loss of supply against the <u>expected</u> impact to the estuarine resource, particularly for Block 1 and low flow condition.

8. The allowable flow reduction when flow is "above the median" seems counter-intuitive to the reduction allowable when flow is "below the median." The discussion given for Block 1 is used as an example.

   When flow (Q) is below the median (M), the allowable withdrawal is 10% of the flow or 0.1Q. This indicates that the regulatory threshold is independent of the median, other than the median being a "hinge" point at which the allowable percentage of flow changes. Furthermore the allowable withdrawal would decrease if the median flow decreases with time. When flow is above the median, the allowable withdrawal is described as 10% of the median + 23% of the flow above the median which expressed mathematically equals 0.1M + 0.23(Q-M) or 0.23Q - 0.13M.

The "above the median" rule implies that greater withdrawals can be made if the median decreases over time, and vice versa. This also prompts the question regarding how long a baseline median should be retained as a regulatory threshold.

9. Page 8-3, Section 8.3.1. It is stated that the selection of 2 ppt in lieu of 5 ppt is because "… 2 ppt in SC requires a higher flow ….than 5 ppt." It is not clear from this statement whether the 2 ppt is any more protective of water resource values 2 and 3 (fish and wildlife habitats and the passage of fish and estuarine resources) than 5 ppt.

10. The proposed MFL for the 7.55 Km stretch of Shell Creek below the dam is based upon no more than a 15% reduction in habitat less than 2 ppt. What is not examined in the report is the question of how much of the entire amount of less than 2 ppt habitat within the Lower Peace River system is the portion that Shell Creek represents. With respect to the < 2 ppt salinity value, the Jassby et al. (1995) publication was reviewed. The 2 ppt isocline clearly applied to San Francisco Bay ("the utility of this value may be peculiar to this estuary" , p. 275) and was chosen 1) "because it is a useful length-scale for parameterizing the salt field of the estuary" and 2) it describes the boundary between downstream and upstream reaches characterized by vertical stratification and little to no stratification, respectively.

11. Although the SWFWMD does cite several reasons in support of the < 2 ppt value used, the metric is not clearly well justified with regard to SC, although it does not appear to be unreasonable as a placeholder. It might be useful to determine the allowable flow reductions associated with, for example, 3 or 4 ppt.

12. The 15% threshold of loss in habitat (i.e., volume) although somewhat arbitrary does not appear unreasonable. Significant harm is inherently a values based decision. However, it is not clearly evident from the Report that, for Shell Creek, the reduction level for the 2 ppt metric would definitely constitute "significant harm". Dr. Emery notes "The proposed MFL for the 7.55 Km stretch of Shell Creek below the dam is based upon no more than a 15% reduction in habitat less than 2 ppt. What is not examined in the report is the question of how much of the entire amount of less than 2 ppt habitat within the Lower Peace River system is the portion that Shell Creek represents." (see comment 10), and this is a very important point. It is not very clear from the Report how Shell Creek interacts with the LPR ecologically or how important the 2 ppt habitat within Shell Creek is to the LPR system as a whole.

13. Volume was selected for use in flow reduction scenario impact calculations for Shell Creek because the other two habitat metrics (bottom area, shoreline length) were highly correlated with volume. The main body of the report in 7.2.6 does not detail these correlations. It could be instructive to consider these other metrics. For the LPR, these metrics were not highly correlated. Tables 8-2, 8-3 and 8-4 report the allowable percent

reductions in flow based on volume, bottom area and shoreline length for the LPR. The tables show that percent reductions in flow increase as bottom area and shoreline are considered. The volume metric provides the most conservative allowable flow reduction values.

14. The statute requires "structural alterations" to be taken into account by the water management districts in the establishment of MFLs. The District has done this in a different MFL involving a dam and a water supply withdrawal upstream of the dam (Lower Hillsborough River MFL). It is not clear that the District has treated the City of Punta Gorda's situation in a similar fashion.

15. Based on the current draft MFL Report, it appears that Shell Creek would be in recovery. Is it the District's position that significant harm has occurred and that a recovery plan is needed? This appears to be a unique assertion - i.e., since it is assumed that significant harm will occur with a 15% loss of habitat and since it can be demonstrated that a 15% loss of a narrowly defined habitat has occurred, then significant harm has occurred. Again, it begs the question - has significant harm occurred?

Recommendations

1. It would be useful to generate a flow duration curve for baseline, MFL, and the city's current withdrawal schedule (either by permit or actual). There may be very little difference between the MFL scenario and the "City" scenario. Parsed into blocks, there may be some noticeable difference in Block 1. Given the lack of demonstrated significant harm, and the impact to City, some adjustment to the MFL could be appropriate.

   The City may want to point out the limited amount data available, the lack of a clear indication of real significant harm, and the application of the procedure to a controlled river.

2. What really seems to be limited by the MFL is the movement of the 2 ppt isohaline to about 85% of its baseline position (i.e., position without withdrawal) relative to the dam. Is there evidence that the movement of the 2 ppt isohaline has caused significant harm? It might be move appropriate to evaluate the habitat volume between two isohalines that exists under baseline conditions and that are unaffected by the physical footprint of the dam (e.g., the change in volume of habitat between 5 and 7 ppt under baseline versus MFL condition).

3. The City can examine current water demands, reasonable future projected demands over the next permit cycle, and discuss with the SWFWMD how the District may be able to utilize the "structural alteration" component of the statute to allow the City some adjustments to the MFL. The City of Punta Gorda can point to the "seasonal adjustment" scale provided to the City of Tampa by the District as an example.

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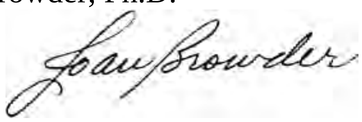
Date: July 28, 2009

To: Sam Stone
Environmental Affairs Coordinator
Peace River/Manasota Regional Water Authority

From: Joan Browder, Ph.D.



Subject: Comments on Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek Report dated April 2009

Thanks for the opportunity to review the final version of the MFL report. I reread sections 7 and 8 and also the appendix that includes the scientific peer review (Montagna et al) and the description of the statistical model for Shell Creek and the hydrodynamic model for the Lower Peace River.

I like the approach, as well as the information about faunal relationships to salinity that helps support the approach. But I question the decisions derived from the approach, especially the non-transparent way that the decisions were made. There is a lot of information missing from the report that needs to be present. The reader needs to see a table that shows the sensitivity of the three habitat metrics to flow reductions, by degree. While this is shown in the CDF plots, the area values that decisions are being based upon need to be shown in a table. The reader needs to see the percent flow reduction, by block, for different percentages of habitat lost (i.e., 5%, 10%, 15%, 20%). Furthermore, the reader needs to see the habitat loss by river zone (1 through 4), not just for LPR overall. While I like the concept of the application of the model, I am concerned about the accuracy of the model in predicting salinity—particularly at the extremes. Both the managers and the reviewers/readers need to see the model error in predictions at different salinity levels. One presentation of error might be as a histogram of error by salinity interval. The risk of leading to wrong decisions that these errors pose needs to be determined and shown.

The CDF plots in section 7 suggest, visually, that shoreline length is the most sensitive metric responding to flow (e.g., shoreline length < 2 ppt in Block 2); however the statement is made that volume is the most sensitive metric, and, based on that, only allowable withdrawal percentages based on volume are shown in the tables and proposed for MFL regulation. Again, I suggest a table that shows the calculated area between the curves for each of the metrics. It also would be informative to see the information, by metric, determined separately for each of the four zones of the Lower Peace River because the location of the 15% of habitat that is allowed to be lost may be important.

Is 15% habitat loss acceptable? What is the error involved in determining 15% habitat loss and what is the risk associated with the error? Maybe 10% habitat loss should be considered as a more conservative acceptable loss to account for the error in predictions.

The MFL report states that a low-flow threshold was not recommended because no statistical relationships were found between salinity and biological criteria in either the Lower Peace River or Shell Creek. This statement seems strange because the extent of work relating fauna to salinity in MFL sections 4 and 5 is substantial; and.a number of statistically significant relationships between fauna and salinity were presented. The MFL authors dismissed the regression relationships, even though highly significant, because the R^2's were no higher than 0.41. In fact, salinity was the variable that related best to faunal metrics. I question the rejection of statistically significant relationships with R2 <= 0.41 as "ecologically meaningless". Furthermore, I question the lack of a cutoff rule. The cutoff rule that has been used to protect the Peace River from water plant withdrawals has been extremely useful, as has the rule that limits removals to no more than 10% of flow except when flow is below the threshold. The cutoff rule serves a valuable role in protecting the river and estuary. Apparently it has been replaced by a block 1 opportunity to take up to 16% of flow, regardless of how low the flow might be. Is that sufficiently protective? A cutoff rule such as the one presently employed at the Peace River/Manasota water plan should be included in the MFL. Will the cutoff rule for the Peace River/Manasota water plant be discontinued because of the stated lack of support of a cutoff rule in the MFL?

P.S. I noticed in the model description section of the appendix that, several times, the word "Manatee" was used when the word "Myakka" was meant.

COMMENTS BY THOMAS H. FRASER, PhD
Scientific Review Panel Member
22602 Adorn Avenue
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8 June 2009

The Peace River/Manasota Regional Water Supply Authority (PRMRSWA) requested, via email (21 May 2009), the members of the Hydrobiological Monitoring Program Scientific Review Panel to provide comments to the PRMRWA and to the Southwest Florida Water Management District (SWFWMD) on the revised (April 2009) report – Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek.

My comments relate to the suggested flow thresholds (I), use of seasonal blocks for regulated flow withdrawals (II) and the use of differing percent of flow withdrawals associated with seasonal blocks (III).

I. Thresholds below which no regulated (permitted by water use permits) will be allowed.

The SWFWMD defines a low flow threshold as:
"...to be a flow that serves to limit withdrawals, with no withdrawals permitted unless the threshold is exceeded."(p. xvii)

The SWFWMD uses a low flow threshold only in an operational sense. Biological responses to inflow and all of the physical and chemical components carried with flow and interactions with salinity and tides have been set aside. The reliance on salinity to identify zoned habitats (in a continually changing gradient) rather than including primary production, detritus and subsequence food webs omits empirical information about initiation and duration of biological production in the tidal reaches of the Peace River, Shell Creek and in Charlotte Harbor. A low flow threshold or its proxy (salinity zones) without ecological-based definition(s) severely limit the ability to protect existing lower flows from withdrawals or other basin landscape changes that temporarily (long-term severing landscapes by mining or farming activities) or permanently have reduced flows (loss of base flow, dams & water control structures).

A. TIDAL SHELL CREEK

Shell Creek has an existing inline dam and a long history of use as a water supply for Punta Gorda. SWFWMD is proposing no low flow threshold based on the following:
"**After examination of the relationships between flow and several habitat variables, including salinity, chlorophyll *a*, and dissolved oxygen (DO) in Shell Creek, no clear, defensible, low flow threshold was identified for Shell Creek." (pp. xvii, 8-5, 8-7)**

SWFWMD proposes for the tidal Shell Creek maintenance of a year round salinity zone:
"After review of numerous criteria, the most protective criterion selected for Shell Creek was maintenance of the two ppt salinity zone." (pp. xvii)

No areal extent or duration of the <2ppt zone appears to be proposed other than the following statement:
"It should be noted, that if there is no inflow to the reservoir above the dam, then there is no minimum flow required below the dam." (pp.xvii)

Not stated, but perhaps implied is the maintenance of this zone during the dry season or other low flow periods. There is no information in the April 2009 report clarifying what SWFWMD may propose as part of the MFL for the <2 ppt desired zone. There are no estimates of base flow from the watershed above the dam. In the computer modeling, SWFWMD omitted the year 2000 because there was no measurable <2ppt zone below the dam. (pp. 7-39, 8-2). This information could have been compared with the other three years or perhaps the longer record to develop statistics for the area of <2ppt zone downstream of the dam leading to some recommended flows releases from the dam during no flow periods over the dam.

B. TIDAL PEACE RIVER

The tidal Peace River has no in stream dam to block the flow of brackish water upstream or to retain a portion of the flow similar to Shell Creek. The SWFWMD proposes for the tidal Peace River a low flow threshold based on the following:
"It is important to maintain freshwater at the PRMRWSA withdrawal point because saline water hinders the treatment process for the plant. Therefore, an operational criterion of maintaining freshwater (< 0.5 ppt) at the PRMRWSA plant was chosen as an acceptable criterion." (pp. xviii)

In answer to Comments from PRMRWSA HBMP Panel in the Appendices (April 2009) as follows:

"It was not the objective the MFL document to evaluate the PRMRWSA's permit. Rather it was the goal of the MFL to determine at what point withdrawals would constitute significant harm."
"It is more relevant than assessing changes in salinity at any given location, with the exception of salinity near the PRMRWSA intake."

An operational criterion of <0.5ppt has value to the PRMRWSA. No discussion was provided to determine if the application of the criterion needed to meet a specific probability for not pumping raw river water with >0.5ppt. As a practical matter, the PRMRWSA should provide the SWFWMD with estimates of how much water could be taken above the 90 cfs (cubic feet per second) threshold at daily flows less than 130 cfs, the present permit threshold. This answer might be followed with a question about is it practical to turn the pumps on for small amounts of water (see p.8-9)?
"An empirical analysis yielded a low flow threshold of 90 cfs for the sum of the flows from Peace River at Arcadia, Joshua Creek at Nocatee, and Horse Creek near Arcadia in order to maintain freshwater at the PRMRWSA plant." (pp. xviii)

The above statement is based on the following (pp. xvii, 7-23):
"The minimum flow regime for the Lower Peace River included a low flow threshold. Models were developed to relate flows to ecological criteria in the Lower Peace River, but there were no breakpoints or inflections in these relationships at low flows, thus it was concluded that a low flow threshold based on ecological criteria was not necessary."
"Since the continuous recorder is 3 km downstream of the plant, this number is conservative, because the salinity at the plant will always be less than the salinity at the continuous recorder."

There was no discussion or comparison with SWFWMD's identification of an inflection point based on monitoring data from the HBMP reports. This empirically-base inflection point was used in the 1989 permitting process to create a low flow threshold of no withdrawals <130 cfs.

Ninety cfs is not protective of brackish water >0.5ppt from being pulled in at the intake point for PRMRWSA during the latter parts of the dry season (April-June) – see HBMP reports. The continuous recorder's record is not a lengthy record and empirical data from HBMP stations clearly show that 90 cfs is not protective at all times. The statements on page 7-24 about salinity differences between the recorder and the water intake are true, but not the point. The records of the PRMSWSA show that low brackish water has been inadvertently pumped into the water treatment system even with compliance under the permitted low flow threshold.

Assume that the PRMRWSA either did not exist or had its withdrawal point above tidal brackish water effects, then these report statements might imply that water could be withdrawn down to near zero flow. Dismissing the need for determining a range of thresholds from ecological data (an MFL issue) does not allow for any comparisons with the operational criterion (a permitting issue). Perhaps SWFWMD first should have used the computer model to develop statistics for the <2ppt zone shoreline/area/volume criteria. Without suffice flow in the spring, there will be no spring phytoplankton bloom in the tidal reaches of the Lower Peace River, see data in the HBMP reports. By extension, missing spring blooms may occur in Shell Creek and upper Charlotte Harbor.

There is no ecological precautionary guidance from the SWFWMD with respect to developing the proposed threshold of 90 cubic feet per second, summed at the Peace River Arcadia gage, Horse and Joshua Creek gages simultaneously.

An examination of the number of days flows would be <90 cfs in contrast to flow-days below <130 cfs is provided in Table 1. Dropping the existing threshold of <130 cfs to <90 cfs increases the number of potential days for allowable withdrawals to increase by about 32-55% depending on the year intervals examined. If the existing threshold were to remain at <130 cfs, then the potential percentage of days of on withdrawal would increase about 10-31% depending on the year intervals examined.

I recommend that the SWFWMD consider the <90 cfs threshold for the Lower Peace River as an emergency reduction during severe droughts and the <130 cfs threshold as ecological precautionary threshold for the proposed Lower Peace River MFL as place-holder thresholds pending the statements at the end of the report (p. 8-10):

"Insofar as the District's recommended MFL is not unique, the District acknowledges that alternative combinations may be proposed by the regulated community. The District also recognizes that establishing estuarine MFL's is an evolving science. To this end, the District is committed to verifying the models and assumptions applied in the current determination and intends to conduct a re-evaluation in the future."

I recommend that the PRMRWSA support the existing 130 cfs permit threshold as the ecological precautionary threshold for the proposed Lower Peace River MFL pending a more complete examination of flows likely suppression of spring phytoplankton blooms and flows that sponsor such important blooms. The PRMRWSA should support an internal review of what an operational low flow threshold should be, how it should be determined, and after consideration by its staff and board request a modification to its permit.

II. Use of seasonal periods of time (blocks) in estuarine systems

The SWFWMD describes seasonal periods in the following manner:
"Seasonal blocks corresponding to periods of low, medium, and high flows, previously defined for the development of minimum flows in the middle Peace River, were used to establish minimum flows for both the Lower Peace River and Shell Creek."

There was no analysis or ecological justification for how such an alternative to a straight percent of daily flow is more protective for inflow to Charlotte Harbor or any estuary. SWFWMD accurately describes the dilemma of fixed block dates as follows (p. 8-10):
"In reality, in half of the cases the Block 3 flows on the day following the transition from Block 1 will be lower than prior day and in the strictest sense of application, the allowable withdrawal in the Peace river would transition from 17% representing Block 1 to 38 % representing Block 3. If the actual Block 3 flows remained depressed due to climatological conditions, the increase in withdrawals could be stressful on the biological resources."

A simple fixed percent of allowable daily withdrawals have none of the above issues and easy for the regulated entities to implement. There may be benefits to devising monitoring programs which provide empirical evidence of changes resulting from withdrawals of freshwater which otherwise flow to the tidal Peace River and Charlotte Harbor. SWFWMD discarded seasonal (monthly) dates in 1989 precisely because of excessive withdrawals during dry months and prohibition of withdrawals set too high during wet months.

I recommend that the SWFWMD propose a simple fixed percent of allowable daily withdrawals for the MFLs of the Lower Peace River and Shell Creek. More time needs to be spent on examining the relative value and complexity of use seasonal blocks as a regulatory standard in estuaries. What may work in rivers and streams may not be the best choice in tidal systems.

I recommend that the PRMRWSA support a simple fixed percent of allowable daily withdrawals.

TABLE 1.

Expected changes for daily flow availability as the result of the proposed low flow threshold of <90 cfs for the tidal Peace River compared with the permitted cutoff at <130 cfs.

Gaging Stations	years total N	90 cfs low flow cutoff					130 cfs low flow cutoff					Increase days for withdrawal at 90 cfs	Decrease % of threshold days	Expected % of threshold days at <130 cfs
		N1	cfs interval	Interval frequency	cumulative **N2**	cumulative frequency	**N3**	cfs interval	Interval frequency	cumulative **N4**	cumulative frequency	**N4-N2=N5**	**(N5/N4)*100**	**(N4/N)*100**
Arcadia	1931-2008 N=28400	1877	0-90	0.0659	1877	0.0659	3946	0-130	0.1385	3946	0.1385	2069	52.43	13.89
		1866	361-451	0.0655	14254	0.5003	2324	390-520	0.0816	15416	0.5411			
		517	1082-1128	0.0182	21239	0.7455	796	1041-1171	0.0279	21239	0.7455			
		125	2705-2751	0.0044	25714	0.9026	158	2732-2862	0.0055	25784	0.9050			
Arcadia	1981-2008 N=10227	1250	0-90	0.1222	1250	0.1222	2188	0-130	0.2139	2188	0.2139	938	42.28	21.39
		652	361-451	0.0638	5676	0.5550	1199	260-390	0.1172	5273	0.5156			
		197	993-1083	0.0193	7917	0.7741	301	911-1042	0.0294	7828	0.7654			
		44	2347-2437	0.0043	9223	0.9018	70	2344-2474	0.0068	9249	0.9044			
Arcadia	1999, 2001-2002 N=1095	244	0-90	0.2228	244	0.2228	335	0-130	0.3059	335	0.3059	91	37.3	30.59
		55	271-361	0.0502	565	0.5160	80	260-390	0.0731	584	0.5333			
		18	902-992	0.0164	838	0.7507	28	922-1042	0.0283	832	0.7598			
		9	2527-2617	0.0046	988	0.9023	5	2474-2604	0.0046	987	0.9014			
Arcadia Horse Joshua	1950-2008 N=21430	966	0-90	0.0451	966	0.0451	2157	0-130	0.0778	2157	0.0761	1191	55.21	10.06
		1098	480-570	0.0512	11061	0.5161	1505	385-455	0.0702	11215	0.5233			
		327	1380-1470	0.0153	16139	0.7531	455	1367-1497	0.0212	16215	0.7566			
		92	3270-3360	0.0043	19297	0.9005	119	3254-3384	0.0056	19313	0.9012			
Arcadia Horse Joshua	1981-2008 N=10277	786	0-90	0.0409	786	0.0409	1545	0-130	0.1511	1545	0.1511	759	49.12	15.05
		1305	390-480	0.1276	5149	0.0504	799	390-520	0.0781	5373	0.5254			
		151	1200-1290	0.0148	7700	0.7529	227	1171-1302	0.0222	7723	0.7552			
		45	3180-3270	0.0044	9215	0.9010	68	3124-3254	0.0032	9211	0.9007			
Arcadia Horse Joshua	1999, 2001-2002 N=1095	157	0-90	0.1434	157	0.1434	234	0-130	0.2137	234	0.2137	77	32.9	21.36
		37	360-450	0.0338	555	0.5068	70	325-455	0.0639	561	0.5123			
		15	1350-1440	0.0137	826	0.7543	17	1302-1432	0.0155	825	0.7534			
		4	3630-3720	0.0037	986	0.9005	7	3644-3774	0.0064	990	0.9041			

III. Percent of flow, method of identifying allowable levels, identification of salinity zones and study boundaries.

A. The SWFWMD report described the percent of flow method as follows (p. 1-3):
"The percent-of-flow method allows water users to take a percentage of stream flow at the time of the withdrawal. The percent-of-flow method has been used for the regulation of water use permits since 1989, when it was first applied to withdrawals from the Lower Peace River.
"A goal of the percent-of-flow method is that the natural flow regime of the river be maintained, albeit with some flow reduction for water supply."

A continuation of the percent of flow is the best method to use in the proposed MFL report.

Mimicking Nature with regard to the discharge of water to Charlotte Harbor and its coastal water sounds simple enough to do. The 10% withdrawal of the previous day's flow at the U.S. Geological Survey's gaging station in Arcadia above a certain minimum flow was proposed to General Development Utilities and the Southwest Florida Water Management District more than two decades ago. Fortunately, both organizations agreed to this concept to minimize impacts to Charlotte Harbor's natural resources. This proposal assumed an acceptable level of potential impacts because this method mimicked the variation in daily flow and was less than observed impacts from withdrawing 20% or more elsewhere in the world – and requiring physical and biological monitoring because nothing was specifically known about actual natural resources impacts to the tidal Peace River or Charlotte Harbor.

Changes in rainfall patterns drive daily, seasonally or decadal watershed flows. What has become all too apparent from the Peace River Cumulative Impact Study is that Peace River Basin flows have become highly altered over the past 80-100 years as agriculture, human habitation and mining all increasingly converted natural basin characteristics. These changes in Charlotte Harbor's watershed result in altered flows and altered biological responses.

Neither the current withdrawal limits for the Peace River/Manasota Regional Water Supply Authority nor the new draft Minimum Flows and Levels for the Peace River and Shell Creek mimic nature in the sense of unaltered conditions. These methods of existing and potential withdrawals mimic natural responses to the alterations humans have made in the Peace River Basin. To my knowledge, there has been no reasonable attempt to assess changing flow discharges to Charlotte Harbor from the permanent loss of spring flows (seasonal or year round) and by extension loss of base flow to the upper Peace River, the loss of nearly 343 miles of natural low order streams, the loss of more than 51 square miles of wetlands, the emphasis by Southwest Florida Water Management District on using surface flows now that additional ground water is off limits because of over permitting, Punta Gorda's in-line reservoir, or proposed/actual small in-stream agricultural reservoirs. A percent of flow merely reduces additional potential adverse effects in Charlotte Harbor's ecosystem.

The proposed MFLs may continue the drying of Florida's only large barrier island estuary south of Apalachicola estuaries on the West Coast of Florida with a continuous, mostly free-flowing river. We must have a rational understanding of lost river flows and altered flow patterns. Such information will permit an evaluation 'after the fact' of natural flow responses to these alterations. Then, flow characteristics occurring in relation to the current 10% limit or implementing a final Minimum Flows and Levels with its proposed threshold of significant harm (15% habitat change under defined conditions that were modeled) can be placed in a better context of the continuing long-term impacts to Charlotte Harbor. Sustaining the Charlotte Harbor Aquatic Preserve is figuratively and physically last in line for receiving flow as demand for water increases and upstream regulations change responding to growing human demands.

B. The SWFWMD described the boundaries of the study as follows (p. xvii):
"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 lower segment of the Peace River, defined as the reach of the river from the United States Geological Survey Peace River at Arcadia gauge downstream to Charlotte Harbor. This reach includes the total inflow from the Peace River at Arcadia gauge, Joshua Creek at Nocatee gauge, and Horse Creek near Arcadia gauge. Additionally, minimum flows are proposed for Shell Creek, which extends downstream from the City of Punta Gorda dam (Hendrickson Dam) to the confluence of Shell Creek with the Lower Peace River."

The SWFWMD describes a cumulative distribution function as follows (p. 7-24):
"**Habitat availability may be described in terms of space and time. In simple terms, we seek to quantify how much habitat is available and for what amount of time. The tool used to evaluate temporal persistence and spatial extent of habitat meeting a biologically relevant salinity is a cumulative distribution function (CDF) plot.**"

The Scientific Peer Review Panel's report (30 April 2008) mentioned inflow/salinity model issues as follows (p. 7) even after the responses by SWFWMD in Dr. Kelly's memorandum of 10 April 2008 responding to questions posed in the Panel's 3 April 2008 request for additional information :
Unfortunately, the model results for predicting salinities are fairly poor (e.g., Figures C-3 to C-15 in Appendix 7-2), which brings into question the CDF results for salinity concentrations in volumes/areas/shoreline lengths.

The downstream boundary of the Lower Peace River meets the definition by the U. S. Geological Survey. The effect of this map boundary is not present in salinity responses to flow, nor is there a physical boundary for chemical reactions or a living boundary for biological habitats or productivity. Much like the Shell Creek dam foreshortened salinity gradient, the mapped boundary of the Peace River excludes a significant portion of Charlotte Harbor from the modeling analyses and development of the cumulative distribution function to assess habitat changes during higher flows. The downstream boundary of Shell Creek is subject to similar criticisms in omitting habitat influenced by higher flows

The report describes the relations between nutrients, inflow residence time and phytoplankton responses as measured by chlorophyll α (p.6-13):
As inflow rate increases even higher, the increase in nutrient supply becomes offset by the reduction in residence time, and the resulting chlorophyll *a* concentrations will peak. At higher inflow rates, the negative effects of shortening residence time become greater than the positive effects of increasing nutrient supply, and the chlorophyll *a* concentrations decline. The effects are expected to be less responsive downstream than upstream due to physical dilution effects. Chlorophyll *a* concentrations in the Lower Peace River exhibit distinct spring and fall peaks that are influenced by both the timing and volume of freshwater inflows (PBS&J 2004).

Figures 1-5 describe dilution curves for four dates in Charlotte Harbor and the tidal Peace River. The salinity gradient with distance shows low salinities can extend well beyond the study boundary (Figure 1). Chlorophyll α concentrations show significant phytoplankton production beyond the study boundary. Color values mixing with salinity show the lack of inflection points as salinity increases for the four samples. There is every reason to believe that the color/salinity relationship exists for all flows. Salinity/color fronts do exist in Charlotte Harbor as temporary phenomena broken up by tidal mixing and wind effects.

Our understanding of how stratification at higher flows below the U.S. 41 bridges and the changes in habitats as defined in this report affects CDF plots does not appear clearly laid out. There are two functional habitats separated by vertical density differences. Salinities in the surface layer are lower and may run far down Charlotte Harbor (as long as wind stresses are low and inflow remains high). Volume estimates cannot be calculated/used or compared as if the water column were mixed. Bottom and surface areas would have different salinity distributions

A summary of Peebles (2002) study was part of the MFL study (pp. 5-20 to 5-22). Of note was the following statement in the MFL study:
“The majority of estuarine and estuarine dependent taxa had positive responses to high inflow that were delayed 3-6 months. The very high flows of the 1997-1998 El Nino event was followed by very large peaks of these taxa several months after the event.”

Figure 6 taken from Peebles shows these biological responses to a high flow period for six species. These more extreme flow events do show that there are connections between inflow and harbor/tidal river production. Such connections may be more difficult to identify at moderate flows. The failure of the chosen models to identify (p. xvii-xviii, 7-23, 8-5, 8-7) robust relationships between inflow and ecological criteria may suggest that existing data were not suitable, models were ineffective or both.

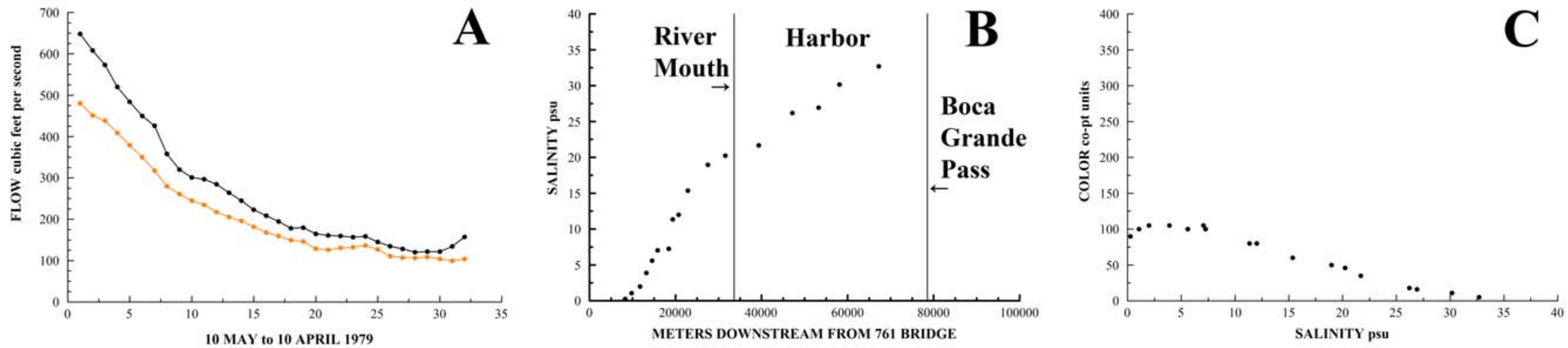

Figure 1. April 10, 1979 dilution sampling. A. Black line = Arcadia+Joshua+Horse+Shell, Orange line = Arcadia+Joshua+Horse. The last day of flow on the graph is the sampling day for the dilution curves. B. Salinity changes with distance from the 761 Bridge. C. Mixing of the relatively conservative freshwater color with saltwater from the Peace River to Gulf water.

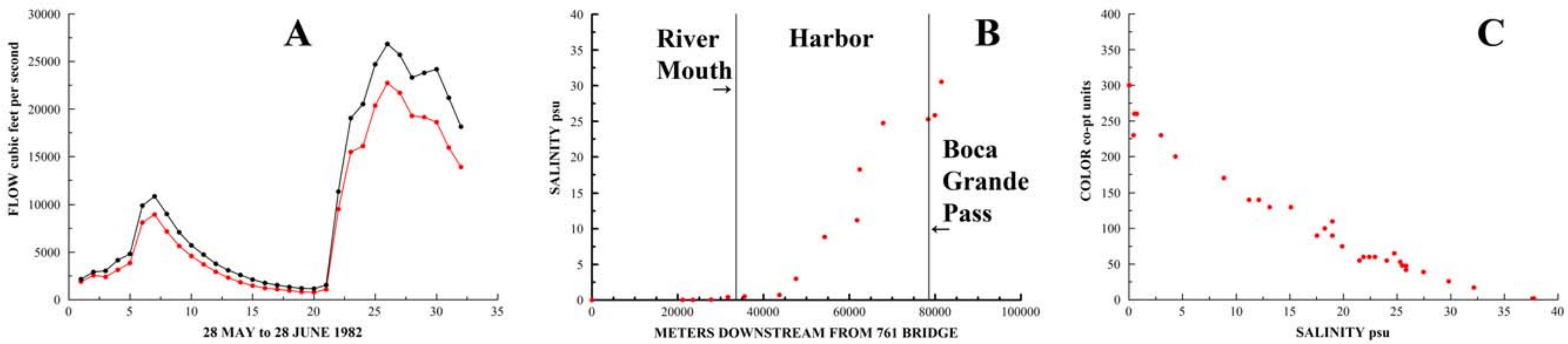

Figure 2. June 28, 1981 dilution sampling. A. Black line = Arcadia+Joshua+Horse+Shell, Red line = Arcadia+Joshua+Horse. The last day of flow on the graph is the sampling day for the dilution curves. B. Salinity changes with distance from the 761 Bridge. C. Mixing of the relatively conservative freshwater color with saltwater from the Peace River to Gulf water.

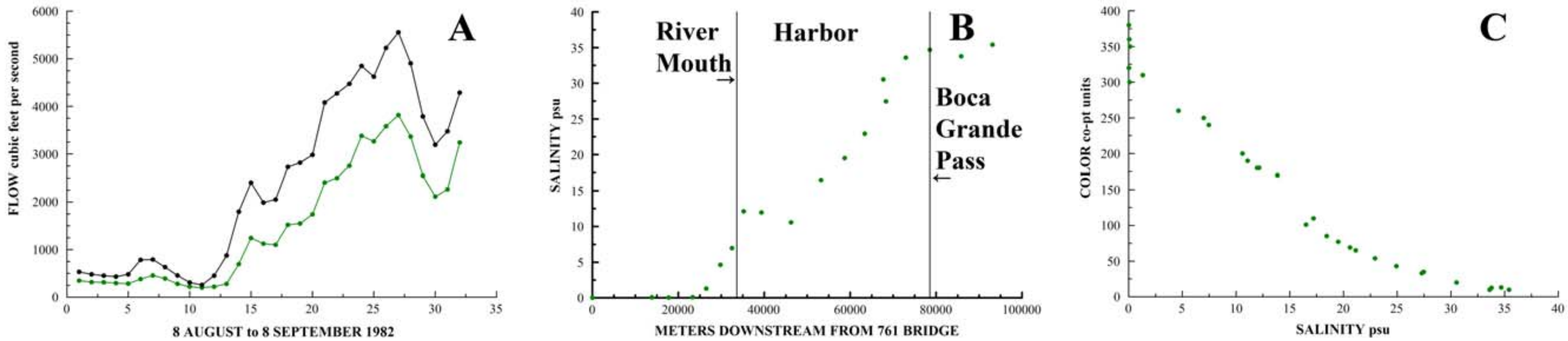

Figure 3. September 8, 1982 dilution sampling. A. Black line = Arcadia+Joshua+Horse+Shell, Green line = Arcadia+Joshua+Horse. The last day of flow on the graph is the sampling day for the dilution curves. B. Salinity changes with distance from the 761 Bridge. C. Mixing of the relatively conservative freshwater color with saltwater from the Peace River to Gulf water.

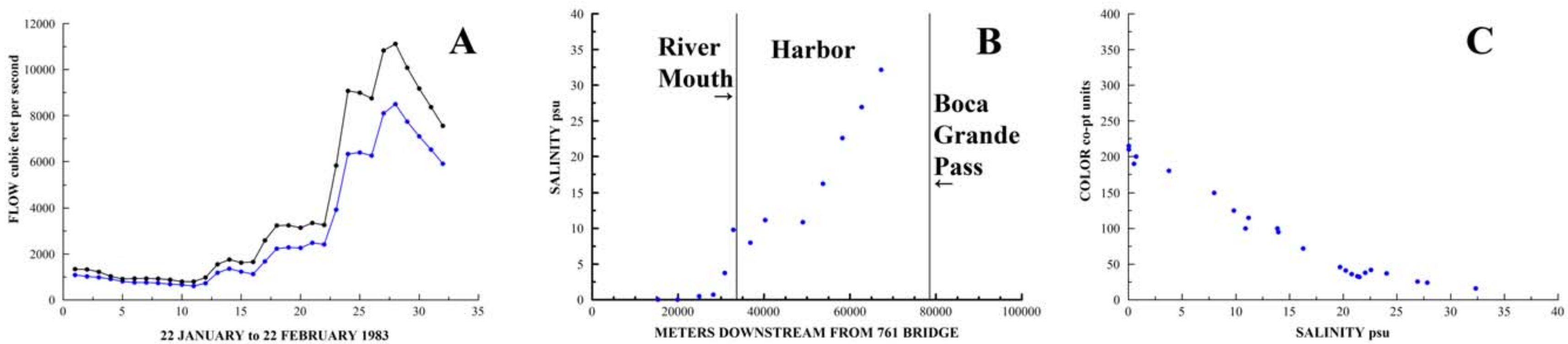

Figure 4. February 22, 1983 dilution sampling. A. Black line = Arcadia+Joshua+Horse+Shell, Blue line = Arcadia+Joshua+Horse. The last day of flow on the graph is the sampling day for the dilution curves. B. Salinity changes with distance from the 761 Bridge. C. Mixing of the relatively conservative freshwater color with saltwater from the Peace River to Gulf water.

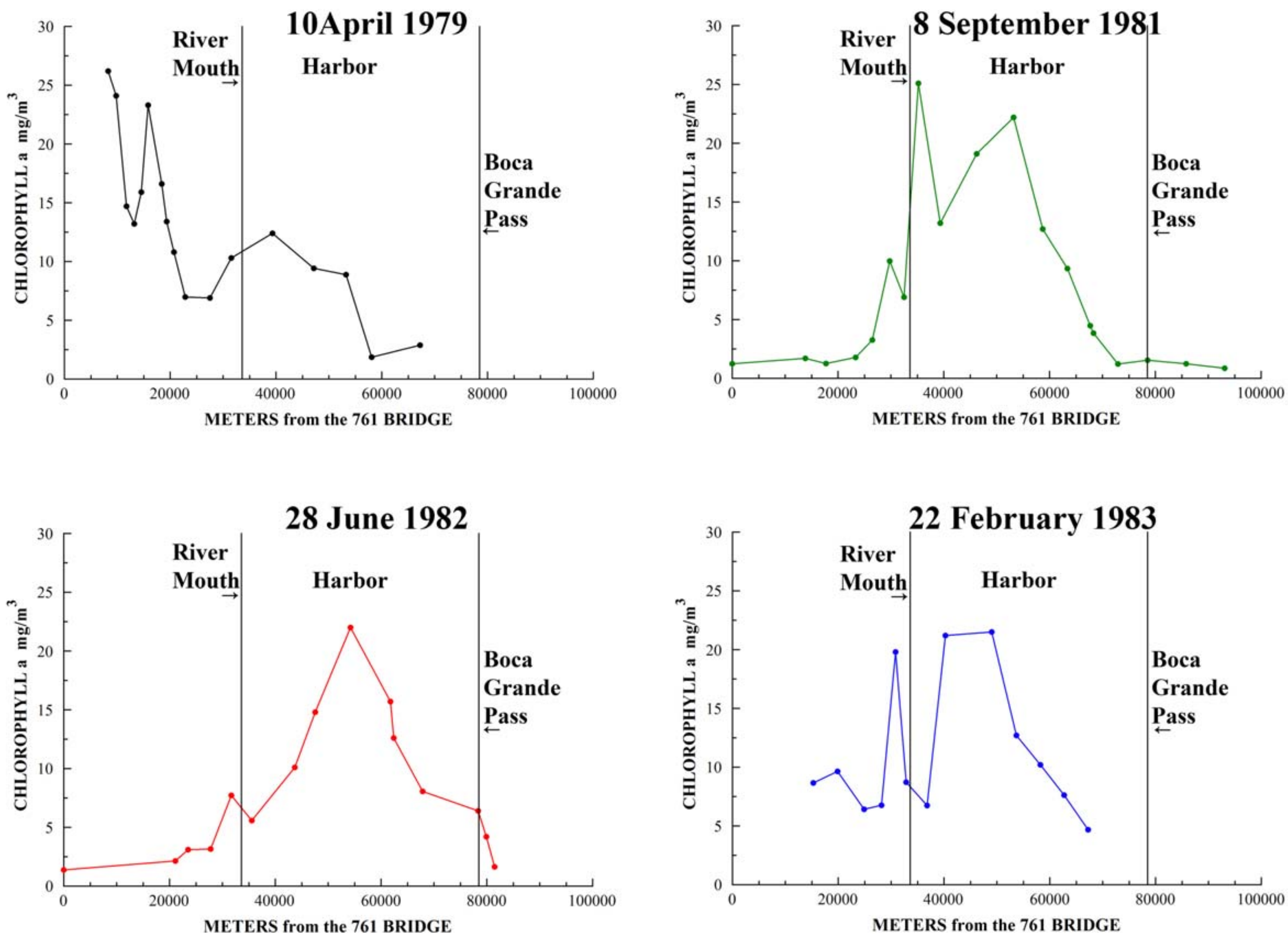

Figure 5. Chlorophyll a values from four dilution sampling trips.

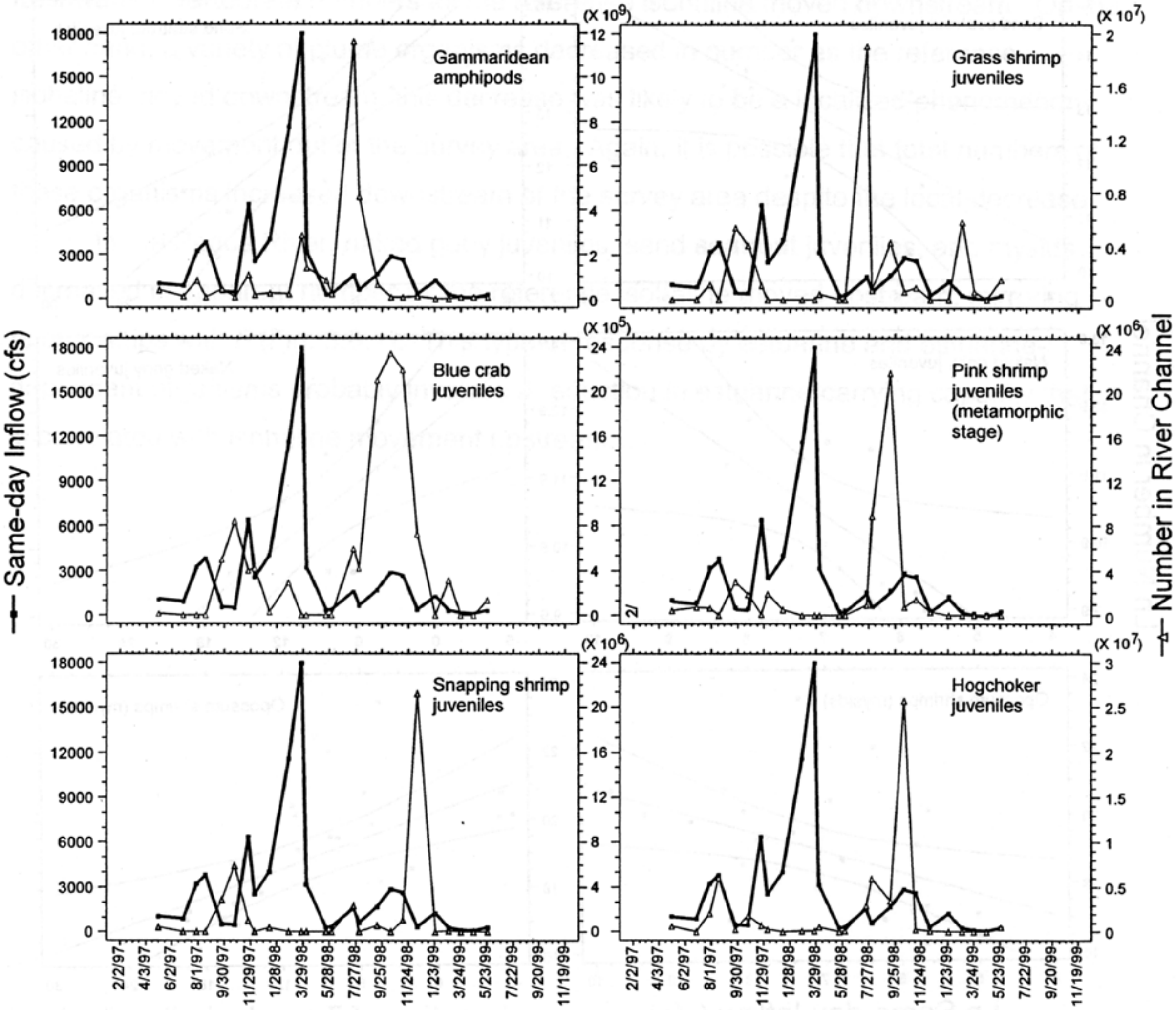

Figure 6. Taken from Peebles (2002) showing the estimated number of individual for six estuarine species in the tidal Peace River, all peaking in numbers months after a winter high flow period.

I conclude that models results, at best, are defensible only for Block 1 at 16% (Table 8-6). Virtually the entire habitat for these lower flow months were included within the study boundary. Take 15% of the freshwater inflow should generally reduce habitats (in sliding scales) for defined salinity zones by about 15%. This idea is supported by conservative dilution color curves with salinity. Thus, I believe that this same ratio (15% less inflow = 15% change within any define salinity zone as a proxy for habitat) would apply to all of the results had the lower Peace River boundary been flexible (nonexistent, or letting predicted salinities fill defined discrete salinity zones). Blocks 2 and 3 of Table 8-6 and all blocks in Table 8-2 illustrate unintended consequences of having a fixed lower boundary for the Peace River. The model and resulting CDF plots must be missing part of the habitat that have to be 'pulled' upstream into the fix study zone before the appropriate change (>15%) can be measured for given withdrawals. Model outputs resulted in over predictions of the safe amount of water that could be withdrawal from the Peace River.

"The recommended MFLs for LPR by are presented in Table 8-6."

Table 8-6. Summary of allowable percent reduction in flow for Lower Peace River by Block.

Block	Allowable Percent Reduction in Flow Under:
Block 1 (April 20 – June 25)	**16%**
Block 2 (October 27 – April 19)	**29%**
Block 3 (June 26 – October 26)	**38%**

"The allowable percent flow reduction by block and flow condition based on the volume of water between 8 and 16 ppt in Lower Peace River Zone 3 is presented in Table 8-2. As with other habitat metrics that were analyzed, the volume between 8 and 16 ppt in Zone 3 was less sensitive than the volume less than two ppt."

Table 8-2. Summary of allowable percent reduction in flow based on the volume of water between 8 and 16 ppt for Lower Peace River Zone 3 by Block.

Block	Allowable Percent Reduction in Flow Under:
Block 1 (April 20 – June 25)	**28%**
Block 2 (October 27 – April 19)	**+40%**
Block 3 (June 26 – October 26)	**+40%**

As an example, calculations of maximum allowable percent reduction in flows by blocks (Table 8.6) for the calender year 1989 for the sum of all flows at Arcadia, Horse, Joshua and Shell Creeks divided by the sum of all withdrawals result in the removal of 33.86% of the total inflows. No withdrawals possible for a duration of 30 day. A small number of days had withdrawals at less than the allowable percentages because of the 90 cfs threshold on the Peace River (Figure 7). Perhaps the flow record for all years should be inspected to determine potential long-term changes at proposed maximum allowable minimum flows and levels.

Potential damage to the Charlotte Harbor Barrier Island estuary at block levels of 29-38% reduction in primary production will echo up the food web expressed in fewer shrimp, crabs, fish (for example, the bay anchovy – a dominant prey species for fish and birds) wading birds, terns, seagulls and pelicans maybe unintended consequences of approving the proposed allowable reductions in flow in the future.

In answer to Comments from PRMRWSA HBMP Panel in the Appendices (April 2009) as follows:
Will some overall minimum/maximum total MFL be used to protect Charlotte Harbor which receives the impacts of any allowable withdrawals? There is no text discussing this issue.
"The District's believes that by not allowing significant harm to occur in the estuarine reaches of inflow streams (e.g., Peace, Myakka), Charlotte Harbor will be protected from significant harm due to withdrawals."

I recommend that the PRMRWSA support only the lowest percentage as consistent with the defined no more than 15% harm (change) to specific habitats as a valid placeholder for all flows. The recommendations of the Panel has been to focus on the low flow periods for monitoring as the best chance of detecting changes from withdrawal of freshwater.

I recommend that the SWFWMD approve only the lowest percentage at this time as a year round fixed percent of flow withdrawal limit as the upper limit to protect the tidal Peace River and Charlotte Harbor from significant harm, pending revising the study boundaries at higher flows. It may be wise to have precautionary limits below the edge of significant harm that would be the actual (functional) limits to allow for monitoring and not to over permit water use from the Peace River watershed.

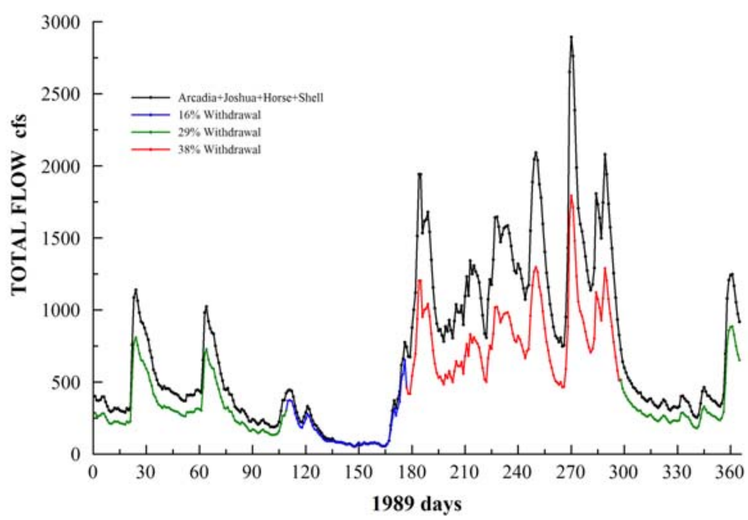

Figure 7. Freshwater withdrawals at the proposed maximum allowed percent-daily flow from the combined gaged daily flows of stations at Arcadia on the Peace River and Joshua, Horse and Shell Creeks.

C. The SWFWMD described significant harm in the report as follows (p. 8-1):
"Significant" harm has been operationally defined as a 15% loss of available habitat. "The minimum flow criterion for Shell LPR and SC is the flow that results in no more than a 15% reduction in available habitat relative to the Baseline flow condition."

An operational definition and its justification is in the eye of the beholder. The original 10% value was an operational definition with a judgement that 20% approached levels of measurable changes in estuaries based on literature available at the time. Therefore, some level of safety was build into using 10% and not including flows from Joshua or Horse Creek in the allowable percentage.

One of the three biologically relevant salinities zones was the <2 ppt (p. 7-2):
"**<2 ppt - this critical salinity is supported by several pieces of evidence – Jassby *et al.* (1995) use the 2 ppt isohaline as an indicator of overall ecosystem productivity in the Sacramento - San Joaquin estuary system; fish studies on the LPR and SC showed that many freshwater fish and invertebrates have mean salinity of capture values of less than 2 ppt; analysis of fish community structure in the Lower Peace River (Figures 5-11 and 5-12) reveals break points for distinct groups of these organisms at approximately 2, 5, and 15 ppt; Clewell *et al.* (1999) and Clewell *et al.* (2002) described glycophytes as having low salinity tolerances with several species being most abundant where median yearly salinities are below 2 ppt; and the Lower Suwannee River MFL was based on "average salinities of high tide waters flooding the swamps should be kept <2 ppt, with briefer periods of higher salinity tolerable." (WRA *et al.* 2005).**"

The boundary extent of the <2 ppt salinity zone for the lower Peace River is not clear in the report. Is it <0.5ppt to <2 ppt? Is it <2ppt to the upstream boundary of the model? The most likely case for the upstream boundary is the upstream end of the model. If so, there may be unintended over weighting due to the high percentage of the areas at <2 ppt for moderate and high flows even with less of the relevant habitat zones.

Figure 21 from Appendix J of the Fishes in the Peace River Watershed (2007) suggests that fishes that occupy the water column differ (many fewer) in species composition from those taken in seines. Figure 24 from Appendix J of the Fishes in the Peace River Watershed suggest that most of the fishes reported by Florida Fish and Wildlife Conservation Commission's (FWC) independent inshore fish monitoring program from 0-18 ppt are euryhaline. Figure 25 suggests that with the same data, a cluster analysis show fish preference breaks at 0, 1-6, 7-14 and 15-16 ppt.

It has not been convincingly shown that the most 'sensitive' salinity zone for marine fishes is the <2 ppt defined zone. Other data in Appendix J supports the idea of separating the FWC fish data into primary freshwater fishes (probably<0.5 ppt), secondary freshwater fishes (probable >1 to <14) and marine fishes (>7 to <16 ppt). The data listed in Tables 5-4 and 5.5 and the principal component analysis (Figures 5-11 and 5-12) may not have examined FWC's data for these three ecological/evolutionary groups and their differential use of tidal habitats. The report's analysis combines all of this information so any subtle information may be muted.

Comments on the Proposed Minimum Flows and Levels for the Lower Peach River and Shell Creek Report (April 9, 2009) prepared by the Southwest Florida Water Management District (SWFWMD)

by

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The Southwest Florida Water Management District (SWFWMD) has been legislatively mandated to establish minimum flows and levels (MFL) for the streams and rivers within its boundaries. **Minimum flows are defined by statute 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".** The impact of freshwater withdrawals on the estuarine portions of rivers and streams is included in this mandate. The proposed minimum flows and levels for the lower segment of the Peace River (from the Arcadia gauge, including Joshua Creek, Horse Creek and Shell Creek to Charlotte Harbor) were described in the report entitled "Proposed Minimum Flows and Levels for the Lower Peach River and Shell Creek". This document reviews and comments on the above cited SWFWMD report.

The Peace River/Manasota Regional Water Supply Authority (PRMRSWA) requested that the members of the HBMP provide comments to PRMRSWA on the Proposed Minimum Flows and Levels for the Lower Peach River and Shell Creek Report in April 2009. The HBMP Scientific Review Panel previously commented on a draft version of this report in late 2007. SWFWMD responses to the HBMP Scientific Peer Review Panel comments on the draft report were provided as in the Appendices to the Final Report. Some of the comments provided below are a re-emphasis of the concerns listed provided for the draft report. This was necessary because some of the original concerns were not adequately addressed in the Final Report or in the SWFWMD responses provided in the appendices of the Final Report.

My comments mainly relate to the:

- Scientific approach and methods used;
- Evaluating the scientific basis for methods, findings and interpretations; and
- Implications of findings and interpretations to ecological processes and cumulative environmental impact of freshwater withdrawals to the Peace River and related ecosystems.

Major concerns I have are listed below as bullets and include:

- **SWFWMD Operational definition of "significant harm":** Section 373.042, F.S. defines the minimum flow for a surface watercourse as "the limit at which further withdrawals would be significantly harmful to water resources or the ecology of the area". SWFWMD operationally defined "significant harm" a 15% loss of specified habitat metrics from baseline conditions. The habitat metrics evaluated by SWFWMD included measures representing impacts to habitat volume, bottom area and shoreline length. Results were presented for seasonal time blocks, representing low, high and intermediate flow periods. For the most part results were presented as cumulative distribution functions that identified losses in habitat metrics to flow reductions of 10%, 20%, 30% and 40%.

  As noted in my comments on the draft document, this operational definition for "significant harm" was based on analyses and studies for the upper freshwater, free flowing Peace River (Gore et al. 2002). This is problematic since the amount of critical habitat loss that may cause significant harm in a tidal ecosystem may not be tightly linked to changes in water level which seems to be the scientific basis for the 15% threshold suggested by Gore et al. 2002. No scientific peer reviewed references or ecological theory basis was provided for applying the 15% habitat loss criterion to estuarine environments (i.e., Shell Creek and lower Peace River).

  I am not aware of any scientific studies or theories that would suggest a 15% loss in important estuarine habitat would not result in significant ecological harm. This is especially true for spawning or nursery habitat which is the major ecological function of the most severely impacted area. I am also not aware of any evidence that suggests that estuarine populations, communities, and ecosystems have adaptive processes that allow them to compensate (e.g., sustain productivity and critical ecological services) for habitat losses in the 15% range. This would be especially true for fishery populations and impacts to critical spawning and nursery habitat or other rare habitats where the ecological value and services provided by the habitat are disproportional to the amount of the habitat that exists.

- **Decreasing the low flow withdrawal threshold from 130 to 90 cfs for the Lower Peace River:** The benefits, impacts, and potential unintended ecological consequences of the SWFWMD decision to decrease the low flow withdrawal threshold from 130 cfs to 90 cfs were not fully discussed or evaluated using historical data for wet and dry periods. I recommend that the 90 cfs threshold be reserved as a severe drought threshold and that the 130 cfs low flow threshold which has been demonstrated for many years to include a margin of error/safety be retained. This strategy has worked in the past and there is no reason it will not work in the future. Retaining the 90 cfs threshold for severe droughts in effects provides a "margin of safety" that is not provided elsewhere in the report. There is no reason to try to "fix a policy/regulation that is not broken". Such a precautionary approach would be prudent and would ensure water resources are reserved for future/unanticipated severe conditions/uses.

- **Removal of large amounts of freshwater water and nutrients it contains during high flow seasons (Block 3):** In previous comments on the draft MFL report, concerns were raised by many reviewers about the potential ecological consequences of withdrawal of large volumes of water during high flow periods (block 3) on downstream estuarine ecosystems. This omission was problematic because the ecological impacts to downstream ecosystems resulting from removal of large (e.g., >20%) volumes of freshwater is not represented by changes in salinity distributions and related effects on amount of critical habitats (the assessment approach used by SWFWMD for establishing MFLs). These impacts are probably better represented by decreases in nutrient loadings and the consequences of nutrient reductions on the productivity and survival of early life stages of representative important species. Nutrient reductions may also affect other important ecological processes (e.g., biodiversity; nutrient transformations; system complexity, sustainability and resilience).

  I am not aware of any literature that establishes a scientific basis or approach for quantifying how much flow withdrawal is "too much" during high flow periods (i.e., the amount that would result in significant harm). Historical data, however, suggests large changes in estuarine productivity occur between wet/high flow and dry/low flow years that have long term consequences on overall ecosystem production. This is clearly a case where "more is not better" and a "do no harm approach" should be followed. Until the ecological consequences of reductions in nutrient loads on estuarine productivity are identified and evaluated, I recommend that a precautionary approach be followed in establishing MFLs for the lower Peace River.

- **Using Peace River flow during 1999-2002 to represent baseline conditions for model evaluations:** The "baseline period" for the lower Peace River was defined as 1985-2004 which represents a wide range of hydrographic conditions (wet and dry periods as well as global scale climatic fluctuations). Unfortunately, I interpret the report to say that model runs, and therefore, estimates of impacts on habitat metrics were limited to the flows that occurred from 1999-2002. The only justification provided for using 1999-2002 to represent the baseline period for modeling runs was it was consistent with the modeling period used by SWFWMD for the lower Myakka River MFL. Limited discussion was provided that demonstrated that flows in the Peace River during the 1999-2002 period were representative of the baseline period. In the draft report, a comparison of flows for a previously used model period (1996-1999) and the baseline period were provided. Even if the selected model period cumulative distribution function closely tracks the baseline period cumulative distribution function, I have concerns that using such a short period of record may oversimplify extreme conditions, which are likely to be greatest concern.

- **Safety factors and measures of uncertainty:** The 15% habitat loss threshold and the 90 cfs low flow threshold recommended by SWFWMD for the lower Peace River do not include a safety factor. Measures of uncertainty in the calculations and approaches used to establish MFLs were also not provided. Even in well understood engineering systems and processes that have far less social, economic and ecological consequences than freshwater withdrawals from natural aquatic ecosystems, society requires safety factors and measures of uncertainty be incorporated into calculations (e.g., bridge and road construction).

Hydrodynamic models are numerical representations of natural systems that make specific assumptions about environmental conditions. Such models are very useful tools for characterizing and understanding linkages between and among system components and for predicting system responses to alterations in conditions. If appropriately calibrated and validated, models are particularly useful for estimating the direction and relative magnitude of system responses to changes in conditions. Incorporation of safety factors and measures of uncertainty into model calculations is a time consuming process that usually involves large numbers of model simulations to changing environmental and boundary conditions. SWFWRD did not incorporate measures of model uncertainty or include safety factors in their model calculations of significant harm.

I again recommend a precautionary approach be followed that has a built in safety factor when defining minimum flow levels, especially in high flow periods. A more detailed evaluation of the ecological consequences of seasonally (i.e., block) adjusted withdrawals schedules needs to be conducted. The current assessment appears to be limited to the changes in the amount of habitat metrics (bottom area, volume, and shoreline length were used as indicators). No information was provided on the amount and degree to which ecological services or functions may be impaired under various withdrawal schedules (e.g., decreases in nutrient loading and potential consequences on system productivity).

- **Rare habitats vs. abundant habitats:** In estuarine environments, habitats that have highly valued ecological functions but occupy a small area frequently have ecological value that is disproportionate to their size or area. For example, the size of tidal fresh (0-0.5 ppt) and oligohaline (0.5-5ppt) habitats is generally small relative to habitats with a salinity >5 ppt. These lower salinity habitats, however, support spawning and nursery functions that are disproportionate to their size. These low salinity zones are also frequently high depositional environments that have critical roles in many ecological processes (e.g., sedimentation, pollution transformations and removal, primary productivity). The analysis approach used by SWFWMD did not appear to evaluate if 15% declines in the habitat metrics used in valued and rare habitats was "too much". Perhaps in rare habitats that support critical functions the definition of significant harm should be reduced to 5% or 10% reduction in habitat metrics. Until this evaluation has been conducted, I feel it is prudent to keep MFLs at the present levels.

- **Effects on Monitoring Activities:** In my comments on the draft MFL report I suggested that the salinity thresholds and habitat metrics defined by SWFWMD as part of their MFLs determinations would significantly impact expensive and valuable long-term monitoring activities conducted for many years by PRWRWSA. The SWFWMD response to this comment was that impacts on monitoring activities was an important consideration, but it was not the intent of the MFL report to develop a monitoring plan. SWFWMD stated that developing a monitoring plan was the responsibility of PRWRWSA as part of their permit. While these are true statements, SWFWMD would appear to have some responsibility for ensuring that the monitoring activities that they have required as part of past PRWRWSA permits have the greatest possible future value. It would not seem prudent to take actions that do not"throw the baby out with the bathwater". If long-term monitoring activities are not useful for ensuring newly implemented MFLs do not cause significant harm or are of low value in an adjudicated proceedings then perhaps PRWRWSA should be reimbursed for their loss.

- **Validation of hydrodynamic model:** In the last paragraph of the final report SWFWMD provides statements that they are "committed to verifying the models and assumptions applied" in the developing their recommendations for MFLs. This is a laudable goal and SWFWMD should be held too it by not implementing the proposed MFLs until the hydrodynamic model has been validated.

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June 30, 2009

Samuel S. Stone
Environmental Affairs Coordinator
Peace River / Manasota Regional Water Supply Authority
8998 SW County Road 769
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Dear Mr. Stone:

RE: Technical Review Memorandum on Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek.

The purpose of this communication is to provide my technical review of the final proposed minimum flows and levels (MFL) for the Lower Peace River and Shell Creek estuaries. My submission is made as a member of the Scientific Review Panel for the Authority's Hydrobiological Monitoring Program (HBMP).

My understanding of the present situation is that the Southwest Florida Water Management District (the District) read and considered previous public comments on their Draft MFL report, including those by members of the above referenced Panel, in order to develop their "final" April 9th MFL report. In response to these previous comments, a number of significant changes were made in the District report:

1. The District report includes an analysis of some potential hydrodynamic model errors.

2. The District report includes additional model runs to evaluate the effect of establishing the Lower Peace River MFL prior to developing the Shell Creek MFL.
3. The District report deletes the use of median flows within a Seasonal Flow Block for further refining the allowable percent of flow reduction from the "baseline" condition, since this is accommodated implicitly or explicitly in the empirical (i.e., statistical) and mechanistic models used to assess salinity/habitat changes.
4. The District report now uses the period from 1999 to 2002 for hydrodynamic modeling to eliminate atypically high Block 2 flows in the previously used period from 1996 to 1999, to better represent the long-term flow record of the Peace River, both annually and seasonally within Blocks, and to coincide with that being used by the District to establish the MFL for the nearby Lower Myakka River, since they both are major contributors to the estuary's primary bay, Charlotte Harbor.
5. The District report also includes adjustments to Shell Creek flows to account for agricultural return flows (i.e., augmentation) and a correction to the flow record related to withdrawals from the Shell Creek reservoir to better recreate the "baseline" historical flow record.
6. And finally, the District report combines the potential fish and wildlife habitats lost in the Peace River and Shell Creek under the MFL's 15% threshold of "significant harm" from simultaneous flow reductions on both of the inflow sources to this portion of the estuarine system; thus, the remaining Myakka River and Charlotte Harbor are not included.

General Comments

The quantity, quality and timing of freshwater input are characteristics that define an estuary. Freshwater inflows affect estuarine (tidal) areas at all levels; that is, with physical, chemical and biological effects that create a vast and complicated network of ecological relationships (Longley 1994). The effects of changes in inflows to estuaries are also described in Sklar and Browder (1998) and reviewed in Alber (2002). This scientific literature describes and illustrates how changing freshwater inflows can have a profound impact on estuarine conditions: circulation and salinity patterns, stratification and mixing, transit and residence times, the size and shape of the estuary, and the distribution of dissolved and particulate material may all be altered in ways that negatively effect the ecological health and productivity of coastal bays and estuaries.

Inflow-related changes in estuarine conditions consequently will affect living estuarine resources, both directly and indirectly. Many estuarine organisms are directly linked to salinity: the distribution of plants, benthic organisms and fishery species can shift in response to changes in salinity and the presence of marine predators, parasites and disease organisms (Overstreet and Howse 1977, Overstreet 1978, Drinkwater and Frank 1994, Ardisson and Bourget 1997). If the estuarine habitat and animal distributions become uncoupled, estuarine biota may be restricted to areas that are no longer suitable habitat for their survival, growth and reproduction. Potential effects of human activities, particularly freshwater impoundment and diversion, on the adult and larval stages of fish and invertebrates include impacts on migration patterns, spawning and nursery habitats, species diversity, and distribution and production of lower trophic (food) level organisms (Drinkwater and Frank 1994, Longley 1994). Changes in inflow will also affect the delivery of nutrients, organic matter and sediments, which in turn can effect estuarine productivity rates and trophic structure (Longley 1994).

There are a number of approaches for setting the freshwater inflow requirements of an estuary. The District has selected to use a “percent-withdrawal” method that sets upstream limits on water supply diversions as a proportion of river flow. This links daily withdrawals to daily inflows, thereby preserving natural streamflow variations to a large extent. This type of inflow-based policy is very much in keeping with the approach that is often advocated for river management, where flow is considered a master variable because it is correlated with many other factors in the ecosystem (Poff et al. 1997, Richter et al. 1997). In this case, the emphasis is on maintaining the natural flow regime while skimming off flows along the way to meet water supply needs. Normally, regulations are designed to prevent impacts to estuarine resources during sensitive low-inflow periods and to allow water supplies to become gradually more available as inflow increases. The rationale for the District’s approach to MFLs, along with some of the underlying biological studies that support the percent-of-flow approach, is detailed in Flannery et al. (2002).

A great deal has been said about the District's use of seasonal flow blocks. In this reviewer's opinion, blocking off increments of space and time is one of the first ways researchers attempt to refine an ecosystem-level estimate of important properties. Further, I agree with members of the Upper Peace River MFL Peer Review Panel (Gore et al. 2002), who noted that "...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 predevelopment history. 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."

In this case, the District's block approach to seasonal flows does not fully mimic natural streamflows, as would say allowing a constant percentage of flow to be diverted for beneficial use (e.g., 10-20%), but it may be considered a reasonable means for maintaining similar hydrological conditions, as long as everyone recognizes that significant dampening of the amplitudes of natural flow cycles may occur at times when the percentage of water diversion varies from season to season. This dampening effect is certain to draw more scientific concerns about eventual impacts on biological communities in the river and the estuary.

A primary policy problem with the use of seasonal blocks is if administrative rules are written to somehow <u>require</u> flows in the blocks, say to eliminate water quality problems or to guarantee fish and wildlife habitats. While these are laudable goals for maintaining ecological health and productivity, you can't require a rainstorm in a water permit, even if the environment needs the flow, as this is considered an "Act of God" in most legal proceedings. Neither can you require substantial reservoir releases when there are no inflows to the impoundment without jeopardizing water yield and failure of the water supply system. What you can do safely in a water permit is limit the ability of an applicant to capture flow for recognized beneficial uses that support the people and their socioeconomic system which is, interestingly, more fragile and less robust than natural ecosystems are.

Moreover, in order to avoid using a good time rule in bad times, most balanced solutions involve installing “condition appropriate” multi-stage operating rules for water impoundment and diversion projects that provide for some pass-through of streamflows to downstream habitats, particularly during periods of normal to below normal flow. In addition, the presence of an identified physical, chemical or biological threshold (e.g., a low-flow, dissolved oxygen water quality standard) most often results in setting a minimum instantaneous flow below which no additional withdrawals are allowed. Indeed, even where a threshold has not been identified and the impacts appear to be more or less continuously bad as flows decrease, it is still a standard practice to set conservative, practical operating limits for environmentally safe withdrawal schedules to avoid any unnecessary or unintended harm to the ecological health and productivity of such major living ecosystems.

This means that the theoretical limits in an MFL analysis do not have to be followed slavishly in a water supply permit or in the practical limits of system operations of impoundment and diversion activities, which may be phased-in over time or otherwise treated more conservatively than the MFL would suggest. Relaxing this aggressive stance on water management helps the District build community confidence in the MFL, particularly where the crucial numerical results come only from a model (note: as someone with a long professional history of working with models and modelers, I agree with them that “all models are wrong, but some are useful”). It also avoids the risk and expense of overstepping water supply plant operations and then having to pull back. Verification monitoring in the future is required to help ensure that the protective aspects of the District’s administrative rules and the Authority’s plant operations are having their intended effect of maintaining the ecological health and productivity of the living aquatic ecosystems of interest here. In a way, the District acknowledges this by declaring at the end of the final MFL report that it intends to conduct a re-study of the environmental flow needs in the future when more and better data and models are available.

The District employs a criteria of no more than a 15% change in salinity habitats of the lower Peace River, as compared to the estuary's baseline condition of natural flows, as the legal threshold for "significant harm." While the use of 15% as a threshold is a more or less arbitrary management decision, many peer reviewing scientists and engineers have found it a reasonable public policy approach for avoiding the most serious negative impacts on the ecosystem, providing that the correct inflow-habitat variables (e.g., sediments, nutrients and salinity gradients) are being evaluated. Even better would be knowing the effects of a 15% reduction in the survival, growth or reproduction of ecologically characteristic species, including economically important fish and shellfish, in these Gulf Coast estuaries. Depending upon only one variable, salinity, weakens scientific confidence in the result, suggesting a go-slow approach to any aggressive water management plans.

The District's Final MFL Report

The District (2009) reports in the final proposed MFL document that after examination of the relationships between flow and several habitat variables, including salinity, chlorophyll *a*, and dissolved oxygen (DO) in Shell Creek, they still could not identify a clear, defensible, low flow threshold. Since this is not the same thing as saying there is no ecological need for flow, particularly in the stream segment below the Hendrickson Dam from the City of Punta Gorda to the confluence of Shell Creek with the Lower Peace River, the District adopted a protective but somewhat arbitrary standard of maintaining a low (< 2.0 ppt) salinity zone in Shell Creek below the dam. This was based, at least in part, on the District's fish studies which showed that many freshwater fish and invertebrates have mean capture salinity values of less than 2 ppt.

The District found that fish community structure in the Peace River and Shell Creek was generally separated into rather different assemblages above and below the confluence of the two waterways. Relatively little difference was observed between the Peace River above the confluence and nearby Shell Creek. However, there was a significant difference between these two stream segments and the Peace River below the confluence with Shell Creek. Here the Lower Peace River becomes much more estuarine and exhibits well-defined seasonal patterns of recruitment and use as a nursery area by resident estuarine species, as well as by migratory estuarine-dependent marine species of fish and shellfish. Overall, the comparisons of freshwater inflow to population center-of-abundance and overall relative abundance showed that many estuarine and marine species move upstream during periods of low flow and high salinity to get back to a more comfortable lower salinity zone. They reach their maximum abundance at intermediate levels of flow and salinity, not at the extremes of fresh and salt water. Certainly, the presence of low DO (hypoxia) in the lower Peace River can affect the distribution of fish and shellfish (Figure 1).

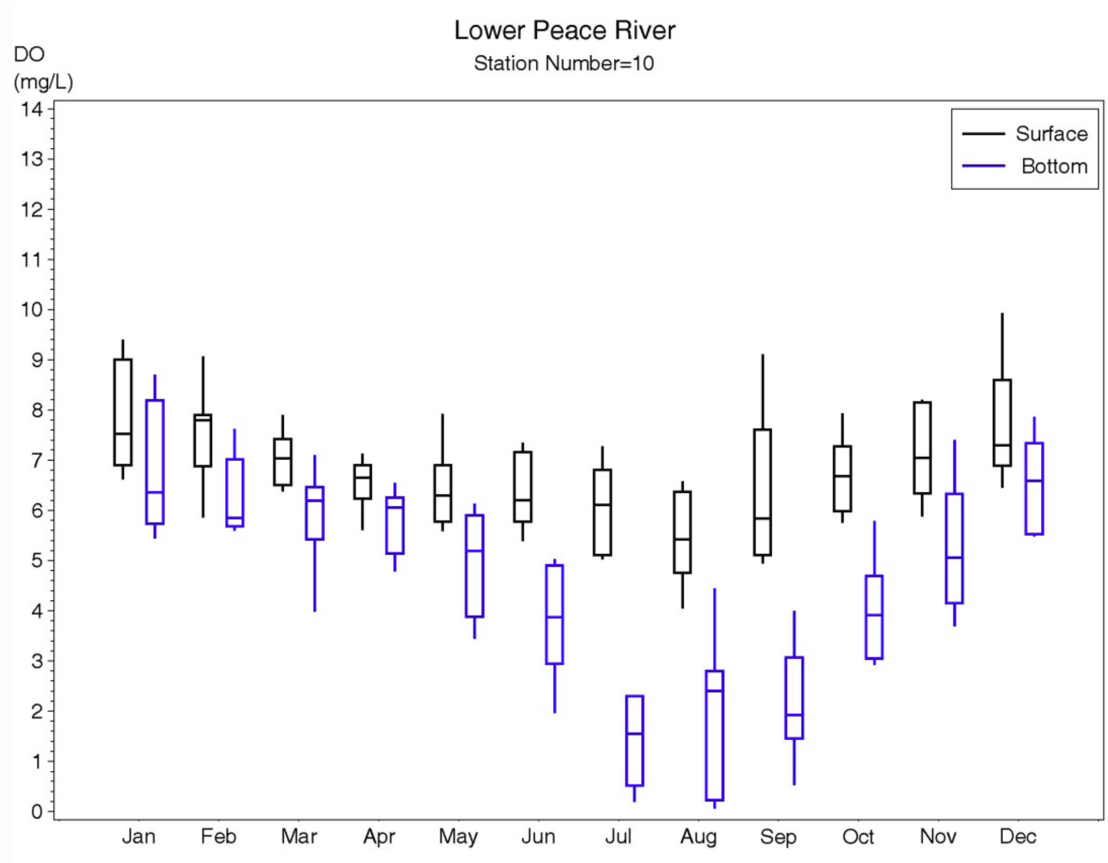

Figure 1. Monthly distribution of surface and bottom DO (1997-2004) at LPR Station 10. Boxes represent the 25th, 50th, and 75th percentiles, while whiskers represent the 10th and 90th percentiles.

The low DO shown in Figure 1 also creates potential violations of Florida's state water quality standards, which contain DO criteria for Class III marine waters such as these that call for an instantaneous minimum of 4 parts per million (ppm) and a daily average of not less than 5 ppm (4 and 5 mg/L DO concentration, respectively). This standard may be practical and scientifically appropriate for inland freshwaters, but it is problematic in warm shallow estuaries with high biological productivity. For example, with 100% saturation of 25ºC (77ºF) freshwater (0 psu) at sea level atmospheric pressure (760 mm), the DO concentration is 8.4 mg/L, declining to 6.2 mg/L when both salinity and temperatures are high (35 psu at 30ºC or 86ºF), and this is for sterile water with no biological or chemical oxygen demand. If the coastal waters are alive with biota and contain any pollutant runoff, then there is no way to consistently maintain DO concentrations above 4 mg/L at night when plants switch from O_2 production (i.e., sunlight-driven photosynthesis) to O_2 consumption (i.e., plant respiration).

Most fishes and macro-invertebrates that are adapted to live in shallow tropical or sub-tropical coastal estuaries are also adapted to tolerate the low (~2 mg/L) DO concentrations that frequently occur in these warm waters at night. However, they generally require DO saturation to be above 30% for continued survival, which at 30ºC is equivalent to ~2.5 mg/L DO. Waters below 30% saturation are referred to as “hypoxic,” a condition that induces great physiological stress and mortality in most aquatic animals. When hypoxia occurs, most free-swimming organisms will stop using the area’s habitats.

According to the District’s final report, a hydrodynamic model developed by District staff was applied to the Lower Peace River estuary for simulation of circulation and salinity patterns. The numerical model developed for this estuarine complex was a coupled 3D – 2DV model named LESS that dynamically links a laterally averaged two-dimensional (2D) hydrodynamic model (LAMFE) with a three-dimensional hydrodynamic model (LESS3D). A particle tracking subroutine was used to also compute estimates of the riverine estuary’s hydraulic residence time and pulse-residence time (Chen 2008). The model’s domain (Figure 2) was described as including the northern portion of Charlotte Harbor, the Myakka River, the tidally influenced portion of Shell Creek, and the Lower Peace River downstream of Arcadia, which means that this model application does not simulate the potential impacts of flow reductions on Shell Creek or the estuary’s primary bay system, Charlotte Harbor. Specifically, the 3-D portion of the domain included upper Charlotte Harbor, the downstream 1.74 kilometers (km) of Shell Creek, the downstream 15.5 km of the lower Peace River, and the downstream 13.8 km of the lower Myakka River. The 2-D in-the-vertical only portion of

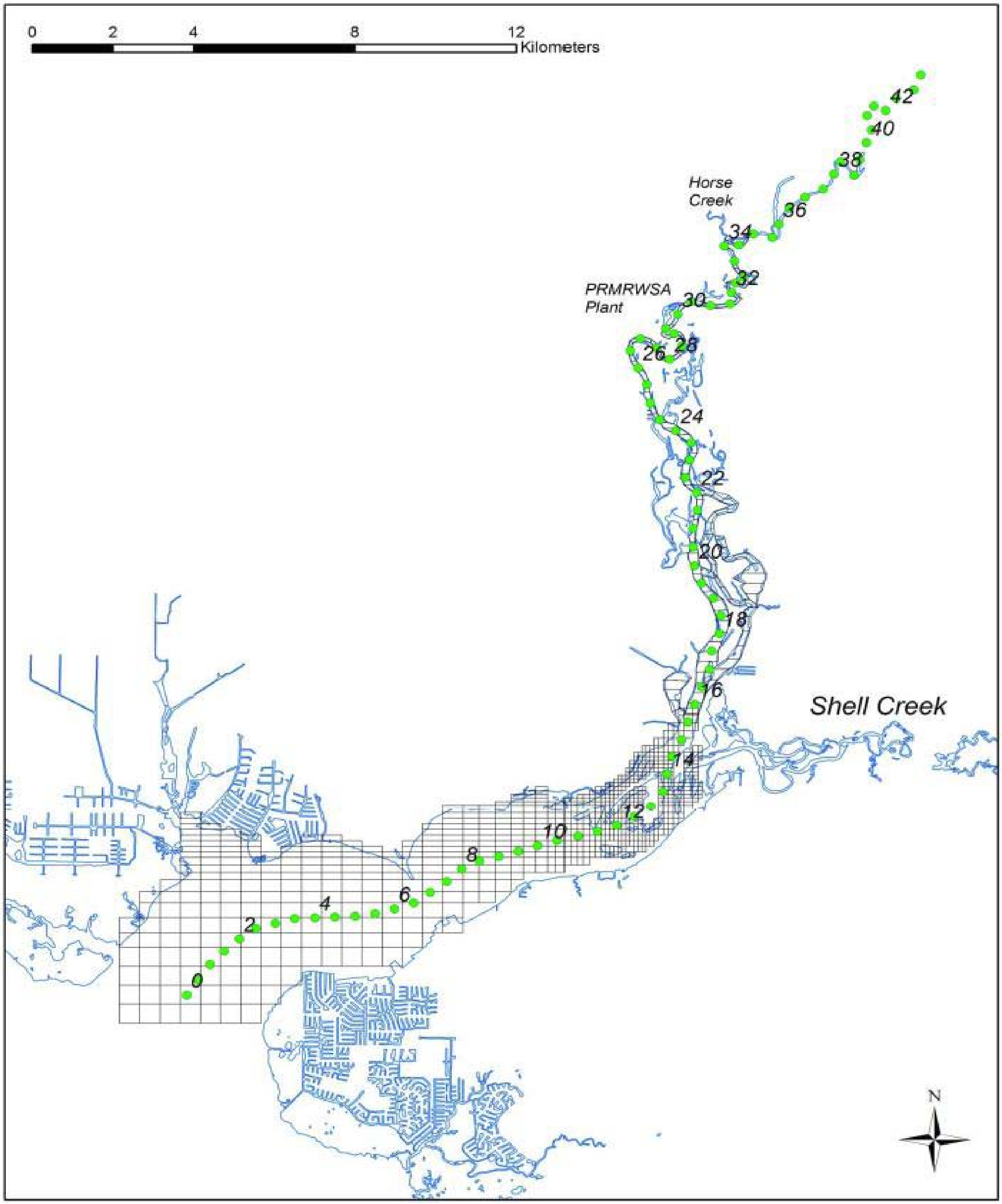

Figure 2. The computational grid over the domain of the District's hydrodynamic model used to simulate this portion of the estuary's circulation and salinity patterns.

the domain included the lower Peace River from river kilometer (rkm)15.5 upstream to Arcadia, the lower Myakka River segment from rkm 13.8 to rkm 38.4 upstream, Shell

Creek from rkm 1.74 upstream to the dam, and the downstream 4.16 km of Myakkahatchee Creek.

In relatively narrow estuaries, the salinity can be stratified over the water depth but exhibit little variation over the width of the estuary. For these types of water bodies, the governing 3-D equations may be integrated over the width to yield 2-D laterally-averaged equations in a finite-difference scheme. With such models, the variation of the flow and salinity or temperature in the water column profile is computed longitudinally down the primary axis of the reservoir or estuary. These models, including the District's LAMFE model, are referred to as finite difference 2-D laterally-averaged hydrodynamic models.

The LAMFE model accounts for the influence of water density variations, caused by differences in the concentration (weight) of the salt in various water layers, on the flow field in the momentum equation (i.e., baroclinic terms are included). Having a model that includes more resolution of the vertical (depth) dimension is often viewed by scientists as essential in coastal rivers because the vertical salinity gradient in the water column of the riverine estuary can be quite pronounced at times, stratifying the water column and causing, among other things, increased DO problems (read: mortality) for living organisms.

The numerical solution scheme employed in the LAMFE model results in free-surface gravity wave speeds and values of vertical viscosity/diffusion and friction that do not restrict the allowable computational time-step. However, the time-step is still restricted by the speed of a transient water particle, but this is not normally overly restrictive in this type of application to a coastal stream. This means that the LAMFE model can be extremely computationally efficient, running many times faster than older but more widely used river model codes (e.g., RMA2).

Another interesting feature of the LAMFE model is how it models the free surface of the water. In many models using a Cartesian vertical coordinate, the top layer is initially set to be thick enough that as the water surface declines, it can never fall though the bottom of the top layer, which would constitute an instability causing the model to "bomb." In many of the early laterally averaged models (e.g., the early CEQUAL-W2, which was based on LARM), the water surface is allowed to move between vertical layers, but the top layer has to be the same for all longitudinal columns. However, the LAMFE model allows for the water surface to move among vertical layers without it having to be in the same vertical layer in every longitudinal column. As with the treatment of the bottom, this is accomplished by constructing control volumes in which computations are made that can extend over more than one layer.

At least one scientific review panel has previously concluded that the LAMFE computer code is a well-developed numerical hydrodynamic model that contains all the physics required to accurately simulate water bodies that can be represented in a laterally-averaged sense (Powell et al. 2008). This means that any problems with its application to the lower Peace River would probably be in the areas of data input, calibration and verification. One important missing piece of data is ungaged flows, which were first estimated with the HSPF rainfall runoff model, and then adjusted based on a comparison to results generated by Janicki Environment, Inc. using the SDI method (SWFWMD 2007). It is important to remember that errors in estimating rainfall runoff from ungaged drainage areas are among the greatest uncertainties in such hydrological analyses, far exceeding the ±10% error typical of mechanical streamgaging stations and their related stage-discharge relationships.

According to the District (Chen 2008), the hydrodynamic model was calibrated against measured water levels, currents, salinities, and temperatures at a total of eight stations (water velocity data were only available at one station) in the modeled domain during a 3-month period from January 10 to April 9, 2004. It was then verified against field data measured at the same eight stations during a 6-month period before the calibration period and a 3-month period after the calibration period. In the end, the District reports that the model generally performed adequately in predicting water levels, velocities, and temperatures during the two verification periods before and after the calibration period, but the model does underpredict salinities in wet months and overpredicts them in dry months.

Unfortunately, it appears that no additional attempt was made to verify the model using the HBMP's refined salinity regression models and related data from the additional continuous-recording water quality stations in the Peace River in more recent years. Differences with model estimates and tidal phase problems should be highlighted as model deviations from reality. Again, relying on a single variable, salinity, and a single model to estimate it with, weakens scientific confidence in the proposed MFL.

The District used a mechanistic (i.e., hydrodynamic) model for the lower Peace River and an empirical (i.e., statistical) model for estimating Shell Creek salinities as a practical substitute for a preferred high-resolution hydrodynamic model, but nothing is presented concerning impacts, if any, on the ecological health and productivity of the primary bay (Charlotte Harbor) of this estuarine complex. In large part, this is may be due to comments by members of the Authority's HBMP Scientific Review Panel (this author included), which concluded that impacts of the Authority's water supply operations are hard to detect and measure against the natural background variation of this estuary, except in the near-field effects on the Peace River immediately above and below the Authority's water supply facility to the bay. As a result, we (the HBMP Panel) have repeatedly recommended more focused studies of near-field effects, including more continuous-recording water quality instrumentation, pump-tests and other technical approaches. The District appears to have accepted and integrated the Panel's concern about the tidal (i.e., estuarine) portion of the streams into its MFL analysis of the Lower Peace River and Shell Creek (Figure 3).

This does not mean that the impacts of allowed reductions in the flow of contributing basins, such as the Peace and Myakka rivers, should not be included in a subsequent evaluation of the environmental flow needs of the Charlotte Harbor bay and estuary system. If the inflow needs of the entire bay and estuary ecosystem are different than the sum of its individually estimated parts, then some adaptive management will be needed in order to avoid having to prorate or otherwise reset the individual MFL's around the estuary. This is not an administratively desired conservative outcome in water management. In fact, estimating errors being what they are, one would expect that a more geographically limited physical, chemical and biological analysis of a tidal stream's

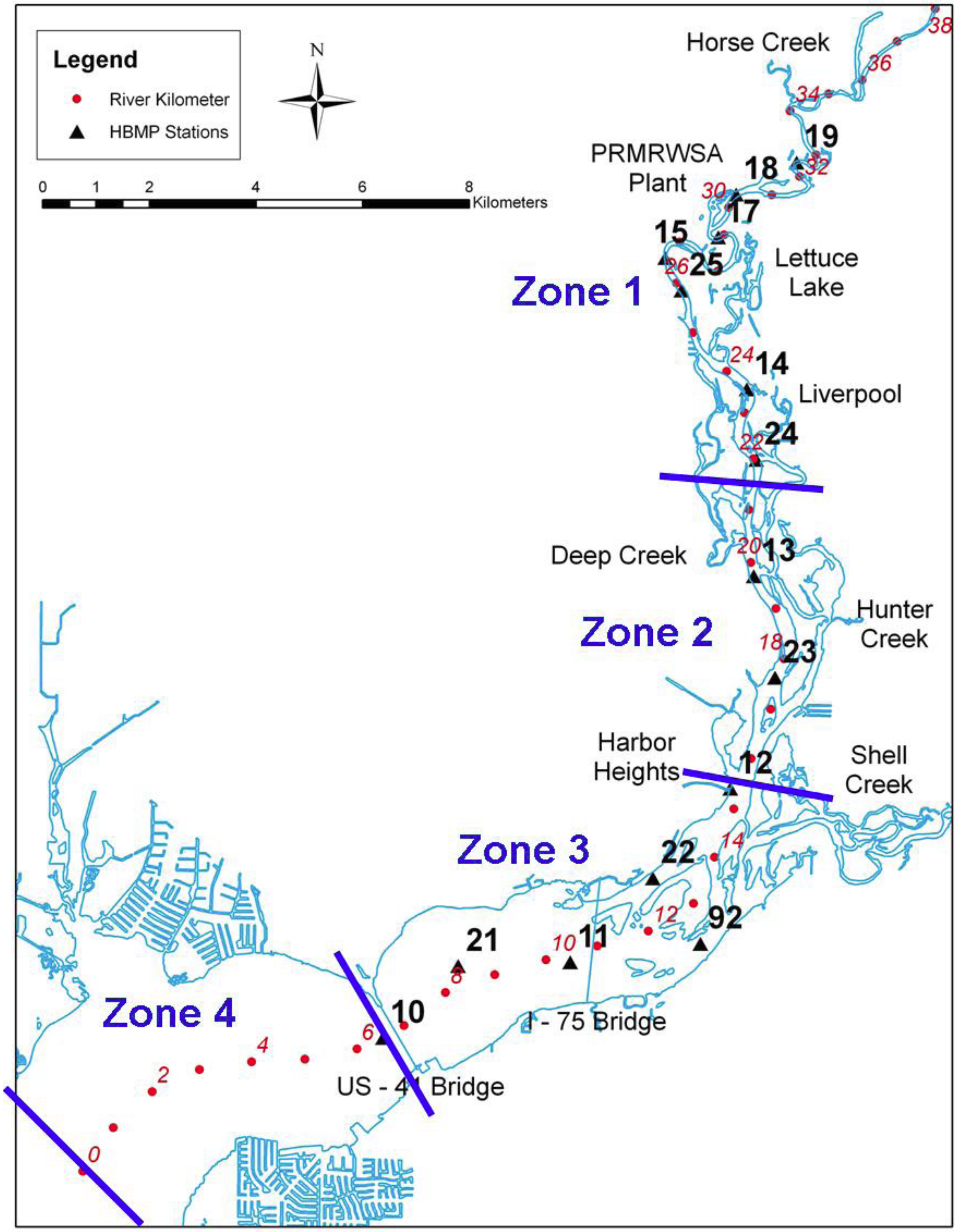

Figure 3. The Lower Peace River study area including salinity zones (in blue) as defined by Mote Marine Laboratory (2002), HBMP fixed monitoring stations (black triangles), and the centerline of river kilometers (in red).

estuarine habitats to be more accurate than a similar gross analysis of the entire bay and estuary system's flow needs. Nevertheless, estimating the freshwater inflow needs of major bays and estuaries from their source drainage basins is achievable and may eventually be required (Longley 1994, Powell et al. 2002).

A more or less “naturalized” flow was represented in the baseline condition of the lower Peace River by not including the Authority’s withdrawals at the river diversion and treatment facility in the model simulation. In addition, a conservative estimate of flows was used in the baseline condition by including Shell Creek flows minus the maximum daily allowable withdrawals under the District’s proposed MFL for Shell Creek. A range of flow reductions (10-40 percent) was then simulated by the model to support development of the MFL. This was done by estimating the amount of salinity habitats <2 ppt, <5 ppt and <15 ppt along linear shorelines, bottom areas, and water volumes in the computational grid under the model’s flow reduction scenarios. The volume of water with salinity between 8 and 16 ppt in Zone 3 of the lower Peace River (Figure 3) was also analyzed because a previous study found this region of the river characterized by salinities typically in that range (Mote 2002).

Potential loss of habitat from reduced flows in Shell Creek was determined using a statistical regression equation ($r^2 = 0.82$) that predicts daily salinity at points in the stream as a function of flow and other contributing factors, including the location in the stream, season, tide stage, Peace River flow, and salinity in the northeastern portion of Charlotte Harbor. Since the water column is relatively well mixed in the vertical dimension, the model was kept simple and only predicts the average salinity of the water column. Evaluating the Shell Creek flow record from 1966 through 2004 in this manner allowed seasonal reductions from naturalized flows to be identified that would not cause an estimated loss of more than 15% of the low (< 2.0 ppt) salinity habitat in the creek, the type of habitat considered the most in jeopardy. The allowable Shell Creek flow reductions were estimated at 13% from April 20 through June 25, the lower flow seasonal interval (defined by the District as Block 1); 58% during the higher flow season from June 26 through October 26 (Block 3); and 30% during the intermediate flow period from October 27 through April 19. (Block 2).

In the previous draft MFL report (SWFWMD 2007), the District evaluated Shell Creek and the lower Peace River sequentially, setting the tributary's MFL first. The fallacy of sequentially establishing the MFLs was acknowledged by the District in the final (April 9, 2009) report. In this case, the simulated withdrawals established for the second MFL change the salinity boundary conditions that were used to determine the first MFL, causing an error in the analysis. As a result, the District elected to treat the flow reductions from the baseline (naturalized) conditions the same in both of the streams. This means that a 10% reduction in Peace River flows is matched by a 10% reduction of flows in the tributary, Shell Creek. Since the relative amount of salinity habitats under baseline conditions is much greater in the lower Peace River, a new disproportionate bias over Shell Creek was created in the MFL analysis. For example, the allowable (maximum 15%) loss of low (<2 ppt) salinity habitat in the lower Peace River occurs with flow reductions of 38% in seasonal Block 3; however, these same flow reductions are similarly estimated to cause only a 5% loss in Shell Creek.

In the end, the District proposes an MFL based only on the loss of low (<2 ppt) salinity habitat because this class of salinity habitat is most sensitive to water withdrawals. The resulting limits were a 16% flow reduction from the baseline flow estimated for seasonal Block 1, a 19% flow reduction in Block 2, and a 38% flow reduction in Block 3. In each case, the limit is established by maximum allowable (15%) habitat losses in the lower Peace River, not in Shell Creek, due to the previously mentioned bias in the analysis. Nevertheless, it is somewhat comforting to know that neither the median predicted location of the chlorophyll-*a* maximum of the phytoplankton (primary production), nor the predicted median center of abundance for common fish and shellfish species (secondary production), were significantly different in the lower Peace River under the proposed MFL.

Peace River Facility Operations

The March 1996 permit allowed the Authority's river facility to divert 10% of the flow of the lower Peace River, up to a maximum 90 mgd (139 cfs), as long as streamsflows upstream at Arcadia are above the 130 cfs cutoff. However, as a practical matter, the facility's pump diversion capacity was only about 44 mgd (68 cfs) and its water treatment capacity an even lower 24 mgd (37 cfs). Moreover, when streamflows drop below about 100 cfs, salinity intrusion during such low-flow (drought) periods rapidly made the lower river too salty for use as a potable water supply.

Since the District failed to develop any "defensible" ecological criteria from analytical plots with little or no inflection points, the new low-flow cutoff in the District's MFL was set as the operational limit for maintaining freshwater (< 0.5 ppt) at the Authority's river facility. An earlier empirical model (salinity regression) estimated that a minimum 90 cfs was needed in order to maintain freshwater at a point 3 km downstream, providing a margin of safety in water supply operations upstream at the Authority's facility during low flow periods. Thus, the 130 cfs threshold should prevail under normal flows, while the 90 cfs should be considered a drought-contingency threshold for drought operations.

The fact that average annual gauged streamflows above the facility are about 796 mgd (1233 cfs) would suggest that most detectible impacts are going to be limited to near-field changes in salinity and perhaps some lower food chain responses under all but the most dire drought conditions. Indeed, previous HBMP reports (2004 and 2006) estimated that salinity changes would be on the order of 0.1–0.5 psu, which would make them virtually undetectable against a background of high natural variability of freshwater inflows, Gulf tidal flows and salinities in the lower river and upper Charlotte Harbor. This is why the HBMP Panel (December 2007) recommended deployment of more continuous-recording water quality meters in the vicinity of the facility, both upstream and downstream.

In an effort to keep up with growing regional water demands, The Authority is currently completing a Facility expansion that includes increasing its pump capacity to 90 mgd (139 cfs), doubling its water treatment capacity to 48 mgd (74 cfs), and constructing a 6 billion gallon surface water reservoir to provide an operational buffer against days when streamflows are too low to allow diversion of raw river waters. By continuously conducting the HBMP to watch for any negative environmental impacts, as well as planning and developing additional water supply capacity as needed, the Authority is acting as a responsible regional water supply authority. However, any aggressive move to the District's proposed MFL limits allowing up to a 38% withdrawal of river flows should be considered premature in view of the rather limited and somewhat flawed analyses presented so far. Basically, there is far more to consider here in this estuary's freshwater inflow needs, including the physical, chemical and biological needs for flow. In this case, the best available data may not be sufficient to move with scientific certainty towards a much more aggressive (up to 38%) water withdrawal schedule. The Precautionary Principle suggests gradual, phased-in increases under future water management.

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CHARLOTTE HARBOR NATIONAL ESTUARY PROGRAM
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June 19, 2009

Governing Board
Southwest Florida Water Management District
2379 Broad Street
Brooksville, FL 34604-6899

Re: Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek, 2009

Dear Governing Board members:

The Charlotte Harbor National Estuary Program (CHNEP) appreciates the opportunity to review and provide comments on the Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek dated April 9, 2009. The CHNEP received the document on June 10, 2009, along with a presentation by Dr. Marty Kelly during the CHNEP Science Forum. Our full technical and policy review of the MFL would require until at least August 21, 2009. We have attached initial comments for the interim.

The CHNEP is a partnership program established by an amendment to the Clean Water Act (Section 320) to identify, restore and protect estuaries along the coasts of the United States. In 1995, the estuarine system around Charlotte Harbor was recognized as an "estuary of national significance," creating the CHNEP. The program's *Comprehensive Conservation and Management Plan* (CCMP) identifies the region's common priority environmental issues and actions needed to solve them. Quantifiable Objective HA-1 states: "By 2015, identify, establish and maintain a more natural seasonal variation (annual hydrograph) in freshwater flows for … the Peace River and its tributaries".

The CHNEP reiterates its December 28, 2007, request that the District **delay** rulemaking for the Lower Peace River Minimum Flows and Levels (MFLs) **until after an evaluation of the cumulative effects of the combined MFLs** for the Upper and Middle Peace, Upper and Lower Myakka and Lower Caloosahatchee Rivers on the Charlotte Harbor estuary **has been completed**. We recommend using the nearly completed Peace River basin integrated groundwater/surface water model and pre-development habitat mapping to develop a natural systems mode to assist in the evaluation of cumulative effects.

Should the Governing Board decide that the District initiate rulemaking for the Lower Peace River MFLs prior to the completion of the evaluation of cumulative effects, the CHNEP recommends the following actions be implemented as an interim step:

- Adopt MFLs that limit allowable reductions to 10% during the low flow season (Block 1) and 15% during transition and high flow seasons (Blocks 2 and 3) for both the Peace River and Shell Creek.
- Maintain a 130 cfs low flow threshold for the Lower Peace River.

- Begin the low flow seasonal Block 1 on April 1 (calendar day 91) to represent the natural hydrograph.
- Delay initiating rulemaking by 3 months to allow adequate time for a thorough review of the report, methods and models by the scientific community.

The CHNEP requests that the adoption of MFLs for the Lower Peace River be delayed until adequate scientific review can be completed, especially as it relates to the cumulative impacts of the Peace, Myakka and Caloosahatchee Rivers MFLs on the Charlotte Harbor estuary.

Thank you for the opportunity to comment.

Sincerely,

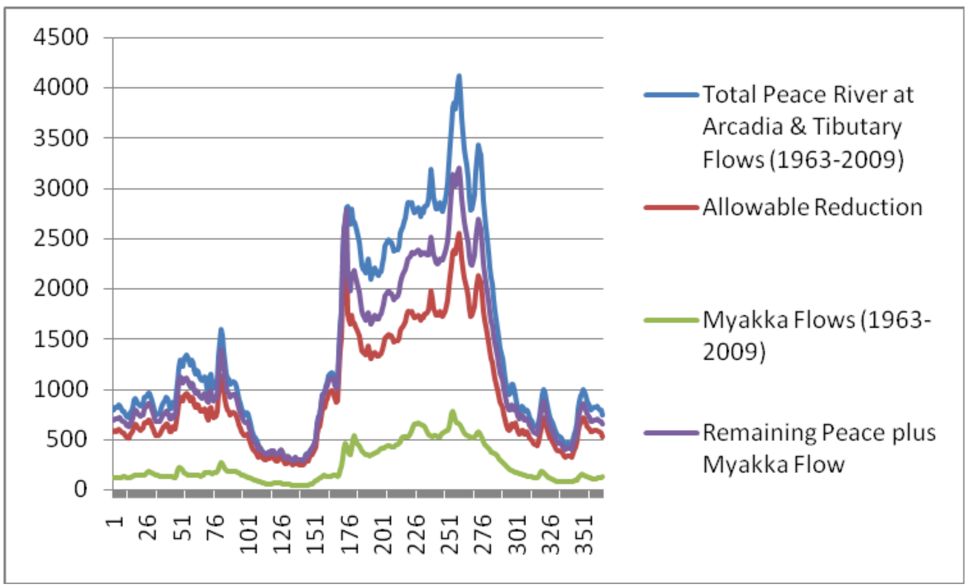
Lisa B. Beever, PhD, AICP
Director

Draft Charlotte Harbor National Estuary Program Comments – 6/19/09
Proposed Lower Peace River and Shell Creek Minimum Flows and Levels, April 9, 2009

I. The proposed allowable reductions of Lower Peace River flows exceed the total Myakka River flows.

To evaluate potential effects of the proposed Lower Peace River MFLs on the Charlotte Harbor estuary, it is critical to understand how these proposed allowable reductions in the Lower Peace River compare to other primary freshwater sources to estuary. Therefore, CHNEP compared average daily river flow from the Lower Peace River with and without MFL reductions to those of the Myakka River.

As shown in the graph below, CHNEP used average daily flows for the Peace River estimated from 4 available stations (Peace River at Arcadia, Horse Creek near Arcadia, Joshua Creek at Nocatee, and Prairie Creek at Fort Ogden), applied the allowable reduction for the Lower Peace River and compared the same period of record (1963-2009) to the Myakka River at Sarasota. As clearly shown on the graph, the allowable reduction exceeds Myakka River Flows at Sarasota.



For the 1963-2009 period, average flows for the Peace River were 1427 cfs and Myakka River were 244 cfs. The proposed MFLs would allow reductions to the Peace River of 477 cfs, almost twice the Myakka River flows. By comparison, using the recommended 10% allowable reductions during the low flow season (Block 1) and 15% during transition and high flow seasons (Blocks 2 and 3) would allow reductions to the Peace River of 205 cfs, or 85% of Myakka River flows. This raises questions regarding sustaining adequate freshwater inflows to Upper Charlotte Harbor.

II. The proposed allowable reduction of Peace River flows are half of the historic flows.

To avoid institutionalizing human altered hydrologic changes to the Lower Peace River and Charlotte Harbor estuary, it is important to compare the estimated changes in flow allowed by the proposed Lower Peace River MFLs to historic river flows. Because the District lacks a natural systems hydrologic model, in the past we accepted the District's use of available historic flows information to establish baselines. The documentation did not present a comparison of flows under the proposed MFLs with historic flows in the current document. Therefore, the CHNEP compared historic flows (1950-1969) in the Lower Peace River to recent flows, adjusted for withdrawals under the proposed MFL. Data from 3 available stations on tributaries to the Lower Peace River (Peace River at Arcadia, Horse Creek near Arcadia, and Joshua Creek at Nocatee) were obtained and then the allowable percent reductions to the 1970-1999 and the 2000-2009 periods of record were applied. Comparison of historic flows (1950-1969) to recent flows, adjusted for the proposed MFLs, demonstrates that average reductions in flow would be between 47% and 53%.

Using Proposed MFL

Period	1950-1969 Mean Daily cfs	1970-1999 Mean Daily cfs	2000-2009 Mean Daily cfs	Allowable Reduction applied 1970-1999 Flows	Resulting 1970-1999 Reduction based on 1950-1969 Flows	Allowable Reduction applied 2000-2009 Flows	Resulting 2000-2009 Reduction based on 1950-1969 Flows
Block 1 (4/20-6/25)	886	479	689	403	55%	579	35%
Block 2 (10/27-4/19)	965	807	589	573	41%	419	57%
Block 3 (6/26-10/26)	2,851	1,894	2,617	1,174	59%	1,623	43%
Average	1,607	1,121	1,261	747	53%	859	47%

Using Recommended MFL

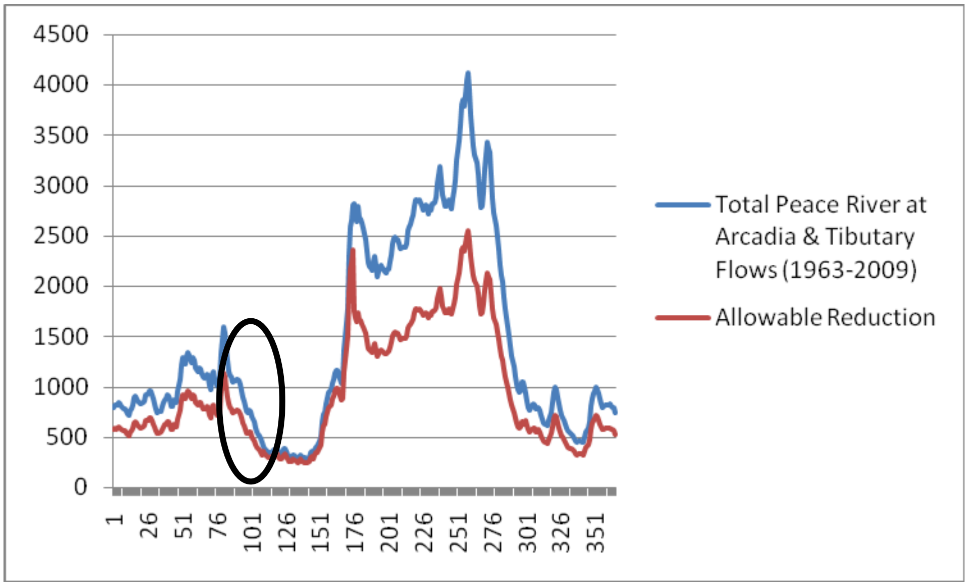
Period	1950-1969 Mean Daily cfs	1970-1999 Mean Daily cfs	2000-2009 Mean Daily cfs	Recom-mended MFLs applied 1970-1999 Flows	Resulting 1970-1999 Reduction from 1950-1969 Flows	Recom-mended MFLS applied 2000-2009 Flows	Resulting 2000-2009 Reduction based on 1950-1969 Flows
Block 1 (4/1-6/25)	886	479	689	509	43%	544	39%
Block 2 (10/27-3/31)	965	807	589	680	30%	530	45%
Block 3 (6/26-10/26)	2,851	1,894	2,617	1,610	44%	2,225	22%
Average	1,607	1,121	1,261	958	40%	1,112	31%

Comparison of historic flows to the recommended MFL of 10% in Block 1 and 15% in Blocks 2 and 3, shows that reductions in flow would be between 31 and 40%. Although this recommendation does not achieve CCMP objective HA-1, it is far better than the proposed MFL.

A preferred analysis of MFLs in the Charlotte Harbor estuary would be a natural systems model based on predevelopment land uses coupled with recent rainfall records for comparison with actual flows and measures of significant harm. With District assistance, CHNEP has funded the completion of the pre-development mapping in the Peace River basin, scheduled to be completed at the end of the year.

III. Annual hydrographs indicate that the low flow season (Block 1) should begin April 1 (Calendar day 91)

The annual hydrographs for the Lower Peace River reflect a rapid rate of declining flow starting in early April of each year, as show on the graph below. In preparation for the driest period within the hydrograph, the reduced allowable reduction associated with Block 1 should begin on April 1 (Calendar day 91), concurrent with these typical rapid flow declines.



IV. The Lower Peace River Proposed MFL Report doesn't clearly explain the methods or support the conclusions.

The technical information provided in the April 2009 Lower Peace River MFL report does not clearly explain the details of methods used, making it difficult to understand how the data and modeling results support the proposed MFLs. Relevant research regarding regional, Peace River and Charlotte Harbor macroinvertebrate, fishery and water quality data is available, and does not appear to be incorporated into these MFL calculations. This lack of clarity and documentation raises questions that should be resolved prior to determining whether the proposed MFLs will achieve the long term sustainability of the Lower Peace River and Charlotte Harbor estuary. Specifically:

1. What is the cumulative effect of all the MFLs for the Upper, Middle and Lower Peace, Upper and Lower Myakka and Caloosahatchee Rivers on the Charlotte Harbor estuary?
2. How can a 38% reduction in high flow volumes result in less than 15% reduction in the water volume, inundated river area and shoreline of the river?
3. How are Shell and Prairie Creek flows considered in calculations?
4. How are the OFW and Aquatic Preserve regulatory requirements (no degradation below ambient conditions) that exist below the US 41 bridge incorporated into the MFL calculations?
5. What is the documentation that the block flows with different allowable percent reductions are more effective at the long term sustainability of ecological health of the Lower Peace River and Upper Charlotte Harbor than one simple percent of allowable daily withdrawals, down to a low flow threshold?
6. What is the documentation that the 90 cfs low flow threshold will better sustain the ecological integrity of Lower Peace River and Upper Charlotte Harbor than the current 130 cfs?
7. Is the 90 cfs low flow threshold high enough to support minimum salinity levels at the currently permitted PRMRWSA intake?
8. Why wasn't the full historical data set used, and why was the period of data changed from 1996-1999 (relatively dry) to 1999-2002 (relatively wet)?
9. How were the 1951-2004 data incorporated into the MFL calculations, as indicated for Figure 8-5 on page 8-10?
10. How was tide stage incorporated into the MFL calculations?
11. What is the documentation that defines the 15% reduction in water volume, area and shoreline length at 2, 5 and 15 PSU's as being the most relevant to the Charlotte Harbor system?
12. What is the documentation that the 2, 5 and 15 PSUs are most appropriate indicators for the sustainable health of the Peace River and Charlotte Harbor?
13. How are the critical salinity ranges for sensitive benthic invertebrates and larval fish stages of 0-2 PSUs incorporated into the MFL calculations?

    How will the potential increases in nutrients and salinities affect Charlotte Harbor, especially the hypoxia duration and extent, (which appears to be exacerbated by stratification and increased nutrients)?
14. What are the anticipated reductions in habitat availability to other important benthic invertebrates (especially mollusks), fishery, ichthyoplankton (for which seasonal riverine salinity levels are critical), submerged vegetation (seagrasses) and emergent wetland vegetation, especially those requiring low salinities most sensitive to even small changes?

15. How will these stresses be evaluated and minimized?
16. Given the meandering nature of the Peace River and associated lengths of inundated shoreline vegetation and critical timing for fishery development, what are the anticipated impacts on long term populations and are these acceptable?
17. How are the estimated changes in median flow along the river centerline used to calculate the actual area and the shoreline of habitat affected across the river and its meanders?
18. What will the changes in river habitat area and shoreline be at the extreme lowest and highest ends of river flow and salinity where the organisms will most sensitive to changes?
19. How is amount of time that particular habitats are inundated with specific salinities incorporated into the calculations?
20. How will potential future "significant harm" in the river, creek and harbor be measured and defined?
21. If "significant harm" is observed and/or measured in the river, creek and harbor, what are the written requirements to implement correction measures immediately, as well as in the short and long term?
22. How are the increasing levels of surface water conductivity associated with irrigation and groundwater discharges incorporated into the potential impacts of changes in salinity on habitat associated with the proposed MFLs?
23. How will changes in flows associated with surface runoff associated with potential major changes in land uses (mining, agriculture, residential use) be incorporated into the Lower Peace R MFLs?
24. Are the proposed Lower Peace R MFLs based on current or "recovered" flows from the Upper and Middle Peace R?
25. Are the proposed Lower Peace River MFLs based on current or “recovered” flows from Shell Creek?
26. Have the proposed Lower Peace River MFLs been reviewed for consistency with federal Essential Fish Habitat requirements?
27. How are potential effects of the MFLs on Critical Sawfish habitat in the Lower Peace River evaluated and incorporated?

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July 10, 2009

JUL 1

Lisa B. Beever, Ph.D., AICP
Charlotte Harbor National Estuary Program
1926 Victoria Avenue
Fort Myers, Florida 33901

Subject: Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek, 2009

Dear Ms. Beever:

The Southwest Florida Water Management District (District) wishes to acknowledge receipt of your letter dated June 19, 2009, regarding the proposed Minimum Flows and Levels (MFL) for the Lower Peace River and Shell Creek and your request to delay action on rule adoption. It should be noted that the District Governing Board did take action to initiate rulemaking at its June meeting; however, the Board was not presented a rule for adoption. The Board received a copy of the MFL document and an overview of its contents. The Board was also provided copies of all recent correspondence including a copy of your letter and made aware of the several requests to delay rule adoption. Rule adoption will be delayed until a reasonable amount of time is allowed for review and comment by all interested parties. District staff will prepare a written response to initial comments provided by the Charlotte Harbor National Estuary Program (CHNEP) and forward these to you in the near future. However, I would like to address a couple of issues raised in your letter.

While the District agrees to delay rulemaking until adequate time is allowed for review and comment, we do not believe that rulemaking should be delayed until after an evaluation of the cumulative effects of the combined MFLs for the Upper and Middle Peace, Upper and Lower Myakka, and Lower Caloosahatchee Rivers on the Charlotte Harbor estuary has been completed. The District addressed this issue when responding to comments received over a year ago, and our response was reviewed by the peer review panel charged with reviewing the draft MFL document. Please note that the CHNEP letter dated December 28, 2007, was included in materials forwarded to the Peer Review Panel, along with comments received from others, as well, and the District's response to these comments.

In our earlier response provided to the Peer Review Panel that was copied to those submitting comments, the District maintained,

> *"it makes sense to first establish minimum flows for the tidal estuarine portions of Shell Creek and the Peace and Myakka Rivers before considering*

> *minimum flows for Charlotte Harbor. We suggest that this approach is a more sensitive method for evaluating the potential for significant harm to critical parts of the estuary. It is well documented, including extensive studies from Charlotte Harbor and the Peace and Myakka Rivers that low salinity zones in the tidal rivers serve as critical nursery habitat for the early life stages of many important fish and shellfish species. Many estuarine dependent species migrate to these low salinity areas as juveniles to utilize the habitats and rich food resources found there. Analyses of benthic and planktonic invertebrate communities also show the tidal rivers maintain distinct communities comprised of many taxa that are important prey items for juvenile fishes. Due in part to the much smaller volume of the rivers compared to the harbor and differences in their mixing characteristics, the relative effect of freshwater withdrawals on salinity, nutrients, sediments, and primary productivity will generally be greater within the tidal rivers than in the harbor.*
>
> *Rivers contain many species and communities characteristic of oligohaline and mesohaline waters, as opposed to organisms with more marine affinities that are common in the harbor. Granted, large scale changes in freshwater inflow are important to ecological processes in the harbor; however, due to the hydrographic and physical-chemical characteristics of the system, we conclude that unacceptable ecological changes (significant harm) from a given rate of freshwater withdrawal will likely be first manifested within the rivers before unacceptable changes occur in the harbor.*
>
> *This approach was considered by the HBMP panel for the PRMWRSA permit, who concluded that monitoring for that program should be focused in the river to evaluate any effects of freshwater withdrawals. The topic of bay vs. tributary minimum flows was also considered at a workshop sponsored by the Tampa Bay National Estuary Program. Although it was pointed out that bays are priority water bodies for minimum flows establishment, the summary document for that workshop stated – 'Several participants indicated that the rivers are more sensitive than the bay to changes in freshwater inflow, and that if the MFLs set for the rivers were adequate to protect resources in the rivers from significant harm, they should also protect the Bay's resources. There also appeared to be general agreement of the workshop participants with Janet Llewellyn's recommendation to complete the MFLs for the rivers, then analyze cumulative effects on the Bay and revise the river MFLs if necessary' (Tampa Bay National Estuary Program. 2001. Proceedings of a Water Budget Workshop for Tampa Bay). We suggest that this approach is also appropriate for Charlotte Harbor."*

Having repeated this, it is reiterated that comments provided by individuals and the CHNEP were provided to the MFL Peer Review Panel and this was documented in their response. *"The Panel also reviewed comments from the PRMRWSA HBMP Scientific Peer Review Panel to this proposed MFL as well as comments from the Charlotte Harbor National Estuary Program. Most useful was the District's clear, cogent, and consistent response to the varied comments of the PRMRWSA HBMP Scientific Peer Review Panel. Finally, the Panel had access to the Peace River Basin Resource Management Plan (FDEP 2007) and the Peace River Cumulative Impact Study (CIS) Final Report (PBS&J 2007) to further enrich their understanding of the regional ecosystem."* After their review, the Peer Review panel concluded, "***We concur with the District's statement: 'The greatest changes in flow related habitat and associated biota are believed to occur in those reaches likely to see the greatest changes in salinity, which are the tidal rivers…(A)ssessing freshwater inflows to the harbor is important, but the tidal rivers are more sensitive to potential impacts from freshwater flow reductions, and are the first places to look for significant harm.***'"

While there are obvious differences over the approach that could be taken, the District has responded to this question a number of times in the past, and the Peer Review Panel did "concur" with our position.

With respect to use of the Peace River Integrated Model (PRIM) and the setting of MFLs on the Peace River and the cumulative analysis of the entire Harbor, this model is being developed to assist in setting mid- and high-range flows for the upper Peace River only. The District developed minimum low flow recommendations for the upper Peace River, since it was clear that most of loss of baseflow was attributable to groundwater withdrawals. However, the District refrained from setting mid- and high-range flows because we could not separate out how much of the flow decline in the upper Peace River was attributable to structural alterations and changes (e.g., ditching and draining) or groundwater withdrawals, an important distinction in developing MFLs for these ranges. The PRIM is the tool being developed to make this determination. With respect to the Lower Peace River MFL, this model is not needed, as the District has relied on previous analyses that concluded that there have not been appreciable anthropogenic flow declines in the lower Peace River. The District has consistently maintained as did PBS&J (2007) in their recently completed Peace River Cumulative Impact Study, that, unlike the upper Peace River, most of the flow decline as measured at the Peace River at Arcadia gage is due to climatic rather than anthropogenic factors. Though the upper portion of the river has experienced a decline in base flow as a result of groundwater withdrawals, the middle and lower portions of the river are much less susceptible to these effects.

We thank you for your input and, as noted above, will copy you as soon as staff has prepared responses to comments received from the CHNEP and reviewed the effect, if any, that MFLs might have on the habitat of the small-toothed sawfish. We also urge you to review the April 9, 2009, Minimum Flows and Levels report and associated appendices (copies enclosed and available on our web site under the reports and publications page), since we feel that many of the issues raised have been previously addressed.

If you have any questions, please feel free to call Marty Kelly at the telephone number listed above, extension 4235.

Sincerely,

Bruce C. Wirth

Bruce C. Wirth, P.E.
Deputy Executive Director

BCW/brm
Enclosure
cc: Governing Board Members
David Moore, SWFWMD
Richard Owen, SWFWMD
Marty Kelly, SWFWMD
Log #24436-09

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July 31, 2009

Lisa B. Beever, Ph.D., AICP
Charlotte Harbor National Estuary Program
1926 Victoria Avenue
For t Myers, Florida 33901

Subject: Proposed Minimum Flows and Levels for Lower Peace River (LPR) – Response to Initial Comments

Dear Dr. Beever:

As committed to in our previous correspondence (July 10, 2009), staff has prepared written responses to initial comments and questions submitted by the Charlotte Harbor National Estuary Program (CHNEP). Each of the CHNEP's comment/question is repeated in bold lettering followed by our response.

I. **The proposed allowable reductions of the lower Peace River flows exceed the total Myakka River flows.** This statistic is not relevant to the evaluation of the MFL for the lower Peace River. In addition, the example given by CHNEP is technically inaccurate in that it does not actually compare total Myakka River flows to total lower Peace River flows, but compares a relatively small portion of Myakka River flows to a relatively greater proportion of the lower Peace River flows. The Myakka River near Sarasota gage that is used in the CHNEP example measures flow from less than one half of the Myakka River watershed, and does not take into account the ungaged flow component which is substantial. The Myakka River near Sarasota gage captures flow from 593 sq km or about 38 percent of the entire Myakka River watershed. The Myakka River flow at Sarasota is, on average, only about 17 percent of the total flow of the LPR at Arcadia, Horse Creek near Arcadia, and Joshua Creek at Nocatee. It should not be too great a surprise that the allowable LPR reduction might be higher than the Myakka River near Sarasota gage.

II. **The proposed allowable reduction of Peace River flows are half of the historic flows.** This statement is misleading and unsupported by recent research. The District does not agree that the time period between 1950-1969 represents the historic flows for benchmark purposes. In doing so CHNEP has taken the position that there is no anthropogenic effect or climatic effect relative to the 1970 to 1999 or 2000-2009 time periods and that flows in these latter time periods should be identical to those of 1950-1969 in the absence of anthropogenic impacts. This comparison disregards previous District conclusions (Basso and Schultz 2003, Kelly 2004, Kelly et al. 2005) and also ignores the almost identical conclusion reached by PBS&J (2007) in the Peace River Cumulative Impact Assessment. While the District has presented data to support its findings on the historic flows, we cannot provide a technical response to CHNEP's position as no analysis or data were cited to support the statement or demonstate why either the District's or PBS&J's conclusions are erroneous. Any analysis or statements to the contrary should explain why there have been almost identical flow changes in the Charlie Creek watershed where land use changes have been minimal. The District through the setting of low flows on the upper Peace River has clearly identified loss of baseflow due to ground water withdrawals as "significant harm", and has committed considerable resources to recovery of baseflow conditions; however, this loss of baseflow in the upper Peace in no way accounts for the continued assertion that there has been a 30 to 40 percent decline in historic mean annual flows due to anthropogenic factors. Most of the flow decline as measured at the Peace at Arcadia gage is due to climatic rather than anthropogenic factors. This is most graphically demonstrated not by looking at Peace at Arcadia flows in isolation, but by also looking at Charlie Creek flows where it has been shown that landuse is the most unchanged in the Peace River watershed, with only minimal urban or mining impacts. "*Among the nine basins in the Peace River watershed, the Charlie Creek basin has . . . undergone the least amount of change since the 1940s. There is no phosphate mining, urbanization is limited, and there has not been the same degree of conversion to more intense forms of agriculture seen in the more southern basins*" (PBS&J 2007).

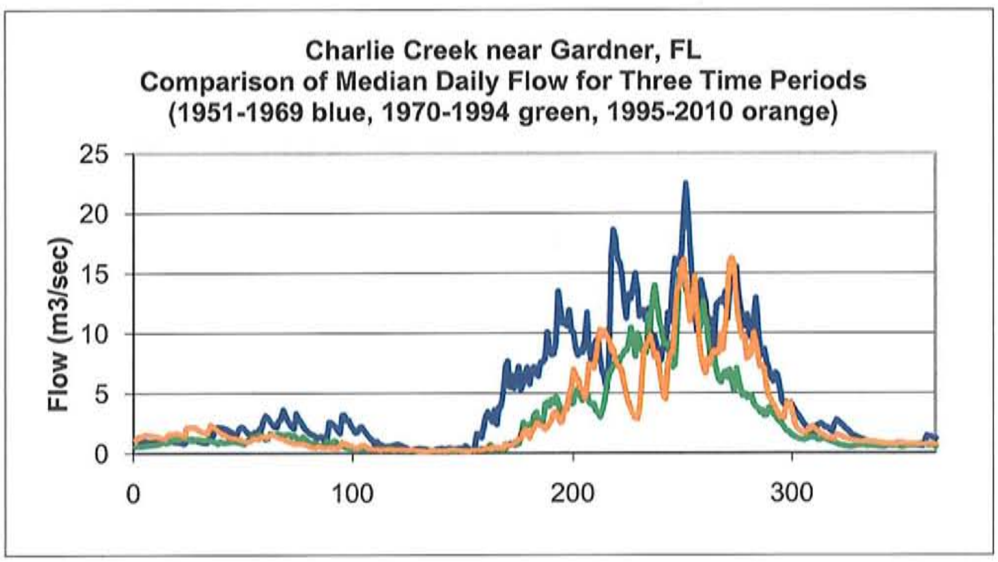
Please examine the attached table and graphic for Charlie Creek and offer an explanation for the 35 percent decline in mean annual flows between the two periods (1951 to 1969 and 1970 to 1995). What major anthropogenic effects have contributed to this flow decline? Is it coincidence that the difference in mean annual flows expressed in inches between these two periods is approximately 4.5 inches and equivalent to the reported 4 to 5 inches difference in mean total annual rainfall between these two periods? "*Long-records indicated that annual rainfall during the last 30 years has been about five inches/year less when compared with the period 1940-1970*" (PBS&J 2007). Again quoting from PBS&J (2007), "*Further analyses indicated that variation in annual total flows at the long-term river gages downstream of Bartow coincided with similar long-term patterns outside the Peace River watershed at the Withlacoochee at Croom USGS gauging station. These results indicate similar variations in total annual flows within and outside the Peace River watershed due to natural long-term variations in rainfall that influenced southwest Florida (Kelly 2004). The Withlacoochee River at Croom gauging site was selected for comparison due to the proximity to the northern portion of the Peace River watershed and flows that are not strongly influenced by major spring flows, phosphate mining, extensive intense agriculture, or urban development.*"

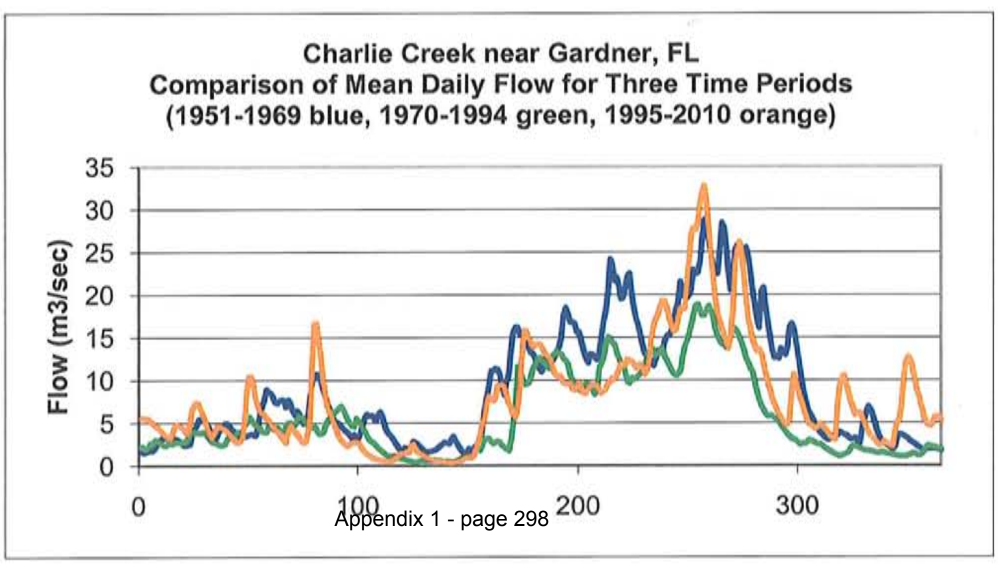
Finally, while the District must provide a scientifically defensible position for its recommendations, there is no technically defensible justification given for any of the CHNEP's recommended allowable percentage flow recommendations. As noted in Chapter 1 of the District's report, Section 373.042 F.S. states that, "*minimum flows and levels are to be established based upon the best information available. When* *appropriate, minimum flows and levels shall be calculated to reflect seasonal variation."* Given these considerations, the District proposed MFLs are based on quantifiable relationships and explicitly address natural seasonal fluctuations in flows through the Block Approach.

USGS 02296500 CHARLIE CREEK NEAR GARDNER FL

Watershed Area = 330 square miles

Multidecadal Period	Median Annual Q		Mean Annual Q		
	inches	cfs	inches	cfs	cfs/sq mile
1951 to 1969	6.85	166	13.36	324	0.98
1970 to 1994	3.89	94	8.44	205	0.62
1995 to 2010	4.40	107	11.58	281	0.85





III. **Annual hydrographs indicate that the low flow season (Block 1) should begin April 1 (Calendar day 91).** Is the technical basis for this statement simple inspection of the hydrograph? Please refer to the MFLs documents for both the middle and lower Peace (Kelly et al. 2005, SWFWMD 2009) for an explanation of how the flow blocks were derived. Block 1 includes the driest 67 days based on flow falling below and staying below the lowest quartile of flows based on the period of record. This method is designed to protect the most sensitive time of the year. It is possible to propose other objective schemes for deriving blocks, but understand that the proposed percentage allowable withdrawals could change as a result. For example, beginning Block 1 on April 1 instead of April 20 will include some less dry days (days with higher flows) and generate a higher percentage allowable reduction.

IV. **1. What is the cumulative effect of all the MFLs for the Upper, Middle and Lower Peace, Upper and Lower Myakka and Caloosahatchee Rivers on Charlotte Harbor estuary?** Please see our response to your letter dated June 19, 2009 (attached).

2. How can a 38% reduction in high flow volumes result in less than a 15% reduction in the water volume, inundated river area and shoreline of the river? This occurs because the volume of water in a given salinity zone is not a simple linear function of freshwater flow volume. Evidence from other minimum flow analyses which involved salinity modeling shows the relationship between the percentage withdrawal rate and the reduction of habitat is not linear. There are several factors which contribute to this observation. Technically, the salinity response is a change in volume at or less than a particular salinity relative to a total volume between two points. The forcing function is rate of flow, not volume of flow. First as the rate of flow increases, the total volume of water beween the two points increases as the river stage rises. Thus the total volume of water is not constant. (These seasonal and tidal changes are computed with the hydrodynamic model at time intervals of 30 to 180 seconds and averaged to daily values.) These variations in stage can be easily discerned (refer to Chen, 2008 – Figure 7 of Appendix 1). Another factor is that the river is wider at the mouth than it is upstream, leading to another non-linear relationship (see Figure 2-8). To reduce a given salinity volume by 15% at the mouth will require a much larger volume of freshwater for dilution than a comparable reduction at an upstream location where the river is narrower. A third non-linear function is the inverse relationship between salinity and flow. For example, a plot of salinity (y-axis) and the reciprocal of flow (1/Q) along the x-axis gives a non-linear plot which is steepest at low flow (high salinity) and tapers asymptotically to a zero salinity as the flow increases. All of this volume would be included in the less than 2 PSU volume. For any given location in the river, at some rate of flow the salinity will become zero regardless of how much more the rate of flow is increased. The combination of several non-linear functions explains why, for example, flow can be reduced 38% before there is a 15% reduction in the volume of water less than 2 PSUs during the typical wet season (i.e., Block 3).

3. How are Shell and Prairie Creek flows considered in the calculations? The interaction between the LPR and Shell Creeks flows is explicitly handled in the model and discussed in Chapter 7 of the report titled, "Application of Modeling Tools that Relate Freshwater Inflows to Salinity in Shell Creek and the Lower Peace River". Prairie Creek flows are not addressed separately, since they contribute to Shell Creek flows just as, for example, Bowleg Creeks flows are incorporated into flows as measured at the Arcadia gage.

4. How are the OFW and Aquatic Preserve regulatory requirements (no degradation below ambient conditions) that exist below the US 41 bridge incorporated into the MFL calculations? Chapter 373 explicitly states that, "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." The establishment of MFL's is similar to the establishment of an OFW and Aquatic Preserve in that they all provide for regulatory threshold criteria. The establishment of an MFL is not an activity, and, therefore, not applicable to the regulatory requirements referenced. Additionally, the MFL is clearly not a "no degradation below ambient conditions" standard. This question is misleading in that OFW and Aquatic Preserve regulations apply to the permitting of surface water management systems or land use changes and their associated direct or indirect pollutant discharges, through such programs as Florida Department of Environmental Protection (FDEP) NPDS permitting or Environmental Resource Permitting (ERP). According to the FDEP's fact sheet on OFWs, the regulatory significance of the OFW designation from their perspective is that, "In general, DEP cannot issue permits for direct pollutant discharges to OFWs which would lower ambient (existing) water quality or for indirect discharges which would significantly degrade the Outstanding Florida Water." From the WMD perspective, upon establishment of a minimum flow, the protection of that flow rate becomes a condition of issuance in ERP (ref. 40D-4.301(1) (g), F.A.C.). Another ERP condition of issuance requires that proposed activities "not adversely affect the quality of receiving waters....including any anti-degradation provisions of paragraphs 62-4.242(1) (a) and (b), subsections 62-4.242(2) and (3) and Rule 62-302.300, F.A.C." (ref. 40D-4.301(1) (e), F.A.C.). ERP applicants must meet both conditions (and all other conditions for issuance) to receive a permit.

5. What is the documentation that the block flows with different percent reductions are more effective at the long term sustainability of ecological health of the Lower Peace River and Upper Charlotte Harbor than one simple percent of allowable daily withdrawals, down to the low flow threshold? The objective of MFLs is to determine the amount of withdrawals that can occur without causing "significant harm". The statute establishing the mandate to develop MFLs specifically directed that, "*[w]hen appropriate, minimum flows and levels shall be calculated to reflect seasonal variation.*" Examination of any reasonably natural hydrograph in Florida reveals a distinct seasonality in flow. It is also reasonable to assume that the ecology of such systems has adapted to this seasonality. This seasonality has been extensively researched and peer reviewed and accepted as a rationale for establishing MFL's. Compared to a single percentage withdrawal rate, the use of seasonal blocks is intended to be most protective of the resource during sensitive low flow times of year and allow greater water use (as a percent withdrawal rate) when flows are higher. Losses of habitat are analyzed within these seasonal blocks to determine when significant harm will occur. Given the nonlinear nature of many physical-chemical and ecological relationships in estuaries to freshwater inflow, it is unlikely that a single minimum flow would produce the same level of resource protection at all times of year.

6. What is the documentation that the 90 cfs low flow threshold will better sustain the ecological integrity of the Lower Peace River and Upper Charlotte Harbor than the current 130 cfs? Using the percent of flow method, the impacts of withdrawals on the ecology of the river are intended to be small compared to the effects of natural variations in flows. This is particularly true in Block 1 when the allowable percent flow reduction is the lowest. Low flow thresholds (LFT) can be applied if there are clear inflections in certain ecological relationships with flow that justify not allowing any withdrawals. As described on page 7-23 of the report, "*Models were developed that relate flow to ecological criteria in the Lower Peace River (e.g., salinity, chlorophyll a). However, there were no breakpoints or inflections in these relationships at low flows, thus it was concluded that a low flow threshold based on ecological criteria was not necessary.* However, there is an important need for an LFT based on the upstream movement of brackish water to the location of the PRMRWSA intake during low flows. When brackish water is in the vicinity of the PRMRWSA intake all withdrawals from the river should cease. That criterion was used to determine the LFT presented in the report.

7. Is the 90 cfs low flow threshold high enough to support minimum salinity levels at the currently permitted PRMRWSA intake? This is a relevant question, since the stated purpose of the LFT that is being proposed for the lower Peace River is to protect the water resource (i.e., PRMRWSA intake). District staff is re-evaluating the rate of flow at which brackish water, which is unsuitable for routine potable supply, occurs in the river near the location of the PRMRWSA intake. Also, due to the recent drought, the PRMRWSA has been operating on an "emergency order" that allows them to withdraw water from the river down to a LFT of 90 cfs. The District will examine the PRMRWSA's withdrawal schedule to determine at what flow rates(s) brackish water occurred at the plant intake, and when the Authority ceased withdrawing water to avoid unacceptable impacts.

8. Why wasn't the full historical data set used, and why was the period of data changed from 1996-1999 (relatively dry) to 1999-2002 (relatively wet)? This is a two part question. First - why wasn't the full historical data set use? Please refer to page 7-19 in the current MFL document, but appreciate that this explanation was also in the previous version, and has not changed since 2007. *"Establishment of an MFL for the Lower Peace River requires the hydrodynamic model to provide predicted salinities for a Baseline Scenario and a series of flow scenarios with different percent flow reductions. The hydrodynamic model requires a significant amount of computer time to simulate changes in water levels and salinities in the LPR. As such it is impractical to simulate the entire 20-year reference period for the series of modeling scenarios that is necessary to support development of an MFL for the LPR. Because of this impracticality it was necessary to identify a shorter surrogate time period on the order of 3-5 years that reflects a similar range of hydrologic conditions to that observed over the entire 20-year reference period" (SWFWMD 2009, page 7-19).*

The second question, Why was the period of data changed from 1996-1999 (relatively dry) to 1999-2002 (relatively wet)? This question was answered on page 7-22 of the report, "*A number of candidate modeling periods were examined. This was accomplished by defining the flow duration curve for the baseline period (1985 to 2004) and comparing the flow duration curves for each candidate modeling period. It was found that a minimum 4-year period is necessary to attain reasonable concordance to the 20-year flow duration curve. Evaluating daily discharge without regard to seasonal Blocks, the flow duration curve for the 1996-1999 period most closely resembled the 1985 to 2004 flow duration curve (Figure 7-11). In the initial evaluation reported in the peer review draft, 1996 to 1999 was selected as the period to be used for modeling of the Lower Peace River. However, the initial selection was based on CDF plots of daily flow values without regard to seasonal Blocks.*" Subsequent work that compared CDF plots of flows within seasonal blocks revealed major deviations in Block 2 because of the unusually high flows that occurred from the winter of 1997 through the spring of 1998 as a result of the 1997-1998 El Nino. Comparison of a number of moving four-year periods showed that the 1999-2002 period was more representative of the recent flow regime of the lower river. Therefore, the period 1999-2002 was selected as the modeling period.

9. How were the 1951-2004 data incorporated into the MFL calculations, as indicated for Figure 8-5 on page 8-10? In the letter dated June 19, 2009, CHNEP generated almost identical graphics using mean daily flows for the period 1963 to 2009 instead of median daily flows for the period 1951 to 2004. The existing daily flow record (the sum of Arcadia, Horse and Joshua flows) was used to generate daily medians which were then plotted (the blue line in the graphic). For each daily flow in this record, the proposed allowable percentages were then taken, except that no withdrawals were allowed below 90 cfs and withdrawals were not allowed to lower the flow below the 90 cfs LFT, and then median daily flows (instead of means) were generated and plotted (red line). If the question is, "Was the entire 1951 to 2004 flow range used to derive allowable percent reductions", the answer is "no" as explained in response to Question 8, above.

10. How was tide stage incorporated into the MFL calculations? Tide stage is an intrinsic part of the hydrodynamic model. The hydrodynamic model is described in some detail in an appendix document prepared by Dr. XinJian Chen of the District. The Appendix document is entitled *Hydrodynamic Simulations of the Lower Peace River – Lower Myakka River – Upper Charlotte Harbor System in Support of Determining Minimum Flows for the LPR and LMR in Southwest Florida* (88 pages).

11. What is the documentation that that defines the 15% reduction in water volume, area and shoreline length at 2, 5 and 15 PSU's as being the most relevant to the Charlotte Harbor system? It is not clear if the question is directed at use of a 15 percent reduction as the "significant harm" standard or the selection of the 2, 5 and 15 PSU's. While related in the analysis, the logic for their respective selections was different. The logic train is that "significant harm" occurs when there is a 15 percent or greater loss of habitat, and that relevant habitat loss is determined as loss of water volume, shoreline length, or bottom area exposed to one of several salinity zones. The justifications of the <2, <5, and < 15 PSU salinity zones are discussed on pages 7-2 and 7-3 of the report.

The selection of the 15 percent significant harm criterion has been discussed in the text and in several previous responses. While one may or may not agree with the selection, the criterion has not changed since the original peer review draft was released in 2007, nor in the most recent draft. The significant harm criterion is discussed in some detail in a memo to the MFL Peer Review Panelists dated April 10, 2008 and appended to the current document, and in response to several questions from PRMRWSA peer reviewers also appended in the current document. It should be noted that the 15% criterion has been the basis for all our river MFL's thus far and that each has been peer reviewed and found to be acceptable.

12. What is the documentation that the 2, 5 and 15 PSUs are most appropriate indicators for the sustainable health of the Peace River and Charlotte Harbor?
See response to Question 11 above.

13. How are the critical salinity ranges for sensitive benthic invertebrates and larval fish stages of 0-2 PSUs incorporated into the MFL calculations?
The salinity range of <2 PSUs was one of the three salinity ranges specifically addressed with the modeling analysis (see for example, Section 7.1.1 – Definition of Biologically-Relevant Salinity Zones; Section 7.3.8 – Results of the Quantification of Habitat Availability as a Function on Inflow in the Lower Peace River,). Since the <2 PSUs was the most sensitive of the ranges tested, this is the one that the minimum flows recommendations were based on. It was also found that using a loss of 15 percent of available habitat as the criterion, that the volume of water <2 PSUs was also more sensitive than either the bottom area exposed to <2 PSUs or shoreline length exposed to <2 PSUs.

How will the potential increases in nutrients and salinities affect Charlotte Harbor, especially the hypoxia duration and extent, (which appears to be exacerbated by stratification and increased nutrients)? The clear implication of this question is that withdrawals would somehow increase nutrients and exacerbate stratification. The exact opposite is true; there would be decreases in nutrient loading to the Harbor as a result of increased withdrawals. While hypoxia is exacerbated by stratification, vertical stratification in Charlotte Harbor is exacerbated by increased freshwater flow, not decreased flow. In short, there will be potential decreases in nutrient loading and a decrease in stratification, neither condition will be exacerbated by the establishment or implementation of minimum flows.

14. What are the anticipated reductions in habitat availability to other important benthic invertebrates (especially mollusks), fishery, ichthyoplankton (for which seasonal riverine salinity levels are critical), submerged vegetation (seagrasses) and emergent wetland vegetation, especially those requiring low salinities most sensitive to even small changes? As described above, the < 2 PSU salinity zone was the most sensitive to change as a result of flow reductions. For those nektonic organisms (e.g., fishes, ichthyoplankton) that utilize habitats based on the volume of water the habitat of the less < 2 PSU water will be reduced by no more than 15 percent; for those benthic organisms (e.g., mollusks, benthos) that are affected by salinity of the overlying bottom water , their habitat of water <2 PSU is reduced by less than 15 percent, since the volume of water was more sensitive to change than the bottom area exposed; for those organisms that are affected by salinity at the river shoreline (marshes and forested wetlands), their habitat of < 2 PSU water is reduced less than 15 percent since the volume of water in a given salinity range was more sensitive to change than shoreline length exposed.

15. How will these stresses be evaluated and minimized?
a.) Compliance with MFLs is evaluated on an annual basis and reported to the District's Governing Board.
b.) Permittees are required to implement a hydrobiological monitoring program as a permit condition.
c.) MFLs are subject to re-evaluation as needed.

16. Given the meandering nature of the Peace River and associated lengths of inundated shoreline vegetation and critical timing for fishery development, what are the anticipated impacts on long term populations and are these acceptable? The simplest answer is that they would be no greater than 15 percent and not violate the significant harm criterion used. There are no quantitative relationships that the District is aware of that establishes a relationship between fish populations (which metric would you use, which species would you target, would critical timing be different for different species, etc.) and inundated shoreline vegetation in a given salinity range. It should be appreciated that tidal fluctuations determine for the most part the timing and extent of inundation of shoreline vegetation while varying flows determine salinity within these habitats. The hydrodynamic model used on the lower Peace took into account not only salinity, but also the wetting and drying of shoreline habitats under changing tidal and freshwater inflow conditions when computing volume, shoreline length and bottom area inundated. As previously described, the volume in a given salinity range was more sensitive to flow changes and the significant harm criterion (15 percent reduction in available habitat) was crossed in volume before either the length of shoreline exposed or bottom area covered by a given salinity. Except under extreme high flows of relatively short duration when the actual length of shoreline increased, under most conditions flow determines salinity at the shoreline and tidal fluctuations determine inundation. So, under most flow conditions, the amount of physical (stationary) habitat is not meaningfully reduced, only the spatial and temporal extent of a given salinity range is changed. The question then becomes which species(s) benefits most from inundation of a particular habitat within a given salinity range. Regardless of where this line of reasoning goes, the quantifiable answer used in the MFL analysis is that reductions in shoreline length or bottom area exposed to a given salinity range will be less than 15 percent since allowable percentage reductions were based on not causing more than a 15 percent decline in volume in a given salinity range. Assuming that a particular species' population is at the carrying capacity of the available habitat, which is rare in nature due to the many dynamics (e.g., predator/prey interactions, over fishing, disease, destruction of physical habitat, etc.) that affect abundance and biomass, then no one species' population should be reduced by more than 15 percent, while some species' population would likely increase by some percentage.

17. How are the estimated changes in median flow along the river centerline used to calculate the actual area and shoreline of habitat affected across the river and its meanders? Estimated changes in median flows along the river centerline were not used to calculate area or shoreline. The grid for 2D/3D model that was developed for establishing MFLs accounts for the braided, meandering nature of the lower river. Salinity changes were calculated separately for each of the many cells and layers that comprise model. Data sets of the predicted salinity values in all the cell and layers were then statistically analyzed to determine loss of habitat. In this manner, the District's model provided a very effective tool to account for the meanders and side channels in the lower river.

18. What will the changes in river habitat area and shoreline be at the extreme lowest and highest ends of river flow and salinity where the organisms will [be] most sensitive to changes? See question above. The model simulated changes in salinity for the flow range that occurred during the 1999-2002 period, which covered a very wide range of flows, including a period of severe record low flows when the estuary was most sensitive to impacts.

19. How is the amount of time that particular habitats are inundated with specific salinities incorporated into the calculations? Allowable percent reductions, be they volume, area or length, were determined by seasonal block. Actual calculations for the hydrodynamic model were computed on a short-time step (varying between 2-3minutes), and model results were compiled for each hour for every cell in the model domain. These values were then reduced to daily average values for each cell. Statistical analyses of these values were then done within each seasonal block to determine the changes in habitat. By comparing the cumulative distribution function (cdf) curves of habitat availability, this approach integrated changes in the spatial amounts of area, volume or shoreline length for a given salinity zone with the length of time that these changes occurred.

20. How will potential future "significant harm" in the river, creek and harbor be measured and defined? See response to Question 15, above.

21. If "significant harm" is observed and/or measured in the river, creek and harbor, what are the written requirements to implement correction measures immediately, as well as in the short and long term? The relevant state statute (373.0421 F.S.) relating to the Establishment and Implementation of Minimum Flows and Levels, reads, *"(2) If the existing flow or level in a water body is below, or is projected to fall within 20 years below, the applicable minimum flow or level established pursuant to s. 373.042, the department or governing board, as part of the regional water supply plan described in s. 373.0361, shall expeditiously implement a recovery or prevention strategy, which includes the development of additional water supplies and other actions, consistent with the authority granted by this chapter, to: (a) Achieve recovery to the established minimum flow or level as soon as practicable; or (b) Prevent the existing flow or level from falling below the* *established minimum flow or level.*

The recovery or prevention strategy shall include phasing or a timetable which will allow for the provision of sufficient water supplies for all existing and projected reasonable-beneficial uses, including development of additional water supplies and implementation of conservation and other efficiency measures concurrent with, to the extent practical, and to offset, reductions in permitted withdrawals, consistent with the provisions of this chapter."

The District's Water Use Permitting Rules also require that water use will not cause adverse impact to wetlands, lakes, streams, estuaries, fish and wildlife, or other natural resources (40D-2.301 (c)). Monitoring plans are frequently required to assure that permitted withdrawals do not cause environmental impacts. The monitoring program that has been associated with the Lower Peace River is one of the most extensive in the state. If adverse impacts are detected or are projected to occur, the District may modify water use permits to remedy or avoid adverse impacts. To date, no adverse impacts to the resources of the Lower Peace River have occurred from permitted water use.

22. How are the increasing levels of surface water conductivity associated with irrigation and groundwater discharges incorporated into the potential impacts of changes in salinity on habitat associated with proposed MFLs? The modeling addressed changes in salinity in the river resulting in the mixing of fresh water with marine waters from the Gulf of Mexico. A constant salinity of 0 PSU was assumed for inflowing river and tributary waters. Secondly, the increases in specific conductance that have been observed in some tributaries are the focus of the current emphasis on management strategies for reducing excess agricultural flows that are now in place.

23. How will changes in flows associated with surface runoff associated with potential major changes in land uses (mining, agriculture, residential use) be incorporated into the Lower Peace MFLs? The District after determining allowable percent reductions has typically produced long term hydrologic statistics (5- and 10-year running mean and median flows) that would result if flows are changed by the maximum withdrawal allowed without violating the significant harm standard. These statistics have been incorporated into previous MFL rules and are used as a backstop against which to evaluate MFL compliance under worst case conditions (i.e., lowest 5 and 10-year running mean and median). Should, for example, the maximum amount of water withdrawal possible under the proposed MFL be permitted, it would be expected that flows should not fall below these long-term hydrologic statistics, unless there has been an anthropogenic change in flow unrelated to withdrawals or the period of record has not adequately captured future climatic conditions.

24. Are the proposed Lower Peace River MFLs based on current or "recovered" flows from the Upper and Middle Peace River? The model used to develop MFLs allowable percent reductions was based on actual flow records for Horse Creek, Joshua Creek, and the Peace River at Arcadia gage for the period

1999 through 2002 as explained in the text in Section 7.3.5 – Definition of Baseline and Model Scenarios for Lower Peace River.

25. Are the proposed Lower Peace River MFLs based on current or "recovered" flow from Shell Creek? Current, corrected for City of Punta Gorda withdrawals and adjusted for agricultural augmentation as explained in Sections 7.2.3 to 7.2.6 of the report.

26. Have the proposed Lower Peace River MFLs been reviewed for consistency with federal Essential Fish Habitat requirements? It is the District's understanding that the Magnuson-Stevens Act was aimed at federal fisheries management programs in an attempt to prevent or limit overfishing in designated habitat areas. Regardless, the use of biologically based salinity zones was chosen as a key variable to analyze in order to protect biological populations including fishes. The report presents the findings of Principal Components Analysis of fish salinity relations for data collected from the Lower Peace River.

27. How are potential effects of the MFLs on Critical Sawfish habitat in the Lower Peace River evaluated and incorporated? District staff have reviewed the *Smalltooth Sawfish Recovery Plan* prepared by the National Marine Fisheries Service, and note the following points from that report:

- Currently, smalltooth sawfish can only be found with any regularity in south Florida between the Caloosahatchee River and the Florida Keys.
- Juvenile smalltooth sawfish generally inhabit the shallow coastal waters of bays, banks, estuaries, and river mouths, particularly shallow mud banks and mangrove habitats.
- The primary reason for the decline . . . has been bycatch.
- The secondary reason is . . . habitat loss and degradation.
- Changes in freshwater flows throughout the historic range of smalltooth sawfish, and in peninsular Florida in particular, may have affected how juvenile sawfish use nursery habitats.
- Little scientific research is available on the salinity preferences and tolerances of this species.
- Public encounter databases and surveys have shown that juvenile sawfish occur most frequently in euryhaline (estuarine) areas. However, there is insufficient information to determine the level of importance of lower salinity areas to smalltooth sawfish.
- Once research has identified the optimal water quality conditions for smalltooth sawfish, authorities must be encouraged to include them in relevant standard regulations, and water management programs.

District staff also reviewed a recent presentation by Dr. J. Galvez that was forwarded to the CHNEP on July 13, 2009. Dr. Galvez is with the South Florida Fisheries Resource Office, and his presentation was titled "Critical Habitat Designation for the Smalltooth Sawfish (*Pristis pectinata*)" and dated June 2009. Dr. Galvez made the following points, in part, with respect to the Critical Habitat Designation:

- Critical habitat is a term used in the Endangered Species Act of 1973

- It refers to specific geographic areas that are essential for the conservation of a threatened or endangered species and that may require special management and protection features.
- These features include space for individual and population growth and for normal behavior; cover or shelter; food, water, air, light, minerals, or other nutritional or physiological requirements; sites for breeding and rearing offspring; and habitats that are protected from disturbances or are representative of the historic geographical and ecological distributions of a species.
- A critical habitat designation does not establish a preserve or refuge nor does it affect individual citizens, organizations, states, local governments, or other non-federal entities that do not require federal permits of funding.

The Smalltooth Sawfish proposed critical habitat consists of two units located along the southwestern coast of Florida between Charlotte Harbor and Florida Bay, and include 1) Charlotte Harbor Estuary Unit (221,459 acres of coastal habitat), and 2) Ten Thousand Island/Everglades Unit (619,013 acres of coastal habitat).

From the District's review, it appears that most of the decline in the smalltooth sawfish is primarily attributable to fishing impacts, and secondarily to physical habitat destruction through activities such as dredging and filling. The preferred habitats for small and juvenile fishes (2-3 feet in length) appears to be red mangrove areas or shallow unvegetated areas where these fish go to avoid predators. While it is implied that flow may be important, the Smalltooth Sawfish Recovery Plan readily acknowledges that, "Little scientific research is available on the salinity preferences and tolerances of this species." As suggested, it may be important to understand the salinity preferences of these animals, and once that is done such information could be relevant in making appropriate management decisions.

Again, thank you for your input. If you have any questions, please feel free to contact me at the telephone number listed above, extension 4235.

Sincerely,

Martin H Kelly

Martin Kelly, Ph.D.
Minimum Flows and Levels Program Director
Ecologic Evaluation Section
Resource Projects Department

MHK/brm/jg
Enclosure
cc: SWFWMD Governing Board Members
David Moore, SWFWMD
Bruce Wirth, SWFWMD
Richard Owen, SWFWMD
Debra Highsmith, Sierra Club
Jim Cooper, Lemon Bay Conservancy

ANALYZING THE DIRECT EFFECT OF STAGE ON TIDAL WETLAND INUNDATION IN THE PEACE RIVER AND SHELL CREEK, AND INDIRECT EFFECTS TO CHARLOTTE HARBOR, DURING PERIODS OF HIGH FLOW AND FLOW DIVERSION.

Being a suggestion employing existing information; providing for impact assessment during high-flow periods; seeking to identify new non-linear relationships of flow to living resources, etc…

E.D. Estevez, Ph.D.
Senior Scientist and Director,
Center for Coastal Ecology
Sarasota, Florida

August 7, 2009

I have not been involved in the computation of the lower Peace River/Shell Creek MFL proposal, and I am not a member of any peer-review or advisory committee connected with Peace River use or management, so I am about as removed from the process as possible while being a subject-matter expert who is very interested in the resources, MFL process, and its outcome.

I have studied the MFL report and comments by Lisa Beever, Joan Browder, Tom Fraser, Fred Holland, and Gary Powell. Representative ideas are quoted with edits, below.

> From Beever, "What is the cumulative effect of all the MFLs … on the Charlotte Harbor estuary; what are the anticipated reductions in habitat availability to other important benthic invertebrates… fishery, ichthyoplankton … submerged vegetation…and emergent wetland vegetation; how is the amount of time that particular habitats are inundated with specific salinities incorporated into the calculations?"

> From Fraser, "Biological responses to … the physical and chemical components carried with flow and interactions with salinity and tides have been set aside; primary production, detritus and subsequent food web [data are needed for] information about initiation and duration of biological production; potential damage… at block levels of 29-38% reduction in primary production will echo up the food web."

> From Holland, "I am not aware of any scientific studies or theories that would suggest a 15% loss in important estuarine habitat would not result in significant ecological harm. This is especially true for spawning or nursery habitat which is the major ecological function of the most severely impacted area… where the ecological value and services provided by the habitat are disproportional to the amount of the habitat that exists; the current assessment appears to be limited to the changes in the amount …bottom area, volume, and shoreline length; no information was provided on …which ecological services or functions may be impaired under various withdrawal schedules."

> From Powell, "If the estuarine habitat and animal distributions become uncoupled, estuarine biota may be restricted to areas that are no longer suitable habitat for their survival, growth and reproduction; potential effects…of diversion, on the adult and larval stages of fish and invertebrates include impacts on migration patterns, spawning and nursery habitats, species diversity, and distribution and production of lower trophic level organisms; there is far more to consider here in this estuary's freshwater inflow needs, including the physical, chemical and biological needs for flow."

Each reviewer made many other comments regarding the resources, studies, and risks involved with the MFL that the District will no doubt consider as the process continues. My interest turns on the concerns quoted above relative to

- what scientifically valid and potentially useful effort exists, if any, that employs existing information to address issues of cumulative effects or linkages between the Peace River/Shell Creek, and Charlotte Harbor?
- whether any effort can be identified that looks specifically at diversions during periods of high river flow, and
- what else might be done to address the existing lack of inflections or break-points in relationships between independent and dependent variables so far examined for the study area?

The challenge is whether existing data or relationships can be evaluated more intensively, or a new relationship discovered and evaluated, to develop useful break-points for MFLs within the river that would also explicitly connect river processes/impacts to harbor resources during periods of high river flow and diversion. Here I explore an approach using existing MFL data and models, and earlier non-MFL data, that could prove helpful.

Using "stage" to mean the non-tidal component of river surface elevation, we may state:
1. Tidal wetlands in rivers are affected by stage as well as flow and salinity.
2. Freshwater flow delivers beneficial nutrients and sediments to tidal wetlands.
3. Higher stages deliver more beneficial nutrients and sediments to tidal wetlands.
4. Higher and longer stages also correspond to lower soil salinities.
5. Within natural limits, tidal wetland primary productivity is benefitted by higher and longer stages.
6. Secondary production in tidal wetlands is indirectly benefitted by increased primary productivity, area of inundated wetlands, and access to wetlands.

These points can be substantiated in the literature, though not in some instances for the Peace River/Shell Creek/Charlotte Harbor area as such. But the preceding does offer the possibility of a new relationship that links near-field (within the river) variables to far-field (Harbor) variables. As indirect but compelling support I cite *Morris et al. (1990) Limnol. Oceanogr. 35(4): 926-930* where the authors demonstrated that primary production by South Carolina *Spartina* is much greater during its growing season (July-August) when sea level is higher than normal (Δ msl). Higher than average sea level lowered marsh soil salinity. A connection to secondary production was shown for the south-Atlantic coast, and Louisiana, for shrimp and menhaden landings and Δ msl. Shrimp and menhaden relationships were time-lagged 0-1 and 3-4 years, respectively.

So, to the extent that river stage is higher than normal during the growing season of marshes and mangroves in the tidal Peace River, one would expect (by analogy, and correlation is not causation, etc.) enhanced wetland condition to follow, with improved secondary production in the Harbor at some later date. Conversely, if river stage is lower, then river wetland condition would be affected adversely, with some potential consequence for subsequent secondary production in both the river and harbor.

Higher flows affect stage in tidal wetlands and sometimes substantially so, depending on system geometry. I would expect higher flows to raise water levels in the Peace River down to at least Shell Creek. And the flows are additive with monthly sea level change. These, and perhaps wind, affect inundation patterns the most. In fact, astronomical tides are zero-sum on a monthly basis. But as shelf water warms and expands, monthly sea levels rise. See the lower left figure at http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8726520 (for St. Petersburg).

Steric effects cause monthly levels to vary as much as 20 cm over the year and sea level is high and rising during the wet season, and this effect extends into the rivers, of course. This effect is very important in intertidal ecology-- see *Provost, MW. (1973). Mean high water mark and use of tidelands in Florida. Florida Scientist 36(1): 50-66*, and *Smith, N. (1986). Rise and fall of the estuarine intertidal zone. Estuaries (9)2: 95-101*. In the summer, steric effects cause up to a 10 cm increase in water level in the harbor and tidal river, compared to annual mean levels.

I don't know about wind effects, which might be a wash over a year, but from the above, a 10 cm summer increase is greater than the difference between MHW and MHHW in the Peace River. See
http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=8725791 HARBOUR HEIGHTS, PEACE RIVER, FL&type=Bench Mark Data Sheets

So even if higher flows add 5 cm to river stage that addition has the potential to affect wetland inundation (area of inundated wetland x frequency of inundation x duration of inundation) considerably.

To illustrate with an example—a typical *Juncus* marsh in the Myakka River near US 41 has an elevation of 1.4 ft above NGVD (SWFWMD Myakka River Phase 1 Aerial Photography with Contours, Sheet No. 35-39-20, 1983). Employing www.tidesandcurrents.noaa.gov (superseded benchmark data for "Myakka River US 41 Station ID 8725837), the marsh elevation can be reset to 2.04 ft MLLW. Mean higher high water at this station is 1.95 ft above MLLW, so the marsh floor is 0.09 ft, or 2.7 cm, higher than MHHW. This is the stage difference that determines marsh inundation.

What existing tools are there to evaluate wetland inundation and diversion effects, using this information? Importantly, the District has wetland maps and more importantly, elevations for the wetland floors[1]. So the area of tidal wetland can be determined by type and also according to

[1] See preceding paragraph for source material used for the Myakka River example; I presume (hope) they exist for the Peace River.

the elevation of marsh and forest floors relative to a tidal or other datum. And these data can be aggregated by river kilometer.

Before doing so, though, it would be informative to study stage data for the lower river. These can be extracted from observations and/or models. To be done properly it would be necessary to consider other causes of stage variance by employing monthly averages that test local weather and all diurnal, semidiurnal, and shallow water effects (Morris et al., 1990). Seasonal steric variation would also have to be considered.

Then the problem reduces to calculating the effect of various diversion rates on the frequency, duration, and area of tidal wetland inundation in the river. If it appears that mean monthly stage is substantially affected by proposed diversions during summer months, then the wetland elevation data could be used to evaluate the extent of the diversions' impacts.

The non-linearity of wetland area along the river (and possible amplification of non-linearity for "low" and "high" wetlands) offers the prospect of (a) finding non-linear relationships of flow to inundation that (b) occur seasonally and vary annually, (c) vary diagnostically with respect to flow diversions, and (d) can be interpreted with confidence as proxies for the direct effects of flow diversion on wetlands, and for indirect effects of diversions on subsequent secondary production in the Harbor.

The suggested analyses are relevant because they would focus on the block of time for which the greatest diversion is being considered. This assessment offers potential as one new piece of evidence on the effects of diversion on tidal river stage during moderate to high flows; upon riverine wetland resources in the given year and (indirectly) upon harbor fauna in subsequent years.

The District has employed stage effects in many of the freshwater MFLs established for the region's rivers. Stage effects have not been considered in any tidal river reaches in SW Florida. To the best of my knowledge, they have not been used in MFL decisions affecting any tidal river in the state, but I may be wrong. In the particular case of the Peace River and Shell Creek, and their relationship to Charlotte Harbor, stage analyses may offer useful new tools for tidal river ecology, management, and regulation.

LEMON BAY CONSERVANCY

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www.lemonbayconservancy.org

June 19, 2009

Governing Board
Southwest Florida Water Management District (SWFWMD)
2379 Broad Street
Brooksville, FL 34604-6899

Re: Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek

Dear Governing Board Members;

We have learned that you have proposed minimum flows and levels (MFL's) for the lower Peace River and Shell Creek and that you are planning to act on these proposals in July. We strongly urge you to please take additional time to consider these new proposals cited below proposals in light of the following issues of which we are aware.

For the past 34 years, the Lemon Bay Conservancy has been and remains passionately dedicated to the protection of Lemon Bay and the health of the larger Charlotte Harbor Estuary which is considered an "estuary of national significance" and a National Aquatic Preserve, managed by the EPA. Many of our members attended the Reservoir Workshop held by the Charlotte Harbor National Estuary Program (CHNEP) in April at which Mr. Brian Armstrong of SWFWMD made a presentation and participated. Many issues were raised by the participants in that Workshop about the scientific questions which continue to exist related to setting minimum flows and levels (MFLs). We note that a list of open questions was assembled by the Workshop participants and, we understand, will be part of the final Workshop report.

Significantly, we are aware of and fully support the many comments being provided to you by the CHNEP which point out many specific problems with the MFL proposals.

REQUEST: *We urge that the District <u>delay</u> any rulemaking until; (1) After an evaluation of each and all of the CHNEP concerns and (2) After you evaluate the cumulative effects of the combined MFLs for the Upper and Middle Peace, Upper and Lower Myakka and Lower Caloosahatchee Rivers on the Charlotte Harbor estuary has been completed*. We adopt agree that the Peace River does not exist in a vacuum. The entire system relating to the Charlotte Harbor Estuary needs to be evaluated as a whole.

You should also be aware the Federal Government recently proposed that the Charlotte Harbor Estuary and surrounding areas be named one of two "Critical Habitats" for the Federally listed Endangered Species: <u>Small-Toothed Sawfish</u>. 73 FR 70290 (11/20/2008).

We strongly believe that the MFL proposal you are considering seriously needs to take into account the effect on this important (Federally listed as endangered in 2003) Small-Tooth Sawfish and the new level of added protection now pending, the Federal designation of Charlotte Harbor (this fall 2009) as “critical habitat” for the endangered small-tooth sawfish. This rare fish totally relies upon freshwater flows to ensure its nursery habit is viable. The further up the Peace River it must travel seeking freshwater, the smaller its nursery area becomes and the larger the impact on this Federally listed (almost extinct) species.

In summary, to be sure there is adequate consideration by the SWFWMD Board of the all the many important actions necessary to fully protect the health of Charlotte Harbor estuary the ***Lemon Bay Conservancy urgently requests***:

(1) You please delay any SWFWMD Board action on any proposed new MFL rules pending a full scientific review of all of the potential cumulative impacts of the MFLs proposed for all systems discharging to the estuary and please include the small-tooth sawfish as a special item of concern.

(2) We also request that you implement all of the many listed recommendations made by CHNEP in its recent comments on your proposal, before you undertake any new MFL changes.

We would like to further bring to your attention that the perception by many folks in our community and our members is that ***the “Summer Florida season” is the absolute wrong timing for any key decisions on very important topics like SWFWMD setting new rules for MFL’s***. For example, our most experienced and best educated members in the specialized fields of fish habitat, hydrology and the potential impacts on downstream areas of The Peace River and Charlotte Harbor, by SWFWMD using artificial methods to manipulate river water flows via MFL’s are not here in Florida at this time of the year.

We would urge you to fully address each and all of the CHNEP items, list and evaluate all of the potential Cumulative impacts for any MFL plans you have which will impact the Peace River and Charlotte Harbor, and then set up a series of public workshops in the Winter this year (2009) and in the Spring (2010) in order to fully educate your many customers, particularly those (like our members) whom are fully dependent upon the Peace River watershed for their drinking water quality and upon the protecting the health of Charlotte Harbor for their economic income.

Thank you for your attention and your demonstrated concern for our environment.

Jim Cooper
Jim Cooper
President, Lemon Bay Conservancy

SIERRA CLUB
FOUNDED 1892

The Greater Charlotte Harbor Group
P.O. Box 27221
El Jobean, Fl 39227
941-276-4219

June 19, 2009

Governing Board
Southwest Florida Water Management District
2379 Broad Street
Brooksville, FL 34604-6899
Fax 352-754-6874

Re: **SWFWMD GOVERNING BOARD MEETING, JUNE 23, 2009**
Agenda Item 64 Approve Initiation of Rulemaking to Amend Chapter 40D-8, F.A.C., to Establish Minimum Flows for the Estuarine Reaches of the Lower Peace River.

Dear Governing Board Members;

We have just become aware that you have proposed minimum flows and levels for the lower Peace River and Shell Creek and that you are planning to act on these proposals in July. We urge you to delay this action in order to consider the following developments.

The Greater Charlotte Harbor Group of the Sierra Club takes an active interest in the health of the Peace River and Shell Creek and of the larger Charlotte Harbor Estuary which is so vital to our area and has been designated a National Aquatic Preserve. Many of our members attended the Reservoir Workshop held by the Charlotte Harbor National Estuary Program (CHNEP) in April at which SWFWMD made a presentation and participated (Mr. Brian Armstrong). You are undoubtedly aware of the numerous issues raised by the participants in that Workshop about the scientific concerns related to setting minimum flows and levels (MFLs). A list of open questions was assembled by the Workshop organizers and is available from CHNEP.

One clear problem in the Reservoir Workshop was the lack of consideration for the economic consequences and a well-founded cost benefit analysis of a strategy based on reservoirs and MFLs. Our current economic circumstances make it all the more important that regulatory approaches, and water planning, be based on a solid and publicly discussed cost-benefit analysis.

We also note that the Federal Government has recently proposed that the Charlotte Harbor Estuary and surrounding area be named one of two Critical Habitats for the Federally Endangered Small-Toothed Sawfish. 73 FR 70290 (Nov. 20, 2008). We believe that the MFL proposal you are considering needs to take into account the effect on this important habitat and pending designation.

Finally, we are also aware of comments being provided to you by the CHNEP which also point out many specific problems with the proposals and urge that the District delay rulemaking until after an evaluation of the cumulative effects of the combined MFLs for the Upper and Middle Peace, Upper and Lower Myakka and Lower Caloosahatchee Rivers on the Charlotte Harbor estuary has been completed. We adopt and endorse these comments. The Peace does not exist in a vacuum and the entire system relating to the Charlotte Harbor Estuary needs to be evaluated as a whole.

Thank you for your attention to our concerns. We urge you to act to allow a full discussion of the consequences of your proposed designation.

Debra L. Highsmith
Conservation Chair

CHARLOTTE HARBOR NATIONAL ESTUARY PROGRAM
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November 16, 2009

Governing Board
Southwest Florida Water Management District
2379 Broad Street
Brooksville, FL 34604-6899

Re: Minimum Flows and Levels for the Lower Peace River and Shell Creek, 2009 Rule-making

Dear Governing Board members:

Thank you for delaying rule-making regarding the *Proposed Minimum Flows and Levels (MFLs) for the Lower Peace River and Shell Creek* until the Charlotte Harbor National Estuary Program (CHNEP) had the ability to review the April 9, 2009 draft proposal. Your staff has been very responsive to CHNEP concerns outlined in our June 19, 2009 written comments. Since that date, we received written responses to our letter from the District. In addition, your staff participated in a CHNEP subcommittee meeting on September 21, 2009 to allow a more in depth discussion of the technical aspects of the proposal, clarify several points, discuss remaining concerns, and develop some level of consensus among scientists and citizens that participate in resource management activities within our study area.

Continuing with our review of the *Proposed MFLs for the Lower Peace River*, we are providing the recommendations below, using our CHNEP "Advocacy and Review Procedures" which aim:

- To implement the quantitative objectives and priority actions of the adopted *Comprehensive Conservation and Management Plan* (CCMP),
- To provide policy-makers with a source of review and comment from an organization which represents considered opinions of diverse interests from throughout the CHNEP study area, and
- To provide a voice for the natural systems within the study area watersheds based on the best scientific information available.

Based on our understanding of the technical information provided, the CHNEP recommends that the following conditions be incorporated into the *Proposed MFLs for the Lower Peace River*:

- Implement as part of the rule a 130 cfs low flow threshold for the Lower Peace River.
- Establish a maximum diversion rate of 400 cfs for the Lower Peace River.
- Establish a trigger of 625 cfs flow in the Lower Peace River before switching from the percentage withdrawal rate for Block 1 into the higher percentage withdrawal rates for Blocks 2 and 3.
- Schedule and conduct a formal reevaluation of the Lower Peace River MFL, including additional relevant research results, to be completed within 5 years. We further recommend incorporating consideration of future concerns, especially anticipated sea level rise and associated higher salinities; discussions of reserving adequate water supply for natural systems;

and discussions of developing "optimal" flows vs. "minimum" flows, recognizing that MFLs potentially cause some level of harm to the natural systems.

Implement as part of the rule a 130 cfs low flow threshold for the Lower Peace River.
The consideration of the 90 cfs low flow threshold was established as part of the original MFL analysis and was subsequently implemented during an emergency declaration period. We recommend that 90 cfs continue to be only available upon an emergency declaration and not as a standard policy. Maintaining the 130 cfs threshold based on the sum of flows measured at USGS gages in the Peace River at Arcadia, Joshua Creek at Nocatee and Horse Creek near Arcadia will increase assurances that adequate water will remain in the river during low flows to protect water quality for existing legal users and sustain biological connectivity.

Establish a maximum diversion rate of 400 cfs in the Lower Peace River.
The SWFWMD Regional Water Supply Plan suggests that the total need for water in the region will not exceed a diversion of 400 cfs until after the year 2025. In addition, there are limitations to the number, size and expansions of water plants, as well as physical limitations to the quantities that water plants can withdraw. For these reasons, we recommend that the maximum diversion rate of 400 cfs be included in the MFLs. SWFWMD is currently developing models and other tools to better evaluate the cumulative impacts of water diversions on biotic and abiotic systems. Components of these tools are currently being developed through CHNEP partnerships, including with SWFWMD, with significant investment of resources. An example of a critical component nearing completion is the pre-settlement habitat map for the Peace and Myakka Rivers watersheds. Establishing a maximum diversion rate of 400 cfs protects the downstream estuary in the interim, until these tools may be fully developed and employed during future modifications of the MFL as part of requests for additional Water Use Permits (WUPs) beyond the 400 cfs maximum diversion. The maximum diversion rate of 400 cfs translates to an average 13-15% withdrawal compared to an average 33% in the current proposed rule. Instituting a maximum diversion rate of 400 cfs is significant for CHNEP and is consistent with SWFWMD projections as presented in the Regional Water Supply Plan. By including a 400 cfs maximum diversion rate, expectations can be better communicated to agencies considering water supply expansions and the public who may not fully recognize the physical limitations of water supply infrastructure.

Establish a trigger of 625 cfs flow in the Lower Peace River before switching from the percentage withdrawal rate for Block 1 into the higher percentage withdrawal rates for Blocks 2 or 3.
The definitions of the seasonal blocks are based on median flow conditions. A continuing concern of CHNEP scientists is related to drought years. If a drought extends past June 25 or begins before April 20, expanding withdrawals to 38% or continuing withdrawals at 29% may not be warranted simply because a particular date is met. Applied to data from 1985 to 2004, the trigger of 625 cfs would create an overall difference of only about 1-7%; however this change would provide assurance that significant withdrawals would not take place when drought conditions overlap the defined blocks.

Schedule and conduct a reevaluation of the Lower Peace River MFL, including additional relevant research results, to be completed within 5 years.
We applaud the efforts of SWFWMD to select the most sensitive salinity ranges (<2 ppt) to be used in the modeling. However, during discussions at our recent Lower Peace River MFL subcommittee and TAC meetings, several concerns were expressed regarding the technical modeling, primarily relating to the use of salinity as a proxy for the complexity of the natural systems. Additional analyses need to be

incorporated along with the modeling efforts to more accurately evaluate potential impacts of the MFLs on freshwater, estuarine and wetland resources. Critical supplemental assessments and discussions include:

- relationships between salinity, physiology and additional habitat factors,
- locations and timing of chlorophyll and zooplankton maxima, hypoxia and sedimentation; and
- fisheries and other biological data from current and pending studies, including data from FWRI Fisheries Independent Monitoring and University of South Florida College of Marine Science results from the Peace River and Charlotte Harbor; and
- processes that guide biotic and abiotic interactions.

The suggested low flow threshold, maximum diversion rate and flow trigger would bring the estimated hydrograph under the proposed Lower Peace River MFL more into better alignment with the natural hydrograph. However, reevaluation of the modeling efforts to incorporate the above considerations could result in a more representative characterization of the potential effects of the MFL on natural the systems in the watershed. A timely, accurate reassessment of allowable withdrawals would benefit both water management agencies and potential users in planning future water needs and requests more accurately. Therefore, we recommend scheduling a formal reevaluation of the Lower Peace River MFL within the approved MFL priority list next year, to be completed within 5 years. We further recommend incorporating consideration of future concerns, especially anticipated sea level rise and associated higher salinities; discussions of reserving adequate water supply for natural systems; and discussions of developing "optimal" flows vs. "minimum" flows, recognizing that MFLs potentially cause some level of harm to the natural systems.

<u>Summary and Conclusions</u>

The addition of the 130 cfs low flow threshold, maximum diversion rate of 400 cfs, and a trigger of 625 cfs flow between blocks to the proposed rule will better ensure that appropriate flows are maintained throughout the river and delivered to Charlotte Harbor and its nationally significant ecosystem. We further recommend additional formal reevaluation of the Lower Peace River MFL be scheduled in the approved MFL priority list and completed within 5 years. We believe that the policies of SWFWMD and needs of potential water users will be better served and more accurately communicated through these actions.

Thank you for the opportunity to comment, your responsiveness, and the efforts of your staff to develop MFLs which are reasonable and science-based.

If you have any questions or need additional information, please do not hesitate to contact me.

Sincerely,

Lisa B. Beever, PhD, AICP
Director

Appendices 2 - 5 (Bound and Numbered Separately)