INITIAL REEVAULATION OF THE MINIMUM FLOWS AND LEVELS FOR THE LOWER PEACE RIVER

FINAL DRAFT

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Southwest Florida Water Management District

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EXECUTIVE SUMMARY

In accordance with State Law, the Southwest Florida Water Management District adopted minimum flows and levels (MFLs) for the lower Peace River (LPR) in July 2010 that became effective in August 2010. The adopted MFLs rule requires the reevaluation of the MFLs within five years of the adoption date to incorporate additional ecological data. Five years from the date of adoption is in July 2015 and in keeping with this timeline, the District has prepared this initial reevaluation report to summarize progress made to date and highlight ongoing activities to support a more comprehensive MFLs reevaluation scheduled for completion in 2018.

One objective of this initial reevaluation report was to assess the status of current minimum flows to the LPR based on the minimum 5-year and 10-year moving yearly mean and median flow statistics set forth in the MFLs rule as a tool for minimum flow assessment. The assessment was conducted by combining flows of the U.S. Geological Survey (USGS) Peace River at Arcadia, FL gage (#02296750) with the flows measured at the USGS Horse Creek near Arcadia, FL gage (#02297310), and the USGS Joshua Creek at Nocatee, FL gage (#02297100), and subtracting the potential maximum withdrawals that do not violate the MFL rule. As part of the assessment, errors associated with development of two of the flow statistics included in the rule were identified and corrected values that should supersede the incorrect values were developed. Since the MFLs adoption year (2010), five and ten-year moving mean and median flows during Block 2 (October 27 to April 19) have frequently been below expected minimum flow statistics issued in the MFL rule, whereas moving mean and median flows during Blocks 1 (April 20 to June 25) and 3 (June 26 to October 27) were predominantly above the expected flow rates for most of the post-MFL years. The lower than expected flows during Block 2 were mainly due to much drier than normal rainfall conditions in 2010, 2011 and 2014. The impact of these drier rainfall conditions were also reflected in the annual moving flow statistics for these years.

The Peace River Manasota Regional Water Supply Authority (PRMRWSA) is the only permittee withdrawing water from the LPR. Under the current MFLs rule and water use permit conditions, PRMRWSA is allowed to withdraw up to 16% of the flow when the previous-day combined flows in the Peace River at Arcadia, Horse Creek, and Joshua Creek is greater than 130 cubic feet per second (cfs). If the previous-day combined flows is, however, above 625 cfs, the PRWMWSA is permitted to withdraw up to 28% of the flow during Block 2 period and up to 28% during Block 3 period. Generally, the District analysis shows that the PRMRWSA has been in compliance with their permit conditions except for some days during low and medium flow seasons when withdrawals slightly exceeded the permitted maximum flows. These minor exceedances were mostly associated with adjustment to provisional USGS flow data for the three gage sites that are used by the PRMRWSA on a daily basis to calculate allowable percentages of flow that may be withdrawn from the LPR.

With the aim of assessing potential impacts associated with PRMRWSA withdrawals, extensive physical, chemical and biological data have been collected as part of the Peace River Hydrobiological Monitoring Program (HBMP). Generally, the HBMP data collected in 2012, 2013 and 2014 do not show any substantial changes when compared to the pre-adopted MFLs (1983-2011) data. Previous study conducted by Atkins, Inc. (2013b) indicates that the expected mean and maximum salinity changes due to the current withdrawals schedule at Rkm 15.5 (i.e., 15.5 kilometers upstream of the river mouth) are modeled to be <0.4 and 2.3 practical salinity unit; psu respectively. To assess the impacts of withdrawals on salinity variation, the 2.3 psu was compared against the daily naturally occurring salinity variations for both the pre- and post MFL adoption periods. Salinity variation is assumed to be natural when the difference between measured daily maximum and minimum salinity is greater than 2.3 psu. For 76% of days during the period 2012-2014, the natural daily salinity change was greater than the maximum salinity change (2.3 psu) attributable to maximum withdrawals under the current schedule. Similarly, during the period 1983-2011, for 80% of days the natural salinity variations was found to be greater than the 2.3 psu salinity change. The small changes in salinity, attributable to the current withdrawal schedule are, therefore, unlikely to alter the overall health of the naturally dynamic estuary. Analyses of chlorophyll levels by Atkins, Inc. (2014b) also indicate that it is unlikely that the PRMRSA withdrawals could affect water color levels to the extent that effects on phytoplankton biomass in the LPR/upper Charlotte Harbor estuarine system would occur. Due to limitation in pumping capacity, the PRMRSA withdrawals influence on water residence time is also minor during periods of low to intermediate flows. The effects of reduced nutrient loading due to withdrawals are similarly not thought to be a major factor in phytoplankton productivity. However, during late spring to the beginning of the summer wet-season, phytoplankton are nutrient starved and respond quickly to pulses of nutrients. During these periods, the PRMRWSA can potentially take large percentages of sporadic moderate to high flows, with permitted withdrawals allowed to increase from 16% to 38% once flows exceed 625 cfs. Withdrawals under these conditions warrant further investigation as they could potentially reduce phytoplankton biomass in LPR/upper Charlotte Harbor estuarine system. In total, the analyses completed for this initial MFLs reevaluation indicate that the current withdrawals schedule included in the water use permit issued to the PRMRWSA for withdrawals from the LPR based on the currently adopted MFLs, has not and is not expected to significantly affect the LPR/Charlotte Harbor estuarine system.

As part of the initial MFLs reevaluation, another major task undertaken was the reassessment of anthropogenic impacts on Peace River flows and the reconstruction of an unimpaired flow record for the LPR, i.e., a flow record that has been modified to remove effects associated with water withdrawals. District staff updated gaged flow data through 2014 for the Peace River and its tributary creeks. Trend analysis using the nonparametric Kendall's tau test, indicated that rainfall and flows in the Peace River at Bartow, Zolfo Springs, and Arcadia and within Charlie Creek exhibited a significant declining trend at alpha level of 0.1, while flows in Payne Creek showed a significant increasing trend. Although decline in rainfall was a major factor, steep declining trends in the Peace River flows at Bartow and Zolfo Springs were observed and attributed to groundwater withdrawals. No declining trend was observed for flows in Horse, Joshua and Shell Creeks, likely due to increased agricultural return flows in recent decades. Baseflow increase from phosphate mining is believed to be a major factor in the increasing flow trend in Payne Creek. Analysis also confirmed that anomalies of Sea Surface Temperature associated with the cooling and warming phased of the Atlantic Multi-decadal Oscillation (AMO) and with the El Niño Southern Oscillation (ENSO) are, respectively, related to dry and wet flows in the LPR. In 2012, the District completed development of the Peace River Integrated Model (PRIM) that aided characterization of the impacts of climate, groundwater pumping and land use changes of river flows. Based on PRIM findings and data for PRMRWSA withdrawals, an unimpaired flow record for the LPR was developed for the period from 1980 through 2014.

Also provided in this initial reevaluation report is a summary of multiple District projects that have been conducted or are planned to further strengthen reevaluation of the LPR MFLs. Projects that have been completed address estimating flows from ungaged portions of the Peace/Myakka rivers, re-mapping of the bathymetry of the LPR/upper Charlotte Harbor estuarine system, production of a LiDAR-based high resolution digital elevation model for the Peace River, installation of a data collection tower in the upper Charlotte Harbor and refinement of a hydrodynamic model for the LPR/Charlotte Harbor estuarine system based on these and other data, and assessing relationships of flow with chlorophyll concentrations in the LPR estuary. An effort currently underway involves development of habitat suitability modeling for evaluating the abundance and distribution of six fish species that are known to be responsive to freshwater inflows. The District is also planning for a project to characterize floodplain features/habitats and evaluate how these habitats may be affected by changes in river flows.

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1. INTRODUCTION

Section 373 of the Florida Statutes (F.S.) provides a legislative mandate for the State Water Management Districts or the Department of Environmental Protection to establish minimum flows and levels (MFLs) to protect water resources from significant harm. Based on this directive, the Southwest Florida Water Management District (SWFWMD or District) establishes (i.e., adopts into rule) minimum flows for springs and rivers, including estuaries, and minimum levels for lakes, wetlands and aquifers within the District boundary. According to Section 373.042(1), F.S., "[t]he minimum flow for a given watercourse shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." In addition, Section 373.042(1), F.S., requires that MFLs be calculated using the best available information and Section 373.0421, F.S., requires that they are developed with consideration of "changes and structural alternations 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." Periodic reevaluation and as needed revision of established MFLs are also required by statute (Section 370.0421(3), F.S.).

Given these legal directives, the District implements established MFLs primarily through its water supply planning and water use permitting and environmental resources permitting activities that collectively ensure the hydrologic requirements of natural environmental systems are met and they are not harmed by excessive water withdrawals. The District's MFLs Program is implemented based on three fundamental assumptions. First, it is assumed that many water resource values and associated features are dependent upon and affected by long-term hydrology and/or changes in long-term hydrology. Second, it is assumed that relationships between some of these variables can be quantified and used to develop significant harm thresholds or criteria that are useful for establishing MFLs. Third, the approach assumes that alternative hydrologic regimes may exist that differ from non-withdrawal impacted conditions but are sufficient to protect water resources and the ecology of these resources from significant harm. MFLs may, therefore, represent minimum acceptable rather than historic or potentially optimal hydrologic conditions.

For the purpose of minimum flows development by the District, "significant" harm may be associated with specific flow rates expressed in cubic feet per second (cfs) and may also commonly be defined as a 15% loss of available habitat/resources relative to a baseline that reflect conditions expected in the absence of water withdrawal impacts, given existing structural alterations. This latter definition of significant harm has been operationally used by the District for minimum flows development since 2005. Although use of criteria based on 15% change in specific environmental values has been criticized, as summarized in Heyl (2015) and Flannery et al. (2014), peer-reviewers convened to evaluate District reports associated with proposed MFLs have been supportive of the use of the criteria for evaluating effects of potential flow reductions.

District work on development of MFLs for the Lower Peace River (LPR) was initiated in 2007 and was based on goals that included maintaining freshwater at the Peace River Manasota Regional Water Supply Authority (PRMRWSA) withdrawal plant on the LPR and biologically-relevant salinities throughout the LPR. After passing though many reviews, including independent scientific peer review, MFLs for the LPR were adopted into the District's Water Levels and Rates of Flow rules (specifically Rule 40D-8.041(8), Florida Administrative Code or F.A.C.; see Appendix A) in July 2010 and became effective in August 2010. The MFLs were adopted to ensure that the minimum hydrologic requirements of the water resources or ecology of the natural systems associated with the estuarine reach of the LPR are met. The MFLs are based on the sum of the combined flows of the USGS Peace River at Arcadia, FL gage (#02296750) plus the flow at the USGS Horse Creek near Arcadia, FL gage (#02297310), and the USGS Joshua Creek at Nocatee, FL gage (#02297100). The MFLs are both seasonal and flow dependent and include a low flow threshold that is applicable throughout the year as well as seasonally dependent (i.e., block-specific) minimum flows that specify allowable reductions in the sum of flows at the three gages denoted above that would occur in the absence of any permitted upstream withdrawals (Table 1-1). The LPR MFLs rule also specifies that the total permitted maximum withdrawals on any day shall not exceed 400 cfs and includes summary flow statistics that can be used as a tool to assess whether flows in the LPR remain above flow rates that are expected to occur with implementation of the MFLs requirements.

The LPR MFLs rule further specifies that the MFLs will be reevaluated to incorporate additional ecological data for the LPR within 5 years of rule adoption. Five years from the date of adoption of the LPR MFLS is in July 2015 and in response to this timeline the District has prepared this initial MFLs reevaluation report and scheduled completion of a more comprehensive reevaluation for 2018. The timeline for the more comprehensive reevaluation was developed to allow for incorporation of additional ecological data that are expected to strengthen the technical basis for the reevaluation.

Table 1-1 Allowable withdrawal-related flow reductions for the Lower Peace River based on combined flow from Horse Creek, Joshua Creek and the Peace River at Arcadia gage.

Table 8-20-Minimum Flow for Lower Peace River based on the sum of flows from Horse Creek, Joshua Creek, and the Peace River at Arcadia gages.			
Period	Effective Dates	Where Flow on Previous Day Equals:	Minimum Flow Is
Annually	January 1 through December 31	≤130 cfs >130 cfs	Actual flow (no surface water withdrawals permitted) Seasonally dependent – see Blocks below
Block 1	April 20 through June 25	≤130 cfs >130 cfs	Actual flow (no surface water withdrawals permitted) previous day's flow minus 16% but not less than 130 cfs
Block 2	October 28 through April 19	≤130 cfs >130 cfs and <625 cfs ≥625 cfs	Actual flow (no surface water withdrawals permitted) previous day's flow minus 16% but not less than 130 cfs previous day's flow minus 29%
Block 3	June 26 through October 27	≤130 cfs >130 cfs and <625 cfs ≥625 cfs	Actual flow (no surface water withdrawals permitted) previous day's flow minus 16% but not less than 130 cfs previous day's flow minus 38%

The reminder of this initial LPR MFLs reevaluation report is organized as follows:

Chapter 2 evaluates compliance of PRMWRSA withdrawals with permit conditions associated with the MFLs rule by analyzing the LPR flow conditions and water withdrawn by PRMWRSA in 2012, 2013 and 2014 in accordance with a District-issued water use permit. The chapter further evaluates the effectiveness of PRMRWSA withdrawals with regard to preventing significant environmental changes to the LPR/upper Charlotte Harbor estuarine system.

Chapter 3 presents the reevaluation of the LPR flow record for anthropogenic impacts and trend analysis. This chapter also presents the reconstruction of unimpaired flows based on recent flow data and modeling results. The unimpaired flow, also known as natural flow or baseline flow, is historically observed flow, adjusted for water withdrawal-associated factors, including withdrawal rates and return flows within the Peace River basin.

Chapter 4 summarizes the ongoing District data collection and modeling efforts to support the MFLs reevaluation.

Chapter 5 provides a summary and conclusions for this initial MFLs reevaluation.

Chapter 6 lists literature cited in the report.

2. ASSESSMENT OF FRESHWATER INFLOWS AND PERMITTED WATER WITHDRWALS

The only major surface water withdrawal on the Peace River is made by PRMRWSA at their Peace River Facility, with the intake located on a slough connected to the west bank of the river approximately 30.6 kilometers upstream of the river mouth (SWFWMD, 2010). The first permit for withdrawals at this site (Water Use Permit 27500016) was issued in 1975, and since then additional permits have been issued to address the withdrawals (Table 2-1).

Table 2-1 Summary of Historic Facility Permits (adapted from Atkins, Inc. 2013a).

Year	December 1975	March 1979	May 1982	October 1988	March 1996
Water Use Permit	27500016	27602923	202923	2010420	2010420.02
Av. Permitted withdrawal (mgd)	5.0	5.0	8.2	10.7	32.7
Max. Permitted withdrawal (mgd)	12 &18	12 &18	22	22	90
Low Flow Cutoff (cfs)	91-664*	91-664*	100-664*	100 & 664*	130**
Max. Percent of Withdrawals (%)	5	5	n/a	10	10

* Withdrawals based on historic monthly averages

** Withdrawals based on the preceding actual daily flow at Arcadia gage

In response to the severity of the 2006-2009 drought, the 1996 version of the current water use permit (2010420.008), which limited withdrawals to 10 percent of the observed flow rate when Peace River flows at Arcadia gage are greater than 90 cfs, was modified several times through issuance of several executive orders as indicated in Table 2-2 (Atkins Inc., 2014a). In addition, the PRMRWSA expanded the Facility in 2009 to increase the pumping capacity from the river to a maximum diversion of 120 million gallons per day or mgd (from 44 mgd) and completed a 6 billion gallon reservoir. In 2011, the District issued a revised version of the water use permit with an updated withdrawal schedule that addressed Facility upgrades and was consistent with the adopted MFLs rule (refer to Table 1-1). Subsequent permit modifications in 2011 allowed annual average and monthly maximum withdrawals to increase from 32.7 to 32.855 mgd and from 38.1 to 38.3 mgd, respectively. Additionally, the previous withdrawal schedule was based solely on flow data at the USGS Peace River at Arcadia, FL gauge while the new schedule incorporates flow data from 3 upstream USGS gauges (Peace River at Arcadia, FL, Horse Creek near Arcadia, FL, and Joshua Creek at Nocatee, FL) with no withdrawals allowed if the combined previous day flow at the 3 gauges was less than 130 cfs.

The recent alterations at the PRMRWSA Peace River Facility and the associated increased withdrawals have the potential to affect downstream ecosystems. To ensure that increased withdrawals do not result in unacceptable environmental impacts throughout the lifetime of the permit, PRMRWSA has been implementing a comprehensive Hydrobiological Monitoring Program (HBMP) in coordination with the District. As reported in numerous HBMP reports (e.g. HBMP, 2011; 2012; 2013a; 2014a), historic water withdrawals at the Peace River Facility have caused no significant long term physical, chemical and biological changes to the LPR/upper Charlotte Harbor estuarine system. The HBMP data and analyses presented in 2013 and 2014 HBMP interpretive annual reports also continue to support these findings (Atkins Inc., 2014a).

Table 2-2 Modifications to the normal 1996 permitted withdrawals schedule (reproduced from Table 2.7 in Atkins Inc., 2014a).

Event	Effective Dates	Low flow Threshold	Gages Used	Withdrawal Issued
Temporary WUP*	12/1/06 to 8/12/08	90 cfs	Arcadia	10%
Executive Order	8/13/07 to 8/29/08	130 cfs	Arcadia + Horse + Joshua	12%
Executive Order	8/30/07 to 10/31/08	90 cfs	Arcadia + Horse + Joshua	12%
Executive Order	11/1/07 to 4/19/09	90 cfs	Arcadia + Horse + Joshua	14% to 330 cfs 21% > 330 cfs
Executive Order	4/20/08 to 6/25/08	90 cfs	Arcadia + Horse + Joshua	10% to 221 cfs 26% >221 cfs
Executive Order	6/26/08 to 10/26/08	90 cfs	Arcadia + Horse + Joshua	12% to 1370 cfs 15% > 1370 cfs
Executive Order**	10/23/08 -7/15/09	90cfs	Arcadia + Horse + Joshua	**4/20-6/25** 10% to 221 cfs 26% >221 cfs **6/26-10/26** 12% to 1370 cfs 15% >1370 cfs **10/27-4/19** 14% to 330 cfs 15% above 330 cfs
Executive Order	7/16/09 to March 2010	Same as above but increases maximum withdrawal from 90 to 120 mgd		
4/30/10 – Executive Orders ended, and withdrawals returned to the original permit conditions				
Revised Permit Withdrawal Schedule Based on Adopted MFL	4/27/11 - Present	130cfs	Arcadia + Horse + Joshua	**4/20-6/25** 16% >130 cfs **6/26-10/26** 16% >130 cfs 28% >625cfs **10/27-4/19** 16% >130 cfs 28% >625cfs

* Note 1: The temp WUP was extended each month by the governing board until the first Executive Order was approved
** Note 2: Variable percent withdrawal based on District proposed MFL criteria

2.1 Permit Compliance and MFLs Status Assessment

PRMRWSA uses “provisional” daily flow data reported by the USGS for decisions regarding Facility withdrawal rates (Figure 2-1a). The provisional data is then reviewed by the USGS through a series of quality assurance checks made as part of their standard data approval process (Figure 2-1b).

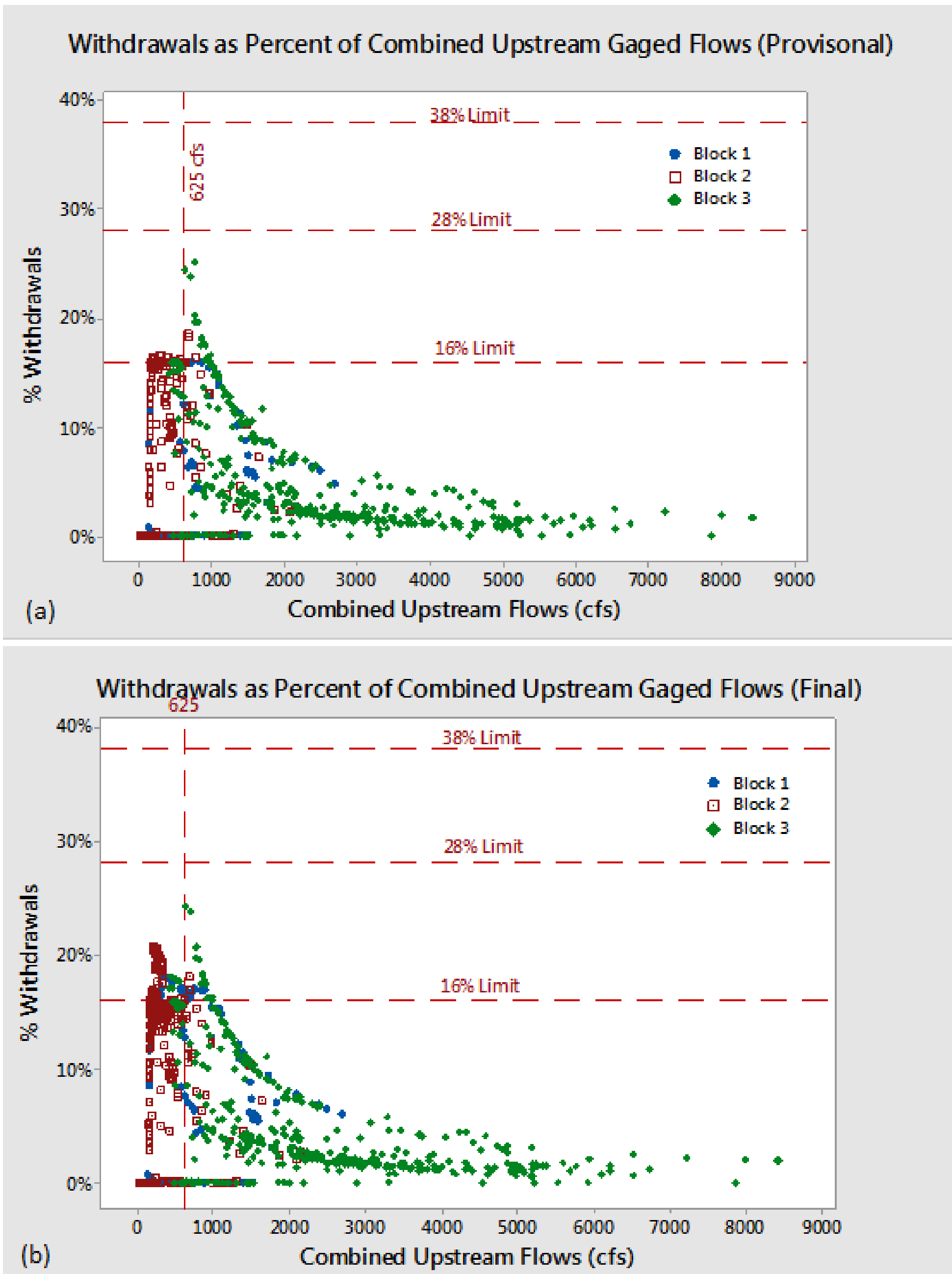

Figure 2-1 Daily PRWRWSA Facility withdrawals from the Lower Peace River as percentage of the combined daily flows (provisional and final) at three upstream U.S. Geological Survey gages during the period 2012-2014.

To determine if PRMRWSA was in compliance with conditions associated with the LPR MFLs rule that are included in the current water use permit issued for Facility withdrawals, percentages of water withdrawn for the period from 2012 through 2014 were plotted relative to preceding combined upstream gaged daily flows for the three gages specified in the rule and permit (Figure 2-1). Total withdrawals during 2012 were approximately 4.6% of the total gaged freshwater flow measured at upstream of the Facility intake. The total withdrawals of upstream gaged flow during 2013 and 2014 were 3.3% and 5.4% respectively.

Using the provisional USGS data as a reference, no violations have occurred during Blocks 1 (low flow season) and 3 (high flow season) of 2012, 2013, and 2014. With the exception of one day, the PRMRSWA complied with the Low Flow Threshold component of their permit, which specifies that withdrawals cease when the combined flows at Arcadia, Horse Creek and Joshua Creek gages falls below 130 cfs. These low flows occurred 141 days during 2012, 95 days during 2013 and 16 days during 2014. However, during Block 2 (medium flow season) of 2012 and 2013, withdrawals exceeded the designated maximum allowed withdrawals identified in the permit for 6 and 2 days respectively (Table 2-3). Most of the exceedance were very small, accounting for less than 1%. The only noticeable over-pumpage event was the 5.96 cfs withdrawal occurring on March 16, 2012 when the allowed withdrawal was zero. According to staff at the PRMRWSA (personal communication, August 11, 2015), metering errors, communication lag and PLC clock errors are some of several reasons for the occurrence of over-pumpage. The case of March 16, 2012, however, was due to human error and withdrawals ceased as soon as the error was found after several minutes of operation. During 2014, the Authority has made several updates on system functionality including electronic calculations to determine daily average river flow and allowed pumpage, as well as to improve communication between the pumps and the system for stopping the pumps. These changes apparently have prevented over-pumpage events since 2013 and are expected to prevent future occurrences.

Using the final USGS data as a reference, over-pumpage occurred during Block 1 of 2012, and 2013 for 9 and 10 days respectively. During Block 2 of 2012 and 2013, the number of days with over-pumpage were 1 and 55 respectively. Withdrawals also exceeded maximum allowable withdrawals on 5 days during Block 3 in 2013. The exceedances observed were relatively minor and their occurrence was associated mostly with changes of reported flows. It is important to note that the change of flows from provisional to final have also resulted in the Authority taking less water than they could have during the days with increased flow changes. It is therefore not uncommon to sometimes observe withdrawals slightly exceeding the percentage-based permitted withdrawal rates as a result of adjustment to USGS provisional data sets. Overall, there were no indications of significant violations of permit conditions.

Table 2-3 Number of days when Facility withdrawals exceeded the designated maximum allowed withdrawals identified in the permit using provisional data.

Date of Occurrence	Block	Water withdrawn by PRMRWSA (cfs)	Allowed Withdrawals (cfs)
3/12/2012	2	37.83	36.64
3/16/2012	2	5.96	0.00
11/1/2012	2	88.59	87.36
11/10/2012	2	64.88	63.36
11/12/2012	2	59.49	58.24
12/5/2012	2	26.04	25.44
11/4/2013	2	59.80	57.60
11/16/2013	2	46.82	45.92

The LPR MFLs Rule 40D-8.041(8c), F.A.C., sets forth minimum five-year and ten-year moving mean and median flow statistics as a tool to assess whether flows in the LPR remain above flow rates that are expected to occur with implementation of the MFLs (see Appendix A). These flow statistics were calculated based on moving five-year and ten-year averages of yearly mean and median values derived from daily combined flows of the USGS Peace River at Arcadia gage plus the flow at the USGS Horse Creek, and the USGS Joshua Creek for the period 1951 through 2008 minus the potential maximum withdrawals that do not violate the MFLs rule. Under normal circumstances, if compliance with the MFLs and the 400 cfs maximum withdrawal rate is maintained, these flow statistics are expected to be met or exceeded. However, factors other than permitted water use (e.g., climate variability and structural alterations) could also potentially affect these flow statistics.

To assess the status of minimum flows in the LPR, five-year and ten-year moving mean and median flow statistics for the periods ending in 2009, 2010, 2011, 2012, 2013 and 2014 were computed by subtracting the daily actual withdrawals from the daily combined flows of the USGS Peace River at Arcadia gage plus the flow at the USGS Horse Creek, and the USGS Joshua Creek. The computed flow statistics along with the reference flow statistics (minimum 5-year and 10-year moving mean and median flow values) included in the MFLs rule (with two exceptions) are provided in Table 2-4, with asterisked values indicating computed statistics that are below the expected minimum values. Exceptions were identified for the 10-year median reference values for Blocks 1 and 2. Values for these statistics included in rule were found to be incorrectly calculated and should be superseded by the values included in Table 2-4.

Table 2-4 Minimum 5-Year and 10-Year Moving Mean and Median flows to the lower Peace River based on the sum of flows from Horse Creek, Joshua Creek, and the Peace River at Arcadia and maximum withdrawals under the MFLs rule and for periods from 1951 through 2008 to 2014.

Minimum Flows	Flows (cfs)							
Block 1	Flow statistics	1951-2008	2009	2010	2011	2012	2013	2014
	10-year Mean	284	624	665	660	640	500	509
	10-Year Median	177[a]	236	272	273	266	233	232
	5-Year Mean	204	694	230	235	255	335	324
	5-Year Median	114	304	193	198	194	207	160
Block 2	10-year Mean	429	489	547	571	479	403*	384*
	10-Year Median	274[b]	270*	308	321	297	262*	244*
	5-Year Mean	330	412	291*	316*	319*	320*	357
	5-Year Median	235	235	197*	211*	209*	212*	254
Block 3	10-year Mean	1260	2,266	2,392	2,175	2,152	2,060	1,686
	10-Year Median	930	1,728	1,814	1,704	1,682	1,668	1,310
	5-Year Mean	980	1,321	1,105	1,207	1,592	2,013	2,052
	5-Year Median	595	910	713	808	1,144	1,676	1,709
Annual	10-year Mean	713	1,112	1,190	1,127	1,072	979	846
	10-Year Median	327	362	408	423	395	347	340
	5-Year Mean	679	770	554*	601*	736	893	922
	5-Year Median	295	334	258*	279*	295	310	347

[a] Differs from value of 264 cfs included in Table 8-21 of Rule 40D-8.041(8)(c), F.A.C; value in rule is incorrect
[b] Differs from value of 383 cfs included in Table 8-21 of Rule 40D-8.041(8), F.A.C.; value in rule is incorrect
* flow rates below expected long term flow statistics

The flow statistics for Blocks 1 and 3 have been exceeded the corresponding expected values since 2009. The 5-year mean flow values for Block 2, however, fell below the expected minimum value of 330 cfs from 2010 through 2013. The 10-year mean and median statistics for Block 2 also shows lower than expected values during 2013 and 2014. Owing to the lower than expected flows during Block 2, the annual 10-year median in 2009 and the annual 5-year mean and median flow values during 2010 through 2013 were below the expected flow rates. Overall, freshwater flows to the LPR during Blocks 1 and 3 of the calendar year were above the long term average, whereas flows during Block 2 remained comparatively below average for the post-MFL years. As mentioned above, compliance with the MFLs-associated withdrawal limits and the 400 cfs maximum withdrawal rate has been maintained by PRMRWSA since the MFLs were adopted. The lower than expected moving flow statistic values during Block 2, are largely attributable to relatively low rainfall in 2010, 2011 and 2014. The impacts of these rainfall conditions were also reflected in the lower than expected annual flow statistics during 2010 and 2011 (Table 2-4).

2.2 Impacts on Environmental Resources

Pursuant to Water Use Permit 20010420 PRMRWSA has been implementing an HBMP since 1976 to provide the District with sufficient information to evaluate the effectiveness of Facility withdrawals with regard to preventing significant environmental changes. Atkins, Inc. (previously PBS&J), contracted by PRMRWSA, has been responsible for all aspects of the HBMP. Over the years, a series of individual HBMP reports have been submitted by PRMRWSA to the District and findings summarized in the reports indicate that withdrawals seem to have had very little measurable influence on the biological health and productivity of the LPR (PBS&J, 1999 through 2010 and Atkins, Inc., 2011 through 2014).

Elements of the HBMP have been modified throughout time to enhance understanding of the LPR/upper Charlotte Harbor estuarine system. Much of the recent HBMP data collection has focused on physical factors (water temperature, color and extinction coefficients), water quality (salinity, nitrogen, phosphorus, nitrate/nitrite and reactive silica), and phytoplankton biomass (chlorophyll *a*) that may be directly linked to the freshwater inflow variation. It is beyond the scope of this report to discuss all HBMP findings regarding these factors. Rather, in this section, emphasis is given to salinity and chlorophyll *a* changes, which have been shown to directly be influenced by freshwater withdrawals. Much of the information discussed in this section were taken from the 2011, 2012 and 2013 HBMP annual reports prepared for PRMRWSA by Atkins Inc.

2.2.1 Salinity Distribution

Alterations to timing and amount of inflow to the LPR has a direct and instantaneous impact on salinity while the impact on other water quality constituents and biological communities could be indirect and are typically manifested on longer time scales (e.g., Atkins, Inc., 2013a). Since many biotic communities are dependent on estuarine salinity variation for survival, salinity was selected as the most protective criterion for establishing the LPR MFLs (SWFWMD, 2007; 2010).

Monthly salinity data collected at fixed stations in the LPR denoted by relative river kilometer (Rkm) from the river mouth (Rkm 2.4, 6.6, 15.5, 23.6, and 30.7) over 18 years shows that salinity was lowest during the wet season, from July through September and highest during the dry season, from January to March. In addition, 11 continuous recorders (15-minute intervals) deployed at and downstream of the Facility by USGS and the PRMRWSA to assess river conductance (salinity) in real-time to provide information on river salinities. Also, the location of four non-fixed surface salinity zones (practical salinity units or psu 0, 6, 12, and 20) have been monitored since 1983 as part of the

HBMP. Figure 2-2 presents the location of these four salinity zones for 2012, 2013, 2014, and for the long term average (1983-2011). Due to the influences of the drier than usual flow condition in 2012, a slight upstream movement of the salinity zones was observed relative to the long term average locations.

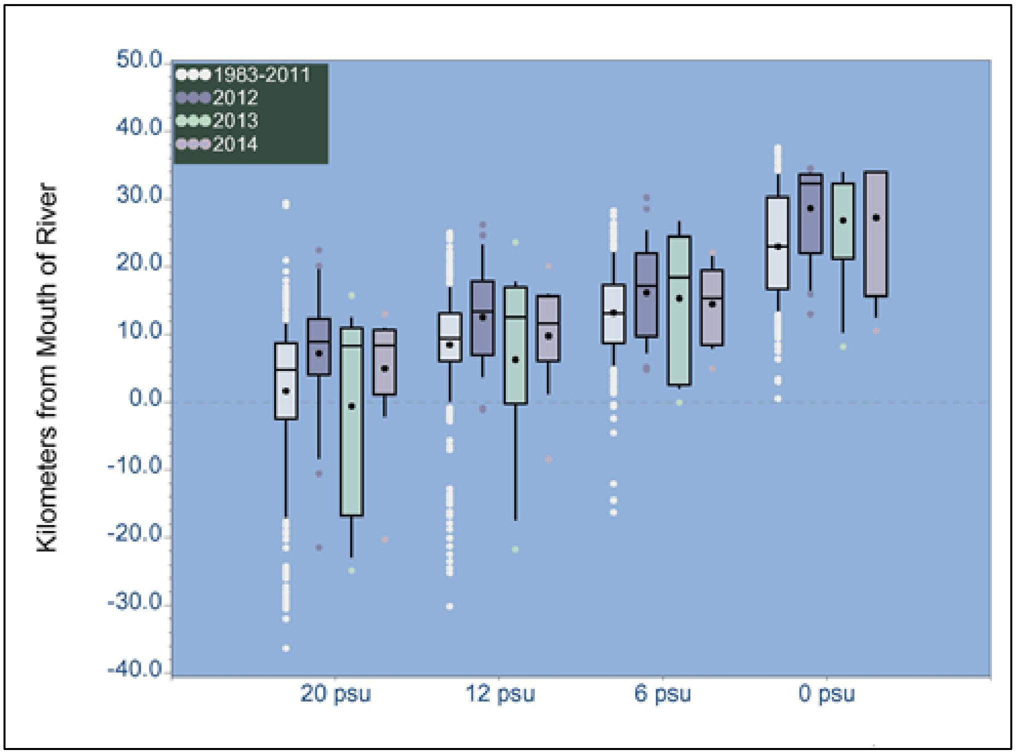

Figure 2-2 Box and whisker plots of distance of salinity zones from the mouth of the Peace River for 2012, 2013, 2014 and the long term average (1983-2011).

The 2011 HBMP comprehensive summary report (Atkins, Inc., 2013b) indicates that the expected mean and maximum salinity changes due to the current withdrawals schedule are modeled to be <0.4 psu and 2.3 psu respectively. The maximum predicted salinity difference of 2.3 psu occurred near the USGS Peace River at Harbor Heights, FL (02297460) gage site (Rkm 15.5) during the summer wet-season. The location and timing of this maximum withdrawal induced salinity difference may reasonably be predicted because at this location the balance of salt and freshwater is approximately equal; therefore, a change in one is expected to proportionally influence the other more than in any other location in the river.

The report also indicates that the modeled maximum change in the movement of isohalines due to withdrawals has increased from 0.1-0.5 kilometers under the 1996 withdrawals schedule to 1.1 to 1.4 kilometers in 2011 under the current MFLs-based schedule. No detailed information was provided by Atkins, Inc. (2013b) concerning the accuracy of these modeled changes. Nevertheless, to determine the significance of the increased salinity changes associated with the current withdrawal regime, natural and withdrawal induced salinity variability were compared. It is important to bear in mind that salinity variation is assumed to be natural when the difference between measured daily maximum and minimum salinity is greater than 2.3 psu. Observations from April 2011 to April 2014 indicate salinity at Rkm 15.5 varied from 0.02 to 16.6 psu over a single day, due to tidal influences (Figure 2-3). Median daily salinity change for surface and bottom water were 6.9 and 7.1 psu respectively. From April 2011 through April 2014, 83% of days exhibited natural daily salinity change greater than the mean salinity change attributable to withdrawals under the MFLs-based schedule (< 0.4 psu; Figure 2-3). Whereas, 76% of days had natural salinity variations greater than the maximum salinity change predicted under the current withdrawal schedule (2.3 psu; Figure 2-3). Data from the preceding years (1996-2011) prior to implementation of the current MFLs-based schedule showed that natural salinity variations at Rkm 15.5 varied from 0.00 to 20.9 psu over a single day (Figure 2-4). Median daily salinity change for surface water was 5.58 psu and 6.19 psu for bottom waters. For 91% of days, the natural daily salinity change was greater than the mean salinity change attributable to withdrawals under the current schedule (< 0.4 psu; Figure 2-4). Whereas, 80% of days had natural salinity variations greater than the maximum salinity change that is modeled from the current withdrawal schedule (2.3 psu; Figure 2-4).

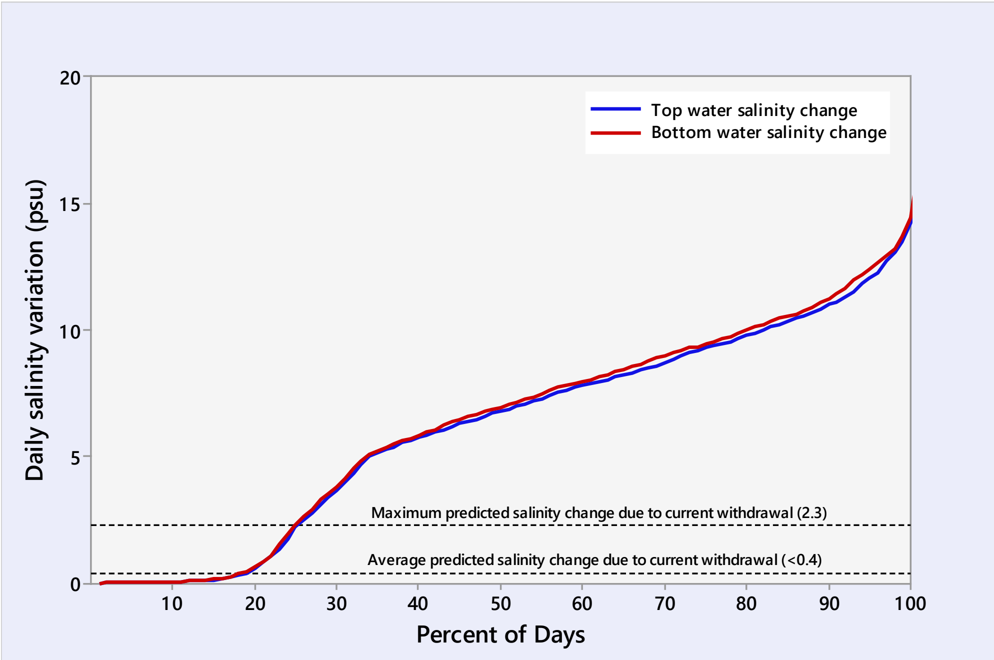

Figure 2-3 Cumulative distribution function of daily salinity variation at the USGS Harbor Heights (Rkm 15.5) station for the period April 2011 to April 2014.

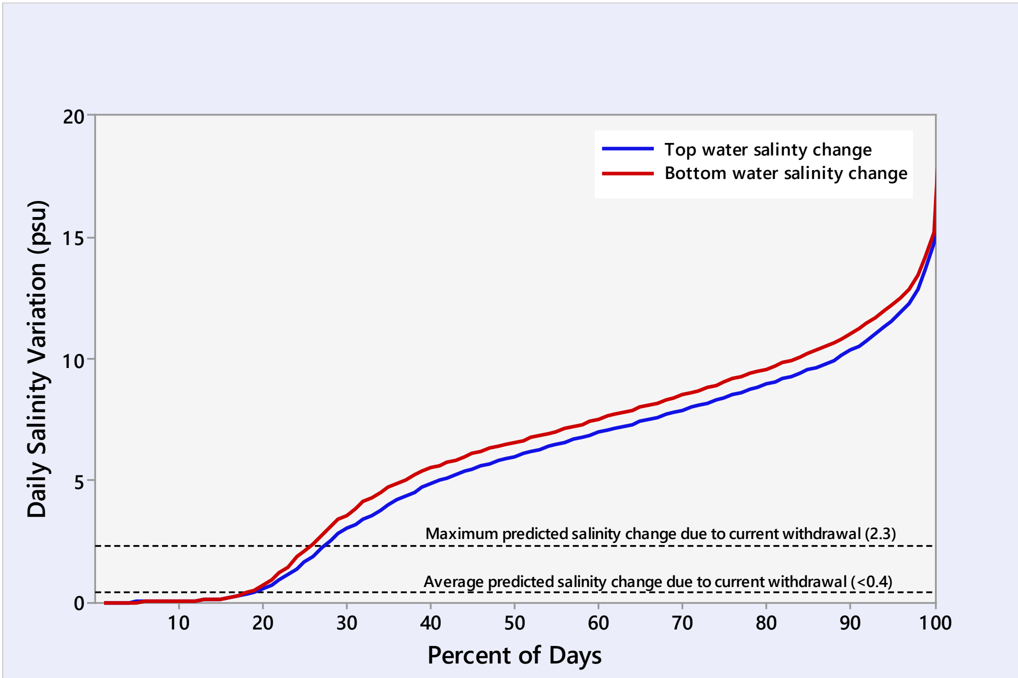

Figure 2-4 Cumulative distribution function of daily salinity variation at the USGS Harbor Heights (Rkm 15.5) station for the period April 1996 to March 2011.

It is important to note that these salinity variations are only noticeable during incoming tides. Additionally, the maximum salinity shift due to withdrawals at the most environmentally sensitive area of Harbor Heights will only occur occasionally when flow magnitudes are close to block-specific withdrawal thresholds (i.e., 130 cfs for Block 1 and 625 cfs for Blocks 2 and 3). Due to the naturally variable osmotic environment associated with salinities in estuaries, estuarine organisms are adapted to cope with a wide range of salinities and durations of atypical salinity events. Therefore, the small changes in salinity, attributable to the currently permitted withdrawal schedule, is unlikely to alter the health of the naturally dynamic estuary from its state (Atkins, Inc., 2011, 2012, 2013a).

2.2.2 Phytoplankton Biomass (Chlorophyll a)

As part of the reevaluation processes, Atkins Inc. was contracted by the District (from November 2012 to July 2014) to evaluate relationships between freshwater inflow and nutrient loading with chlorophyll concentrations and primary production in the LPR/upper Charlotte Harbor estuarine system. The District's primary interests in supporting this effort was to determine whether the seasonal timing and locations of chlorophyll maximum changes in the estuary is associated with and can be predicted from withdrawals from the river. For this project, the influences and interactions of multiple variables (e.g., solar radiation, river segments, freshwater inflows, water ages, water color, upstream nutrient loadings, chlorophyll concentrations, carbon uptake, salinity, dissolved oxygen, etc.) were evaluated using graphical analyses, correlation and multivariate statistical analyses (e.g., PCA, SAS RSREG, and SAS STEPWISE). Although the study did not produce robust models that can be used to predict the temporal/spatial changes in chlorophyll levels associated with withdrawals from the river, it was useful for identifying temporal patterns of phytoplankton abundance and production within certain regions of LPR/upper Charlotte Harbor estuarine system. In the downstream upper portion of Charlotte Harbor (<Rkm 2.1), a smaller phytoplankton peak often occurs in the spring season when periods of high freshwater inflow introduce nutrients into the slow moving, clear harbor waters. The highest chlorophyll concentration, however, occurs during the late fall when freshwater inputs start to decline after exporting sufficient nitrogen loadings, allowing tidal inputs to decrease water color and allow more light penetration. The mixture of sufficient nutrients, increasing light availability, and warm water temperatures leads to highest phytoplankton production (Figure 2-5). In the upper portion of LPR (<Rkm 27.1) high chlorophyll levels occur during the spring dry season conditions when the low freshwater inflows provide enough nutrients to support phytoplankton production and water age (i.e., residence time) is relatively long (Figure 2-5).

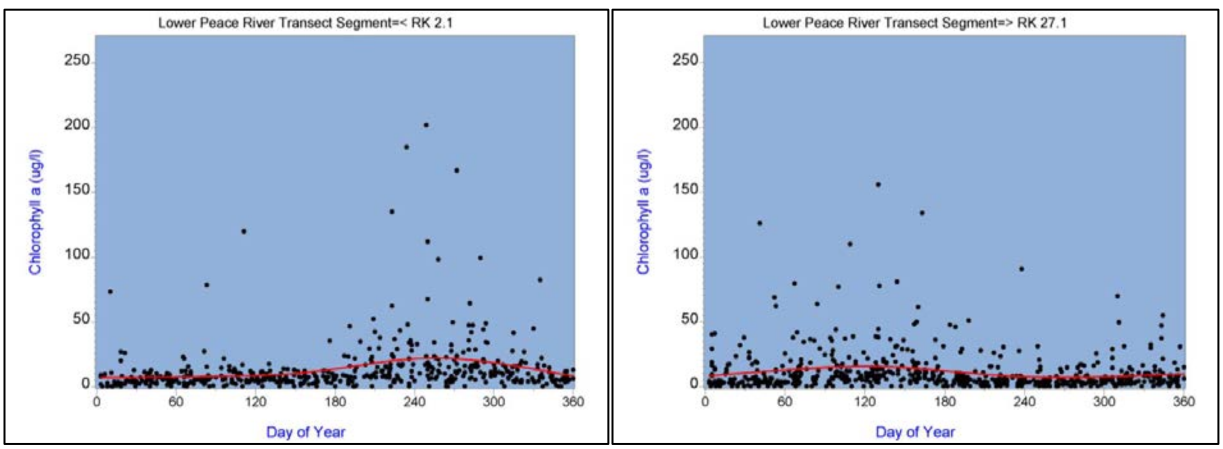

Figure 2-5 Plots of Chlorophyll in the most downstream (Rkm 2.1) and most upstream (Rkm 27.1) river segments (Atkins, Inc., 2014b).

The middle portion of the LPR (Rkm 10.8-19.5) has been identified as the area most susceptible to flow related changes, in terms of effects on phytoplankton (Atkins, Inc., 2014b). This area is dominated by intermediate salinities with 6 and 12 psu isohalines commonly found in the river segment. Depending on the magnitude of flows, water color and water age, high chlorophyll levels may occur throughout the year. As in the upper Charlotte Harbor, this area also exhibits two distinct periods of phytoplankton growth. During the early summer, freshwater inflow initiates an increase in phytoplankton abundance in the middle portion of the LPR. This early summer bloom is of greater magnitude and duration than the spring bloom that occurs in the upper harbor. Likewise, the fall bloom in the middle LPR is of greater magnitude and duration than the fall bloom in the upper harbor. This bloom begins later in the year than the fall bloom in the upper harbor and is initiated by the same drivers. i.e., mixing with tidal water causing more light penetration, higher residence times, and sufficient nutrients (Atkins, Inc., 2014b).

Figure 2-6 depicts chlorophyll levels measured at the four salinity zones (psu- 0, 6, 12, and 20) in 2012 through 2014 relative to preceding long-term average values for the period from 1983 through 2011. Chlorophyll concentrations within the salinity zones during 2012 were generally similar to the preceding long-term corresponding averages, while the 2013 data indicates generally decreased chlorophyll levels than the long term corresponding averages, with the exception of the 0 psu isohaline zone. During 2014, chlorophyll levels measured at the four salinity sampling zones were also slightly lower than the long-term corresponding averages.

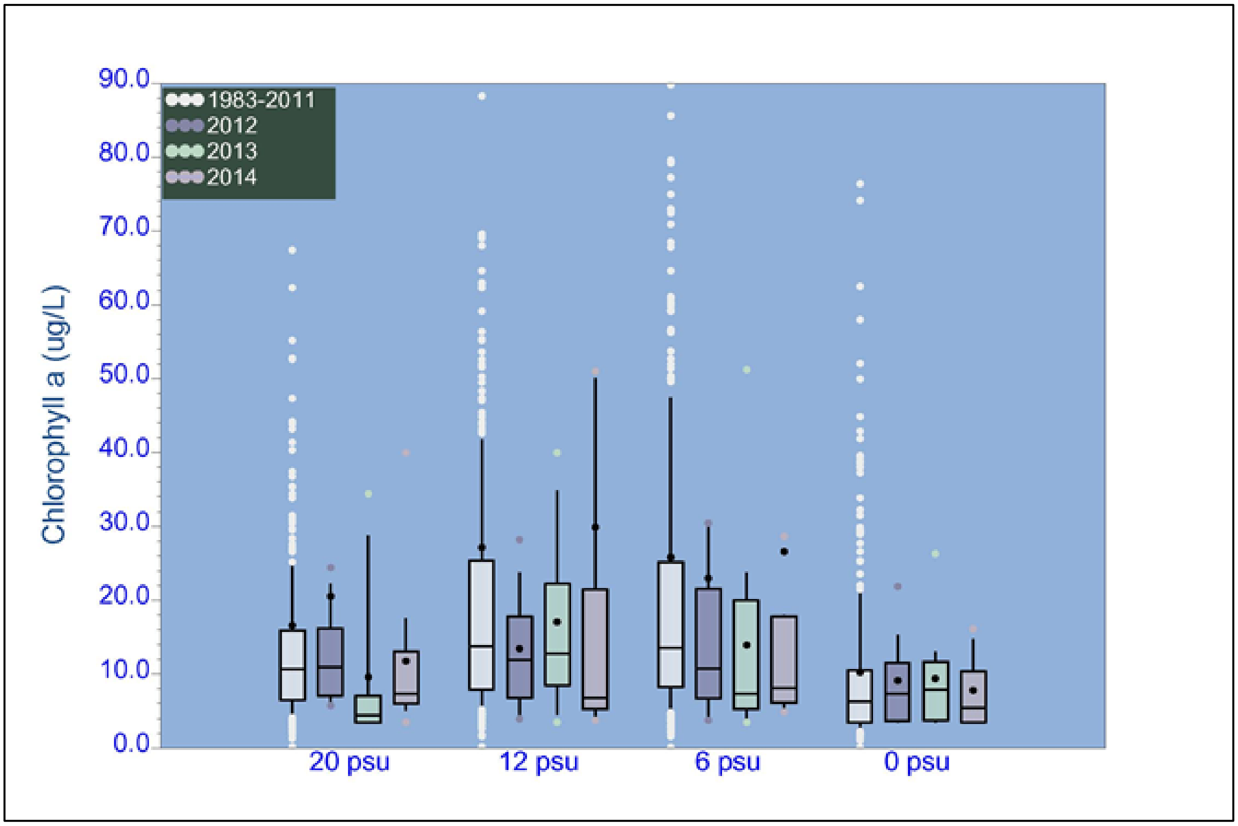

Figure 2-6 Box and whisker plots of chlorophyll concentrations at salinity sampling zones for 2012, 2013, 2014.

Conceptually, freshwater withdrawals have the potential to influence chlorophyll levels primarily through one of three major mechanisms: decreased water color, reduced nutrient loading and changing residence time. Water color would be reduced with decreases in freshwater flow, thereby fueling phytoplankton production through more light penetration into the water column. Nutrient loading has a positive relationship with flow and chlorophyll levels, whereas, residence time has a negative relationship with flow. The location of peak chlorophyll concentration would be expected to coincide with the zone of maximum residence time in the LPR/upper Charlotte Harbor estuarine system.

The majority of their withdrawals are made when the Facility reservoirs are filled during the summer high-flow period (July-August). Once the reservoirs are full, withdrawals are relatively equal to demand and only a small percentage of streamflow is withdrawn from the river. The small percentage of streamflow withdrawals toward the end of the wet-season is expected to have little to no effect on the timing of the typical fall phytoplankton bloom (Atkins Inc., 2014b).

The most sensitive time for nutrient limitation of phytoplankton is in the late spring through the beginning of the summer wet-season when phytoplankton are nutrient starved and respond quickly to nutrient pulses. This period is often associated with sporadic high flow events that follow the driest months of the year, and it occurs during Block 2 when permitted withdrawals increase from 16% to 28% once flows exceed 625 cfs (refer to Table 2-2). Withdrawing relatively large percentages of flows when phytoplankton are responding to the first inflows of limiting nitrogen has the potential to significantly reduce phytoplankton production in the LPR. However, the current annual water withdrawals of the Facility are limited to less than 6% of combined upstream flows and are unlikely to result in substantial reduction of nutrient loadings.

When residence time is relatively long, typically during the low flow season (Block 1), the PRMRWSA only withdraws small amounts of water from the LPR or is not withdrawing at all based on the Low Flow Threshold. Conversely, during high flow season (i.e., Block 3), withdrawals are limited by pumping capacity, and are not expected to decrease residence time substantially. It is therefore unlikely that any changes in residence time due to withdrawals should have much influence on phytoplankton production (Atkins Inc., 2014b).

3. RECONSTRUCTION OF UNIMPAIRED FLOWS

A number of investigators (e.g., Hammett, 1990; Flannery and Barcelo, 1998; SWFWMD, 2005; Kelly, 2004; Kelly and Gore, 2008) have examined trends in Peace River flows and have reached a variety of conclusions regarding anthropogenic effects on the river's flows. Using data collected through 1985, Hammett (1990) concluded that "much of the flow decline seen in the Peace River is attributable to factors other than rainfall." In contrast, others (e.g. SWFWMD, 2005; Kelly, 2004; Kelly and Gore, 2008) have identified climate as a major factor for most of the flow decline observed for the river from the 1970s through the 1990s.

Assessing the LPR flow record for anthropogenic impacts is essential for reevaluation of the adopted MFLs. To support this effort, flow data were updated through 2013. Flow variation associated with warming and cooling of the Atlantic Multi-decadal Oscillation (AMO) and El Niño Southern Oscillation (ENSO) were also investigated. To gain a better understanding of the factors that control the Peace River flows and simulate the effects of climate, groundwater withdrawals, land use change, the District findings from the Peace River Integrated Model (PRIM) project which was completed in 2012 were also evaluated. Collectively, these data were used to reconstruct an unimpaired flow regime for LPR as described in the following subsections of this report.

3.1 Flow Trends and Possible Causes

For trend analysis, flow data for USGS Peace River at Bartow, FL (02294650), Peace River at Zolfo Springs, FL (02295637), Peace River at Arcadia, FL (02296750) and its major tributaries including Horse, FL (02297310), Shell, FL (02298202), Charlie, FL (02296500), Payne, FL (2295420) and Joshua FL (02297100) Creeks collected through 2013 were compiled. Rainfall data from 1951 through 2013 for the Peace River watershed were obtained from the District's database which can be accessed at (http://www.swfwmd.state.fl.us/data/hydrologic/rainfall_data_summaries).

Using the nonparametric Kendall's tau test, areal rainfall and flows at Bartow, Zolfo Springs, Charlie, and Arcadia exhibited a significant declining trend at alpha level of 0.1, while flows at Payne Creek exhibited a significant increasing trend (Table 3-1). Trend tests (p-values) for the Peace River at Arcadia and Charlie Creek were very similar to the p-values scored for rainfall, supporting the evidence that human influences on streamflow at Arcadia and in Charlie Creek are minimal. However, the steep declining trends in the Peace River at Bartow and Zolfo Springs partly reflect the effect of increased groundwater withdrawals, even though the decreases in flow are largely the result of rainfall. In contrast, the lack of a declining trend at Horse Creek, Joshua Creek and Shell Creek is the result of flow increases from agricultural return flows in recent decades. Baseflow increases in phosphate mining areas have also resulted in higher than expected streamflow volumes in Payne Creek. Among the watersheds in the Peace River basin, Charlie Creek remains relatively un-impacted with no phosphate mining and limited urbanization (PBS&J, 2007b).

Table 3-1 Trend analysis for rainfall and flows in the Peace River at Bartow, Zolfo Springs, and Arcadia, and Horse, Shell, Charlie, Payne and Joshua Creeks.

	Downward Trend (P value)	Upward Trend (P value)
Peace River Rainfall	0.040*	0.965
Peace River at Bartow	0.002*	0.998
Peace River at Zolfo	0.006*	0.994
Peace River at Arcadia	0.050*	0.953
Horse Creek	0.196	0.803
Joshua Creek	0.790	0.301
Charlie Creek	0.063*	0.936
Shell Creek	0.571	0.429
Payne Creek	0.999	0.001*

* p values significant at alpha level of 0.1

Using flows from Charlie Creek as a reference, a comparison of median daily flows per unit area for three periods for the Peace River at Arcadia, Horse Creek and Joshua Creek is presented in Figure 3-1. If climate is the major controlling factor, one should expect similar flow patterns in these neighboring watersheds. Figure 3.1 suggests that flow patterns in the Peace River at Arcadia for the periods 1970-1995 and 1996-2013 remain very similar to the pattern observed during the period 1950-1969, indicating that there has not been a significant anthropogenic impact over time as seen in Horse and Joshua Creeks. The 1950-1969 flow patterns for Horse and Charlie Creeks were similar for most of the year with the exception that Horse flows during May-June were relatively lower than the flows in Charlie Creek. During the periods of 1970-1995 and 1996-2013, however, the May through June flows in Horse Creek increased over time (see middle and lower panel of Figure 3-1). These increases are consistent with the timing of growing season where return flows from irrigated fields is expected to contribute to streamflow. The flow in Joshua Creek clearly shows an increasing trend throughout the year since the early 1970s and the trend has increased significantly during the 1996-2013 period (Figure 3-1, lower panel). This is attributed largely to return flows from irrigated fields. Historic data for conductivity and nitrite+nitrate nitrogen in Joshua Creek also shows an increasing pattern due to changes to more intensive agricultural land uses and discharges of mineralized groundwater into the creek.

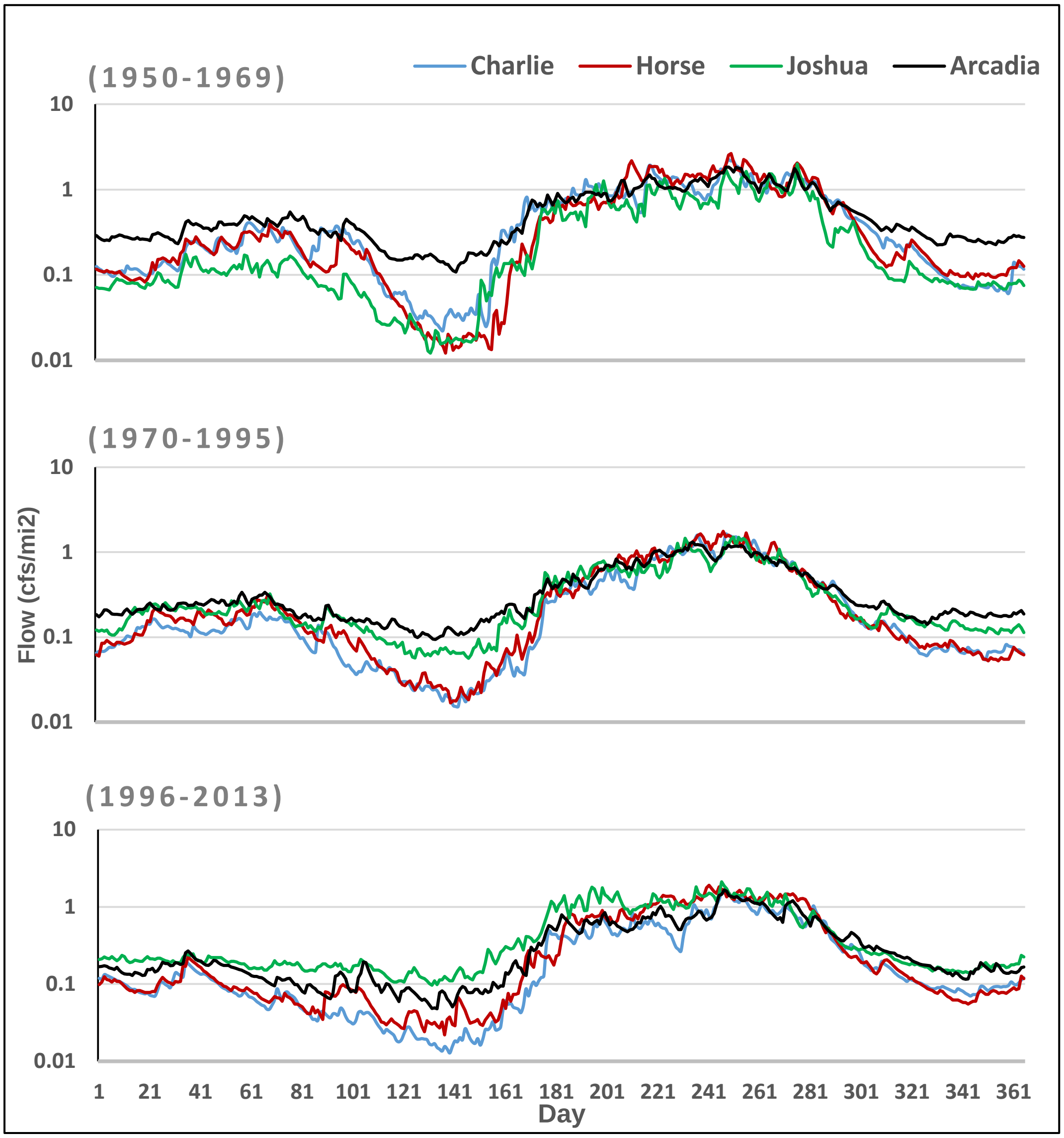

Figure 3-1 Comparison of median daily flows [logarithmic scale] for three time periods for the Peace River at Arcadia, Charlie Creek, Horse Creek and Joshua Creek.

The AMO is an index of Sea Surface Temperature (SST) anomalies averaged over the North Atlantic from 0–70°N and has a strong influence on summer rainfall over the conterminous U.S. (McCabe et al., 2004). The ENSO, a naturally occurring phenomenon associated with an irregular cycle of warming and cooling of SSTs in the tropical Pacific Ocean (5°N to 5°S, 150° to 90°W) is also known as dominant force causing climate variations over the U.S. and much of the globe (Hansen et al., 1997). To better understand how these climate indices are related to the temporal variability of streamflow in the LPR, the mean annual SST patterns tracked by these two indices and the LPR streamflow were normalized. Plots of 5- and 10-year moving average window of the normalized values of AMO and the LPR streamflow is shown in Figure 3-2. They exhibit a similar pattern, with higher flows occurring during a warmer AMO phase and low flows occurring during cooler AMO phase. The Pearson's coefficients between 5-year running means of AMO and LPR streamflow series is 0.68, while the Pearson's coefficients between 10-year running means of AMO and LPR streamflow series is 0.83. This is consistent with Kelly's (2004) previous findings for the river. Superimposed within the AMO cycle, the ENSO anomalies were also related to the year-to-year streamflow variability in the LPR as shown in Figure 3-3.

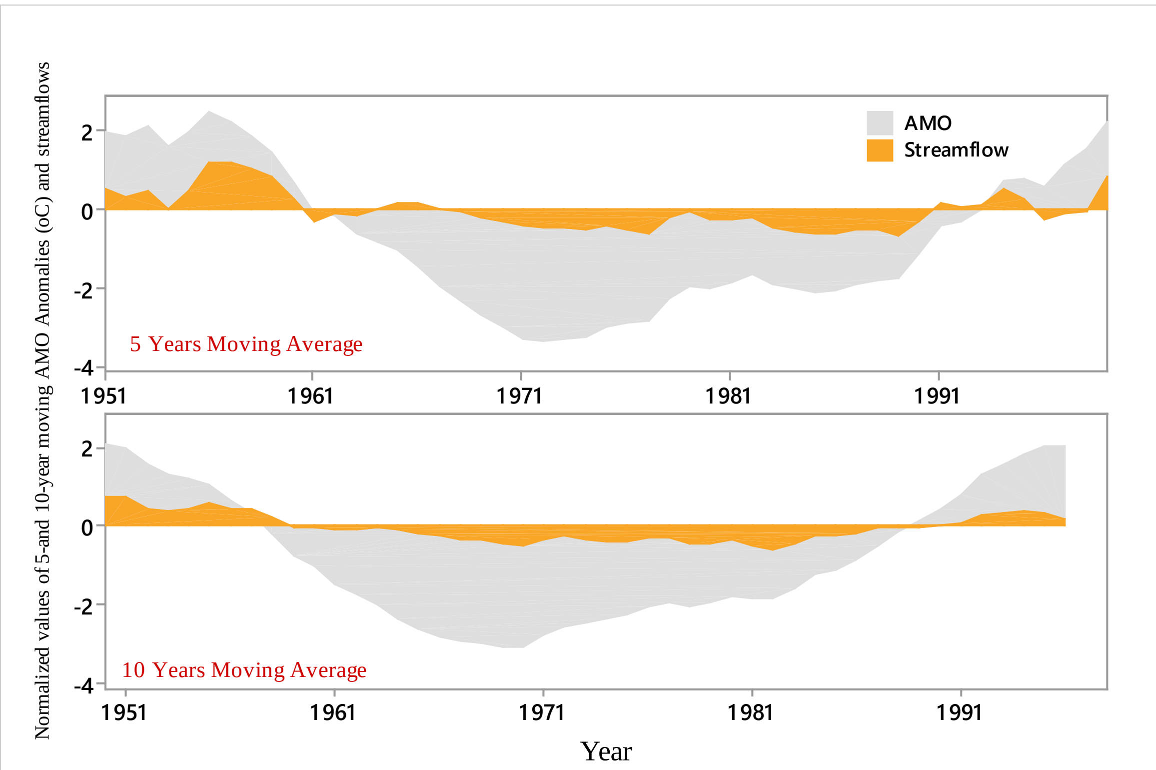

Figure 3-2 Normalized values of 5-and 10-year moving averages of annual AMO Anomalies (°C) and LPR streamflows for the period 1951 through 1998.

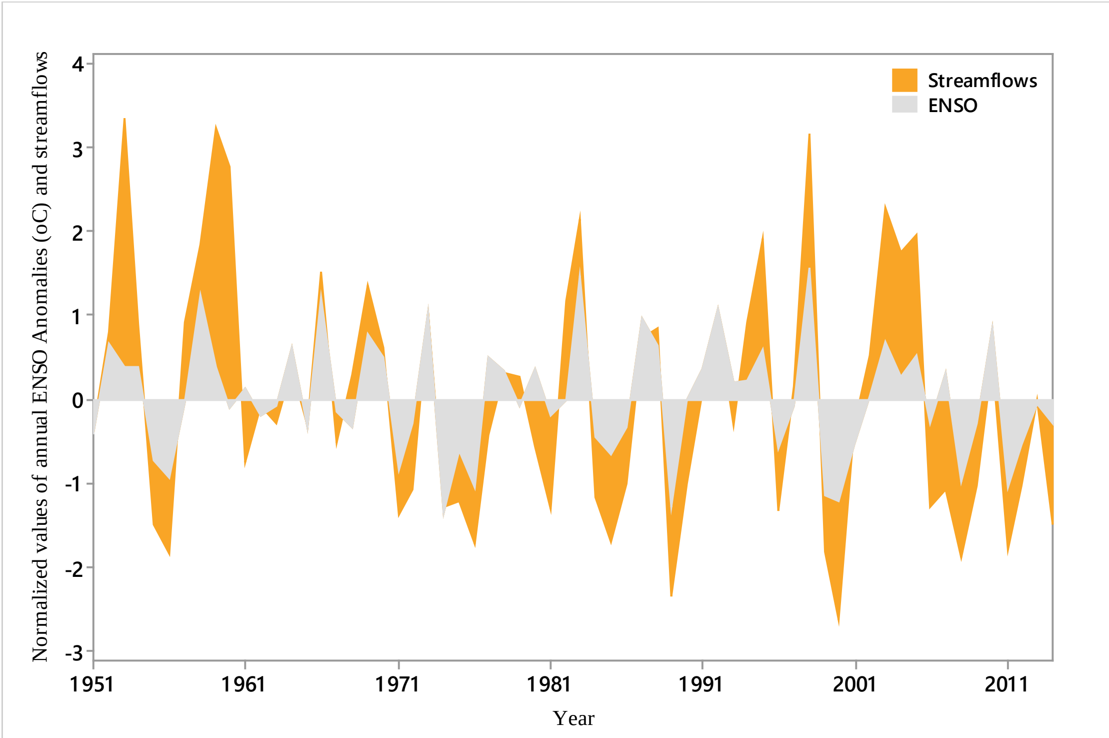

Figure 3-3 Normalized values of annual ENSO Anomalies (°C) and LPR streamflows for the period 1951 through 2013.

While we believe that the variations in Peace River flows are largely controlled by climate, a comprehensive study was necessary to better understand the relative impact of anthropogenic factors that influenced flow decreases in the upper and middle Peace River and flow increases in Horse, Payne and Joshua Creeks. The District developed the PRIM for investigating effects of climate variability, groundwater pumping, land use changes and other factors on flows in the Peace River. Detailed information on model components, required inputs and the results of calibration and validation as well as scenarios that have been simulated are documented in HydroGeoLogic, Inc. (2009, 2011 and 2012). The PRIM was run for a 13 year period from 1994 to 2006 with measured groundwater withdrawals. The daily flows produced by PRIM agreed fairly well with the observed streamflow in the Peace River at Arcadia (r^2=0.82), Joshua Creek (r^2=0.57) and Horse creek (r^2=0.78) that collectively make-up the LPR flows. After calibration with measured flows that potentially integrate withdrawal effects, PRIM was run for two groundwater withdrawal scenarios (25% and 50% reduction) to assess the effects of reducing pumping on streamflow in the Peace River Basin. Effects of reduced groundwater withdrawals were strong at Bartow and Ft. Meade (6% increase in flow), moderate at Zolfo Springs (2.1% increase in flow) and *de minimis* at Arcadia and in Horse Creek (<1% increase in flow) for a 50% groundwater withdrawal reduction. The modeled simulations also indicated a 3.8% decrease in Joshua Creek flows when groundwater withdrawals were reduced by 50% (Table 3-2). This result is indicative of the degree to which agricultural return flows from groundwater pumping have increased flows in Joshua Creek. Generally, the lesser impacts to Peace River flows below Zolfo Springs at Arcadia and in Horse Creek are due partly to the tighter confinement on the upper Floridan Aquifer in the lower Peace River area. In addition, streamflow reduction due to groundwater withdrawals may partly be compensated for by excess baseflow associated with agriculture (HydroGeoLogic, Inc., 2012).

Table 3-2 Impact of groundwater withdrawals on streamflow in the Lower Peace River and selected tributaries.

Gage Site	Streamflow changes	
	75% Pumping Change (%)	50% Pumping Change (%)
Peace River at Bartow	3.00%	6.00%
Peace River at Ft. Meade	3.00%	6.00%
Peace River at Zolfo	0.91%	2.09%
Peace River at Arcadia	0.22%	0.65%
Horse Creek	0.00%	0.00%
Joshua Creek	-1.84%	-3.75%
Charlie Creek	-1.49%	-2.26%
Payne Creek	0.50%	0.50%

Since groundwater demands vary seasonally, a daily unimpaired flow regime corrected for seasonal effects of groundwater withdrawals, rather than yearly average, is required for MFLs analysis. The reconstruction of a daily LPR unimpaired flow record based on seasonal groundwater withdrawals is briefly discussed in the sub-section which follows.

3.2 Unimpaired Flows

Results from the PRIM simulations indicate a strong linear relationship between groundwater withdrawal percentage change and streamflow. Daily flows for zero groundwater withdrawals were therefore extrapolated using linear regressions developed from the PRIM scenarios results. However, given the uncertainties associated with model inputs and simplified assumptions and approximations of complex hydrologic interactions in the model, the daily flows generated using PRIM should not be used as an exact sequence of the simulation; rather, the simulation should be aggregated into a longer time scale than daily for establishing a reasonable cause-effect relationship between unimpaired and impacted flows. The steps undertaken to reconstruct the LPR daily unimpaired flows were as follows:

(1) The daily simulated flows for both the actual and zero pumping scenarios were aggregated into seasonal flow blocks corresponding to the periods of low, medium and high flows used to establish the LPR MFLs;
(2) The 13 years seasonal flow blocks (1994-2006) were averaged to calculate the average percentage change between the pumping vs zero pumping scenarios;
(3) The daily gaged flows measured in the Peace River at Arcadia, Horse Creek and Joshua Creek were corrected for the effects of groundwater withdrawals using the average percentage flow change calculated for each seasonal block in step 2; and finally;
(4) The daily unimpaired flows for LPR for the period from 1980 through 2013 were calculated by combining the corrected daily flows for these three gage sites and adding the daily surface water volume withdrawn at the PRMRWSA Peace River Facility intake for the period 1980-2013.

Estimated seasonal streamflow percentage changes in the absence of groundwater withdrawal for flows in the Peace River at Arcadia, Horse Creek and Joshua Creek are presented in Table 3-3. Although the percentage differences in flow at Arcadia and Horse Creek do not significantly differ between actual and the estimated zero groundwater withdrawal condition, the estimated streamflow is diminished in the dry season (Block 1) for reduced (zero) pumping. This is due predominantly to agricultural groundwater withdrawn from surficial and intermediate aquifers discharging into the rivers. The effects of agricultural runoffs are most pronounced in flows at Joshua. This indicates that agricultural groundwater withdrawals constitute a significant percentage of the Joshua's flows throughout the year.

Table 3-3 Seasonal percentage changes in the absence of groundwater withdrawals.

	Seasonal streamflow percentage changes		
Gauge	Block 1	Block 3	Block 2
Arcadia	-1.03%	0.78%	2.15%
Horse	-1.15%	0.63%	0.30%
Joshua	-21.36%	-6.14%	-8.46%

Monthly combined flow totals for the three gage sites averaged over the period 1980-2013 for unimpaired vs gaged flows in the LPR are shown in Figure 3-4, labeled with percentage differences. The monthly flow reduction due to withdrawal-related effects generally ranged from 1.26% (214 cfs) in April to 2.45 (495 cfs) in December. During May and June, the monthly average unimpaired flows is shown to decrease by 1.30% and 1.45% respectively due to removal of agricultural return flows from the total streamflows.

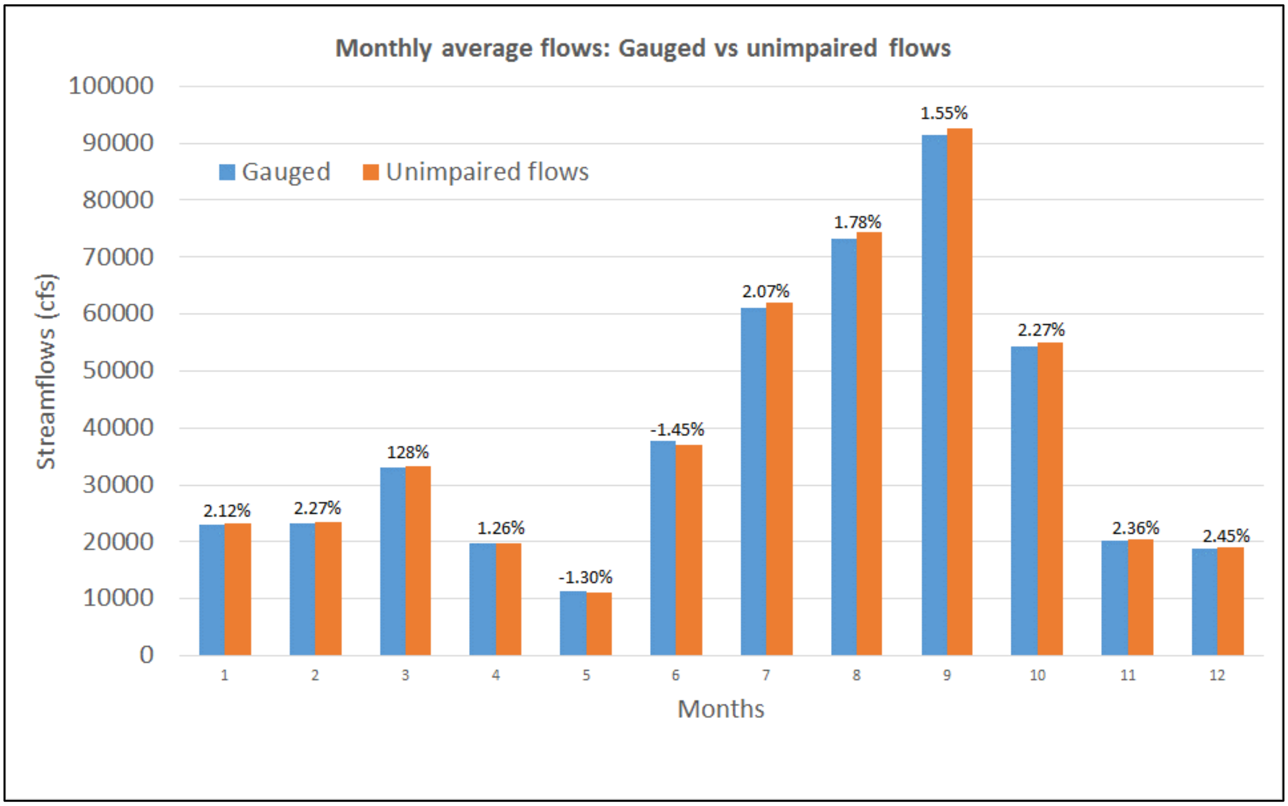

Figure 3-4 Monthly average flows for unimpaired vs. gaged flows and differences expressed as a percentage of the gaged flows.

The PRIM was developed to account for all major hydrologic processes, including rainfall, runoff, groundwater exchange, evapotranspiration, net evaporation from lakes, wastewater returns by municipal, industrial and agricultural uses, as well as groundwater pumping and discharges. However, like any physically-based model, PRIM is limited by numerous uncertainties that stem mainly from model assumptions, input errors and parameter estimation. To minimize these uncertainties, seasonal, rather than, daily or monthly adjustments were used for application of PRIM results for the reconstruction of unimpaired flows for the LPR.

4. COMPLETED AND ONGOING PROJECTS TO SUPPORT THE MFLs REEVALUATION

Since 2011, the District has initiated a number of technical projects to support reevaluation of the adopted LPR MFLs through: (1) further improvement of the calibration and validation of the District's hydrodynamic model for the LPR and extending its application to the LPR floodplain system and the entire Charlotte Harbor through improved estimation of ungaged flows, simulation of new model boundary conditions and enhanced bathymetric/topographic mapping; (2) development of Habitat Suitability Index (HSI) models for predicting fish abundances and distribution in the LPR and Charlotte Harbor; (3) improved understanding of the relationships between chlorophyll concentrations and seasonal variations in freshwater inflows in the LPR/upper Charlotte harbor estuarine system; and (4) obtaining additional ecological data to assess floodplain features/habitats in the LPR and how their inundation may be affected by changes in river flow. Many of those supporting projects are completed or will be completed within the next few years.

4.1 Improving the Hydrodynamic Model

The District's LESS3D (Lake and Estuarine Simulation in Three Dimensions) hydrodynamic model (Chen, 2004) will be run using unimpaired (i.e., corrected for withdrawal impacts) and numerous reduced flow scenarios to aid in the identification of desirable flow requirements for floodplain and estuarine habitats. To support model reliability and expand its application to the entire Charlotte Harbor system, the following projects were undertaken.

4.1.1 Flow Estimation for Ungaged Areas

For calibration and validation purposes, the LESS3D model requires observed streamflow records for the Myakka and Peace Rivers. Due to tidal influences, however, the lower portions of both rivers remain ungaged. Also, there are several small ungaged streams, creeks and canals that directly or indirectly flow into the Upper Charlotte Harbor Basin (Figure 4-1). Thus, the estimation of daily streamflow from those ungaged sites is necessary to accurately simulate the salinity interface, water temperature and flow regimes in the tidally influenced area of the Upper Charlotte Harbor Basin. Previously, Ross et al. (2005) attempted to simulate the flows from those ungaged sites using a surface water model HSPF, Hydrological Simulation Program-FORTRAN (Bicknell et al., 1997). Although comparisons between LESS3D modeled and observed flows at known sites show acceptable agreement in terms of correlation coefficients and index of agreement values, the HSPF model has been less useful for accurately simulating the timing and magnitude of large storm events. This is not totally unexpected, given that streamflow in this area is strongly affected by surface/groundwater interactions, and for modeling purposes, these interactions typically require explicit representation of the hydro-geologic processes that control baseflow. In addition, large portions of the contributing basin have been altered to urban land use, and not knowing how much of the urbanized area is directly flowing into the drainage systems and how much is draining into wastewater treatment systems also affects model accuracy. Also, because surveyed lakes/wetland cross sections were not available for the model domain, model accuracy was likely diminished based on the need for simplifying assumptions concerning depth and volume relationships used to simulate day-to-day storage attenuation of lakes and wetlands.

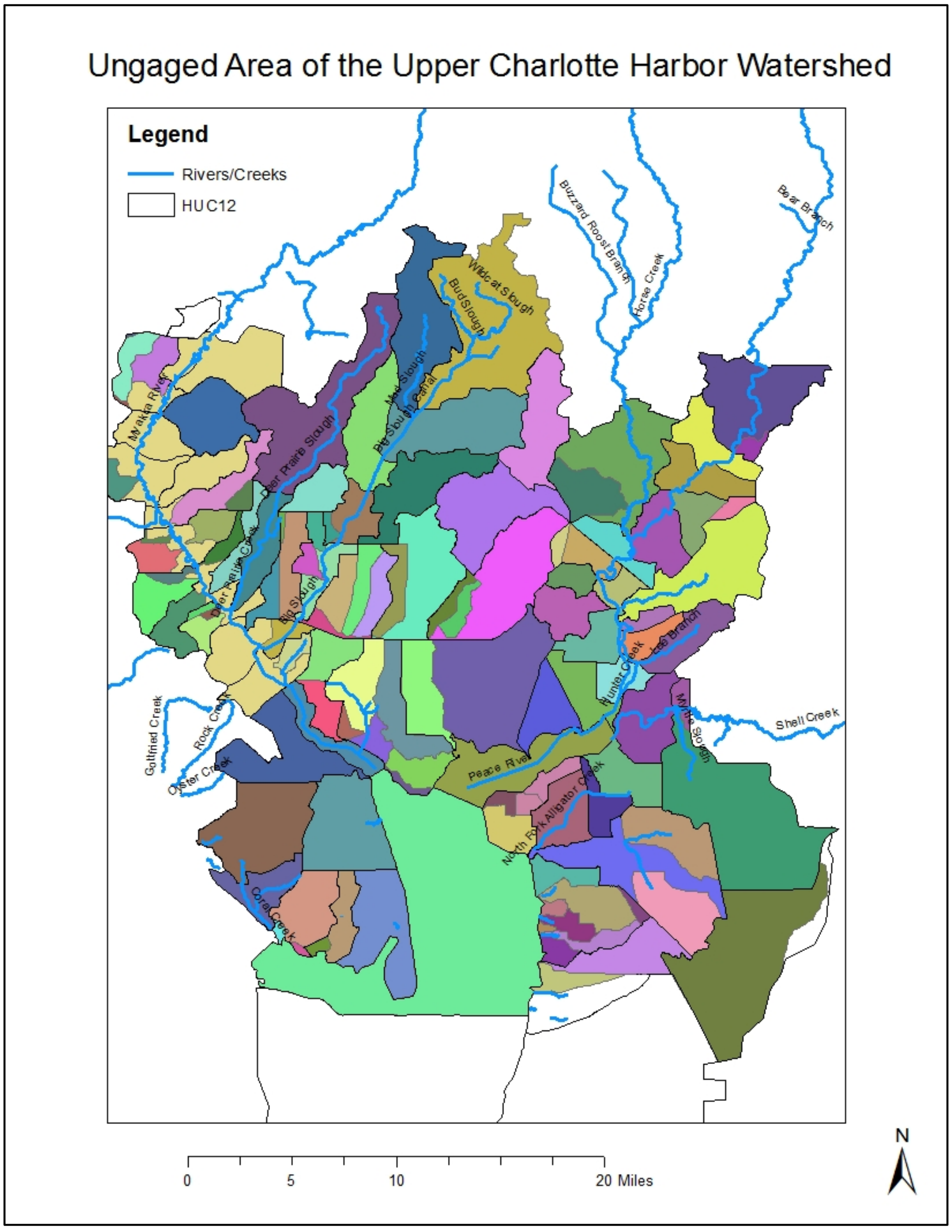

Figure 4-1 Overview of ungaged area and its HUC12 basins.

Based on these issues, lumped rainfall-runoff modeling with HSPF may not be the most appropriate approach for simulating ungaged flows in the Upper Charlotte Harbor Basin. As an alternative, simple drainage ratio based methods were used to estimate streamflow at ungaged sites from neighboring gaged sites. A combined streamflow (Q_d) at the ungaged basin from multiple gaged sites was estimated using a weighting scheme technique developed by Shu et al. (2012). The gaged sites are weighed based on their proximity and similarity in runoff response to a given ungaged site.

$$Q_d = \frac{\sum_{i=1}^{n} w_i Q_{di}}{\sum_{i=1}^{n} w_i}$$

where Q_{di} is the streamflow estimation from the gaged site i, n is number of gaged basins, and w_i is the weight assigned to the gaged site and it was computed as

$$w_i = \frac{{}^{1}/_{d_i}}{\sum_{i=1}^{n} {}^{1}/_{d_i}}$$

where d_i is the similarity measure between, the weighting schemes (distance, runoff response) for gaged basin (X_i) and target ungaged basin (X), respectively.

$$d_i = \sqrt{(X_i - X)^2}$$

For this purpose, historic streamflow record from 10 gaged basins were collected and the ungaged area was discretized into 115 USGS HUC12 units. The drainage area ratio method assumes that the gaged and ungaged sites share the same hydrologic characteristics except for the scaling factor due to differences in their sizes. Distance weights were used for those ungaged basins surrounded by multiple gaged sites of similar hydrologic characteristics. Runoff response weights were used mostly for altered ungaged basins (e.g., urban) that do not possess runoff responses similar to their neighboring gaged basins. Average runoff response for each unit was obtained from the HSPF simulations previously run by Ross et al (2005) for the period of 1989-2004. The drainage area ratio methods generally allowed to maintain the hydrograph patterns observed in the gaged basins. Once the calibration work is completed, improvements in the performance of the LESS3D model based on the new ungagged flow estimates will be evaluated.

4.1.2 Data Collection Tower and Boundary Condition Simulations

To support the recalibration and validation of the LESS3D model and extend its application to the entire Charlotte Harbor area, the District entered a contract with Mote Marine Laboratory in 2012 for installation of a scientific instrumentation platform (tower) in upper Charlotte Harbor and data collection at the site (Figure 4-2). After several site reconnaissance visits and consultation with the District, a tower was installed at 26° 48' 14.76''N latitude and 82° 5' 18.77'' W longitude, located approximately 4.8 km north of the channel entrance to Burnt Store Marina and 11.2 km south of Ponce de León Park in Punta Gorda. There were no submerged structures and/or vegetation at the tower site.

Figure 4-2 Instrument platform in Charlotte Harbor (Culter et al., 2015).

Parameters measured at the tower site included vertical current profiles, water level, temperature and salinity at near surface, mid and bottom depths in the water column, and wind speed, wind direction, barometric pressure, air temperature, relative humidity, rainfall, and solar radiation for the period from February 7, 2013 through August 31, 2014. Periodic maintenance, calibration and quality assurance were performed as needed during the monitoring period. Removal of the tower and submission of all required data were completed by April 2015.

The District also contracted the Ocean Circulation Group in the College of Marine Science at the University of South Florida to run the regional West Florida Coast Ocean Model

(WFCOM) and generate boundary conditions for hourly sea level, velocity components, salinity, and temperature along the boundary of the District's hydrodynamic model of the Charlotte Harbor estuary. The WFCOM domain spans from west of the Mississippi River Delta to south of the Florida Keys and Figure 4-3 displays a portion of the WFCOM grid system, focusing on boundary condition sites for the District's LESS3D hydrodynamic model area.

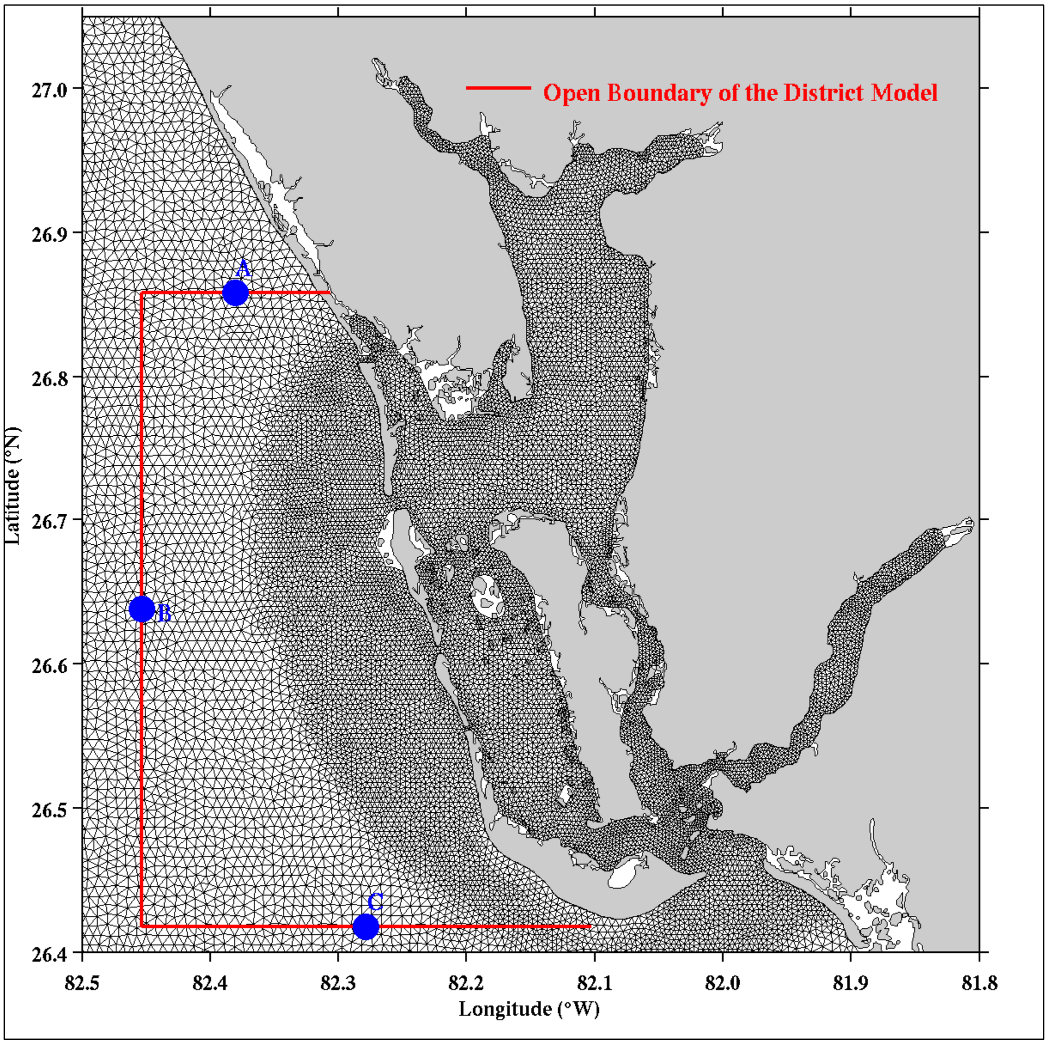

Figure 4-3 The WFCOM grid system focusing on three locations (A, B and C) selected for development of boundary conditions for the District's hydrodynamic model. Red line shows the open boundary of the hydrodynamic model (image source: Zheng and Weisberg, 2015).

The WFCOM model was run from January 2013 through August 2014 and provided a simulation of hourly sea level and near surface salinities and temperatures at three selected locations (shown in Figure 4.3). The simulations were then interpolated to the District's hydrodynamic model boundary conditions. The red lines in Figure 4.3 shows the open boundary of the hydrodynamic model. For data quality assurance, WFCOM model outputs were compared against observations collected from varying federal and local agencies. This project has been completed and the boundary conditions were delivered to the District in February 2015.

4.1.3 Remapping Bathymetry and Improved LiDAR Data

In an effort to improve the modeling capabilities of the LESS3D hydrodynamic model, the District funded two projects titled "LiDAR Hydrographic and Topographic Surveying" for the Peace River and "Shoreline Mapping and Bathymetric Survey" for the Charlotte Harbor and Lower Peace/Myakka River System. The Light detection and Ranging (LiDAR) photogrammetric mapping was conducted by Aerial Cartographic of America, Inc. (2015) and covered an area of approximately 150 square miles, extending from Lake Hancock in Polk County to Sand Hill in Charlotte County (Figure 4-4a). The LPR portion of the LiDAR data collection effort was conducted primarily to support development of the District's hydrodynamic model and reevaluation of the LPR MFLs, while the data collected for the upper and middle Peace River areas were obtained to support development of a separate watershed management model. All LiDAR data were collected using approved Multi-beam Green & Infrared LiDAR photogrammetric mapping sensors. Routing sensor calibration and maintenance were performed as needed to ensure proper function of the LiDAR system. The LiDAR data was verified by Wantman Group Inc. and delivered to District in March 2015. District staff have completed a final data review and a digital, high resolution elevation model (DEM) is being produced for input to the hydrodynamic model.

Bathymetric data that were used in the previous hydrodynamic simulations for the LPR had some discrepancies when compared to the recently collected survey data (i.e., LiDAR data) in some portions of the LPR and the Myakka River. These discrepancies may have been associated with landscape alterations associated with hurricane Charley in 2004. To eliminate these discrepancies and improve model performance, new shoreline maps and bathymetric survey for the upper Charlotte Harbor and the tidal reaches of the Myakka and Peace rivers (Figure 4-4b) were conducted in 2013. Wang (2013) mapped the shoreline using a Trimble RTK GPS mounted on board the survey vessels, and bottom elevations for inundated areas were measured using a synchronized Odem narrow beam precision echo sounder with the RTK GPS. A total of 4,862,650 survey points and over 1,600 km surveys lines were collected for the assessed area. Measurement errors associated with motion waves and tidal water-level variations were filtered-out using accepted techniques and the final processed data were delivered to the District in March 2013.

The new topographical information (high resolution DEM and bathymetric data) are vital inputs to the District's hydrodynamic model and are expected to improve model simulations of water level, velocity and salinity zones in the Charlotte Harbor and Lower Peace/Myakka River System.

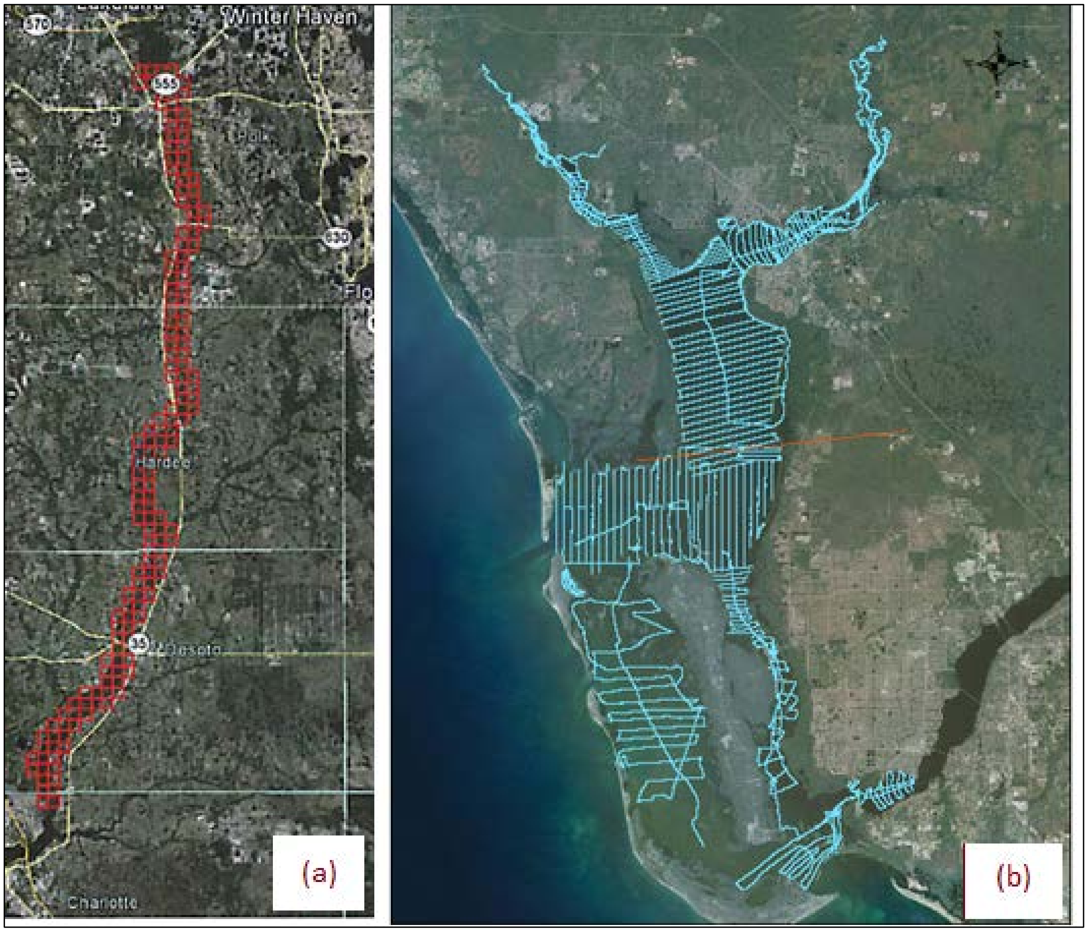

Figure 4-4 Surveyed area for (a) LiDAR and (b) shoreline mapping and bathymetric survey.

4.2 Incorporation of New Ecological Indicators

The District approach for setting MFLs is habitat-based and the maintenance of volume and distribution of various salinity zones were used to establish the LPR MFLs in 2011. The MFL were established on the premise that if changes in the area and volume of these key salinity zones could be limited to reductions of less than 15%, then the estuarine resources (e.g., fish, benthic, vegetation community) would be protected. To further investigate and potentially strengthen the protection of estuarine resources, the District is conducting or funding a number of projects as part of the LPR MFLs reevaluation. An ongoing project involves development and use of habitat suitability indices to evaluate the abundance and distribution of six fish species that are known to be responsive to freshwater inflows. Because the floodplain system of the LPR provides a diverse array of habitat for plants and animal populations, the District is also planning a number of projects related to floodplain habitats.

4.2.1 Fish Habitat Suitability Index Modeling

Rubec et al. (2001) have developed a spatial Habitat Suitability Index (HSI) and related mapping for a number of estuarine dependent fish species in Tampa Bay and Charlotte Harbor. Habitat layers and abundance-based suitability index values derived from Fishery Independent Monitoring (FIM) conducted by the Florida Fish and Wildlife Research Institute (FWRI) of the Florida Fish and Wildlife Conservation Commission were used to produce HSIs and maps by life stage and season in the two estuaries for spotted seatrout (*Cynoscion nebulsus*), bay anchovy (*Anchoa mitchilli*), and pinfish (*Lagodon rhomboides*). An ongoing project for the LPR MFLs reevaluation will update and extend the application of the previously developed HSI indices/models for six species-life stages that are known to be responsive to freshwater inflows in the LPR/Charlotte Harbor region. The models will be built using FIM data collected from 2004-2013 and data collected from 1996-2003 will be used for their validation.

Non-linear splines will be fit to fish catch per unit effort (CPUE) abundance data across gradients for water temperature, salinity, dissolved oxygen, bottom type, and depth. Various graphical outputs will be created to assist in determining which factors are most significant for HSI model development. Once best-fit models have been built, they will be used to predict CPUE values per square meter for a prediction grid of about 4 million 15 x 15 m cells (associated with habitat variables derived from interpolation of environmental data) across the estuary. By partitioning the prediction grid into 4 zones, GIS maps representing *low, moderate, high,* and *optimum* zones of fish abundance will be created. The HIS model maps will also depict zones of abundance and the spatial distributions of each species-life stages. These products will be produced for scenarios associated with no freshwater withdrawals (unimpaired condition) and maximum withdrawals that would be allowed based on proposed MFLs that are developed or identified as part of the LPR MFLs reevaluation. This project is expected to be completed by December 31, 2016.

4.2.2 Floodplain Ecology Indicators

Periodic inundation of riparian floodplains is typically a major factor affecting the biological productivity of river ecosystems (Amoros and Bornette, 2002). Floodplain features (e.g. swamps, bottomland forest and hydric hammock) are very important habitats for many fish and wildlife species and inundating these habitats for sufficient periods is critical to primary production, uptake and transformation of nutrients and the maintenance of aquatic food webs (Kuensler 1989; Gregory et al., 1991; Hunter et al., 2008). For example, recent findings from the FWRI indicate that Snook (*Centropomis undecimalis*) use floodplain habitats in tidal freshwater zone of the Peace River above the Highway 761 Bridge, approximately 30 to 49 kilometers upstream of the river mouth. This research has shown that the abundance and condition of snook is associated with high flows in Peace River that inundate the river floodplain and make additional food resources available (Blewett et al., 2015).

To support reevaluation of the LPR MFLs, the District plans to examine various floodplain features, including soils and vegetation communities along selected riverine/floodplain cross-sections and evaluate how their inundation may be affected by changes in river flows. Soils occurring along the cross-sections will be evaluated for the presence of hydric indicators. Dominant vegetation communities will be delineated and elevations of hydrologic indicators of historic inundation (e.g., cypress buttresses, lichen lines, moss collars) will be surveyed.

A variety of modeling approaches will be used to evaluate inundation characteristics associated with the surveyed floodplain features during seasonally high flow periods. The District's hydrodynamic model (LESS3D) will be used to characterize the flows in the LPR and establish flow-stage relationships at each of the selected instream cross-sections. For snook habitat, a regression model (Blewett et al., 2015) will be used to evaluate the changes in abundance and body condition of snook associated with variations in freshwater flows/depths. Then, flow reductions that resulted in no more than 15% reduction in snook habitat will be determined. For evaluation of floodplain hydrologic indicators (vegetation/soils), mean habitat elevations will be first determined from survey data. Then, based on the flow-stage relationship obtained from the LESS3D model and daily flow records for LPR, the number of days the mean elevations are inundated during seasonal flow blocks will be determined. A flow reduction that would result in no more than 15% reduction in the number of inundated days for the features will be calculated.

5. SUMMARY AND CONCLUSIONS

The LPR MFLs rule requires the reevaluation of the MFLs within five years of its adoption to incorporate additional ecological data. Five years from the date of adoption of the LPR MFLS is in July 2015 and in response to this timeline, the District has prepared this initial reevaluation report to summarize progress made to date and highlight ongoing activities to support a more comprehensive MFLs reevaluation scheduled for completion in 2018.

Major objectives of this initial report were to evaluate the current MFL status using the expected minimum flow statistics issued in the LPR MFLs rule and investigate compliance of PRMWRSA withdrawals with water use permit conditions associated with the MFLs rule. As part of these assessments, errors associated with development of two of the flow statistics included in the rule were identified and corrected values that should supersede the incorrect values were developed. Since 2010, moving 5- and 10-year moving mean and median flows during Block 2 have frequently been below the expected values, whereas moving mean and median flows during Blocks 1 and 3 were predominantly above the expected flow rates. The lower than expected flows during Block 2 were mainly due to much drier than normal rainfall conditions in 2010, 2011 and 2014. The impacts of these drier rainfall conditions were also reflected in the annual moving flow statistics for these years. Assessing compliance with permit conditions for the withdrawals at the PRMRWSA Facility on the LPR, we found no significant violations, albeit slight exceedance of maximum allowable withdrawals on some occasions due to changes to reported provisional flows by USGS. The LPR Hydrobiological Monitoring Program (HBMP) reporting subsequent to adoption of the LPR MFLs rule (2011 through 2014) indicates that current withdrawals at the Facility have not caused any significant long-term physical, chemical or biological changes in LPR/upper Charlotte Harbor estuarine system. The small changes in salinity, chlorophyll concentrations and other water quality parameters attributable to the current withdrawal schedule are within acceptable limits and are unlikely to alter the health of the naturally dynamic estuary.

The District has initiated numerous projects to comply with the rule requirement that additional ecological data be incorporated in the reevaluation of the LPR MFLs. Many of these projects have been successfully completed, including the estimation of flows from ungaged portions of the Myakka/Peace Rivers, re-mapping of the bathymetry of the LPR/upper Charlotte Harbor estuarine system, producing a LiDAR based high resolution DEM for the Peace River, installation and collection of data at a new data collection tower and the generation of hourly boundary conditions in the upper Charlotte Harbor to support hydrodynamic modeling efforts, and assessing relationships of flow with chlorophyll concentrations in the LPR estuary. Additional projects are currently underway and are expected to be completed within the next two years. The District has also planned new projects for Fiscal Year 2016 to assess various floodplain features, including soils and vegetation communities along selected riverine/floodplain cross-sections and evaluate how their inundation may be affected by changes in river flows.

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Appendix A – Minimum Flows Rule for the Lower Peace River

CHAPTER 40D-8

WATER LEVELS AND RATES OF FLOW

40D-8.041 Minimum Flows.

(8) Minimum Flows for the lower Peace River.

(a) The Minimum Flows are to ensure that the minimum hydrologic requirements of the water resources or ecology of the natural systems associated with the estuarine reach of the lower Peace River are met.

(b) Minimum Flows for the estuarine reach of the lower Peace River are based on the sum of the combined flows of the USGS Peace River near Arcadia Gage #02296750 plus the flow at the USGS Horse Creek near Arcadia Gage #02297310, and the USGS Joshua Creek at Nocatee Gage #02297100, and are set forth in Table 8-20 below. Minimum Flows for the lower Peace River are both seasonal and flow dependent. One standard, the Minimum Low Flow Threshold, is flow based and applied continuously regardless of season. No surface water withdrawals shall be permitted that would cumulatively cause the flow to be reduced below the Minimum Low Flow Threshold of 130 cfs based on the sum of the mean daily flows for the three gages listed above. Additionally, permitted withdrawals shall cease when flows are below the Minimum Low Flow Threshold of 130 cfs. The total permitted maximum withdrawals on any day shall not exceed 400 cfs. There are also three seasonally dependent or Block specific Minimum Flows that are based on the sum of the mean daily flows for the three gages denoted above that would occur in the absence of any permitted upstream withdrawals. The Block Minimum Flows are based on potential changes in habitat availability for select salinity ranges within a season.

Table 8-20-Minimum Flow for Lower Peace River based on the sum of flows from Horse Creek, Joshua Creek, and the Peace River at Arcadia gages.

Period	Effective Dates	Where Flow on Previous Day Equals:	Minimum Flow Is
Annually	January 1 through December 31	≤130 cfs >130 cfs	Actual flow (no surface water withdrawals permitted) Seasonally dependent – see Blocks below
Block 1	April 20 through June 25	≤130 cfs >130 cfs	Actual flow (no surface water withdrawals permitted) previous day's flow minus 16% but not less than 130 cfs
Block 2	October 28 through April 19	≤130 cfs >130 cfs and <625 cfs ≥625 cfs	Actual flow (no surface water withdrawals permitted) previous day's flow minus 16% but not less than 130 cfs previous day's flow minus 29%
Block 3	June 26 through October 27	≤130 cfs >130 cfs and <625 cfs ≥625 cfs	Actual flow (no surface water withdrawals permitted) previous day's flow minus 16% but not less than 130 cfs previous day's flow minus 38%

(c) Minimum five-year and ten-year moving mean and median flow values are set forth in Table 8-20 as a tool to assess whether flows to the lower Peace River remain above flow rates that are expected to occur with implementation of the Minimum Flow described in Table 8-21 and a daily maximum withdrawal rate of 400 cfs. The means and medians are based on evaluation of daily flow records for the three gages listed above for the period 1951 through 2008. Yearly means and medians were computed for January 1 through December 31 of each year, then moving five-year and ten-year averages were calculated from these yearly values. Therefore, the five-year and ten-year means and medians are hydrologic statistics that represent the flows that will be met or exceeded if compliance with the Minimum Flow and the 400 cfs maximum withdrawal rate is maintained during hydrologic conditions similar to the 1951-2008 period. Climatic changes or future structural alterations in the watershed could potentially affect surface water or groundwater flow characteristics within the watershed and flows in the river. Therefore, as additional information relevant to Minimum Flows development becomes available, the District is committed to periodically evaluate whether any declines in these minimum moving average values below that expected with the application of the Minimum Flow are due to factors other than permitted water use.

(d) The Minimum Flows for the lower Peace River will be reevaluated to incorporate additional ecological data for the Lower Peace River within 5 years of adoption of this rule.

Table 8-21 Minimum Five-Year and Ten-Year Moving Mean and Median flows for the lower Peace River based on

the sum of flows from Horse Creek, Joshua Creek, and the Peace River at Arcadia

Minimum Flow	Hydrologic Statistic	Flow (cfs)
Annual Flow	10-Year Mean	713
	10-Year Median	327
	5-Year Mean	679
	5-Year Median	295
Block 1	10-Year Mean	284
	10-Year Median	264
	5-Year Mean	204
	5-Year Median	114
Block 2	10-Year Mean	429
	10-Year Median	383
	5-Year Mean	330
	5-Year Median	235
Block 3	10-Year Mean	1260
	10-Year Median	930
	5-Year Mean	980
	5-Year Median	595