



*PERFORMANCE MEASURE METHODOLOGIES FOR
COLLECTIVE SOURCE CONTROLS IN THE LAKE
OKEECHOBEE AND CALOOSAHATCHEE WATERSHEDS*

**DRAFT – TECHNICAL SUPPORT DOCUMENT:
LAKE OKEECHOBEE WATERSHED
PERFORMANCE MEASURE METHODOLOGIES**



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In Association With

**South Florida
Water Management
District**



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ACRONYMS AND ABBREVIATIONS

AAF	area adjustment factor
ac	acre
ac-ft and AF	acre feet
BMP	best management practice
CAFO	concentrated animal feeding operation
CERP	Comprehensive Everglades Restoration Plan
CERPRA	Comprehensive Everglades Restoration Plan Regulatory Act
cfs	cubic feet per second
Conc	concentration
District	South Florida Water Management District
EAA	Everglades Agricultural Area
EBCWD	East Beach Water Control District
ECP	Everglades Construction Project
ERP	Environmental Resource Permit
ESWCD	East Shore Water Control District
F.A.C.	Florida Administrative Code
FDACS	Florida Department of Agriculture and Consumer Services
FDEP	Florida Department of Environmental Protection
FECR	Fisheating Creek
FLUCCS	Florida Land Use, Cover, and Forms Classification Systems
F.S.	Florida Statutes
ft	feet
FWM	flow-weighted mean
GIS	geographic information system
IFAS	University of Florida's Institute of Food and Agricultural Sciences
in	inches





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***Technical Support Document
Lake Okeechobee Watershed Performance Measures***

kg	kilogram(s)
lb and #	pound
ln	natural logarithm
LOPA	Lake Okeechobee Protection Act
LOPP	Lake Okeechobee Protection Plan
LOOP	Lake Okeechobee Operating Permit
LOWOD	Lake Okeechobee Works of the District
MA	moving average
mt	metric tons
NEEPP	Northern Everglades and Estuaries Protection Program
NGVD	National Geodetic Vertical Datum
NPDES	National Pollutant Discharge Elimination System
R ²	coefficient of determination
SFCD	South Florida Conservancy District
SFWMD	South Florida Water Management District
SSDD	South Shore Drainage District
STA	stormwater treatment area
SWIM	Surface Water Improvement and Management
ppb	parts per billion
TCNS	Taylor Creek-Nubbin Slough
TMDL	Total Maximum Daily Load
TN	total nitrogen
TP	total phosphorus
UCL	upper confidence limit
USGS	United States Geological Survey
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
µg/L	microgram per liter





DRAFT

***Technical Support Document
Lake Okeechobee Watershed Performance Measures***

WAM	Watershed Assessment Model
WOD	Works of the District
WY	water year, extending from May 1 to April 30 and identified by the calendar year when the water year ends, e.g., WY2010 extended from May 1, 2009 to April 30, 2010
yr	year





1 **1. EXECUTIVE SUMMARY**

2
3 ***1.1 Background and Purpose***

4
5 This *Draft Technical Support Document* was developed in support of the South Florida
6 Water Management District’s (District’s) Regulatory Source Control Program (Chapter 40E-
7 61, F.A.C, Works of the District) which is being amended to meet Northern Everglades and
8 Estuaries Protection Program (NEEPP) mandates. The Regulatory Source Control Program
9 was established in 1989 in the Lake Okeechobee Watershed under the authority of the
10 Surface Water and Improvement Management (SWIM) Act. The portion of the SWIM Act
11 relating specifically to Lake Okeechobee was subsumed and eventually became the NEEPP
12 (373.4595 F.S.). The NEEPP mandates complementary source control programs by the three
13 coordinating agencies (the Florida Department of Environmental Protection (FDEP or
14 Department), the District and the Florida Department of Agriculture and Consumer Services
15 (FDACS)), encompassing an expanded Lake Okeechobee Watershed, and the St. Lucie River
16 Watershed and the Caloosahatchee River Watershed. The NEEPP states that “by January 1,
17 2004 the District shall submit to the Department a permit modification to the Lake
18 Okeechobee structure permits to incorporate proposed changes necessary to ensure that
19 discharges through the structures covered by this permit achieve state water quality
20 standards, including the total maximum daily load established in accordance with S. 403.067.
21 These changes shall be designed to achieve such compliance with state water quality
22 standards no later than January 1, 2015”. Total phosphorus (TP) is the pollutant of concern
23 for Lake Okeechobee while TP and total nitrogen have been identified as pollutants of
24 concern for the St. Lucie River and Caloosahatchee River Watersheds. In response to these
25 legislative changes, the District must amend the 1989 Chapter 40E-61, F.A.C., to effectuate
26 the NEEPP requirements.





28 One of the fundamental components of the Regulatory Source Control Program is water
29 quality performance metrics coupled with water quality monitoring. The water quality
30 performance metrics currently specified in Chapter 40E-61, F.A.C, are not in alignment with
31 the Total Phosphorus Total Maximum Daily Load goals established in the NEEPP (140
32 metric tons per year (mt/yr) TP load, including 35 mt/yr due to atmospheric deposition). The
33 performance metrics for the 1989 Chapter 40E-61, F.A.C. were concentration based limits
34 from individual parcels within the watershed and were aligned with the 360 mt/yr TP load
35 SWIM Plan target for Lake Okeechobee. Further, the NEEPP mandates that monitoring be
36 conducted at representative sites to verify the effectiveness of the source control programs.

37

38 This *Draft Technical Support Document* presents 14 preliminary water quality performance
39 metrics recommended for consideration in amendments to Chapter 40E-61, F.A.C., as
40 presented in **Table 1-1**. These performance metrics estimate the TP reductions in runoff that
41 are reasonably expected from the long term implementation of the source control programs
42 mandated by the NEEPP based on monitoring sites that are representative of runoff. The
43 quantitative methods are referred to as “performance measure methodologies”. When the
44 performance measures are discussed as a whole, the term “basin” will be used to describe the
45 sub-watersheds, summary basins, and hydrologic units. The resulting metrics are referred to
46 as performance measures or performance indicators depending on the characteristics of the
47 data on which they are based. Performance measures are typically TP loads incorporating
48 hydrologic variability based on a representative base period dataset. Performance indicators
49 are also generally TP loads incorporating hydrologic variability based on a representative
50 reference period. However, performance indicators are recommended when all the criteria for
51 establishing a performance measure are not met. Performance metrics provide justification
52 for implementation of additional water quality improvement activities, or re-evaluation of the
53 existing activities by the respective agencies. The level of activities that may be triggered in
54 each case will be defined by the coordinating agencies based on jurisdiction. For areas where
55 no performance measure methodology is being proposed for reasons described in Section 3.0





56 of this report the water quality will be assessed annually to determine if there is an increasing
57 trend. The NEEPP establishes that a Memorandum of Understanding shall be executed
58 among the agencies to ensure a complementary approach. The current MOU was executed in
59 2011.

60 **Table 1-1. Lake Okeechobee Watershed TP Load Performance Metrics.**

61

Basin	Performance Measure or Performance Indicator	Base Period	Base Period Median Load mt	Recommended Source Control Reduction
S-133	Performance Measure	WY1977-1986	7.4	25%
S-154	Performance Measure	WY1977-1984	8.3	35%
S-191	Performance Measure	WY1977-1988	89.7	40%
Lower Kissimmee	Performance Measure	WY1977-1990	56.1	30%
C-44	Performance Measure	WY2000-2010	52.9	35%
L-8	Performance Measure	WY1995-2003	17.1	20%
Indian Prairie	Performance Measure	WY1989-2001	67.6	30%
Fisheating Creek	Performance Measure	WY1998-2008	67.6	30%
S-4/Industrial Canal	Performance Measure	WY1993-2001	17.6	30%
East Caloosahatchee	Performance Measure	WY1982-1990	54.9	30%
Arbuckle Creek	Performance Indicator	WY1997-2007	38.8	0%
Josephine Creek	Performance Indicator	WY1997-2004	3.0	0%
Boggy Creek	Performance Indicator	WY2001-2008	5.0	0%
Shingle Creek	Performance Indicator	WY1999-2007	17.4	0%

62

63

Notes:

64

1. No performance metric will be assigned to the S-135, S-154C and Nicodemus Slough basins. However, the water quality from these basins will be assessed annually to determine if there is an increasing trend.

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66

67

2. See Section 3.9 for a summary of the South Lake Okeechobee Sub-watershed performance measure metrics.

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69

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In Section 1.2 below is a description of how performance metrics were developed, how performance will be evaluated every year, and a description of the performance metrics for each of the basins, individually. This is a preliminary recommendation for performance metrics and may be refined during the technical and stakeholder review process prior to adoption.

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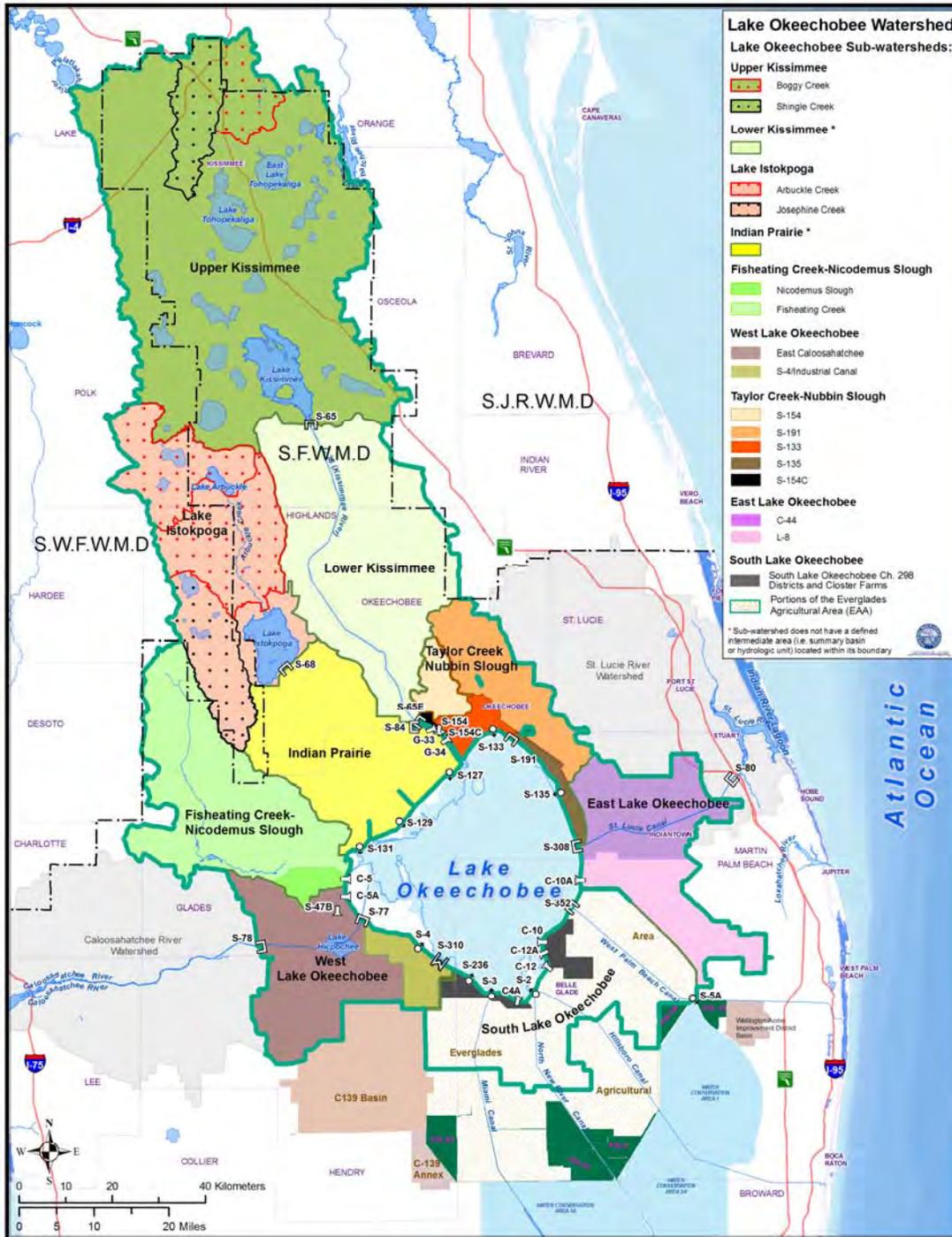
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Figure 1-1. Sub-watershed level map of the Lake Okeechobee Watershed.



76





77 ***1.2 Performance Measures Methodologies Development***

78 In order to develop these performance measure methodologies, the following general
79 activities were conducted.

- 80 1. Monthly and annual runoff and TP load for each basin within the watershed were
81 calculated based on available historical data through Water Year 2010 (WY2010) for
82 appropriate basin structures. When a basin received inflows from upstream sources
83 (e.g., other basins or Lake Okeechobee) the pass-through load was accounted for
84 using the method applied to the Everglades Agricultural Area (EAA) under Chapter
85 40E-63, F.A.C.
- 86 2. Representative rainfall monitoring stations were identified and an equation to
87 estimate basin rainfall using a Thiessen polygon weighting method was developed.
- 88 3. A base period (for performance measures) or reference period (for performance
89 indicators) was selected for each basin. The base period or reference period is the
90 benchmark period of historical observed data on which performance metrics are
91 based. Base periods met, as much as possible, the following criteria: having at least
92 eight years of concentration and flow data to adequately represent nutrient levels
93 through a wide range of hydrologic conditions; being representative of current
94 operating conditions affecting nutrient loading (unless these conditions can be
95 corrected through data adjustments); having a reasonable correlation between rainfall
96 and nutrient loads; preceding full implementation of collective source control
97 measures; being free of trends in rainfall, flow or loads (unless these trends can be
98 eliminated through data adjustments); and being free of unexplained outliers in the
99 rainfall, flow, or load data.
- 100 4. Ninety TP load annual prediction equations were examined for each basin to
101 determine which equation would better estimate the base period or reference period
102 TP annual load in response to hydrologic variability from year to year. Multiple
103 selection factors were used to select the recommended regression equation including,





104 the strength of the correlation, the statistical significance of the regression
105 coefficients, the standard error of the regression equation, the variance of the
106 residuals, collinearity of predictor variables, the presence of outliers, the presence of
107 temporal trends during the base period or reference period, and the presence of
108 overparameterization.

109 5. Nutrient reductions were estimated based on work completed in the development of
110 the watershed protection plans for Lake Okeechobee, St. Lucie River, and
111 Caloosahatchee River (Bottcher 2006 and SWET 2008). These reductions are based
112 on implementation of regulations and best management practices (BMPs) applicable
113 to each land use (e.g., FDACS Notice of Intent owner-implemented BMPs,
114 operational BMPs or activities required by existing permits or regulations). For the
115 Lake Istokpoga and Upper Kissimmee tributaries, in order to estimate requirements
116 for TP reduction due to source controls, the first step was to review historic water
117 quality data against the numeric nutrient criterion (120 µg/l for TP) (Chapter 62.302,
118 F.A.C.). Maintaining base period or reference period levels was considered
119 reasonable when the period of record median flow weighted mean (FWM) TP
120 concentration was below this criterion.

121 6. Since the goal of the performance metrics is to evaluate the effectiveness of the
122 source control programs, independent from regional water quality treatment
123 construction projects (e.g., stormwater treatment area), this *Draft Technical Support*
124 *Document* provides a methodology to account for such projects. In such cases, the
125 basin's measured runoff load will be adjusted to account for the load reduction
126 occurring within the regional project. In addition, the basin's calculated Annual
127 Load Target and Limit will be adjusted to account for the land occupied by the
128 regional project. The adjustment will be similar to the adjustment used in the
129 Everglades Agricultural Area (EAA) under Chapter 40E-63, F.A.C. The same
130 methodology will be used for future regional projects after they become operational.





131 **1.3 Annual Performance Determination**

132

133 Total phosphorus loads measured in discharges at each basin outlet structure, after
134 accounting for pass-through loads and regional projects, will be assessed annually against
135 two performance metrics: an Annual Load Target and an Annual Load Limit (**Figure 1-2**).
136 The Annual Load Target and the Annual Load Limit are further defined in Section 2.5. In
137 general, the Target represents the expected level of load or concentration resulting from the
138 regulatory source control implementation. In the case of many performance measures the
139 Target level varies annually to account for rainfall. The Limit represents the upper 90
140 percent confidence limit of a Target. Previous regulatory programs have established this as
141 an acceptable level to balance assurance that exceedance is not due to random variation and
142 also the resource is protected from exceptionally high annual levels.

143

144 The Target and Limit are applied in combination to evaluate annual and longer-term success
145 in meeting required levels. The Limit is an effective indicator for a single year's levels, but
146 it may not detect a less drastic shift or trend increase above regulated levels. Therefore a
147 Target test is also applied, which approximates the 90% confidence level on three
148 consecutive years of data. If the source controls are performing as expected, random
149 variation will result in annual levels with equal chance of being above and below the Target.
150 The statistical logic of a three year Target test equating to an 87.5% confidence level is
151 explained by the following "coin flip" analogy.

152 • A single year the Target is exceeded, there is a 50% chance that source controls are
153 performing as expected.

154 • For two consecutive years to both be above the Target there is still a 25% chance
155 that source controls are performing as expected.

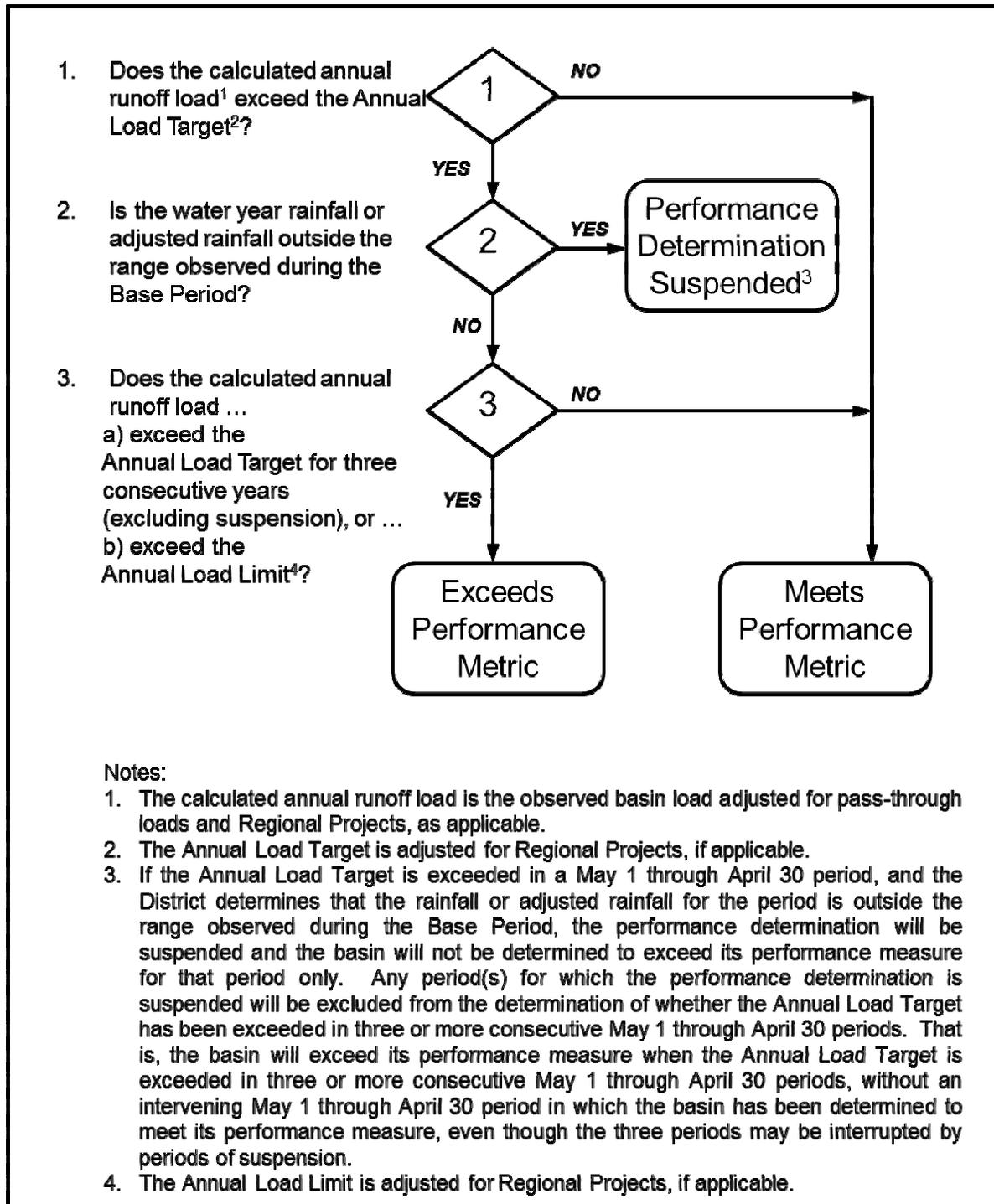
156 • For a third consecutive year to exceed the Target, only a 12.5% chance exists that the
157 source controls are performing and random variation is causing the exceedance. This
158 equates to 87.5% confidence that levels are exceeding expectations.





159

Figure 1-2. Flowchart - annual performance determination.



160





161 **Tables 1.2 through 1.15** present the performance metrics for each of the 14 basins with
 162 adequate water quality and flow data for the development of performance metrics. The
 163 metrics include the equations for calculating the annual load targets, limits, and standard
 164 errors of the predictions, along with the minimum and maximum rainfall (or adjusted
 165 rainfall as applicable) ranges within which the performance metrics can be evaluated.
 166 **Figures 1-3 through 1-16** provide comparisons of the *scaled* load data with the proposed
 167 targets and limits for the base (or reference) periods. Scaled means that the annual loads of
 168 the base (or reference) period are decreased by the Recommended Source Control
 169 Reduction, thus the graph depicts the fit of the prediction.

170

171 The variables used in the prediction equations are defined below:

172 $X =$ 12-month total rainfall for the evaluation year (inches), or $\ln(\text{rainfall})$,
 173 if applicable

174 $X_m =$ average value of annual rainfall in the base period, or $\ln(\text{rainfall})$, if
 175 applicable

176 $P =$ 12-month total rainfall for the previous water year (inches), or
 177 $\ln(\text{rainfall})$, if applicable

178 $P_m =$ average value of the predictor (previous rain) in the base period, or
 179 $\ln(\text{previous rain})$, if applicable

180 $C =$ coefficient of variation calculated from 12 monthly rainfall totals), or
 181 $\ln(\text{coefficient of variation})$, if applicable

182 $C_m =$ average value of the rainfall coefficient of variation in the base
 183 period, or $\ln(\text{coefficient of variation})$, if applicable

184 $S =$ skewness calculated from the 12 monthly rainfall totals, or
 185 $\ln(\text{skewness})$, if applicable

186 $S_m =$ the average value of the rainfall skewness in the base period, or
 187 $\ln(\text{skewness})$, if applicable

188 $SE_p =$ standard error of the prediction (mt, $\ln(\text{mt})$ or $\text{sqrt}(\text{mt})$ as applicable)





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Table 1-2. S-133 Summary Basin TP Load Performance Measure.

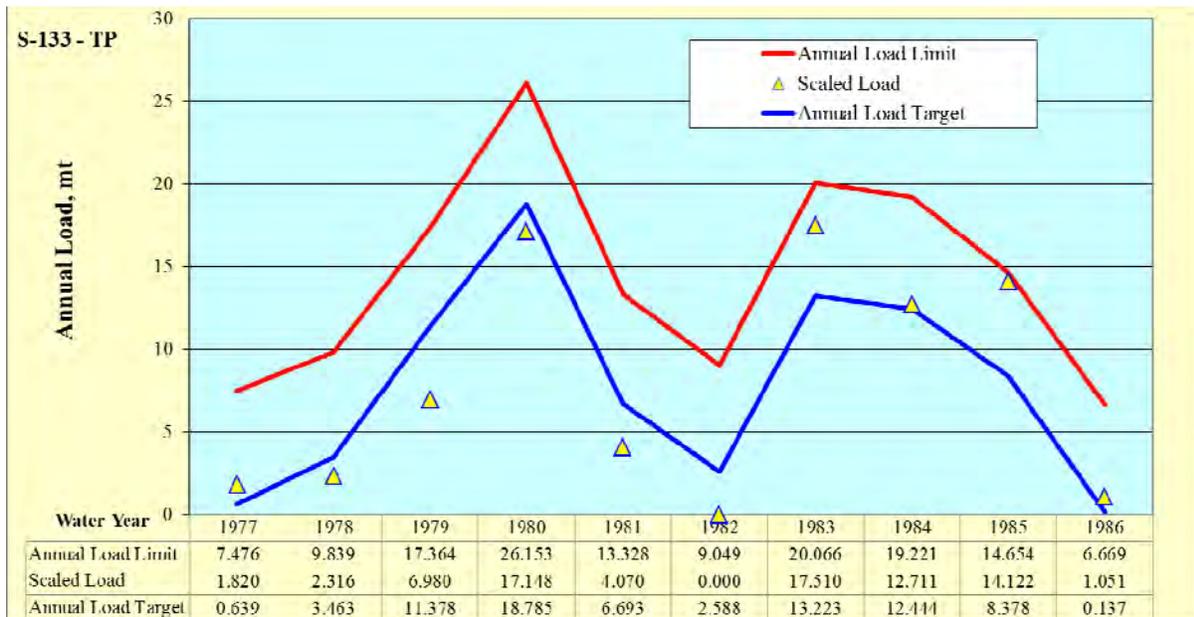
Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R ²)	Recommended Source Control Reduction	Base Period Rainfall ¹	
				Minimum inches	Maximum inches
7.4	5.5	79%	25%	30.03	77.63
Target = -200.98003 + 19.638 X + 29.41568 P + 30.52657 C					
Limit = Target + 1.43976 SE					
SE = 3.88541 [1 + 1/10 + 3.01635 (X-X _m) ² + 4.00198 (P-P _m) ² + 10.51972 (C-C _m) ² + 0.38068 (X-X _m) (P-P _m) + 2.9188 (X-X _m) (C-C _m) + 8.67534 (P-P _m) (C-C _m)] ^{0.5}					

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¹ Based on adjusted rainfall values

X = ln(Rain) and X_m = the mean of the log transformed annual rain for the base period

P = ln(Prior Year's Rain) and P_m = the mean of the log transformed prior year's rain for the base period



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Figure 1-3. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the S-133 Summary Basin based on a 25% load reduction.



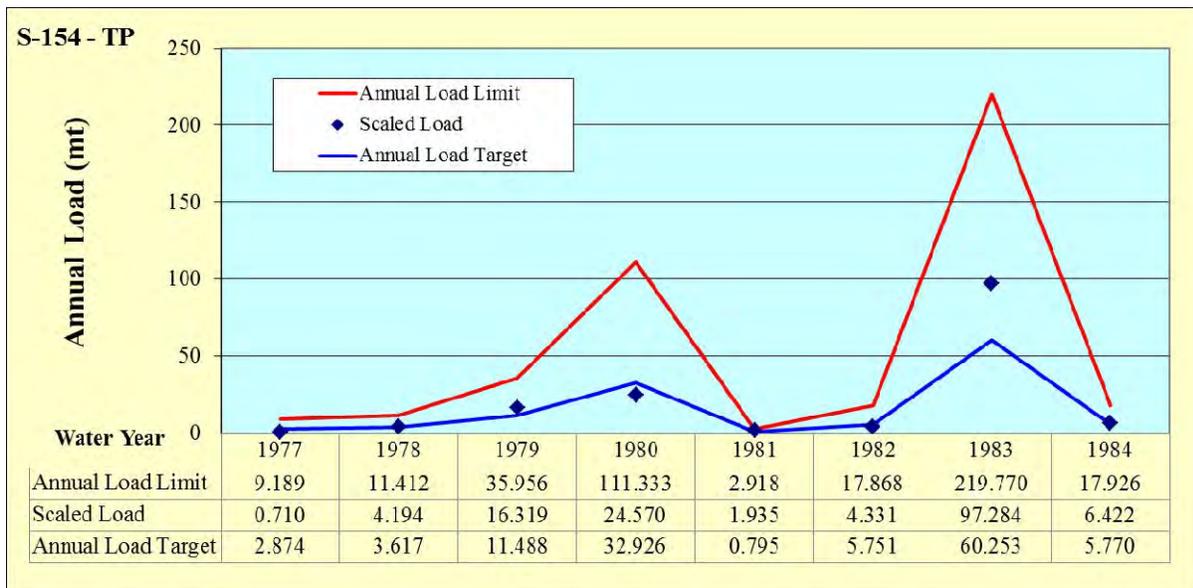


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Table 1-3. S-154 Summary Basin TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R ²)	Recommended Source Control Reduction	Base Period Rainfall	
				Minimum inches	Maximum inches
8.3	5.4	80%	35%	30.06	56.20
Target = exp (-5.20573 + 0.16556 X)					
Limit = Target * exp (1.43976 SE)					
SE = 0.74134 [1 + 1/8 + (X-X _m) ² / 485.64409] ^{0.5}					

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Figure 1-4. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the S-154 Summary Basin based on a 35% load reduction.



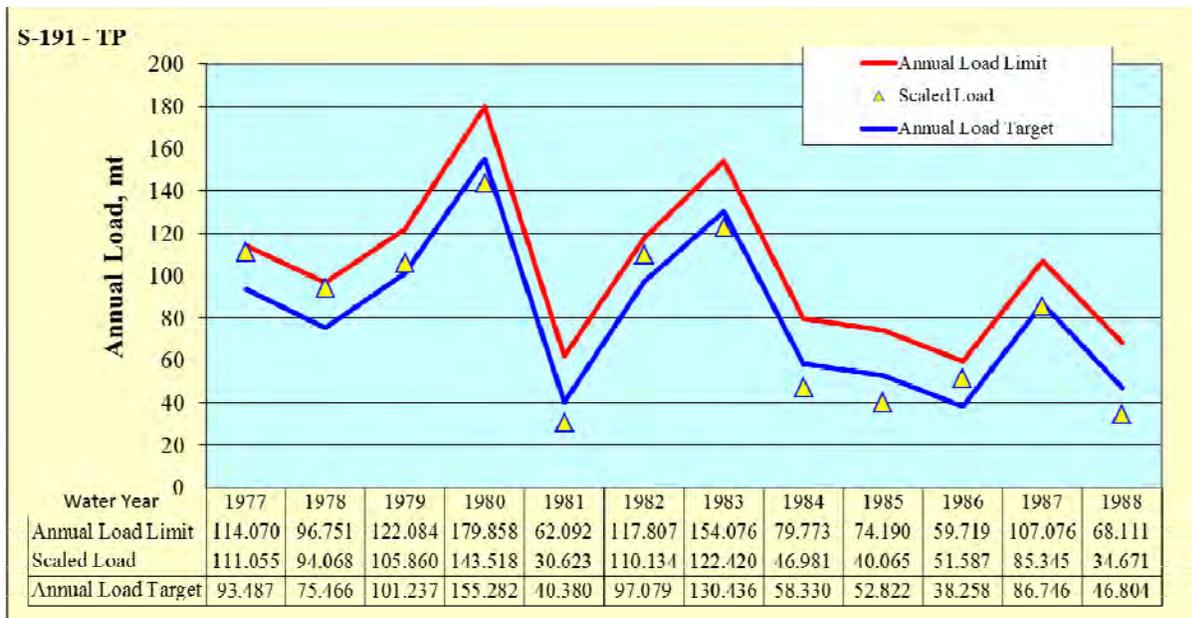


211 **Table 1-4. S-191 Summary Basin TP Load Performance Measure.**

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R ²)	Recommended Source Control Reduction	Base Period Rainfall	
				Minimum inches	Maximum inches
149.5	89.7	89%	40%	36.49	63.56
Target = -692.35612 + 210.9038 X + 84.89757 C					
Limit = Target + 1.38303 SE					
SE = 13.99487 [1 + 1/12 + 3.1233 (X-X _m) ² + 2.11893 (C-C _m) ² + 1.54068 (X-X _m) (C-C _m)] ^{0.5}					

212 ¹ Based on adjusted rainfall values
 213 X = ln(Rain) and X_m = the mean of the log transformed annual rain totals for the base period
 214 C = ln(CV) and C_m = the mean of the log transformed annual CV for the base period
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217 **Figure 1-5. Comparison of the scaled observed Base Period annual TP loads with the**
 218 **annual targets and limits for the S-191 Summary Basin based on a 40% load reduction.**
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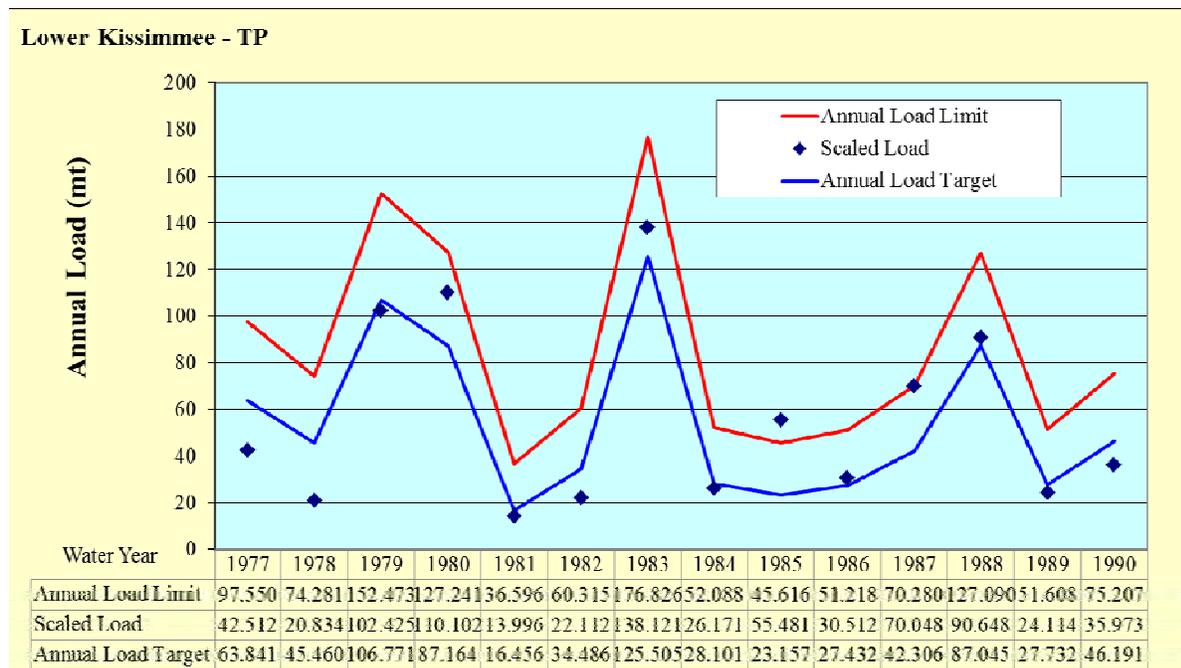


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Table 1-5. Lower Kissimmee Sub-watershed TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R ²)	Recommended Source Control Reduction	Base Period Rainfall	
				Minimum inches	Maximum inches
56.1	39.2	75%	30%	39.33	61.84
Target = [-8.42963 + 0.31747 X] ²					
Limit = [sqrt(Target) + (1.35622 SE)] ²					
SE = 1.33557 [1 + 1/14 + (X-X _m) ² / 641.63129] ^{0.5}					

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Figure 1-6. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the Lower Kissimmee Sub-watershed based on a 30% load reduction.





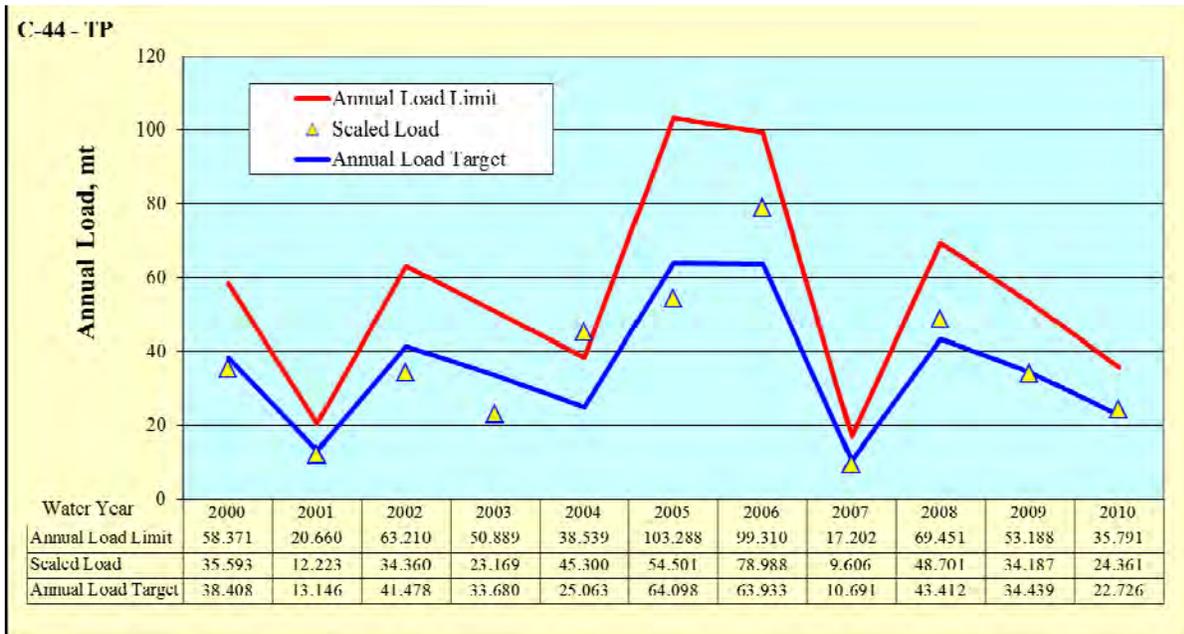
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Table 1-6. C-44 Hydrologic Unit TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R ²)	Recommended Source Control Reduction	Base Period Rainfall ¹	
				Minimum inches	Maximum inches
52.9	34.4	84%	35%	29.81	61.40
Target = exp [-6.33102 + 2.47876 X + 0.32418 S]					
Limit = Target * exp (1.39682 SE)					
SE = 0.28227 [1 + 1/11 + 2.17743 (X-X _m) ² + 0.37715 (S-S _m) ² - 0.19128 (X-X _m) (S-S _m)] ^{0.5}					

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¹ Based on adjusted rainfall values
X = ln(Rain) and X_m = the mean of the log transformed annual rain totals for the base period



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Figure 1-7. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the C-44 Hydrologic Unit based on a 35% load reduction.





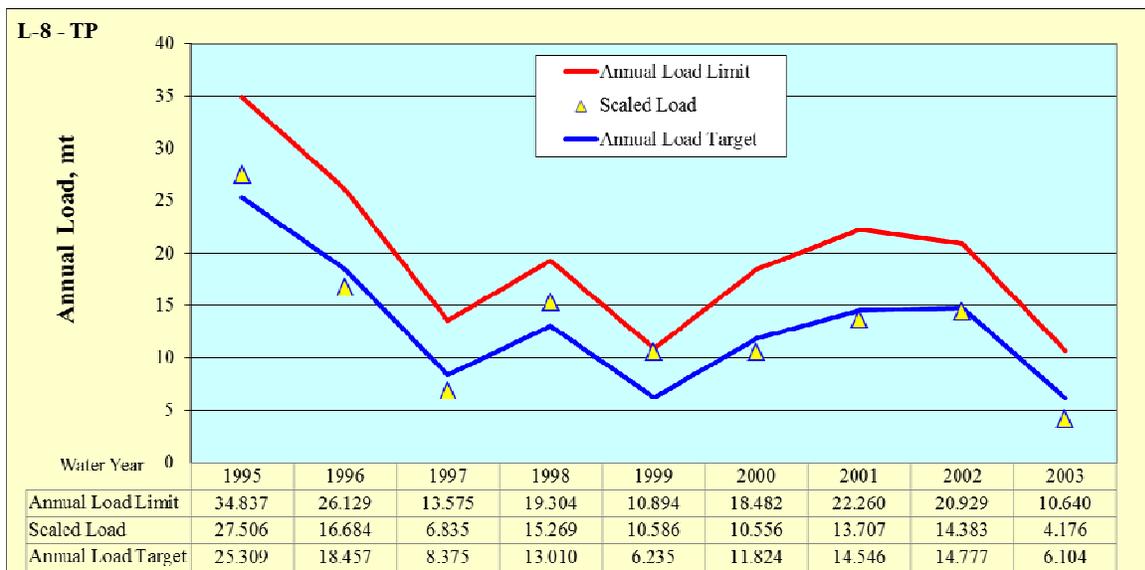
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Table 1-7. L-8 Summary Basin TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R ²)	Recommended Source Control Reduction	Base Period Rainfall ¹	
				Minimum inches	Maximum inches
17.1	13.7	84%	20%	41.28	72.35
Target = (-5.06793 + 0.08241 X -1.54007 S + 6.93876 C) ²					
Limit = [sqrt(Target) + (1.47588 SE)] ²					
SE = 0.46154 [1 + 1/9 + 0.00211 (X-X _m) ² + 0.98133 (S-S _m) ² + 14.63127 (C-C _m) ² - 0.0005 (X-X _m) (S-S _m) + 0.19976 (X-X _m) (C-C _m) - 4.37464 (S-S _m) (C-C _m)] ^{0.5}					

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¹ Based on adjusted rainfall values



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Figure 1-8. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the L-8 Summary Basin based on a 20% load reduction.





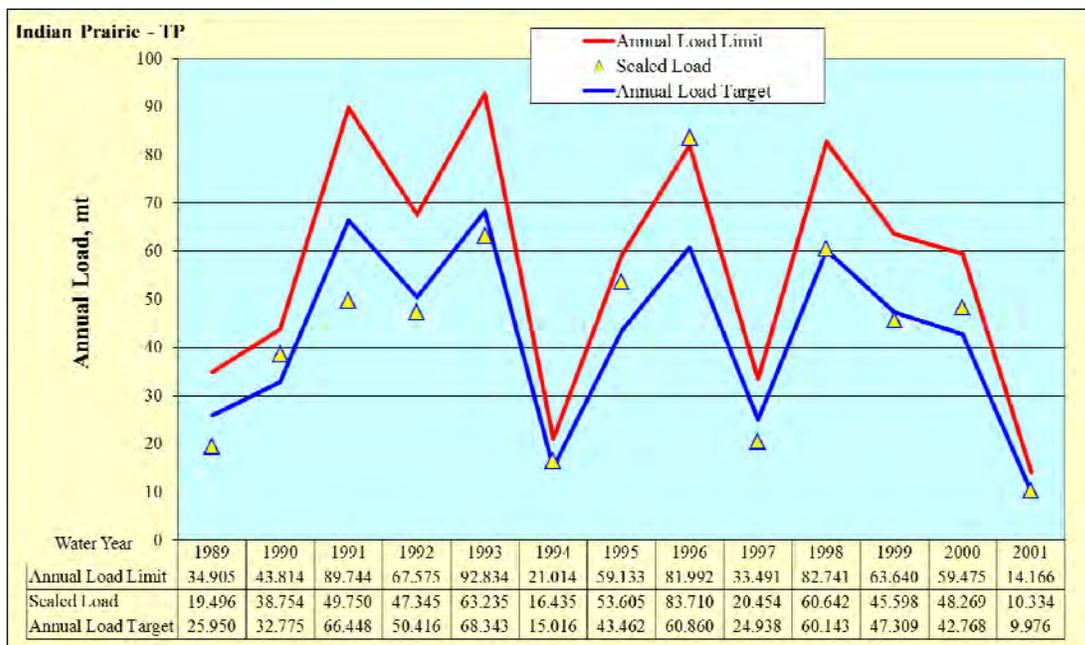
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Table 1-8. Indian Prairie Sub-watershed TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R ²)	Recommended Source Control Reduction	Base Period Rainfall ¹	
				Minimum inches	Maximum inches
67.6	47.3	91%	30%	30.55	49.29
Target = exp (-12.83843 + 4.02124 X + 1.76267 C)					
Limit = Target * exp (1.37218 SE)					
SE = 0.20346 [1 + 1/13 + 3.91995 (X-X _m) ² + 3.19741 (C-C _m) ² + 4.34342 (X-X _m) (C-C _m)] ^{0.5}					

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¹ Based on adjusted rainfall values
X = ln(Rain) and X_m = the mean of the log transformed annual rain totals for the base period



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Figure 1-9. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the Indian Prairie Sub-watershed based on a 30% load reduction.





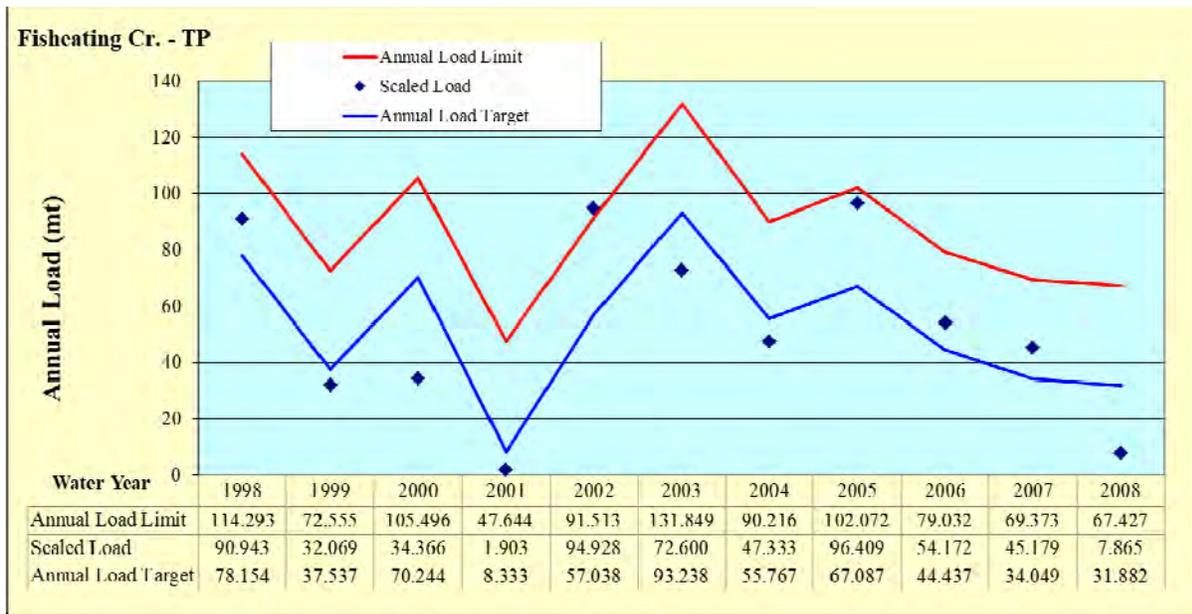
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Table 1-9. Fisheating Creek Summary Basin TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R ²)	Recommended Source Control Reduction	Base Period Rainfall	
				Minimum inches	Maximum inches
67.6	47.3	54%	30%	33.31	78.23
Target = -340.30489 + 99.44445 X					
Limit = Target + 1.38303 SE					
SE = 23.82794 [1 + 1/11 + (X-X _m) ² / 0.59477] ^{0.5}					

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X = ln(Rain) and X_m = the mean of the log transformed annual rain totals for the base period



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Figure 1-10. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the Fisheating Creek Summary Basin based on a 30% load reduction.





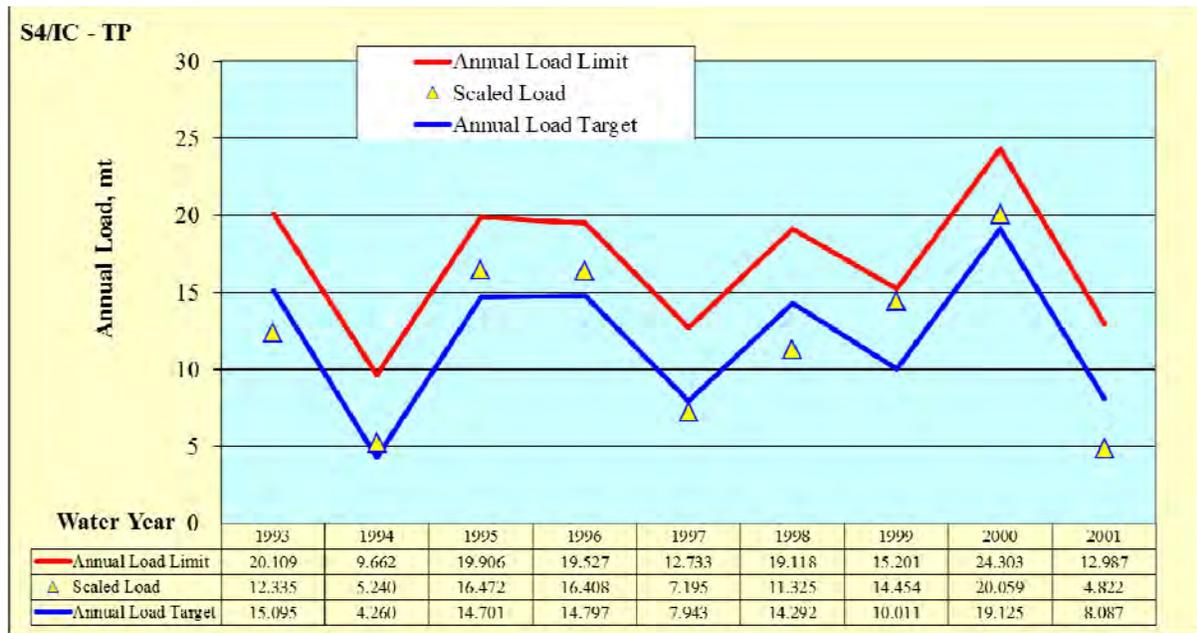
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Table 1-10. S-4/Industrial Canal Hydrologic Unit TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R ²)	Recommended Source Control Reduction	Base Period Rainfall ¹	
				Minimum inches	Maximum inches
17.6	14.3	76%	30%	26.95	62.81
Target = -14.62787 + 0.41452 X + 8.44621 C					
Limit = Target + 1.43976 SE					
SE = 3.02608 [1 + 1/9 + 0.00112 (X-X _m) ² + 2.03794 (C-C _m) ² + 0.00884 (X-X _m) (C-C _m)] ^{0.5}					

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¹ Based on adjusted rainfall values



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Figure 1-11. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the S-4/Industrial Canal Hydrologic Unit based on a 30% load reduction.



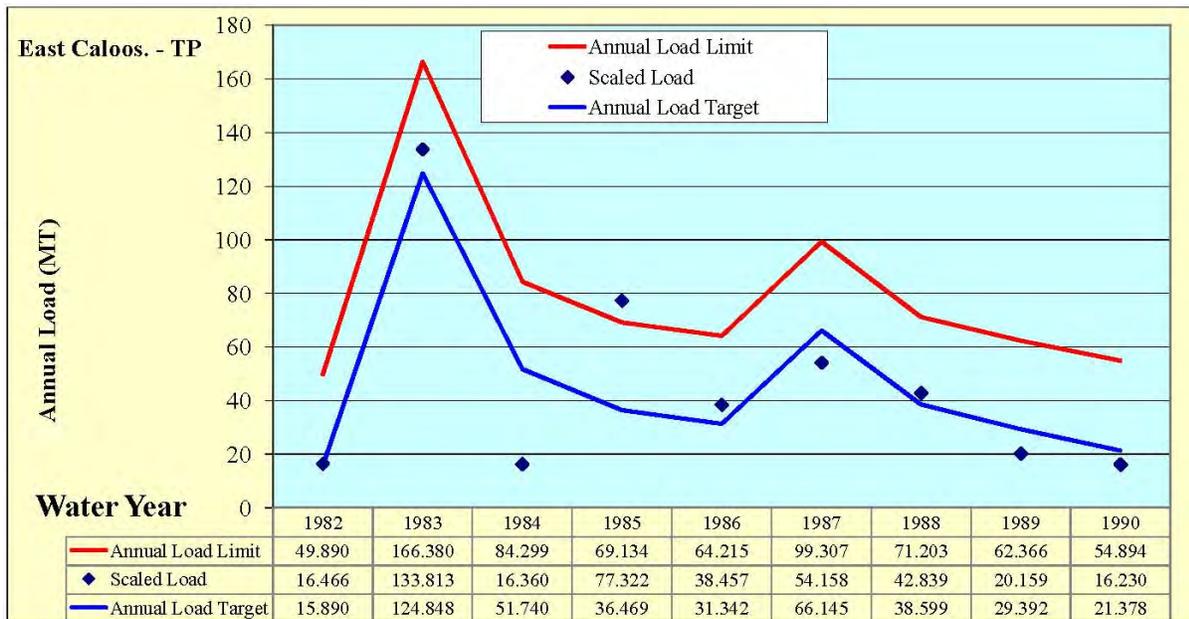


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Table 1-11. East Caloosahatchee Hydrologic Unit TP Load Performance Measure.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R ²)	Recommended Source Control Reduction	Base Period Rainfall	
				Minimum inches	Maximum inches
54.9	38.5	73%	30%	42.29	72.47
Target = -136.788 + 3.61027 X					
Limit = Target + 1.41492 SE					
SE = 21.79613 [1 + 1/9 + (X-X _m) ² / 675.50602] ^{0.5}					

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Figure 1-12. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the East Caloosahatchee Hydrologic Unit based on a 30% load reduction.





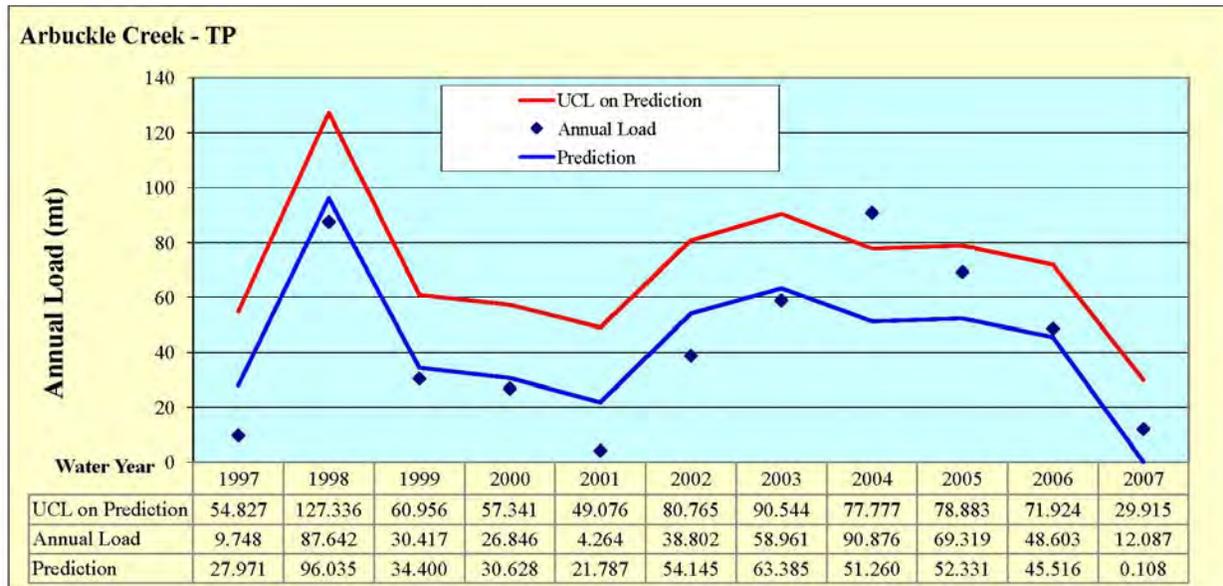
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Table 1-12. Arbuckle Creek Tributary TP Load Performance Indicator.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R ²)	Recommended Source Control Reduction	Base Period Rainfall	
				Minimum inches	Maximum inches
38.8	38.8	68%	0%	33.74	77.45
Target = -406.10066 + 115.44341 X					
Limit = Target + 1.38303 SE					
SE = 18.27506 [1 + 1/11 + (X-X _m) ² / 0.46933] ^{0.5}					

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X = ln(Rain) and X_m = the mean of the log transformed annual rain totals for the base period



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Figure 1-13. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the Arbuckle Creek Tributary based on a 0% load reduction.





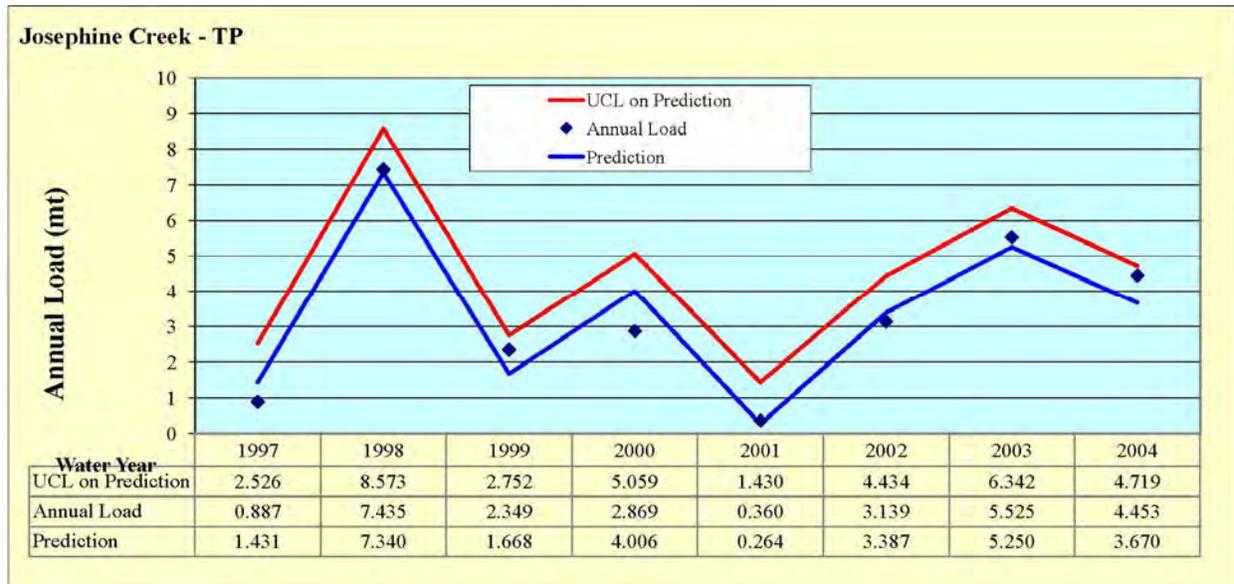
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Table 1-13. Josephine Creek Tributary TP Load Performance Indicator.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R ²)	Recommended Source Control Reduction	Base Period Rainfall	
				Minimum inches	Maximum inches
3.0	3.0	93%	0%	36.85	77.63
Target = -33.98677 + 9.49604 X					
Limit = Target + 1.43976 SE					
SE = 0.68581 [1 + 1/8 + (X-X _m) ² / 0.40023] ^{0.5}					

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X = ln(Rain) and X_m = the mean of the log transformed annual rain totals for the base period



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Figure 1-14. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the Josephine Creek Tributary based on a 0% load reduction.





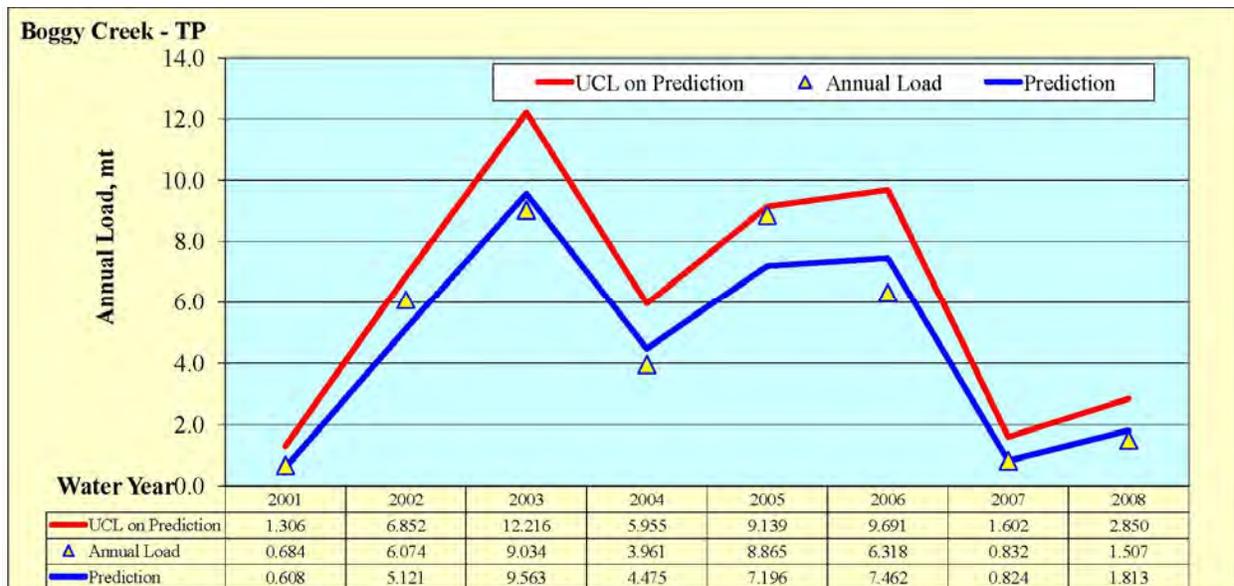
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Table 1-14. Boggy Creek Tributary TP Load Performance Indicator.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R ²)	Recommended Source Control Reduction	Base Period Rainfall ¹	
				Minimum inches	Maximum inches
5.0	5.0	98%	0%	32.89	71.83
$Target = (-2.39491 + 0.05939 X + 1.35719 C)^2$					
$Limit = [\text{sqrt} (Target) + (1.47588 SE)]^2$					
$SE = 0.20722 [1 + 1/8 + 0.0007 (X-X_m)^2 + 3.58103 (C-C_m)^2 + 0.0135 (X-X_m) (C-C_m)]^{0.5}$					

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¹ Based on adjusted rainfall values



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Figure 1-15. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the Boggy Creek Tributary based on a 0% load reduction.





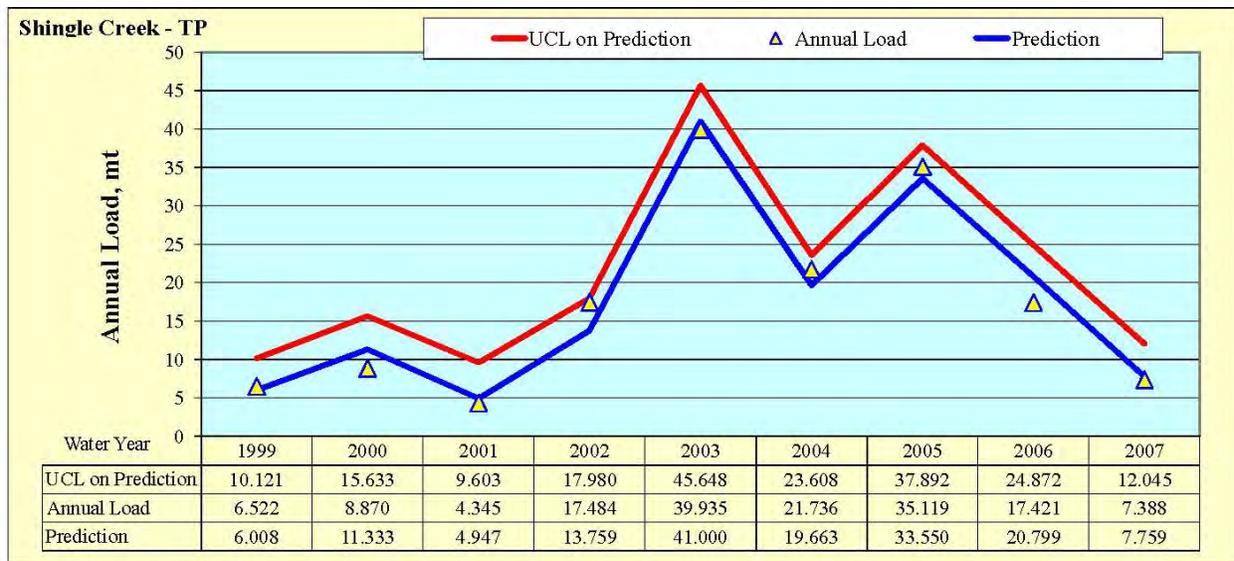
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Table 1-15. Shingle Creek Tributary TP Load Performance Indicator.

Base Period Median Annual Load mt	Median Annual Load with Source Controls mt	Explained Variance (R ²)	Recommended Source Control Reduction	Base Period Rainfall ¹	
				Minimum inches	Maximum inches
17.4	17.4	97%	0%	37.53	86.31
Target = -140.82331 + 43.29617 X + 9.1697 S					
Limit = Target + 1.440 SE					
SE = 2.58225 [1 + 1/9 + 1.7741 (X-X _m) ² + 0.52978 (S-S _m) ² + 0.10178 (X-X _m) (S-S _m)] ^{0.5}					

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¹ Based on adjusted rainfall values



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Figure 1-16. Comparison of the scaled observed Base Period annual TP loads with the annual targets and limits for the Shingle Creek Tributary based on a 0% load reduction.





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351 **2. INTRODUCTION AND OBJECTIVES**

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353 This *Draft Technical Support Document* was developed in support of the District’s
354 Regulatory Source Control Program (Chapter 40E-61, F.A.C, also known as “Works of the
355 District”). The program was established in 1989 in the Lake Okeechobee Watershed under
356 the authority of the SWIM Act. Recent legislative changes have, among other things,
357 directed complementary source control programs by the three coordinating agencies (the
358 FDEP, the District and the FDACS), expanded the Lake Okeechobee Watershed, and
359 expanded source control activities to include the St. Lucie River Watershed and the
360 Caloosahatchee River Watershed.

361

362 In response to these legislative changes, the District must update the 1989 source control rule
363 to effectuate the NEEPP requirements, including developing updated performance metrics.
364 The statute directs that where water quality problems are detected despite the appropriate
365 implementation of the BMPs a reevaluation of the BMPs shall be initiated. The performance
366 metrics will ultimately be incorporated into Chapter 40-61, F.A.C., and will serve to meet the
367 statutory requirement.

368

369 This *Draft Technical Support Document* presents quantitative methods for assessing the TP
370 reductions in runoff resulting from the collective source control programs in the sub-
371 watersheds, summary basins and hydrologic units within the Lake Okeechobee Watershed
372 and portions of the Caloosahatchee River Watershed and St. Lucie River Watershed that
373 overlap with the Lake Okeechobee Watershed boundary¹ (**Figure 2-1** and **Table 2-1**). The
374 quantitative methods are referred to as “performance measure methodologies”.

¹ The performance measure methodologies for the Caloosahatchee River Watershed and St. Lucie River Watershed will be detailed in *Technical Support Documents* for those respective sub-watersheds, including the NEEPP required nitrogen component.





375 **2.1 Organization of the Draft Technical Support Document**

376 **Section 1** of this *Draft Technical Support Document* provided an Executive Summary of the
377 performance measure methodologies for the respective sub-watersheds, summary basins and
378 hydrologic units within the Lake Okeechobee Watershed. Where possible, consistency was
379 maintained with previously documented naming and delineations of these basins. However,
380 this was not always possible as this expansive area has been referenced in a variety of prior
381 documents using different terms, e.g., some summary basins in Lake Okeechobee documents
382 are referred to as sub-watersheds in river watershed documents. Since some of the basins
383 discussed in this document discharge to more than one watershed (i.e., to Lake Okeechobee
384 and to a river watershed), a common terminology was used for those specific basins:
385 “hydrologic units”, for example, “C-44 Hydrologic Unit”. However, when the methodology
386 is discussed as a whole, the term “basin” will be used to describe sub-watersheds, summary
387 basins and hydrologic units.

388
389 **Section 2** provides general background information for the Project. **Section 3** summarizes
390 the performance measure methodologies for basins of the Lake Okeechobee Watershed.
391 **Appendix A** presents supplemental technical details of the individual basins. **Appendix B**
392 presents the regression equations that serve as the foundation for the performance measures
393 and performance indicators. **Appendix C** provides a summary of the flow and water quality
394 stations used in developing the performance measure methodologies.

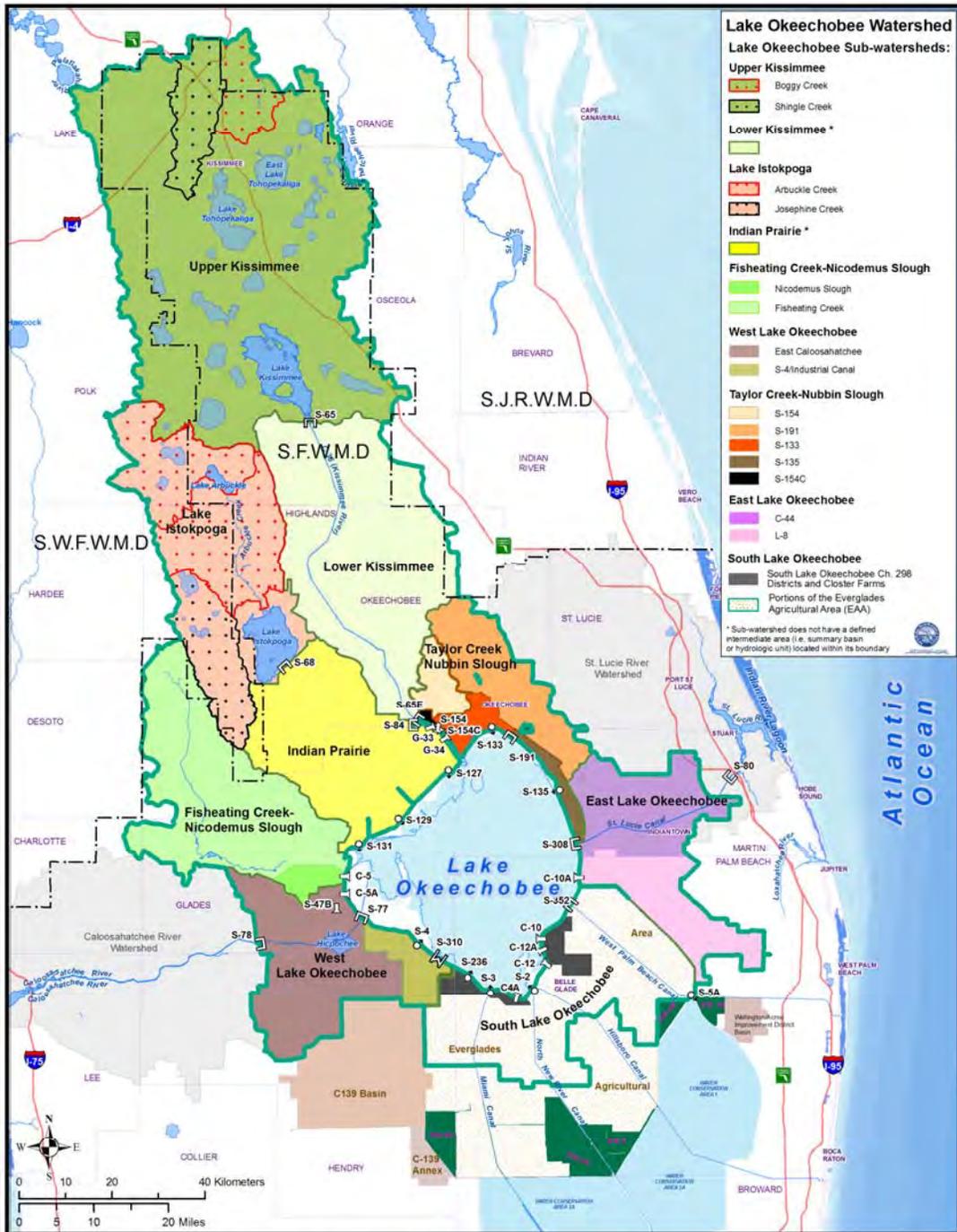
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Figure 2-1. Sub-watershed level map of the Lake Okeechobee Watershed.



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Technical Support Document
Lake Okeechobee Watershed Performance Measures

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Table 2-1. Summary table of basins within the Lake Okeechobee Watershed.

Summary Basin or Hydrologic Unit	Area (acres)	Lake Okeechobee Watershed	St. Lucie River Watershed	Caloosahatchee River Watershed	Everglades Agricultural Area
Upper Kissimmee Sub-watershed					
No Summary Basins	N/A				
Sub-watershed Total	1,028,421	√			
Lower Kissimmee Sub-watershed					
No Summary Basins	N/A				
Sub-watershed Total	429,188	√			
Taylor Creek-Nubbin Slough Sub-watershed					
S-191	119,402	√			
S-133	25,626	√			
S-135	17,756	√			
S-154	31,815	√			
S-154C	2,134	√			
Sub-watershed Total	196,733	√			
Lake Istokpoga Sub-watershed					
No Summary Basins	N/A				
Sub-watershed Total	394,203	√			
Indian Prairie Sub-watershed					
No Summary Basins	N/A				
Sub-watershed Total	276,577	√			
Fisheating Creek-Nicodemus Slough Sub-watershed					
Fisheating Creek	298,713	√			
Nicodemus Slough	19,329	√			
Sub-watershed Total	318,042	√			
West Lake Okeechobee Sub-watershed					
East Caloosahatchee	204,094	√		√	
S-4/Industrial Canal	42,145	√		√	
Sub-watershed Total	246,240	√		√	
South Lake Okeechobee Sub-watershed¹					
715 Farms (Culv 12A)	3,302	√			√
East Beach WCD (Culv 10)	6,624	√			√
East Shore WCD (Culv 12)	8,416	√			√
S-2	106,371	√			√
S-3	62,946	√			√
South FL Conservancy D (S-236)	11,028	√			√
South Shore/So. Bay DD (Culv 4A)	4,134	√			√
S-5A Basin (S-352-WPB Canal)	119,443	√			√
Sub-watershed Total	322,262	√			√
East Lake Okeechobee Sub-watershed					
C-44 ²	132,572	√	√		
L-8 Basin (Culv 10A)	106,440	√			
Sub-watershed Total	239,013	√	√		

¹Note: South Lake Okeechobee Areas is based on LOPP boundaries, all other boundaries are based on ArcHydro.
²Note: The area provided in this table for C-44 was obtained from Deliverable 6.1 Collective Source Control Performance Measures for C-23, C-24, C-25/25E, and C-44 Technical Report (dated September 2011; HDR 2011)
³Note: There are some minor differences between the acreages shown in Table 2-1 and the 2011 LOPP. L-61W was removed from the Indian Prairie Sub-watershed and is now included in the Fisheating Creek Summary Basin. Culvert 5A was moved from the Nicodemus Slough Summary Basin to the East Caloosahatchee Hydrologic Unit. These changes were a result of a review of flow patterns in these areas.

407





408 **Appendix D** presents the methods used to establish recommended nutrient load reductions
409 that could be reasonably expected to result from implementation of collective source control
410 programs. **Appendix E** provides the details of the algorithm to be used to adjust the
411 performance measures to account for regional projects. The Excel spreadsheets containing
412 the specific analyses for the performance measures are included as **Attachment 1** to this
413 *Draft Technical Support Document*.

414

415 **2.2 Authorization and Scope**

416 This *Draft Technical Support Document: Lake Okeechobee Watershed Performance*
417 *Measure Methodologies* constitutes Deliverable 3.5 of Contract 4600002337 - Performance
418 Measure Methodologies for Collective Source Controls in the Lake Okeechobee and
419 Caloosahatchee River Watersheds - between the District and Gary Goforth, Inc. dated
420 January 31, 2011. The objective of this deliverable is to summarize the technical methods
421 utilized for development of performance measures or performance indicators for the
422 individual basins of the Lake Okeechobee Watershed. The *Draft Technical Support*
423 *Document* contains a narrative step-by-step description of the performance measure
424 methodologies, including:

- 425 • An explanation of how monitoring results will be evaluated against each basin's
426 performance measures;
- 427 • A description of how the performance of the collective source control program
428 within each basin will be assessed, consisting of the steps that will be taken at the
429 completion of each water year to determine if a basin has achieved its
430 performance measure.

431

432 This document was prepared by Gary Goforth, Inc., in association with L. Hornung
433 Consulting, Inc., Soil & Water Engineering Technology, Inc. and staff of the South Florida





434 Water Management District, and complements work completed by others, including the
435 following.

- 436 1. The performance measure for the East Caloosahatchee Hydrologic Unit, also referred
437 to as the East Caloosahatchee Sub-watershed within the Caloosahatchee River
438 Watershed, was based in part on historical data analyses conducted by HDR
439 Engineering, Inc. as part of Contract No. ST061298 – WO08 (Data Analysis and
440 Performance Measure Development for the St Lucie and the Caloosahatchee River
441 Source Control Programs) with the South Florida Water Management District (HDR
442 2011b). Additional historical data analyses were conducted as part of this work effort
443 to incorporate revised data.
- 444 2. The historical data analyses and performance measure methodology for the C-44
445 Hydrologic Unit, also referred to as the C-44 Sub-watershed of the St. Lucie River
446 Watershed, were performed by HDR Engineering, Inc. as part of Contract No.
447 ST061298 – WO08 (Data Analysis and Performance Measure Development for the St
448 Lucie and the Caloosahatchee River Source Control Programs) with the South Florida
449 Water Management District (HDR 2011a, HDR 2011c). Additional data analyses
450 were conducted as part of this work effort to incorporate revised information.
- 451 3. The performance measure methodology for the Everglades Agricultural Area (EAA)
452 Basin, which has overlapping boundaries with the South Lake Okeechobee Sub-
453 watershed, was developed as part of Ch. 40E-63, F.A.C.
- 454 4. The proposed performance measure methodology for the Ch. 298 Districts and
455 Closter Farms was developed by District staff with assistance from Gary Goforth, Inc.
456 (Goforth et al. 2011).

457





458 **2.3 Background**

459 This *Draft Technical Support Document* summarizes the quantitative methods for assessing
460 the collective performance of the source control programs for the basins within the Lake
461 Okeechobee Watershed (**Figure 1-1**). The collective source control programs in place or
462 being developed include the source control programs identified in **Table 2-2**.

463

464 **2.3.1 History of Source Controls in the Lake Okeechobee**
465 **Watershed**

466

467 The following section describes over thirty years of federal, state and regional efforts leading
468 up to the current source control programs in the Lake Okeechobee Watershed. A summary
469 of the source control implementation time frame for the Lake Okeechobee Watershed is
470 presented in **Table 2-3**.

471

472 **PROGRAMS THAT BEGAN IN THE 1970s**

473

474 **Federal Clean Water Act**

475 The Federal Clean Water Act was enacted in 1972 and included the National Pollution
476 Discharge Elimination System (NPDES) and Total Maximum Daily Load (TMDL)
477 Programs. The U.S. Environmental Protection Agency (USEPA) delegated responsibility for
478 administration of these programs to the FDEP which until the mid-1990s was known as the
479 Florida Department of Environmental Regulation (FDER). In October 2000, the USEPA
480 authorized the FDEP to implement the NPDES stormwater permitting program in the State of
481 Florida (in all areas except Indian Country lands). The NPDES stormwater program regulates
482 point source discharges of stormwater into surface waters of the State of Florida from certain
483 municipal, industrial and construction activities.





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Table 2-2. Nutrient control programs within the Northern Everglades.

Lead Agency	Program ¹	Non-Point Source	Point Source
South Florida Water Management District (SFWMD)	Works of the District BMP Program ² - Chapter 40E-61, F.A.C.	√	
	Environmental Resource Permitting Program - Chapter 373, F.S. Part IV	√	
	Dairy remediation projects ^{3,5}		√
	Dairy Best Available Technologies Project ^{3,5}		√
Florida Department of Agriculture and Consumer Services (FDACS)	Agricultural BMP Program - Chapter 5M-3, F.A.C.	√	
	Animal Manure Application - Chapter 5M-3, F.A.C.	√	
	Urban Turf Fertilizer Rule - Chapter 5E-1, F.A.C.	√	
Florida Department of Environmental Protection (FDEP)	Dairy Rule/Confined Animal Feeding Operation (CAFO) - Chapter 62-670, F.A.C.		√
	Environmental Resource Permitting Program - Chapter 373, F.S. Part IV ⁵	√	
	Stormwater Infrastructure Updates and Master Planning - Chapter 187, F.S. ⁵	√	
	Municipal Separate Storm Sewer System Permit Program - Chapter 62-624, F.A.C.		√
	Comprehensive Planning – Land Development Regulations - Chapter 163, F.S. Part II ⁵	√	
Florida Department of Health (FDOH)	Biosolids Rule - Chapter 62-640, F.A.C.	√	
	Application of Septage - Section 373.4595, F.S.	√	
University of Florida Institute of Food and Agricultural Sciences ⁴ (UF/IFAS)	Florida-Friendly Landscaping Program - Section 373.185, F.S.	√	

¹Applicable to all three watersheds except where noted in the other footnotes below.

²The rule currently applies to the Lake Okeechobee Watershed. However, as directed by the NEEPP, the rule will be amended to include the adjacent river watersheds.

³Applicable to only the Lake Okeechobee Watershed.

⁴Partially funded by FDEP.

⁵No reductions considered.

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Table 2-3. Summary of the source control implementation time frame for the Lake Okeechobee Watershed.

Timeframe	Event
1970s	FDER Dairy regulatory programs begin
1972	Clean Water Act and Florida Water Resources Act
	South Florida Water Management District Stormwater Permitting Begins
1978	Florida Established Non-Point Source Management Programs
1981	Rural Clean Water Program Taylor Creek Headwaters
1984	FDER Biosolids/Domestic Wastewater Residuals Regulations
1985	Florida State stormwater rule adopted, retention ponds became required for new development
1986	New citrus groves were required to include onsite reservoirs for stormwater runoff.
1987	Surface Water Improvement and Management Act for Lake Okeechobee enacted
1987	FDER Dairy Rule for Lake Okeechobee Basin
1989	Chapter 40E-61, the Lake Okeechobee Works of the District Rule adopted by SFWMD
1990	National Pollutant Discharge Elimination System Programs
1992	Chapter 40E-63, the Everglades Agricultural Area Works of the District Rule adopted by SFWMD
1995	SFWMD Environmental Resource Permitting Regulatory Program adopted
1995	Kissimmee River Restoration Project
1999	Florida Watershed Restoration Act
2000	The Lake Okeechobee SWIM Act is revised to become the Lake Okeechobee Protection Act
2003	FDOH Septage Application requires Agricultural Use Plan
2003	FDACS adopts Rule 5M-3, the BMP rule for the priority basins S-191, S-154, S-65 D and S-65E.
2003	FDACS Land Application of Animal Wastes (Rule 5M-3)
2004	FDOH Wastewater Master Plans
2005	The geographic area of the Lake Okeechobee Protection Act is expanded to include the Upper Kissimmee and the Lake Istokpoga Sub-watersheds.
2006	FDACS expands BMP rule 5M-3 to the entire Lake Okeechobee Watershed
2007	The LOPA is revised to become the Northern Everglades and Estuaries Protection Program
2007	FDACS Urban Turf Fertilization Rule (Rule 5E-1.003)
2011	FDACS amends BMP Rule 5M-3 to the entire Northern Everglades
Beyond 2012	Elimination of land application of biosolids
	Proposed FDEP Numeric Nutrient Criteria

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Lake Okeechobee Watershed Performance Measures*

498 In response to assessments and research from the Area-wide Water Quality Planning
499 Program performed under Section 208 of the Clean Water Act, Florida began implementing
500 programs to minimize nonpoint sources of pollution in the late 1970s. In 1987, the Clean
501 Water Act was amended to add Section 319 which required states to develop nonpoint source
502 management programs. Florida began full implementation of its revised nonpoint source
503 management program in 1989 following submission, review, and approval by USEPA
504 (FDEP 1999).

505

506 **Florida Dairy Programs**

507 In the Lake Okeechobee Watershed, the dairy lagoon regulatory program was implemented
508 by the Federal Soil and Water Conservation Service (which is now the Natural Resource
509 Conservation Service) in the 1970s and required wastewater retention onsite. In 1987, this
510 program was followed by the FDEP dairy rule (Rule 17-6.330) which required specific
511 BMPs for dairies in the Lake Okeechobee Drainage Basin, which at the time consisted of the
512 Lower Kissimmee, Taylor Creek-Nubbin Slough, Fisheating Creek-Nicodemus Slough,
513 Indian Prairie and South Lake Okeechobee Sub-watersheds. During this time there was also
514 a dairy buyout program which was a voluntary program where the state purchased a deed
515 restriction on dairy properties which decided to close instead of implementing the BMPs
516 required under Rule 17-6.330. The deed restriction prevents these properties from being
517 used as a dairy operation.

518

519 In 1996, Rule 17-6.330 was superseded by Rule 62-670, the Feedlot and Dairy Wastewater
520 Treatment and Management program, which required dairies with over 700 cows to apply for
521 an Industrial Waste permit and a concentrated animal feeding operation (CAFO) permit by
522 1989 for discharge of pollutants. Rule 62-670 had additional requirements for dairies
523 operating in the Lake Okeechobee Drainage Basin which was defined as it had been under
524 Rule 17-6.330.

525





526 USEPA finalized the CAFO Rule in 2003 under the Clean Water Act which required all large
527 animal feed operations to obtain permits. In Florida, FDEP administers the permitting
528 program. Large CAFOs (dairies with more than 700 cows) are required to develop and
529 implement nutrient management plans that ensure manure is properly managed in ways that
530 assure utilization by crops and reduce pollution. Dairies were required to convert from their
531 prior Industrial Waste permits to NPDES permits.

532

533 **PROGRAMS THAT BEGAN IN THE 1980s**

534

535 **Florida Stormwater Rule**

536 In 1981, the statewide Florida stormwater rule was adopted by the Environmental Regulation
537 Commission with an effective date of February 1982. This rule required a permit for new
538 stormwater discharges for the purpose of protecting the designated use of the receiving water.
539 Any new stormwater management system that discharged to waters of the state was required
540 to obtain a permit under this rule. FDEP immediately delegated the authority for
541 administering this rule to the water management districts (except the Northwest Florida
542 Water Management District). Permits required that post development flow rates, flow
543 volumes, and nutrient loads be equal to, or less than pre-development levels.

544

545 The Lake Okeechobee Operating Permit (LOOP) was issued to SFWMD by FDEP in 1983.
546 The LOOP required the management of water in the Everglades Agricultural Area (EAA) in
547 the South Lake Okeechobee Sub-watershed for nutrient reduction and flood protection
548 purposes.

549

550 **Federal Rural Clean Water Program**

551 In the 1980s the Rural Clean Water Program provided financial and technical assistance to
552 private landowners and operators having control of rural land. The assistance was provided
553 through long-term contracts to install best management practices in project areas which had





554 critical water quality problems resulting from agricultural activities. In 1981, there were
555 63,109 acres included in the Rural Clean Water Program within fourteen projects in the
556 Taylor Creek-Nubbin Slough Sub-watershed, including dairy farms, beef cattle pastures that
557 were extensively ditched for improved surface drainage, and areas within one-quarter of a
558 mile from a waterway. BMPs which excluded dairy cows and beef cattle from waterways
559 and to control wastewater runoff from dairy barns were installed. In 1988 the program was
560 expanded to include dairies in the Lower Kissimmee Sub-watershed.

561

562 **Florida Biosolids/Domestic Wastewater Residuals Regulations**

563 The regulation of domestic wastewater residuals (now referred to as biosolids) began in 1984
564 and was originally adopted under solid waste regulations (Chapter 17-7). Regulations were
565 adopted under Chapter 62-640, F.A.C. (water regulations) in 1991 and revised in 1998. The
566 latest rule revision, adopted on August 28, 2010, intends to: improve land application site
567 management and accountability, address critical nutrient issues in Florida, address continuing
568 and heightened public concerns and county interest, and support public confidence in the
569 beneficial use of biosolids.

570

571 The revised rule prohibits the application of Class B biosolids in the Lake Okeechobee
572 Watershed after December 31, 2012, unless the applicant completes a nutrient balance
573 demonstration which is FDEP approved. This prohibition does not apply to Class AA
574 biosolids that are marketed and distributed as fertilizer products in accordance with Rule 62-
575 640.850, F.A.C. This could impact the extent of land application of residuals in the
576 watershed and the nutrient loading to Lake Okeechobee. Biosolids provide a low cost
577 agricultural fertilizer. If land application is prohibited, fertilization may be reduced due to
578 economic factors.

579

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581





582 **SFWMD Management and Storage of Surface Waters Program**

583 In 1986, SFWMD amended Rule 40E-4 requiring new applicants to meet specific detention
584 and retention criteria. As a result, new citrus groves were required to include detention
585 reservoirs in their surface water management plans.

586

587 In 1995, the management and storage of surface waters permitting program merged with the
588 wetland resource permitting program from Chapter 403, F.S. to form the Environmental
589 Resource Permit Program. The ERP program requires that new activities or modification of
590 existing activities provide reasonable assurances that they will not cause adverse water
591 quality such that state water quality standards will not be violated, cause adverse flooding or
592 water quantity impacts, or harm wetland of other surface water systems.

593

594 **Florida Surface Water Improvement and Management Program (Section 373.451, F.S.)**

595 In 1987, the State of Florida enacted the Surface Water Improvement and Management
596 (SWIM) Act. This Act required the water management districts to develop and implement
597 plans for restoring and protecting degraded water bodies in the state. The Lake Okeechobee
598 SWIM Plan was prepared by the SFWMD in 1989 and the TP load target for Lake
599 Okeechobee at that time was 360 metric tons. The SWIM Plan was subsequently updated in
600 1993, 1997, and 2002. The SWIM Plan has led to implementation of many initiatives that
601 have been directed at improving the quality of water discharged to Lake Okeechobee.
602 Information about projects initiated as a part of the SWIM program can be found in the 1989,
603 1993, 1997 and 2002 SWIM Plan Reports (SFWMD 1989, SFWMD 1993, SFWMD 1997,
604 SFWMD 2002).

605

606 **SFWMD Works of the District Rule 40E-61, F.A.C.**

607 In 1989, the District adopted Rule 40E-61 regulating phosphorus surface water discharges
608 from certain land uses in the Lake Okeechobee Watershed. At that time, the program
609 included the Lower Kissimmee, Indian Prairie, Fisheating Creek-Nicodemus Slough, South





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Lake Okeechobee Watershed Performance Measures*

610 Lake Okeechobee, East Lake Okeechobee, West Lake Okeechobee, and Taylor
611 Creek/Nubbin Slough Sub-watersheds (see **Figure 2-2**). Approximately 800 permits were
612 issued on parcels of land five (5) acres and greater for the following land uses: improved
613 pasture, heifer farms, vegetable farms, hog farms, poultry farms, goat farms, urban
614 stormwater, golf courses, sugar cane, horse farms, nurseries, land spreading of sludge
615 (biosolids), and sod farms. At the time the rule became effective, the assumption was that
616 landowners were in compliance until their monitoring data indicated otherwise. The permits
617 set a concentration based discharge limit based on the load reductions set forth under the
618 SWIM plan. The Lake Okeechobee Works of the District (LOWOD) permits required a
619 simple statement from permit holders on how they planned to control phosphorus. The
620 majority of the permits included statements such as "I will use low phosphorus fertilizer".
621 Farm-level grab sample monitoring was required and was funded by the SFWMD.
622 Monitoring funds were limited and the number of landowners required to implement
623 additional BMPs for not meeting the TP concentration limit was relatively few. Performance
624 was measured at the parcel level and it has been difficult to determine the overall program
625 performance in reducing phosphorus loading.

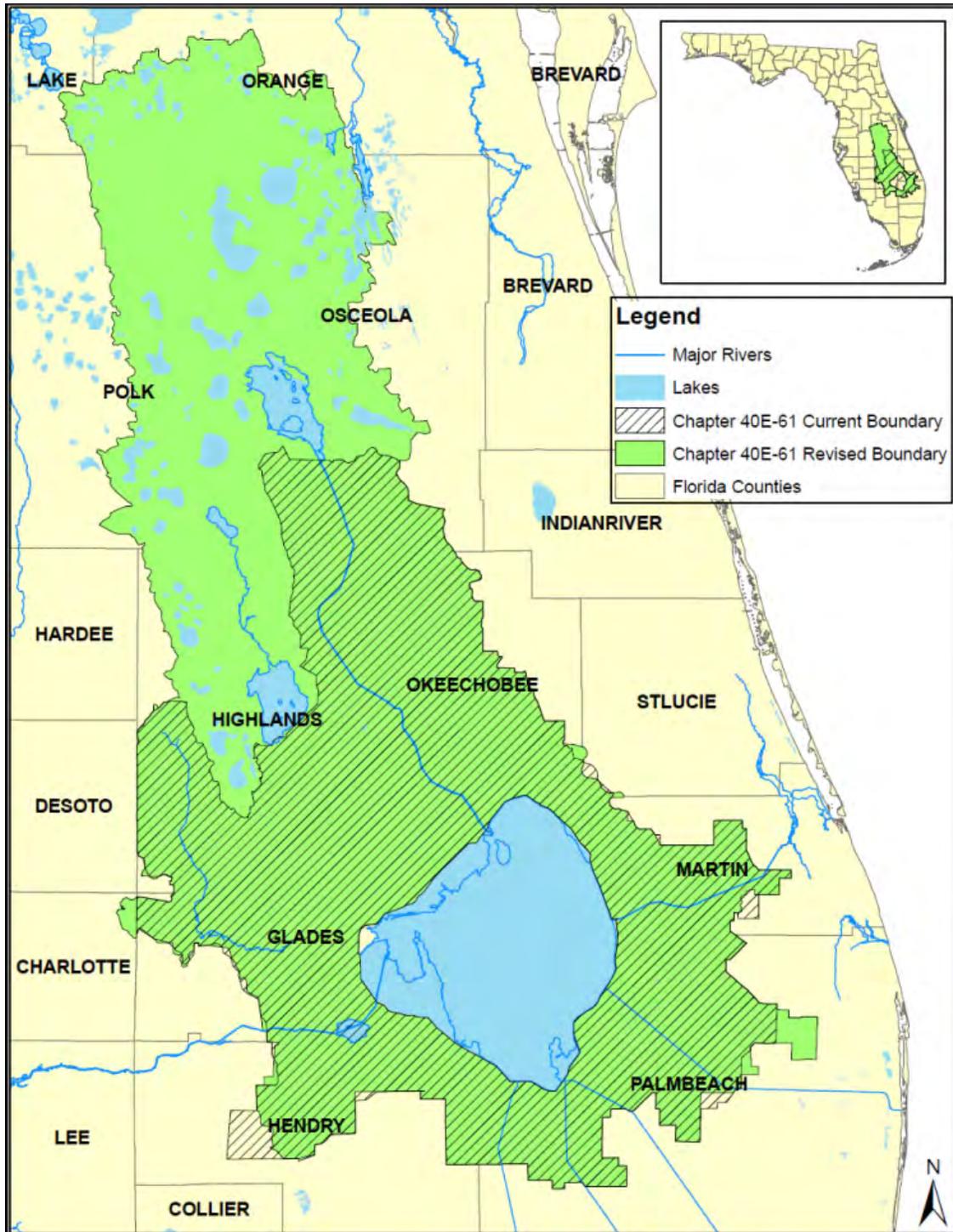
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Figure 2-2. Chapter 40E-61, F.A.C. proposed boundary changes.



631





632 **PROGRAMS THAT BEGAN IN THE 1990s**

633

634 **Federal National Pollutant Discharge Elimination System Programs**

635 The USEPA developed the NPDES stormwater permitting program in two phases. Phase I,
636 promulgated in 1990, addresses "large" and "medium" municipal separate storm sewer
637 systems (MS4s) located in incorporated places and counties with populations of 100,000 or
638 more, and eleven categories of industrial activity, one of which is large construction activity
639 that disturbs five or more acres of land. Phase II, promulgated in 1999, addresses additional
640 sources, including MS4s not regulated under Phase I, and small construction activity
641 disturbing between one and five acres. FDEP's authority to administer the NPDES program is
642 set forth in Section 403.0885, Florida Statutes (F.S.). As the NPDES stormwater permitting
643 authority, FDEP is responsible for promulgating rules and issuing permits, managing and
644 reviewing permit applications, and performing compliance and enforcement activities.

645

646 **Federal Kissimmee River Restoration Project**

647 The Kissimmee River Restoration and the Kissimmee River Headwaters Revitalization
648 Projects were jointly authorized in the 1992 Water Resources Development Act. The
649 primary goal of the Kissimmee River Restoration Project is to reestablish the ecological
650 integrity of the river-floodplain system, which is defined as, "the capability of supporting and
651 maintaining a balanced, integrated, adaptive community having species composition,
652 diversity, and functional organization comparable to that of natural habitat of the region"
653 (Karr and Dudley, 1981). Restoration of ecological integrity requires reconstruction of the
654 physical form of the river (i.e., canal backfilling, removal of water control structures, and
655 elimination of secondary drainage ditches, levees, and roads) and reestablishment of
656 historical (pre-channelization) hydrologic (i.e., discharge and stage) characteristics.

657

658 Successful completion of the Kissimmee River Restoration Project and associated projects
659 has critical implications for other ecosystem restoration projects in South Florida. For





660 example, the restoration project should increase phosphorus retention within the Kissimmee
661 River system through restoration of floodplain wetlands, thus removing a portion of
662 phosphorus loads that would otherwise reach Lake Okeechobee.

663

664 **SFWMD Everglades Works of the District Rule 40E-63, F.A.C.**

665 The 1994 Everglades Forever Act defined that Stormwater Treatment Areas and BMP
666 implementation for the Everglades Construction Project basins are the best available
667 technology for achieving interim phosphorus water quality goals for the Everglades
668 Protection Area. In order to carry out these activities, the Everglades Forever Act mandated
669 the creation of an Everglades Program, including a regulatory component to oversee
670 implementation of BMPs. The District promulgated Chapter 40E-63, F.A.C., which details
671 the scope of the Everglades Regulatory Program for the Everglades Agricultural Area (a
672 portion of which is located in the South Lake Okeechobee Sub-watershed) and the C-139
673 basins. In this rule, the District describes the implementation procedures and compliance
674 measures for the BMP program mandated in the Everglades Forever Act including (1)
675 enforcing implementation of BMPs, (2) conducting a water quality monitoring program to
676 evaluate the effectiveness of BMPs, (3) tracking area-wide phosphorus loads, and (4)
677 developing a mandatory BMP research program for phosphorus and other water quality
678 parameters of concern.

679

680 **SFWMD Environmental Resource Permit program**

681 In the mid-1990s, the State of Florida's Environmental Reorganization Act provided the
682 water management districts independent authority under Chapter 373, F.S., to regulate
683 stormwater quality under the Environmental Resource Permit program.

684

685 **Florida Watershed Restoration Act**

686 The Florida Watershed Restoration Act of 1999 established and implemented TMDLs and
687 encouraged the implementation of agricultural BMPs. In response to the Act, the Cow/Calf





688 BMP Manual was developed and adopted in 1999, updated in 2007, and followed by
689 development of BMP manuals for other land uses. The BMP manuals were developed by a
690 collaboration of multiple organizations and representatives of Federal, State, and local
691 governments.

692

693 **PROGRAMS THAT BEGAN IN THE 2000s**

694

695 **Florida Lake Okeechobee Protection Act/Northern Everglades and Estuaries Protection**
696 **Program**

697 In 2000, the Florida legislature revised the Lake Okeechobee SWIM statute and it became
698 the Lake Okeechobee Protection Act (LOPA) (Section 373.4595, F.S.) The LOPA required
699 the Coordinating Agencies (SFWMD, FDEP, and FDACS) to collaborate in the preparation
700 and implementation of a Lake Okeechobee Protection Plan (LOPP). The LOPP provided a
701 road-map for a comprehensive program that was directed at meeting the Lake Okeechobee
702 TP TMDL. The TMDL was under development at the time the Act was passed, but was
703 finalized in 2000 prior to completion of the LOPP which was developed in 2004 and updated
704 in 2007 and 2011. The LOPP required implementation of a two-phase Lake Okeechobee
705 Construction Project, implementation of urban and agricultural source control measures, and
706 a research and monitoring program. Subsequent renewals of the Lake Okeechobee Operating
707 Permit incorporated specific conditions to assess the achievement with the lake TMDL.

708

709 In 2005, LOPA was revised further and the Upper Kissimmee and Lake Istokpoga Sub-
710 watersheds were included in the Lake Okeechobee Watershed boundary. The 2005 revisions
711 to LOPA directed that phosphorus load reductions be achieved through a phased program of
712 implementing long-term solutions based on the Lake Okeechobee TMDL of 140 metric tons
713 for TP (105 metric tons from contributing sub-watersheds and 35 from atmospheric
714 deposition).

715





716 In 2007, LOPA was subsumed by Northern Everglades and Estuaries Protection Program
717 (NEEPP), which further refined the responsibilities of the coordinating agencies to achieve
718 TP reduction objectives faster. The objectives included (1) continued implementation of
719 existing regulations and incentive-based BMPs, (2) development and implementation of
720 improved BMPs, (3) improvement and restoration of hydrologic function of natural and
721 managed systems, and (4) use of alternative technologies for nutrient reduction. In addition,
722 changes were identified for Chapter 40E-61, F.A.C. to incorporate NEEPP mandates that
723 modify the boundary of the program through the inclusion of the Upper Kissimmee Sub-
724 watershed, Lake Istokpoga Sub-watershed, Caloosahatchee River Watershed, and St. Lucie
725 River Watershed; see **Figure 2-2** for proposed revisions to the boundary of 40E-61.

726

727 **Florida Agricultural BMP Program**

728 In response to the LOPA's requirements, the FDACS, in collaboration with the USDA's
729 National Resource Conservation Service and the University of Florida's Institute of Food and
730 Agricultural Sciences (UF/IFAS), initiated an agricultural BMP program throughout the state
731 including the Lake Okeechobee Watershed. The program provides technical assistance for
732 the development of appropriate management plans and financial assistance for
733 implementation. According to the NEEPP, agricultural land owners that do not implement
734 BMPs are required to implement a monitoring program to demonstrate that the water quality
735 objectives of the District's Lake Okeechobee Works of the District program (Chapter 40E-
736 61) are met.

737

738 In 2003, FDACS adopted the Rule 5M-3 requiring BMPs for the Lake Okeechobee priority
739 basins S-191, S-154, S-65 D and E. In 2006, this rule was expanded to the entire Lake
740 Okeechobee Watershed. In 2011, FDACS amended the BMP Rule 5M-3 to include the
741 entire Northern Everglades (including the St. Lucie and Caloosahatchee Watersheds). The
742 FDACS develops and adopts BMPs by rule for different types of agricultural operations.





743 Most of the BMPs are outlined in commodity-specific manuals, which can be found at
744 <http://www.floridaagwaterpolicy.com/>.

745

746 **FDACS Rules**

747 In 2003, FDACS adopted the Land Application of Animal Wastes Rule which was included
748 as part of Rule 5M-3. It specified areas (i.e. wetlands and water setbacks) in which animal
749 manure cannot be applied and required soil and/or plant tissue tests to determine a
750 phosphorus-based application rate. For applications in excess of one ton per year, a nutrient
751 management plan is required.

752

753 In 2007, the FDACS adopted the Urban Turf Fertilization Rule (Rule 5E-1.003) requiring
754 specific labeling on commercial fertilizers. Products labeled for use on sports turf, urban turf
755 or lawns shall contain no phosphate or low phosphate, and if they are low in phosphate must
756 include specific application directions. Products labeled for sports turf at golf courses, parks
757 and athletic fields shall include directions to follow the procedures described in “BMPs for
758 the Enhancement of Environmental Quality on Florida Golf Courses,” published by the
759 FDEP in January 2007.

760

761 **Florida Department of Health Septage Application**

762 In 2003, the Florida Department of Health initiated a requirement that septage applied in the
763 Lake Okeechobee Watershed include an agricultural use plan to limit application based on
764 phosphorus. Based on soil testing and the UF/IFAS Standardized Fertilization
765 Recommendations for Agronomic Crops phosphorus demand, the appropriate application
766 rate is determined. By 2005, the phosphorus concentrations originating from these sites were
767 required by the NEEPP to be below the limits established in the SFWMD’s LOWOD
768 program.

769

770





771 **BEYOND 2011**

772

773 The 2011 Lake Okeechobee Protection Plan (LOPP) update provides detailed information on
774 near term and long term activities. These activities include such items as continued
775 implementation of BMP programs, dispersed water management projects, wetland projects,
776 aquifer storage and recovery, parcel level chemical treatment, and the development of
777 stormwater treatment areas and reservoirs. More information about specific projects and
778 programs can be found in the LOPP and subsequent updates.

779

780 ***2.4 Regulatory Framework***

781

782 The SFWMD's regulatory source control program began in the Lake Okeechobee Watershed
783 with the SWIM Plan, which was required by the 1987 SWIM legislation (Chapter 373.4595,
784 Florida Statutes (F.S.)). The history of this program and the changes to the legislation which
785 mandated the program was discussed above in Section 2.3.1.

786

787 After these legislative changes, the SFWMD began the process of revising LOWOD
788 regulatory source control program rule to be compatible with current initiatives. The goal is
789 to have a regulatory source control program that is an ongoing program of BMPs
790 implemented through the issuance of permits for agricultural and non-agricultural land uses
791 (new and existing). The rule will be a comprehensive program of BMP plan approval,
792 verification of implementation through field visits, and data evaluation; and be
793 complementary to the FDACS and FDEP state-wide source control programs. The SFWMD
794 will develop a performance metric for the collective source control programs. Performance
795 measures ensure consistent implementation of BMPs, measure actual phosphorus reductions,
796 and allow for the detection of water quality problems so that BMPs can be re-evaluated if
797 necessary.





798 This *Draft Technical Support Document* describes the methodologies for initial proposed
799 performance measures that, once finalized, will be used to determine whether the collective
800 source control programs for the Lake Okeechobee Watershed are meeting the objectives of
801 the NEEPP. This approach requires annual calculation of the TP load leaving the outfall
802 structures from each basin.

803 Because of the critical importance of the Kissimmee-Lake Okeechobee-Everglades
804 ecosystem, many programs work in concert to protect the water resources of the region as a
805 whole. For basins which discharge to more than one watershed, this *Draft Technical Support*
806 *Document* describes the relationships between the source control programs in those areas.

807 ***2.4.1 Total Maximum Daily Loads***

808 Source controls are one of several restoration tools used to support the achievement of the
809 Lake Okeechobee TMDL for TP of 140 metric tons per year (mt/yr), as defined in Chapter
810 62-304.700, F.A.C.²

811 The FDEP issued an operating permit to the District that contains TP discharge limits for the
812 structures discharging into Lake Okeechobee (Lake Okeechobee Operating Permit (LOOP);
813 FDEP 2007). The LOOP requires the District to conduct annual evaluations to determine
814 progress towards achieving the TMDL and associated “regional target phosphorus loads”.
815 The “regional target phosphorus loads” established by the LOOP are 5-yr average annual TP
816 loads for the structures discharging into Lake Okeechobee, grouped into four regions (**Table**
817 **2-4**).

818

² For the purposes of this document only the adopted state Lake Okeechobee TMDL was considered.





819 **Table 2-4. FDEP Lake Okeechobee Operating Permit regional grouping (modified**
820 **from FDEP 2007 to show regional TP load targets).**

WATERSHED	STRUCTURES
Northern Region 5-year moving average annual (MA) load = 78.59 mtons	S-65E, S-71, S-72, S-84, S-127, S-129, S-131, S-133, S-135, S-154C, S-154, S-191, CU-5, C-38W/CULVERT A/G-33, G-207, G-208, L-59E/G-34, L-59W/G-74, L-60E/G-75, L-60W/G-76, L-61E, HP-7, Inflow 1, Inflow2, Inflow 3, Fisheating Creek/FECSR78 ²
Southern Region 5-year moving average annual (MA) load = 9.56 mtons	S-2, S-3, S-4, S-354, Industrial Canal, S-352, S-236, Culvert 12 ³ , Culvert 4A ³ , Culvert 10 ³ , Culvert 12A ³ , S-351
Eastern Region 5-year MA load = 16.84 metric tons	CU-10A, S308 ²
Western Region 5-year MA load = 0.01 metric tons	S-77 ² , CU-5A ²

¹This table contains structures which contribute flows and loads to Lake Okeechobee. The structures have been grouped into 4 regions and a target load has been calculated for each region. For purposes of calculations associated with the target load, data from all of the structures identified in the region should be utilized.

²Identifies structures that are monitored through this permit.

³Identifies structures which are authorized through a separate permit but are included in the target load calculation for a particular region.

821
822 The relationship between the TMDL regulatory framework defined in the LOOP and the
823 performance measure methodologies contained in this document can be described by
824 identifying the similarities and dissimilarities. While the contrasts vary among the sub-
825 watersheds, a general description is provided below. Basin-specific contrasts are clarified in
826 the subsequent section.

827
828 **Similarities.** A common feature between most of the approaches described herein and the
829 TMDL regulatory framework defined in the LOOP is the requirement for an annual
830 assessment of TP loads. For the performance methodologies, the exceptions are when
831 adequate historical data were not available for development of a load-based performance
832 measure, and in some cases a load-based performance indicator was derived. Another
833 common feature between the approaches described herein and the LOOP is the use of the
834 Water Year (May to April) as the averaging interval for reporting nutrient loads.

835



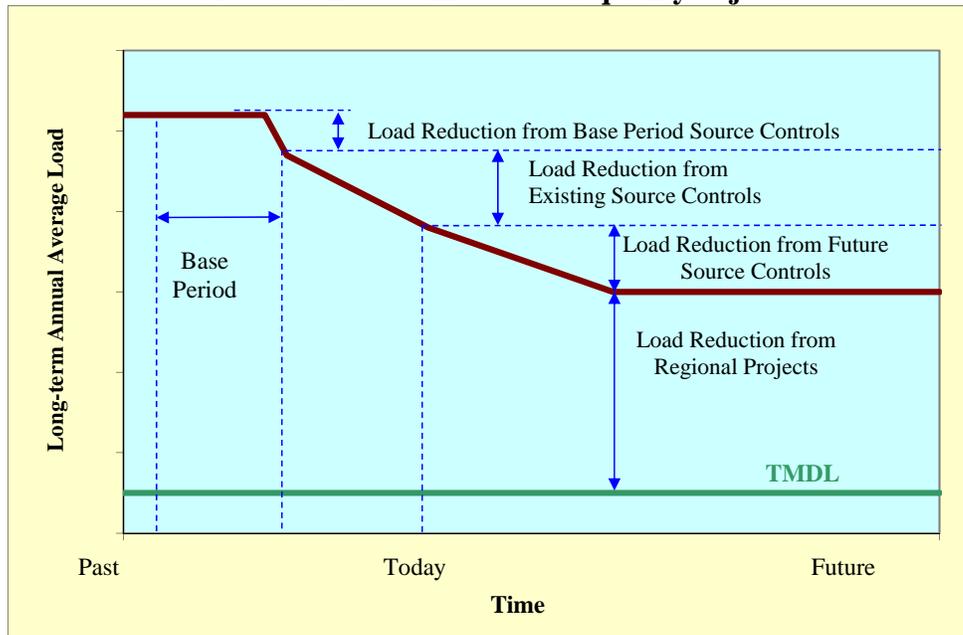


836 **General Contrasts.** General differences between the TMDL regulatory framework defined
837 in the LOOP and the proposed Lake Okeechobee Watershed (LOW) performance measure
838 methodologies are described below.

839 **1. Achievement of the Lake Okeechobee TMDL.**

840 **LOOP.** The load targets within the LOOP are designed to achieve the Lake TMDL
841 based on load reductions resulting from all initiatives described in the LOPP,
842 including source control and regional projects (SFWMD 2011a). Collectively, source
843 control measures and regional projects described in the LOPP are intended to work in
844 concert to meet the applicable TMDL and other water quality objectives (see **Figure**
845 **2-3**).

846 **Figure 2-3. Conceptual diagram of collective source control and regional projects' TP**
847 **load reductions to achieve water quality objectives.**



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850 **LOW Performance Measure Methodology.** The performance measure
851 methodologies described herein only consider source controls which do not by
852 themselves achieve the TMDL for Lake Okeechobee. The goal for the collective TP
853 source control programs in the Lake Okeechobee Watershed will be based on TP load
854 reductions that can reasonably be expected to be achieved through full
855 implementation of BMPs.

856

857 **2. Location of monitoring stations.**

858 **LOOP.** In the LOOP, 40 structures that discharge into Lake Okeechobee are grouped
859 into four regions (**Table 2-4**), and each region has a target phosphorus load.

860 **LOW Performance Measure Methodology.** The Lake Okeechobee Watershed is
861 divided into sub-watersheds, summary basins and hydrologic units to represent
862 discharge from a defined area. These do not always correspond to the four regions of
863 the LOOP, and hence, the regional target phosphorus loads of the LOOP cannot
864 always be compared directly to the grouping of structures used in the Lake
865 Okeechobee Watershed performance measures. A complete cross reference of the
866 LOOP structures is presented in **Table 2-5**.

867 **3. The receiving body or bodies and location of the monitoring stations used for the**
868 **annual assessment.**

869 **LOOP.** In the LOOP, the TP load target is assessed against the observed loads from
870 permitted structures that discharge into Lake Okeechobee, e.g. S-77 of the East
871 Caloosahatchee Hydrologic Unit.

872 **LOW Performance Measure Methodology.** The performance measures and
873 performance indicators described herein establish annual TP targets for the basin





874 runoff regardless of discharge direction. In other words, the performance measure
 875 evaluates the source control program regardless of where the runoff discharges to.
 876 For example, the methodology for the East Caloosahatchee Hydrologic Unit includes
 877 TP loads at S-77 (which discharges into Lake Okeechobee) combined with TP loads
 878 at S-78 (which discharges into the Caloosahatchee River). A comparison of the
 879 receiving waters considered in the LOOP and those considered in the performance
 880 methodologies described herein is presented in **Table 2-6**.

881 **Table 2-5. Cross-reference of LOOP and Lake Okeechobee Watershed structures.**
 882

LOOP Region	Structures	Lake Okeechobee Watershed Sub-watershed	Summary Basin or Hydrologic Unit
Northern Region	S-133	Taylor Creek/Nubbin Slough Sub-watershed	S-133 Summary Basin
	S-135		S-135 Summary Basin
	S-154		S-154 Summary Basin
	S-154C		S-154C Summary Basin
	S-191		S-191 Summary Basin
	S-65E	Lower Kissimmee Sub-watershed & Upper Kissimmee Sub-watershed	
	S-71, S-72, S-84, S-127, S-129, S-131, C-38W/Culvert A/G-33, L-59E/G-34, L-59W/G-74, L-60E/G-75, L-60W/G-76, L-61E	Lake Istokpoga and Indian Prairie Sub-watersheds	
	Fisheating Creek/FECSR78	Fisheating Creek / Nicodemus Slough Sub-watershed	Fisheating Creek Summary Basin
	Culvert 5		Nicodemus Slough Summary Basin
	HP-7	Not included (Note 1)	
	Inflow 1	Not included (Note 2)	
	Inflow 2	Not included (Note 2)	
Inflow 3	Not included (Note 2)		
G-207	Not included (Note 2)		
G-208	Not included (Note 2)		
Southern Region	S-2, S-3, S-351, S-352, S-354	South Lake Okeechobee Sub-watershed	EAA Basin (40E-61)
	Culvert 4A, Culvert 10, Culvert 12, Culvert 12A, S-236		Ch. 298 Districts
Western Region	S-4, Industrial Canal (S-310)	West Lake Okeechobee Sub-watershed	S-4 / Industrial Canal Hydrologic Unit
	S-77		East Caloosahatchee Hydrologic Unit
	Culvert 5A		East Caloosahatchee Hydrologic Unit
Eastern Region	S-308	East Lake Okeechobee Sub-watershed	C-44 Summary Basin
	Culvert 10A		L-8 Summary Basin

Notes:

1. Excluded from the LOW performance measure due to insufficient data
2. Excluded from the LOW performance measure since these structures convey water supply inflow to the sub-watershed, and the conveyed TP loads are subtracted out as flow through

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Table 2-6. Comparison of LOOP and Lake Okeechobee Watershed receiving waters and consideration of pass-through loads.

Table with 5 columns: Sub-watershed, Summary Basin or Hydrologic Unit, LOOP Receiving Water, Basin Receiving Waters, and Pass-Through Loads?. Rows include various sub-watersheds like Taylor Creek/Nubbin Slough, Lower Kissimmee Sub-watershed, East Lake Okeechobee, Indian Prairie Sub-watershed, Lake Istokpoga Sub-watershed, Upper Kissimmee Sub-watershed, and South Lake Okeechobee.

894

4. Treatment of pass-through loads.

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LOOP. The LOOP target loads are based on total TP loads discharged into Lake Okeechobee from the permitted structures. As such, there is no differentiation between basin runoff loads, and those loads that pass through the basin from upstream sources.

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LOW Performance Measure Methodology. In contrast, the proposed approach presented herein differentiates between basin runoff loads, and those loads that pass through the basin from upstream sources. For example, S-65E of the Lower Kissimmee Sub-watershed discharges a combination of basin stormwater runoff and deliveries to Lake Okeechobee from sources outside the summary basin, e.g., the Upper Kissimmee Sub-watershed. These pass-through loads are outside the control of the collective source control programs within the basin and in some cases are

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907 covered under source control programs of the upstream basin. Specific calculations
908 are included to separate the pass-through loads such that only basin runoff loads are
909 compared against the performance measure for the summary basin. The basins that
910 account for pass-through loads are presented in **Table 2-6**.

911 **5. Different evaluation periods.**

912 **LOOP.** In the LOOP, progress towards attainment of the TMDL is based on a five-
913 year moving average of TP loads measured at the permitted structures that discharge
914 into Lake Okeechobee.

915 **LOW Performance Measure Methodology.** In contrast, the proposed performance
916 measures presented herein are based on annual TP loads, with hydrologic variability
917 explicitly addressed through the use of a regression equation that incorporates rainfall
918 characteristics and a two-part (Target/Limit) methodology³.

- 919 i. One part of the methodology, the Annual Load Target, evaluates
920 whether the basin's runoff loads are below or above the median load
921 observed during an appropriate Base Period, adjusted for hydrologic
922 variability. Performance relative to the Target is based upon the results
923 from three consecutive years.
- 924 ii. The second part of the methodology, the Annual Load Limit, evaluates
925 whether a basin's runoff loads are below or above the upper 90 percent
926 confidence limit on the predicted Annual Load Target. A single year's
927 result determines performance relative to the Limit.

928 **6. Different Base Periods for Derivation of Targets.**

929

³ In those basins where insufficient data precluded establishment of a performance measure, an annual performance indicator was established. The characteristics of the performance indicators are described in Sections 3.6 and 3.8.





930 **LOOP.** For the TMDL, the target loads were estimated from models using flows for
931 the 27-year period of record from 1973 through 1999.

932
933 **LOW Performance Measure Methodology.** The performance measure
934 methodologies described in this document used measured flow and water quality data
935 for basin-specific base periods, ranging from eight years to fourteen years in duration,
936 that were selected based on criteria described in Section 1.2.

937
938 **7. Consideration of hydrologic variability.**

939
940 **LOOP.** The LOOP targets are static and are not adjusted for hydrologic variability.
941 However, the derivation and application of the LOOP targets attempted to account for
942 hydrologic variability in two aspects:

- 943 i. The targets were derived from a long-term (27 years) period of flows
944 that occurred during a wide range of meteorological conditions, and
- 945 ii. The targets are assessed against 5-year moving average TP loads.

946
947 **LOW Performance Measure Methodology.** The performance measure
948 methodologies described herein explicitly account for hydrologic variability through
949 the use of one or more annual rainfall characteristics to derive the Annual Load
950 Targets and Annual Load Limits.

951 Basin-specific contrasts are highlighted below.

- 952 1. **Lower Kissimmee Sub-watershed.** For the purpose of the Lake Okeechobee
953 Watershed performance measure, pass-through TP loads measured at S-65 are
954 subtracted from TP loads measured at S-65E in order to calculate the Lower
955 Kissimmee Sub-watershed runoff contribution. No such distinction between the





956 Upper Kissimmee Sub-watershed and Lower Kissimmee Sub-watershed is made in
957 the LOOP.

958

959 2. **Indian Prairie Sub-watershed.** Structures G-207 and G-208 pump water from Lake
960 Okeechobee as necessary to maintain adequate levels in the area’s canals. As such,
961 they do not contribute to the Indian Prairie Sub-watershed basin runoff, and are not
962 included in the sub-watershed’s performance measure. However, these structures are
963 included in the Northern Region of the LOOP, although positive TP loading into the
964 lake has never been reported for these structures. Four minor structures (HP-7,
965 Inflow-1, Inflow-2 and Inflow-3) are located along the east and west banks of the C-
966 41 Canal downstream of S-71, although flow and water quality are not monitored at
967 these structures. Flow and water quality monitoring was initiated downstream of
968 these structures in the C-41 Canal at a location known as C41H78, but the first year
969 of reported TP loading data was not available until WY2010. Therefore, because
970 insufficient data were available, these minor structures were excluded from the
971 derivation of the performance measure for the Indian Prairie Sub-watershed.

972

973 3. **West Lake Okeechobee Sub-watershed.** The water control structures that discharge
974 from the West Lake Okeechobee Sub-watershed are included in two different regions
975 (Southern and Western regions) as defined by the LOOP (see **Table 2-5**).

976

977 4. **South Lake Okeechobee Sub-watershed.** The performance for the South Lake
978 Okeechobee Sub-watershed described in this document considers the performance
979 measures adopted under 40E-63, F.A.C. and the draft performance measures for the
980 Chapter 298 Districts. In contrast, the LOOP considers the S-4/Industrial Canal
981 Hydrologic Unit part of the Southern Region, whereas for this document the S-
982 4/Industrial Canal Hydrologic Unit is considered part of the West Lake Okeechobee
983 Sub-watershed.



984 **2.4.2 Lake Okeechobee Protection Plan**

985 The 2011 update to the *Lake Okeechobee Protection Plan* contains planning-level estimates
986 of the TP load reductions that may be achievable through source controls and regional
987 projects within each sub-watershed, and these are summarized in **Table 2-7**, reprinted from
988 the *Lake Okeechobee Protection Plan 2011 Update* (SFWMD et al. 2011a). The objective of
989 the LOPP is to reduce loads to the lake sufficient to achieve the TMDL. In the LOPP, two
990 general types of source controls are identified for each of the sub-watersheds:

- 991 1. Reductions resulting from BMPs simulated by the Watershed Assessment Model
992 (applied to all basins except EAA basins), and
- 993 2. Reductions resulting from ongoing watershed TP source control projects.

994
995 It should be noted that the objective of the regulatory source control program considered for
996 this project is to reduce loads in runoff by implementing onsite BMPs. The relationship
997 between the 2011 LOPP planning level estimates and the performance measure
998 methodologies proposed in this document can be described by identifying the similarities and
999 dissimilarities. While the contrasts vary among the sub-watersheds, a general description is
1000 provided below.

1001
1002 **Similarities.** A common feature between the approach described herein and the LOPP is that
1003 the estimated load reductions attributable to source controls were developed by Soil and
1004 Water Engineering Technology, Inc. (Bottcher 2006, SWET 2008). In the LOPP, these
1005 estimates are used for planning purposes and to calculate the load reductions expected from
1006 implementation of agricultural and non-agricultural BMPs. The exceptions are when
1007 adequate historical data were not available for development of a load-based performance
1008 measure, and in some cases a load-based performance indicator was derived.

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Table 2-7. Estimates of TP Load reductions in the Lake Okeechobee Watershed (from SFWMD et al 2011a).

Appendix C

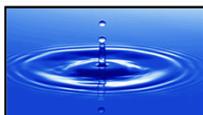
Table C-1: Summary of Estimated P Load Reductions to Lake Okeechobee under the Lake Okeechobee Protection Plan

Sub-watershed	Watershed Baseline Data				Current Activities				Near-Term P Reduction Activities (2011 to 2013)		P Reduction Strategies (6)							
	Area (acres)	Average Annual Discharge (Measured) (2001-2008) (Acre-ft)	Average Annual P Load (Measured) (2001-2008) (Mtons)	Average Annual P Concentration (Calculated) (2001-2008) (ppb)	Owner and Cost share Implemented BMPs (1)		Watershed P Control Projects (2)		Regional Public Works Projects (3)		Other Regional and Sub-Regional Projects (4)		Near-Term P Reduction Activities (2011 to 2013) (5)		P Reduction Strategies (6)			
					Load Red. (Mtons)	Remain. Load (Mtons)	Load Red. (Mtons)	Remain. Load (Mtons)	Load Red. (Mtons)	Remain. Load (Mtons)	Load Red. (Mtons)	Remain. Load (Mtons)	Load Red. (Mtons)	Remain. Load (Mtons)	Load Red. (Mtons)	Remain. Load (Mtons)	Load Red. (Mtons)	Remain. Load (Mtons)
Upper Kissimmee (S-55)	1,021,674	853,368	97	92	0	97	0	97	13	84	0	94	0	83	30	53	60	53
Lower Kissimmee (S-55A,B,C,D,E)	429,283	359,254	57	129	18	39	7	33	8	25	0	26	0	19	6	13	30	13
Taylor Creek/Nubbin Slough (S-191,154,133,135)	198,299	146,800	105	578	18	87	19	68	5	63	2	60	20	40	35	5	30	5
Lake Istokpoga (S-98)	392,147	290,626	40	110	0	39	0	39	0	39	2	38	0	37	27	11	30	11
Indian Prairie Basins (12 basins)	294,147	219,691	101	373	10	91	0	91	0	91	8	82	9	74	66	8	30	8
Fisheating Creek & Nicodemus Slough	315,007	296,324	86	238	6	80	0	80	0	80	0	80	15	65	18	47	129	47
West Lake Okeechobee Basin (S-77)	200,993	29,270	5	138	0	5	0	5	0	5	1	4	0	4	2	2	53	2
EAA Basins	381,707	107,419	20	152	0	20	0	20	9	11	0	11	0	10	3	8	60	8
East Lake Okeechobee Basins (C-44, L-8)	237,831	131,522	29	190	0	29	0	29	0	29	1	28	7	22	2	19	120	19
Total Reductions to the Lake	3,451,087	2,433,464	539	180	52	487	26	461	35	426	15	411	57	355	188	167	56	167
TMQL (inc. including 35 t of atmospheric deposition)																		105
Remaining Load																		62

- (1) Reduction resulting from owner implemented and cost-share BMPs simulated by Watershed Assessment Model (applied to all basins except EAA basins).
 - (2) Reduction due to ongoing watershed P source control projects.
 - (3) Reduction resulting from implementation of LO Critical Projects (5.0 t), Kissimmee River Restoration (KRR) (20.6 t), and the ECP/Diversions (9.4 t).
 - (4) Reduction resulting from other regional and sub-regional projects: FRES-P (5.9 t), HWTT (1.1 t), and Dispersed Water Management Projects (7.6 t).
 - (5) Reduction resulting from the planned regional and sub-regional projects: Dispersed Water Management Projects (16.5 t), FDACS owner-implemented and cost-share BMPs (16.8 t), HWTT at Grassy site (2.9 t), Lakeside Ranch STA Phase I (9 t), Aquifer Storage Recovery (Kissimmee Pilot ASR and Taylor Creek ASR Reactivation) (1.3 t), Fisheating Creek Wetland Reserve Special Project (3.5 t), and C-44 project (6.7 t).
 - (6) Reduction resulting from owner-implemented and cost-share BMPs (18.0 t), the Dispersed WMP - potential sites (6.1 t), Brady Ranch (2 t), Aquifer Storage and Recovery (11.2 t), Chemical treatment to LOWP reservoirs (14.3 t), S-68 STA (8 t), Istokpoga/Kissimmee RASTA (8.9 t), Kissimmee reservoir east (6.5 t), additional P reductions resulting from chemical treatment at the parcel level (46.4 t), Lakeside Ranch STA Phase II (10.0 t), Clewiston STA (2.5 t), and CERP LOWP (54 t).
- * To be conservative, where reductions were projected to result in concentrations less than 30 ppb, the remaining load was estimated by multiplying the basin flow by 30 ppb instead of a lower projected concentration.

C-2

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1014 **Dissimilarities.** Differences between the 2011 LOPP planning level estimates and the
1015 proposed performance measure methodologies are described below.

1016 **1. The direction of discharge and location of the monitoring stations used for the**
1017 **annual assessment.**

1018 **LOPP.** In the 2011 LOPP, the baseline TP load and load reductions are associated
1019 with only the structures that discharge into Lake Okeechobee, e.g. S-77 for the East
1020 Caloosahatchee Hydrologic Unit.

1021 **LOW Performance Measure Methodology.** The performance measures and
1022 performance indicators described herein establish annual TP targets for the basins,
1023 and include TP loads from structures that do not discharge into the lake. For
1024 example, the methodology for the East Caloosahatchee Hydrologic Unit includes TP
1025 loads at S-77 (which discharges into Lake Okeechobee) combined with TP loads at S-
1026 78 (which discharges into the Caloosahatchee River).

1027 **2. Calculation of pass-through loads.**

1028 **LOPP.** While both the 2011 LOPP and the proposed approach differentiate between
1029 basin runoff loads and those loads that pass through the basin from upstream sources,
1030 different algorithms are used to calculate pass-through loads. Please refer to the 2011
1031 LOPP for a description of the algorithm used to calculate pass-through loads.

1032 **LOW Performance Measure Methodology.** The algorithms used to calculate pass-
1033 through loads for the proposed approach are described in Section 2.6.1. When a
1034 downstream basin receives pass-through loads from an upstream basin these loads are
1035 outside the control of the collective source control programs within the basin.
1036 Therefore, the incoming loads from the upstream basin will be accounted for in the





1037 annual performance determination process and will not impact the annual
1038 performance determination of the downstream basin.

1039 **3. Load Reduction Estimates.**

1040 **LOPP.** The planning-level load reduction estimates in the 2011 LOPP reflect load
1041 reductions resulting from all initiatives described in the *Lake Okeechobee Protection*
1042 *Plan*, including both source control and regional projects (SFWMD et al 2011a).
1043 Collectively, source control measures and regional projects described in the *Lake*
1044 *Okeechobee Protection Plan* will combine to meet the applicable TMDL and other
1045 water quality objectives.

1046 **LOW Performance Measure Methodology.** The goal for the collective TP source
1047 control programs in the Lake Okeechobee Watershed will be based on TP load
1048 reductions that can reasonably be expected to be achieved through full
1049 implementation of BMPs. The performance measure methodologies described herein
1050 are used to make annual performance determinations to establish if the BMPs
1051 implemented within individual basins are achieving the TP load reductions that can
1052 be expected. Unlike the planning-level estimates in the 2011 LOPP, the performance
1053 measures methodologies only consider BMPs and do not consider the effectiveness of
1054 other initiatives like regional projects.

1055 **4. Different evaluation periods.**

1056 **LOPP.** In the 2011 LOPP, the planning-level load reduction estimates reflect a long-
1057 term average annual load reduction.

1058 **LOW Performance Measure Methodology.** In contrast, the proposed performance
1059 measures presented herein are based on annual TP loads, with hydrologic variability
1060 explicitly addressed through the use of a regression equation that incorporates rainfall





1061 characteristics, and with a two-part (Target/Limit) methodology⁴ which evaluates
1062 loads annually and over a three year period.

1063 **5. Different Base Periods for Derivation of Targets.**

1064
1065 **LOPP.** For the 2011 LOPP, the baseline loads were established for the 9-year base
1066 period of January 1, 2001 through December 1, 2009.

1067
1068 **LOW Performance Measure Methodology.** The performance measure
1069 methodologies described in this document use measured flow and water quality data
1070 for basin-specific base periods, ranging from eight to fourteen years. These base
1071 periods were selected based on the criteria described in Section 1.2, including because
1072 they precede implementation of most source controls.

1073
1074 **6. Consideration of hydrologic variability.**

1075
1076 **LOPP.** The load reduction estimates presented in the 2011 LOPP do not include
1077 adjustments for future hydrologic variability.

1078
1079 **LOW Performance Measure Methodology.** When possible with the available data,
1080 the recommended performance measure methodologies explicitly account for
1081 hydrologic variability through prediction equations that use one or more annual
1082 rainfall characteristics.

1083
1084
1085

⁴ In those basins where insufficient data precluded establishment of a performance measure, an annual performance indicator was established. The characteristics of the performance indicators are described in Sections 3.6 and 3.8.





1086 7. **Calendar Year vs. Water Year.**

1087 **LOPP.** In the 2011 LOPP, the long-term average annual load reduction is based on a
1088 calendar year averaging interval (January 1- December 31) in order to be consistent
1089 with the TMDL target which is a 5-year moving average based on calendar year
1090 averaging intervals (January 1 – December 31).

1091 **LOW Performance Measure Methodology.** The approaches described herein are
1092 based on the District’s May 1 – April 30 Water Year.

1093

1094 **2.5 Definitions**

1095

1096 For the purpose of this Draft *Technical Support Document*, the following definitions will
1097 apply; these definitions may change over the course of the project, and an up-to-date set of
1098 definitions will be included in the Final *Technical Support Document*.

1099 (1) “Annual Load Target” means the component of the two-part performance measure
1100 methodology that evaluates whether a basin’s runoff TP load levels are below or above
1101 the central measure (e.g., median) of the TP load level of an appropriate reference period,
1102 adjusted for hydrologic variability.

1103 (2) “Annual Load Limit” means the component of the two-part performance measure
1104 methodology that evaluates whether a basin’s runoff TP load levels are below or above
1105 the upper 90 percent confidence limit on the predicted Annual Load Target

1106 (3) “Base Period” means the benchmark period of historical observed data on which
1107 performance measures are based. Base periods should meet, as much as possible, the
1108 following criteria: having at least eight years of concentration and flow data to adequately
1109 represent nutrient levels through a wide range of hydrologic conditions; be representative
1110 of current operating conditions affecting nutrient loading (unless these conditions can be





1111 corrected through data adjustments); have a reasonable correlation between rainfall and
1112 nutrient loads; precede full implementation of collective source control measures; be free
1113 of trends in rainfall, flow or loads (unless these trends can be eliminated through data
1114 adjustments); and be free of unexplained outliers in the rainfall, flow, or load data.

1115 (4) “Calendar Year” means the twelve months beginning January 1 and extending through
1116 December 31.

1117 (5) “Evaluation Period” means the time period for which the observed TP loads for a basin
1118 will be compared to the Annual Target. This period includes a minimum of three water
1119 years, including the most recent complete water year (“Evaluation Year”) but does not
1120 include years when the performance determination was suspended because the hydrologic
1121 conditions during the Evaluation Period do not reflect the hydrologic conditions that
1122 occurred during the historical Base Period.

1123 (6) “Evaluation Year” means the Water Year to be evaluated relative to the performance
1124 measure methodology.

1125 (7) “Hydrologic unit” means a basin that discharges to more than one watershed, i.e., to Lake
1126 Okeechobee and to a river watershed.

1127 (8) “Load” is the mass of the nutrient of concern carried past a specific point of discharge
1128 during a specific period of time by the movement of water, e.g. metric tons of TP per
1129 year. Water quality concentration and water quantity (flow) data are required to calculate
1130 the phosphorus load discharged past the monitoring point, as defined by the following
1131 general equation:

1132
$$\text{TP Load (mass/time)} = \text{TP concentration (mass/volume)} \times \text{flow (volume/time)}$$

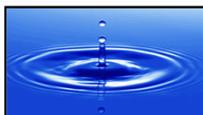
1133 (9) “Pass-Through Flow” is the portion of inflows to a basin from external sources that is
1134 discharged from the basin within a specified time frame (i.e. daily). Basin-level pass-
1135 through flows are calculated as the minimum of the basin inflows or outflows.

1136 (10) “Pass-Through Load” is the inflow load resulting from pass-through flow. Basin-
1137 level pass-through loads are calculated as the product of the basin-level flow-weighted
1138 mean inflow concentration and the basin-level pass-through flow.





- 1139 (11) “Performance Determination” means the process by which total phosphorus levels for
1140 a basin during the evaluation period are compared against an established quantifiable
1141 metric.
- 1142 (12) “Performance Indicator” means a numeric nutrient load goal that could be achieved
1143 through the implementation of source control programs for a basin where the criteria for
1144 establishing a performance measure are not met. A performance indicator may be based
1145 on available data (a reference period), and best professional judgment. A performance
1146 indicator reflects the District’s commitment to adaptive management and continuous
1147 improvement in nutrient reductions.
- 1148 (13) “Performance Measure” means a numeric nutrient load goal that could be achieved
1149 through the implementation of source control programs for a basin, established from a
1150 representative range of historical flow, nutrient, and rainfall conditions that existed
1151 during a specified Base Period.
- 1152 (14) “Performance Measure Methodology” means a description of the process for
1153 assessing the effectiveness of the collective source control programs within a basin. The
1154 methodology could apply to either a performance indicator or performance measure.
- 1155 (15) “Reference Period” means the benchmark period of historical measured data on
1156 which performance indicators are based. Reference Periods shall include, at a minimum,
1157 five years of nutrient concentration or load data measured during a representative range
1158 of conditions affecting nutrient concentration or loading from the basin. Exceptions may
1159 be considered on a case by case basis.
- 1160 (16) “Runoff Load” means the annual nutrient load measured at the outlets of the basin
1161 minus pass-through loads and adjusted for regional projects, if applicable.
- 1162 (17) “Scaled loads” means the observed Base Period loads reduced by the recommended
1163 load reduction.
- 1164 (18) “Sub-watershed” means lands that make up the contributing surface area for which
1165 the District has determined the water quality to be represented by specified monitoring
1166 sites.





1167 (19) “Summary Basin” means an intermediate area which is located within one of nine
1168 sub-watersheds for which the District has determined the water quality to be represented
1169 by specified monitoring sites.

1170 (20) “Water Year” means the period beginning May 1 and continuing until April 30 of the
1171 following calendar year. The water year is named for the year in which it ends.

1172

1173 **2.6 Performance Measure Methodology**

1174 This section presents common elements of the proposed performance measure methodologies
1175 for basins having a minimum of eight years of concentration and flow data which adequately
1176 represent TP in discharge runoff during a wide range of hydrologic conditions. For basins
1177 that discharge to more than one receiving water body (e.g., the C-44 Hydrologic Unit
1178 discharges to both Lake Okeechobee and the St Lucie River/Estuary), the performance
1179 measures are based on the total discharge to all receiving waters.

1180 **2.6.1 Consideration of Pass-through Flow and Load**

1181
1182 If a basin receives flow and TP load from an upstream basin or water body, the performance
1183 measure methodology adjusts the overall observed flow and loads to account for the
1184 component passing through, yielding only flow and loads from basin runoff for the
1185 performance determination (described in Section 2.6.8). The pass through calculation follows
1186 a similar protocol as was used in Chapter 40E-63, F.A.C. Pass-through loads are estimated by
1187 comparing the total basin inflows to the total basin outflows on a daily basis, as generally
1188 described below.

1189

1190 $Inflow_{Basin}$ = cumulative inflow at basin boundary structures

1191 $Outflow_{Basin}$ = cumulative outflow at basin boundary structures

1192 $PassThroughFlow_{Basin}$ = minimum ($Inflow_{Basin}$, $Outflow_{Basin}$)





1193

1194 Basin runoff is then calculated as the difference between the total outflow and the pass-
1195 through flow:

1196 $Runoff_{Basin} = Outflow_{Basin} - PassThroughFlow_{Basin}$

1197

1198 Pass through TP loads are calculated as the product of the pass-through flow and the flow
1199 weighted mean inflow concentration measured at all of the basin’s boundary structures:

1200

1201 $InflowLoad_{Basin}$ = cumulative inflow load at all basin boundary structures

1202 $InflowConcentration_{Basin} = InflowLoad_{Basin} / Inflow_{Basin}$

1203 $PassThroughLoad_{Basin} = PassThroughFlow_{Basin} * InflowConcentration_{Basin}$

1204

1205 The basin runoff TP load is the difference between the total outflow load and the pass-
1206 through load:

1207

1208 $OutflowLoad_{Basin}$ = cumulative outflow load at all basin boundary structures

1209 $RunoffLoad_{Basin} = OutflowLoad_{Basin} - PassThroughLoad_{Basin}$

1210

1211 Basin-specific details of the pass through calculations are provided in Section 3 and in
1212 Appendix A.

1213

1214 2.6.2 Source Control Effectiveness

1215

1216 The effectiveness of source controls is ultimately measured by the reduction of nutrients in
1217 runoff. Conservative reduction estimates from the implementation of collective source
1218 control programs in comparison to a base period were developed. Source control programs
1219 are classified as non-point or point sources (Table 2-2). Note that reductions were not





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1220 considered for programs whose nutrient load reductions are uncertain in the long term or for
1221 projects primarily intended to maintain current nutrient levels.

1222

1223 Source control programs include BMPs and regulations with requirements for BMP
1224 implementation. These programs are complementary to each other to address various sources
1225 based on statutory mandates and agency jurisdiction. For example, the FDACS Agricultural
1226 BMP Program includes nutrient management BMPs for agricultural operations, the Urban
1227 Turf Fertilizer Rule limits the phosphorus and nitrogen content of fertilizers in urban turf and
1228 lawns, and the biosolids and manure rules provide specific requirements for these nutrient
1229 sources. The BMPs upon which the nutrient load reductions are based represent what would
1230 be expected to result from reasonably funded cost share programs or a modest regulatory
1231 approach (Botcher 2006 and SWET 2008). The programs and BMPs applicable to the
1232 primary land uses in the Lake Okeechobee watershed are presented in **Table 2-8**.

1233
1234
1235
1236
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1238
~~1239~~
~~1240~~





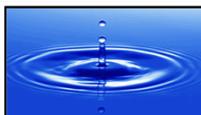
Table 2-3 BMPs assumed to be implemented for estimates of nutrient load reductions (based on Botcher 2009)¹.

Land Use	Citrus	Improved Pastures	Residential and Urban	Dairies	Other agriculture
Water shed average Percentage	7.0 % 4.6 %	22.4 % 21.4 %	6.9 % 13.0 %	0.5 % 0.2 %	18.3 % 23.3 %
Nutrient Mgt	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • P. Soil testing • Includes implementation of biosolids rule • Controlled application (timing & placement, fertigation) • Spill prevention <p><i>High End:</i></p> <ul style="list-style-type: none"> • Slow release fertilizer 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • P. Soil testing • Includes implementation of manure implementation rule, and the septage application rule • Spill prevention • Grass management² and rotational grazing • Reduced cattle density • Alternate water sources, shade, restituted placement of feeders, supplements, and water, fencing <p><i>High End:</i></p> <ul style="list-style-type: none"> • Slow release fertilizer 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Reduced fertilization in accordance with the Urban Turf Fertilizer Rule • Controlled application (timing & placement) • Spill prevention <p><i>High End:</i></p> <ul style="list-style-type: none"> • Florida Friendly Landscape 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • P. Soil testing • Includes implementation of CAFO rule, • Feed management • Grass management² and rotational grazing • Improved forage/sprayfield management – P balanced with high P uptake crop rotations <p><i>High End:</i></p> <ul style="list-style-type: none"> • Solids separation for offsite disposal • Add housing to move animals off field³ 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • P. Soil testing • Includes implementation of biosolids rule • Controlled application (timing & placement, fertigation) • Spill prevention <p><i>High End:</i></p> <ul style="list-style-type: none"> • Slow release fertilizer
Water Mgt	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Storm water detention/retention because of improved irrigation and drainage or ERP permitted systems <p><i>High End:</i></p> <ul style="list-style-type: none"> • Water reuse from existing retention/detention ponds • Wetland restoration 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Wetland restoration • Retention basin by working pens <p><i>High End:</i></p> <ul style="list-style-type: none"> • Stormwater detention/retention 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Dry detention swales (0.25 inch) and wet detention (0.25 inch) <p><i>High End:</i></p> <ul style="list-style-type: none"> • ERP permitted systems, when required • Regional projects for dry detention and wet detention 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Improved Irrigation and Drainage Management • Wetland restoration <p><i>High End:</i></p> <ul style="list-style-type: none"> • Expanded waste storage ponds • Expanded sprayfields • Storm water detention/retention 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Storm water detention/retention because of improved irrigation and drainage, flooded fields, and riser board control or ERP permitted systems <p><i>High End:</i></p> <ul style="list-style-type: none"> • Wetland restoration
Particulate Matter and Sediment Controls	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Grass management between trees • Sediment traps¹ <p><i>High End:</i></p> <ul style="list-style-type: none"> • Grassed swales 	<p>Note: Grass management will also apply to particulate matter and sediment controls</p>	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Street sweeping • Sediment/baffle boxes 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Buffer strips <p>Note: Grass management and improved forage/sprayfield management will also apply to particulate matter and sediment controls</p>	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Cover crops • Sediment traps

¹Based on teleph one conversation with Dr. Botcher on 08/30/12.

²Includes selecting the appropriate grass variety and mowing to ensure healthy and uniform grass coverage.

³Includes associated waste pond and sprayfield expansions (this BMP would also be considered a Water Management BMP)





1243 A spreadsheet model, similar to the tool developed for the Lake Okeechobee, St. Lucie River,
1244 and Caloosahatchee Watershed Protection Plans, was developed to estimate nutrient load
1245 reductions for each basin. The basin reduction was calculated as the nutrient load reductions
1246 for each land use weighted by each land use acreage and unit area load (pounds/acre/year,
1247 lbs/ac/yr). The nutrient load reductions (percentage) per land use and unit area load
1248 coefficients were based on the technical documents produced for the Lake Okeechobee, the
1249 Caloosahatchee, and the St. Lucie River Watershed Protection Plans (Bottcher, 2006 and
1250 SWET 2008), respectively. Land use acreages reflected 1995 conditions and were compared
1251 to current land use acreages to verify that they were generally representative of current
1252 conditions, otherwise warranting adjustment.

1253

1254 It is recognized that there may be a great deal of variability in BMP effectiveness due to
1255 specific implementation, soil characteristics, assimilation, and nutrient responses. Therefore,
1256 ranges of effectiveness from “Low” (limited effectiveness) to “High” (optimal effectiveness),
1257 as well as, a “Typical” (most likely condition), were reviewed to determine those most
1258 appropriate. The typical reduction levels were adjusted to account for partial implementation
1259 of source control programs (or BMPs) in comparison to the base period and current water
1260 quality levels in consultation with District staff. Reductions were rounded to account for the
1261 inherent uncertainty in the data.

1262

1263 These reduction levels relative to the respective base periods provide a preliminary
1264 recommendation for development of performance measures. As additional information is
1265 obtained during the stakeholder technical review process, the nutrient load reduction
1266 percentages presented in **Table 2-9** may be refined. Please refer to Appendix D for
1267 additional clarification on the source control effectiveness methodology.

1268

1269

1270





1271
1272

Table 2-9. Recommended TP load reduction percentages.

Basin	Recommended load reduction percent
S-133	25
S-154	35
S-191	40
Lower Kissimmee	30
C-44	35
L-8	20
Indian Prairie	30
Fisheating Creek	30
S-4/Industrial Canal	30
East Caloosahatchee	30

1273

1274

2.6.3 Significant Digits

1275

1276 The development of the performance measure methodologies used the following protocol for
1277 rounding off data values during calculations:

- 1278 • Daily rainfall station source data were available at the nearest 0.01 inch. Average
1279 daily rainfall values were calculated from the individual station source data using
1280 Thiessen weights provided by the District, and rounded to the nearest 0.001 inch.
- 1281 • Monthly rainfall values were calculated as the sum of the daily values and rounded to
1282 the nearest 0.01 inch.
- 1283 • Annual rainfall values were calculated as the sum of the monthly values and rounded
1284 to the nearest 0.01 inch.
- 1285 • Structure/site flow source data were estimated from structure rating curves, and
1286 available at the nearest 0.01 cubic foot per second - day.
- 1287 • Monthly runoff volumes were rounded to the nearest 0.1 acre foot (AF).





- 1288 • Annual runoff volumes were calculated as the sum of the monthly values and rounded
1289 to the nearest 1 AF.
- 1290 • TP concentration source data were measured from samples collected at representative
1291 structures/sites, and were reported at the nearest part per billion (ppb or $\mu\text{g/L}$).
- 1292 • Monthly TP loads were calculated as the sum of the product of daily flow and daily
1293 concentration assigned by the load algorithm, then rounded to the nearest 0.1 kg.
- 1294 • Annual TP loads were calculated as the sum of the monthly values and rounded to the
1295 nearest 0.001 metric ton (mt).
- 1296 • Monthly flow-weighted mean TP concentrations were calculated from monthly flow
1297 and load values (rounded to the nearest 0.1 AF and 0.1 kg, respectively), and then
1298 rounded to the nearest 1 $\mu\text{g/L}$.
- 1299 • Annual flow-weighted mean TP concentrations were calculated from annual flow and
1300 load values (rounded to the nearest 1 AF and 0.001 mt, respectively), and then
1301 rounded to the nearest 1 $\mu\text{g/L}$.
- 1302 • In order to preserve the above precision,
 - 1303 ○ calculations involving log and square root transformations were carried out to
1304 the fifth decimal place,
 - 1305 ○ regression coefficients were carried out to the fifth decimal place, and
 - 1306 ○ intermediate calculations were carried out to two more decimal places and
1307 then rounded to achieve the above significant digits.

2.6.4 Selecting the Regression Equation

1311 Prediction equations for annual TP load, expressed as a function of the annual rainfall, were
1312 examined to account for hydrologic variability. Fifty-four regression equations correlating
1313 annual load with annual rainfall and monthly rainfall characteristics (coefficient of variation,
1314 skewness and kurtosis) were evaluated (see **Table 2-10**).





1315 Table 2-10. Regression equations evaluated to express annual TP load as a function of
1316 hydrologic variability.

Regr. No.	Response Variable	Predictor Variables	Regression Equation
1	Load	Rain	Annual Load Target = a + b Rain
2	ln(Load)	ln(Rain)	Annual Load Target = exp (a + b ln(Rain))
3	ln(Load)	ln(Rain), S	Annual Load Target = exp (a + b1 ln(Rain) + b2 S)
4	ln(Load)	Ln(Rain), CV, S	Annual Load Target = exp (a + b1 ln(Rain) + b2 CV + b3 S)
5	ln(Load)	ln(Rain), CV, S, K	Annual Load Target = exp (a + b1 ln(Rain) + b2 CV + b3 S + b4 K)
6	ln(Load)	ln(Rain), CV	Annual Load Target = exp (a + b1 ln(Rain) + b2 CV)
7	ln(Load)	ln(Rain), ln(last year's Rain)	Annual Load Target = exp (a + b1 ln(Rain) + b2 ln(last year's Rain))
8	Load	S, CV, Rain	Annual Load Target = a + b1 S + b2 CV + b3 Rain
9	Load	CV, S, K, Rain	Annual Load Target = a + b1 CV + b2 S + b3 K + b4 Rain
10	ln(Load)	ln(Rain), ln(last year's Rain), CV, S, K	Annual Load Target = exp (a + b1 ln(Rain) + b2 ln(last year's Rain) + b3 CV + b4 S + b5 K)
11	ln(Load)	ln(Rain), ln(last year's Rain), CV	Annual Load Target = exp (a + b1 ln(Rain) + b2 ln(last year's Rain) + b3 CV)
12	Load	Rain, last year's Rain	Annual Load Target = a + b1 Rain + b2 (last yr's Rain)
13	Load	S, CV, Rain, last year's Rain	Annual Load Target = a + b1 S + b2 CV + b3 Rain + b4 (last yr's Rain)
14	Load	CV, Rain	Annual Load Target = a + b1 CV + b2 Rain
15	Load	Rain, S	Annual Load Target = a + b1 Rain + b2 S
16	Load	ln(Rain)	Annual Load Target = a + b ln(Rain)
17	ln(Load)	Rain	Annual Load Target = exp (a + b Rain)
18	Load	ln(Rain), ln(last year's Rain)	Annual Load Target = a + b1 ln(Rain) + b2 ln(last year's Rain)
19	Load	ln(Rain), S	Annual Load Target = a + b1 ln(Rain) + b2 S
20	Load	Ln(Rain), CV, S	Annual Load Target = a + b1 ln(Rain) + b2 CV + b3 S
21	Load	ln(Rain), CV, S, K	Annual Load Target = a + b1 ln(Rain) + b2 CV + b3 S + b4 K
22	Load	ln(Rain), CV	Annual Load Target = a + b1 ln(Rain) + b2 CV
23	ln(Load)	S, CV, Rain	Annual Load Target = exp (a + b1 S + b2 CV + b3 Rain)
24	ln(Load)	CV, S, K, Rain	Annual Load Target = exp (a + b1 CV + b2 S + b3 K + b4 Rain)
25	Load	ln(Rain), ln(last year's Rain), CV, S, K	Annual Load Target = a + b1 ln(Rain) + b2 ln(last year's Rain) + b3 CV + b4 S + b5 K
26	Load	ln(Rain), ln(last year's Rain), CV	Annual Load Target = a + b1 ln(Rain) + b2 ln(last year's Rain) + b3 CV
27	ln(Load)	Rain, last year's Rain	Annual Load Target = exp (a + b1 Rain + b2 (last yr's Rain))
28	ln(Load)	S, CV, Rain, last year's Rain	Annual Load Target = exp (a + b1 S + b2 CV + b3 Rain + b4 (last yr's Rain))
29	ln(Load)	CV, Rain	Annual Load Target = exp (a + b1 CV + b2 Rain)
30	ln(Load)	Rain, S	Annual Load Target = exp (a + b1 Rain + b2 S)
31	Load	ln(Rain), S, CV*S	Annual Load Target = a + b1 ln(Rain) + b2 S + b3 CV*S
32	ln(Load)	ln(Rain), S, CV*S	Annual Load Target = exp (a + b1 ln(Rain) + b2 S + b3 CV*S)
33	Load	ln(CV), ln(Rain)	Annual Load Target = a + b1 ln(CV) + b2 ln(Rain)
34	ln(Load)	ln(CV), ln(Rain)	Annual Load Target = exp (a + b1 ln(CV) + b2 ln(Rain))
35	Load	ln(CV), ln(Rain), S	Annual Load Target = a + b1 ln(CV) + b2 ln(Rain) + b3 S
36	ln(Load)	ln(CV), ln(Rain), S	Annual Load Target = exp (a + b1 ln(CV) + b2 ln(Rain) + b3 S)
37	sqrt(Load)	Rain	Annual Load Target = (a + b Rain) ²
38	sqrt(Load)	S, CV, Rain	Annual Load Target = (a + b1 S + b2 CV + b3 Rain) ²
39	sqrt(Load)	CV, S, K, Rain	Annual Load Target = (a + b1 CV + b2 S + b3 K + b4 Rain) ²
40	sqrt(Load)	Rain, last year's Rain	Annual Load Target = (a + b1 Rain + b2 (last yr's Rain)) ²
41	sqrt(Load)	S, CV, Rain, last year's Rain	Annual Load Target = (a + b1 S + b2 CV + b3 Rain + b4 (last yr's Rain)) ²
42	sqrt(Load)	CV, Rain	Annual Load Target = (a + b1 CV + b2 Rain) ²
43	sqrt(Load)	Rain, S	Annual Load Target = (a + b1 Rain + b2 S) ²
44	sqrt(Load)	ln(Rain)	Annual Load Target = (a + b ln(Rain)) ²
45	sqrt(Load)	ln(Rain), ln(last year's Rain)	Annual Load Target = (a + b1 ln(Rain) + b2 ln(last year's Rain)) ²
46	sqrt(Load)	ln(Rain), S	Annual Load Target = (a + b1 ln(Rain) + b2 S) ²
47	sqrt(Load)	Ln(Rain), CV, S	Annual Load Target = (a + b1 ln(Rain) + b2 CV + b3 S) ²
48	sqrt(Load)	ln(Rain), CV, S, K	Annual Load Target = (a + b1 ln(Rain) + b2 CV + b3 S + b4 K) ²
49	sqrt(Load)	ln(Rain), CV	Annual Load Target = (a + b1 ln(Rain) + b2 CV) ²
50	sqrt(Load)	ln(Rain), ln(last year's Rain), CV, S, K	Annual Load Target = (a + b1 ln(Rain) + b2 ln(last year's Rain) + b3 CV + b4 S + b5 K) ²
51	sqrt(Load)	ln(Rain), ln(last year's Rain), CV	Annual Load Target = (a + b1 ln(Rain) + b2 ln(last year's Rain) + b3 CV) ²
52	sqrt(Load)	ln(Rain), S, CV*S	Annual Load Target = (a + b1 ln(Rain) + b2 S + b3 CV*S) ²
53	sqrt(Load)	ln(CV), ln(Rain)	Annual Load Target = (a + b1 ln(CV) + b2 ln(Rain)) ²
54	sqrt(Load)	ln(CV), ln(Rain), S	Annual Load Target = (a + b1 ln(CV) + b2 ln(Rain) + b3 S) ²

1317





1318 For the majority of the hydrologic basins within the Lake Okeechobee Watershed, a
1319 statistically significant prediction equation was found for annual load and an associated
1320 equation derived for the upper confidence limit (UCL), expressed as a function of the annual
1321 rainfall to account for hydrologic variability. If a suitable regression equation expressing TP
1322 levels as a function of hydrologic variability could not be identified, the basin was identified
1323 as needing a performance indicator.

1324
1325 The multiple selection factors used to identify the recommended regression equation are
1326 described below.

1327
1328 1. **Outliers.** All annual values of the independent and dependent variables were
1329 screened for outliers, using the Maximum Normal Residuals technique (Snedecor and
1330 Cochran 1989). If a potential outlier was identified, the physical conditions that may
1331 have produced the value were investigated to assess whether the value should be
1332 retained in the analysis.

1333 2. **Testing the assumption of normality.** Many statistical tests, including linear
1334 regression, assume that the data values or their residuals in the case of regression
1335 equations, are drawn from a normal distribution. Tests for normality were conducted
1336 for the annual values (loads, concentrations, unit area loads and rainfall) and for the
1337 residuals resulting from the regression equations, where

1338
$$\text{residual} = \text{observed value} - \text{the predicted value}$$

1339 To assess the validity of this assumption, the method of Chambers *et al.* (1983) was
1340 used. This is an approximate method using graphical procedures. The data are
1341 plotted against a theoretical normal distribution so that the points should form an
1342 approximately straight line. Departures from a straight line suggest a non-normal





1343 distribution. The plot is formed by placing ordered response values on the Y-axis and
1344 normal order statistic medians on the X-axis.

1345 The test for approximate significance is then based on the probability associated with
1346 the Pearson's Correlation Coefficient between the two sets of statistics. A test for the
1347 lognormal distribution was achieved by converting the observed data values to the
1348 logarithm of the value then re-applying the Chambers *et al.* method (1983).

1349
1350 3. **Standard error of the regression equation** (also known as the standard error of the
1351 estimate and the standard error of the prediction residuals). The smaller the standard
1352 error of the regression equation, the better the equation "fits" the observed data. To
1353 compare the standard error of the regression equation that is based on log-transformed
1354 variables, a back-transformed standard error was calculated, estimated by
1355 transforming the predicted and original values back to original units of the dependent
1356 variable.

1357
1358 4. **Strength of the correlation.** A measure of the strength of the regression relationship
1359 is the Coefficient of Determination, commonly expressed as R^2 , which represents the
1360 proportion of the variance in the dependent variable that can be explained by the
1361 linear relationship with the predictor variable(s). In general, the higher the value of
1362 R^2 , the stronger the correlation between the dependent variable and the predictor
1363 variable(s). By itself, R^2 is not sufficient to demonstrate the strength of the
1364 correlation, and so other tests are performed (see below). The adjusted R^2 , which
1365 accounts for multiple predictor variables, was also used to help determine the best
1366 regression equation.

1367
1368 5. **Statistical significance of the regression coefficients.** In a simple linear regression
1369 equation, where there is one predictor variable (say, annual rainfall) and one





1370 dependent variable (say, annual load), a Student's t-test is performed to determine
1371 whether the regression coefficient (the slope of the line in this simple case) is
1372 significantly different from 0. When the regression equation has multiple
1373 independent variables, a Student's t-test is performed to determine if all the
1374 regression coefficients are significantly different from 0. Regression equations in
1375 which one or more of the predictor variable coefficients were not significantly
1376 different from 0 were not used.

1377

1378 6. **Uniform variance of the residuals (homoscedasticity).** Typically, standard tests are
1379 performed to determine whether there is heteroscedasticity in the residuals of the
1380 regression equation, e.g., White's test or the Bruesch-Pagan test. However, the
1381 sample sizes for those tests need to be larger than 30, considerably larger than the
1382 sample sizes available in the Base Periods used for developing the performance
1383 measure methodologies (typically 8-15). As an alternative, scatterplots of
1384 standardized residuals were prepared for each independent variable to visually inspect
1385 for non-uniform variance, such as increasing or decreasing variance. In addition, the
1386 presence of a trend in the square of the residuals was also tested for the response
1387 variable by performing a Student's t-test on the regression coefficients: if the
1388 coefficients were not statistically different from 0, then it was determined that a trend
1389 in the variance was not present, i.e., homoscedasticity as opposed to
1390 heteroscedasticity.

1391

1392 7. **Collinearity.** For multiple linear regression equations, i.e., those with more than one
1393 predictor variable, the correlation between the predictor variables was calculated
1394 using the Pearson's Correlation Coefficient. A value less than 50 percent was
1395 deemed to be free of collinearity. A value greater than 90 percent triggered a positive
1396 hit on collinearity, and the regression equation was considered unacceptable. Values
1397 between 50 percent and 90 percent triggered an additional check, and the relative





1398 standard error of the regression coefficients (standard error for the coefficient divided
1399 by the coefficient) was evaluated. A value above 200 percent in conjunction with a
1400 correlation of greater than 50 percent triggered a positive hit on collinearity, and the
1401 regression equation was considered unacceptable.

1402
1403 In general, the use of the previous year's rainfall as a predictor variable was avoided
1404 due to concerns of collinearity between rainfall and the previous year's rainfall. In
1405 the case of the S-133 Summary Basin, the highest adjusted R^2 for a regression
1406 equation that did not contain prior year as a predictor variable was only 23 percent
1407 (compared to 79 percent when using a regression equation with prior year's rain as a
1408 predictor variable). Consistent with the guidance above, collinearity was checked for
1409 the Annual Load Target equation, and determined to be acceptable, in that there was
1410 no statistically significant correlation between annual rainfall and prior year's rainfall.

1411
1412 **8. Absence of a temporal trend during the Base Period.** Seasonal Kendall Tau (SKT)
1413 trend analyses using monthly data were performed to determine the presence of a
1414 temporal trend in the data. The presence of a trend in monthly loads or
1415 concentrations during the Base Period that is not related to variations in annual
1416 rainfall may indicate the presence of one or more factors that are contributing to
1417 variations in nutrient levels. For example, phased implementation of source controls
1418 in the watershed could result in a trend in the monthly nutrient levels. If a trend is
1419 detected that is not related to variation in rainfall, de-trending the data may be
1420 necessary. One common approach would be to perform an SKT trend analysis using
1421 the monthly load or concentration data, and then subtracting the "trend," defined as
1422 the slope of the SKT trend line times the elapsed time since the beginning of the data
1423 record.

1424





1425 **9. Avoid overparameterization.** Overparameterization occurs when the number of
 1426 predictor variables approaches the sample size, artificially inflating the value of R^2 .
 1427 All other factors being equal, a regression equation with only one predictor variable
 1428 would be given precedence over a regression equation with two or more independent
 1429 variables. A ratio was used help quantify the degree of parameterization:

$$\text{Ratio} = \text{years in the Base Period} / \text{number of predictor variables}$$

1430
 1431 Haan (1977) suggests a rule of thumb that the ratio should be above 2.86. As a
 1432 reference, the regression equation used for the EAA Basin in Chapter 40E-63, F.A.C.
 1433 had a ratio of $9 / 3 = 3.0$.

1434

1435 2.6.5 Exceedance Frequency Analysis

1436
 1437 The last step in the development of the performance measure was to review the results to
 1438 determine if they were reasonable and defensible compared to theoretical statistical analysis.
 1439 The performance determination for annual TP load is composed of two parts:

- 1440 1. an Annual Load Target, and
- 1441 2. an Annual Load Limit.

1442 Since the performance determination contains two components that are applied
 1443 simultaneously, the cumulative exceedance frequency for the method is greater than the
 1444 exceedance frequencies of either of the individual components. An approximation of the
 1445 cumulative exceedance frequency for the determination methodology was estimated using a
 1446 Monte Carlo approach based on the annual rainfall and the annual TP loads of the Base
 1447 Period. The general approach used is described below.

- 1448 1. A 10,000-year set of annual rainfall data was created that corresponded to the normal
 1449 distribution described by the mean and standard deviation of the rainfall (or log-





1450 transformed rainfall if that transformation was used in the regression equation)
1451 observed during the Base Period.⁵

1452 2. If the regression equation for the Annual Load Target included the rainfall coefficient
1453 of variation, skewness or kurtosis, similar 10,000-year sets of annual values were also
1454 created that corresponded to the normal distributions described by the respective
1455 mean and standard deviation of those parameters for the Base Period.

1456 3. If the performance determination method includes adjusted rainfall, a 10,000-year set
1457 of adjusted rainfall values was then generated.

1458 4. A 10,000-year set of annual residuals was then created that corresponded to the
1459 normal distribution described by the mean and standard deviation of the residuals
1460 observed by comparing the loads predicted using the regression equation and the
1461 actual loads during the Base Period.

1462 5. 10,000-year sets of Annual TP Load Targets and Annual Load Limits were then
1463 generated using the appropriate equations.

1464 6. A 10,000-year set of annual TP loads was generated by adding the calculated annual
1465 residual to the calculated Annual Load Target.

1466 7. The 10,000-year set of annual TP loads was then compared to the Annual Load
1467 Target and the Annual Load Limit, and the cumulative exceedance frequency was
1468 calculated.

1469

1470 **2.6.6 Strength and Defensibility**

1471

1472 For each basin an evaluation was conducted and derived by reviewing the data (gaps and
1473 revisions), assumptions made in performance measure development, the quantitative
1474 statistics (R^2), etc. All of the basins that had load based performance measures were ranked
1475 high or moderate for their overall technical strength and defensibility.

⁵ The Excel random number generator was used to populate the 10,000-year synthetic record of annual rainfall values, with the mean and standard deviation matching the Base Period values to within 0.01 inches.





1476 **2.6.7 Regional Projects**

1477

1478 A description of existing and proposed regional projects can be found in the 2011 Lake
1479 Okeechobee Protection Plan Update (SFWMD 2011a). Performance measures methodologies
1480 will account for regional projects in a similar manner as in Chapter 40E-63, F.A.C.:

- 1481 ➤ After completion of a regional project,
- 1482 ○ the basin's Annual Load Target will be reduced in proportion to the regional
 - 1483 project acreage no longer contributing to basin runoff,
 - 1484 ○ the basin's Annual Load Limit will be calculated using the Annual Load
 - 1485 Target reduced as described above, and
 - 1486 ○ the basin's Runoff Load will be adjusted to take into account the regional
 - 1487 project's load reduction.
- 1488 ➤ Monitoring will be implemented at the inflow and/or outflow of the regional project,
- 1489 as needed to calculate the basin runoff load and the treatment occurring within the
- 1490 regional project.
- 1491 ➤ The basin's Annual Load Target per unit area will be the same before and after
- 1492 completion of regional projects.

1493

1494 Additional details regarding the algorithm to account for regional projects are presented in
1495 Appendix E.

1496

1497

1498

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2.6.8 Annual Performance Determination

Hydrology, specifically discharge and rainfall, is a dominant factor when computing TP loads. Because rainfall and discharge are subject to large temporal and spatial variation in south Florida, the performance measure methodology adjusts the TP load for hydrologic variability. The adjustment for hydrologic variability includes two components:

1. **A model to estimate future TP loads.** The model estimates a future TP load from the Base Period rainfall characteristics by substituting future hydrologic conditions, i.e., during the Evaluation Year, for the conditions that occurred during the Base Period. This predicted future TP load is based on the regression equation described above, and is referred to as the Annual Load Target.
2. **Accommodation for statistical error in the model.** Statistical error in the model was accounted for by specifying a required level of statistical confidence in the prediction of the long-term average TP load. The upper 90 percent confidence limit was selected as reasonable, and is consistent with Chapter 40E-63, F.A.C. This upper confidence limit is referred to as the Annual Load Limit.

Total phosphorus runoff loads discharged at each basin's outlet structures, after accounting for pass-through loads and regional projects, will be assessed annually against the Annual Load Target and the Annual Load Limit, as described below:

- **Annual Load Target: One in three year test.** If a basin's performance is matching expectations the probability of the observed annual load being above the Annual Load Target is 50 percent for any given year. Given this assumption, the probability that the load is above the Target for three consecutive years is 12.5 percent ($= 0.50 \times 0.50$)





1529 x 0.50). In other words, at an 87.5 percent confidence level, we can infer that the
1530 basin achieves its long-term load reduction goal if the observed annual load does not
1531 exceed the Annual Load Target for three consecutive years. The use of a three-year
1532 cycle for the Annual Load Target is consistent with the District's Chapter 40E-63
1533 F.A.C., and has a theoretical Type I error (i.e., false positive) rate of 12.5 percent⁶.

1534

1535 ➤ **Annual Load Limit.** Consistent with the District's Chapter 40E-63 F.A.C., the
1536 Annual Load Limit was derived as the upper 90 percent confidence limit above the
1537 prediction equation for the Annual Load Target, with an associated theoretical Type I
1538 error rate of 10 percent. In deriving the upper 90 percent confidence limit on the
1539 Annual Load Target, the product of the appropriate t-statistic and an expression of the
1540 prediction's standard error (SE_p) is added to the Annual Load Target.

1541

1542 The annual performance determination will be conducted using data collected by water year
1543 (May 1 through April 30) in accordance with the following steps:

1544

1545 1. The Annual Load Target and Annual Load Limit will be calculated according to the
1546 basin-specific equations, described in Section 3.

1547

1548 2. The Annual Load Target and Annual Load Limit may include an area adjustment
1549 factor to account for regional projects. Each basin's Runoff Load is determined as
1550 the annual observed discharge load less calculated pass-through load plus load
1551 reductions attributable to the regional project. Additional details regarding the
1552 calculations to account for regional projects are contained in Appendix E. System
1553 changes affecting the number or location of inflows and outflows, including regional

⁶ The Type I error rate is the probability that the performance measure methodology will reject the null hypothesis (i.e., a determination that the TP load does not meet the performance measure) when in reality the null hypothesis is true – the annual load meets the performance measure, and is therefore also known as the false positive rate.





1554 projects, shall be reflected in updated Annual Load Target, Annual Load Limit, and
1555 Runoff Load calculations.

1556

1557 3. If the Runoff Load in the Evaluation Year is less than or equal to the Annual Load
1558 Target, then the basin will be determined to have met its performance measure, that
1559 is, it will have not exceeded the collective median annual phosphorus loading that
1560 would have occurred during the Base Period, adjusted for hydrologic variability and
1561 adjusted for the source control load reduction goal.

1562

1563 4. Rainfall conditions will be assessed by comparing the Evaluation Year's rainfall
1564 amount to the range of rainfall observed during the Base Period. In those basins
1565 where the regression equation for the Annual Load Target includes more than one
1566 predictor variable, an adjusted rainfall amount will be calculated which reflects the
1567 cumulative effect of the variables that comprise the load target equation. The annual
1568 performance determination will be suspended if the rainfall (or adjusted rainfall) for
1569 the Evaluation Year is outside the range observed during the Base Period and the
1570 Runoff Load exceeds the Annual Load Target calculated above.

1571

1572 5. If the Runoff Load exceeds the Annual Load Target in three or more consecutive
1573 Evaluation Years, and if the annual performance determination is not suspended due
1574 to rainfall for the Evaluation Year, the basin will be determined to have not met its
1575 performance measure, that is, it will have exceeded the annual phosphorus loading
1576 that would be expected to occur during the Base Period, adjusted for hydrologic
1577 variability and adjusted for the source control load reduction goal. Any Evaluation
1578 Year for which the performance determination is suspended will be excluded from the
1579 determination of whether the Annual Load Target has been exceeded in three or more
1580 consecutive Evaluation Years.

1581





1582 6. If the Runoff Load exceeds the Annual Load Limit in any Evaluation Year, and if the
1583 annual performance determination is not suspended due to rainfall for the Evaluation
1584 Year, the basin will be determined to have not met its performance measure, that is, it
1585 will have exceeded the annual nutrient loading that would be expected to occur
1586 during the Base Period, adjusted for hydrologic variability and adjusted for the source
1587 control load reduction goal.

1588
1589 These steps are depicted in **Figure 1-2**.

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1603 **3. PERFORMANCE MEASURE METHODOLOGIES**
1604 **FOR THE LAKE OKEECHOBEE WATERSHED**
1605

1606 The following sections describe the performance measure methodologies of basins within the
1607 Lake Okeechobee Watershed.

- 1608 ➤ Section 3.1: Taylor Creek-Nubbin Slough Sub-watershed
- 1609 ➤ Section 3.2: Lower Kissimmee Sub-watershed
- 1610 ➤ Section 3.3: East Lake Okeechobee Sub-watershed
- 1611 ➤ Section 3.4: Indian Prairie Sub-watershed
- 1612 ➤ Section 3.5: Fisheating Creek-Nicodemus Slough Sub-watershed
- 1613 ➤ Section 3.6: Lake Istokpoga Sub-watershed
- 1614 ➤ Section 3.7: West Lake Okeechobee Sub-watershed
- 1615 ➤ Section 3.8: Upper Kissimmee Sub-watershed
- 1616 ➤ Section 3.9: South Lake Okeechobee Sub-watershed

1617
1618 A summary of the major characteristics of the performance measure methodologies for the
1619 basins of the Lake Okeechobee Watershed is presented in **Table 3-1**.





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Lake Okeechobee Watershed Performance Measures

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Table 3-1. Summary of Lake Okeechobee Watershed performance metrics.

Table with 8 columns: Sub-watershed, Summary Basin or Hydrologic Unit, Base Period or Reference Period, Performance Metric, Pass - Through Loads?, Base Period or Reference Period Median Load, mt, Recommended Load Reduction Goal, Adjusted Rainfall in Performance Determination? Rows include Taylor Creek/Nubbin Slough, Lower Kissimmee Sub-watershed, East Lake Okeechobee, Indian Prairie Sub-watershed, Fisheating Creek/Nicodemus Slough, Lake Istokpoga, Upper Kissimmee, and West Lake Okeechobee.

1630

1631

Notes:

1632

1. PM = Performance Measure

1633

PI = Performance Indicator

1634

2. No performance metric will be assigned to the S-135, S-154C and Nicodemus Slough basins. However, the water quality from these basins will be assessed annually to determine if there is an increasing trend.

1635

1636

1637

3. See Section 3.9 for a summary of the South Lake Okeechobee Sub-watershed performance measure metrics.

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1648 **3.1 Taylor Creek-Nubbin Slough Sub-watershed**

1649
1650 In total, the Taylor Creek-Nubbin Slough Sub-watershed comprises 196,733 acres located
1651 directly north of Lake Okeechobee, and includes the town of Okeechobee Florida (**Figure 3-**
1652 **1**)⁷. The Taylor Creek-Nubbin Slough Sub-watershed is composed of 5 separate summary
1653 basins, S-191, S-135, S-133, S-154, and S-154C. Each of these basins has a distinct
1654 discharge point into Lake Okeechobee. Flow and water quality data from these stations were
1655 used to calculate the annual TP loads from each basin (flow and TP monitoring sites are
1656 identified in **Tables C-1** and **C-2**).

1657 District staff identified the rainfall stations considered to be representative of the Taylor
1658 Creek-Nubbin Slough Sub-watershed and associated basins for the period WY1976-2010. A
1659 schematic of the Taylor Creek-Nubbin Slough Sub-watershed with the various rain stations is
1660 presented in **Figure 3-2**. Monthly rainfall data and weighting factors for the rainfall stations
1661 for each basin were developed and provided by the District. Weighting factors are shown in
1662 **Figure 3-2** for the individual basins. Annual summaries of rainfall values for each basin are
1663 presented in the Sections 3.1.1 through 3.1.5.

1664 The following sections describe the derivation of the performance measure methodologies
1665 for the basins within the Taylor Creek-Nubbin Slough Sub-watershed.

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⁷ Areas used in this Technical Memorandum were calculated by the District; the areas vary somewhat from those reported in the March 2011 update to the Lake Okeechobee Protection Plan.



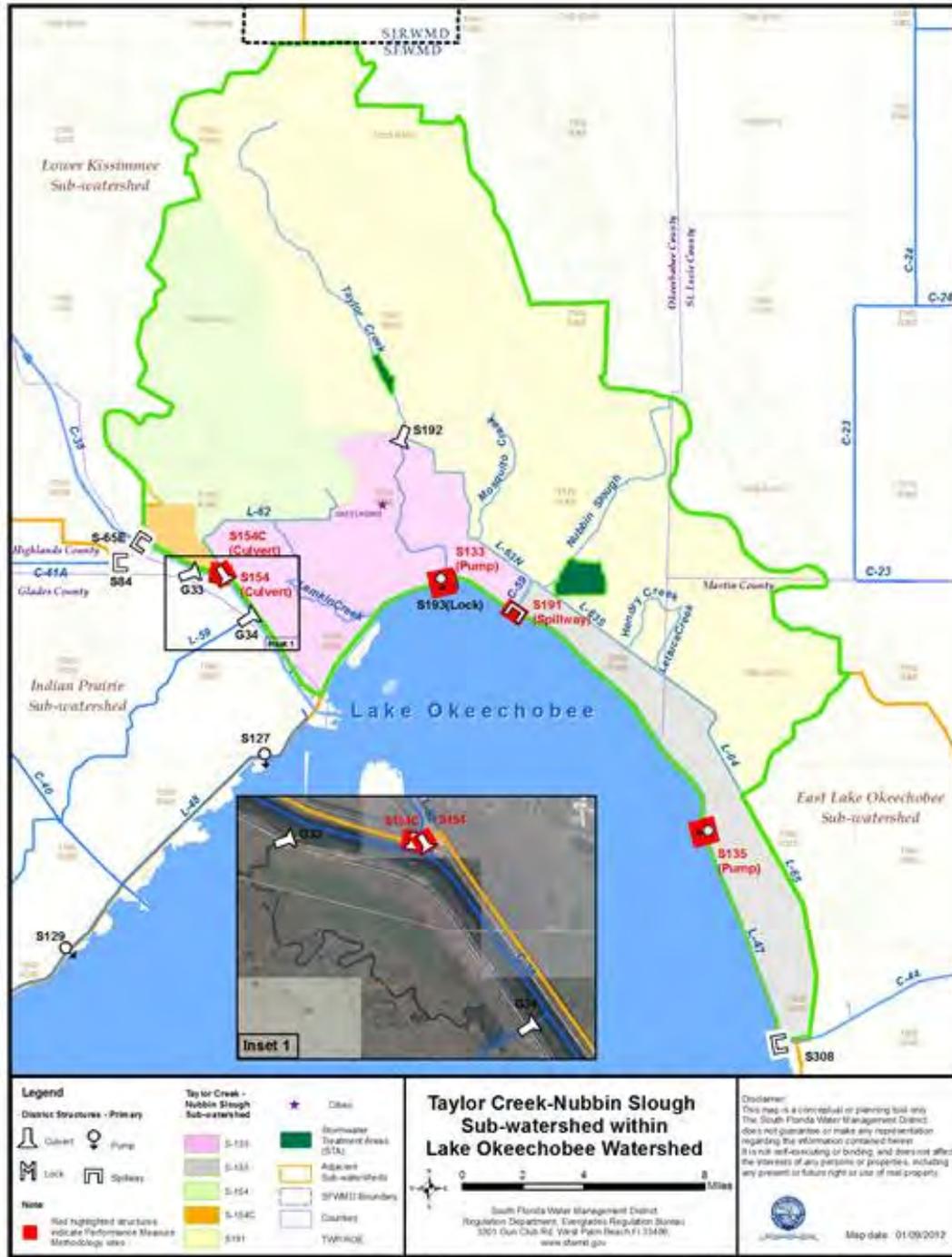


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Lake Okeechobee Watershed Performance Measures

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Figure 3-1. Taylor Creek-Nubbin Slough Sub-watershed boundary and discharge monitoring locations.

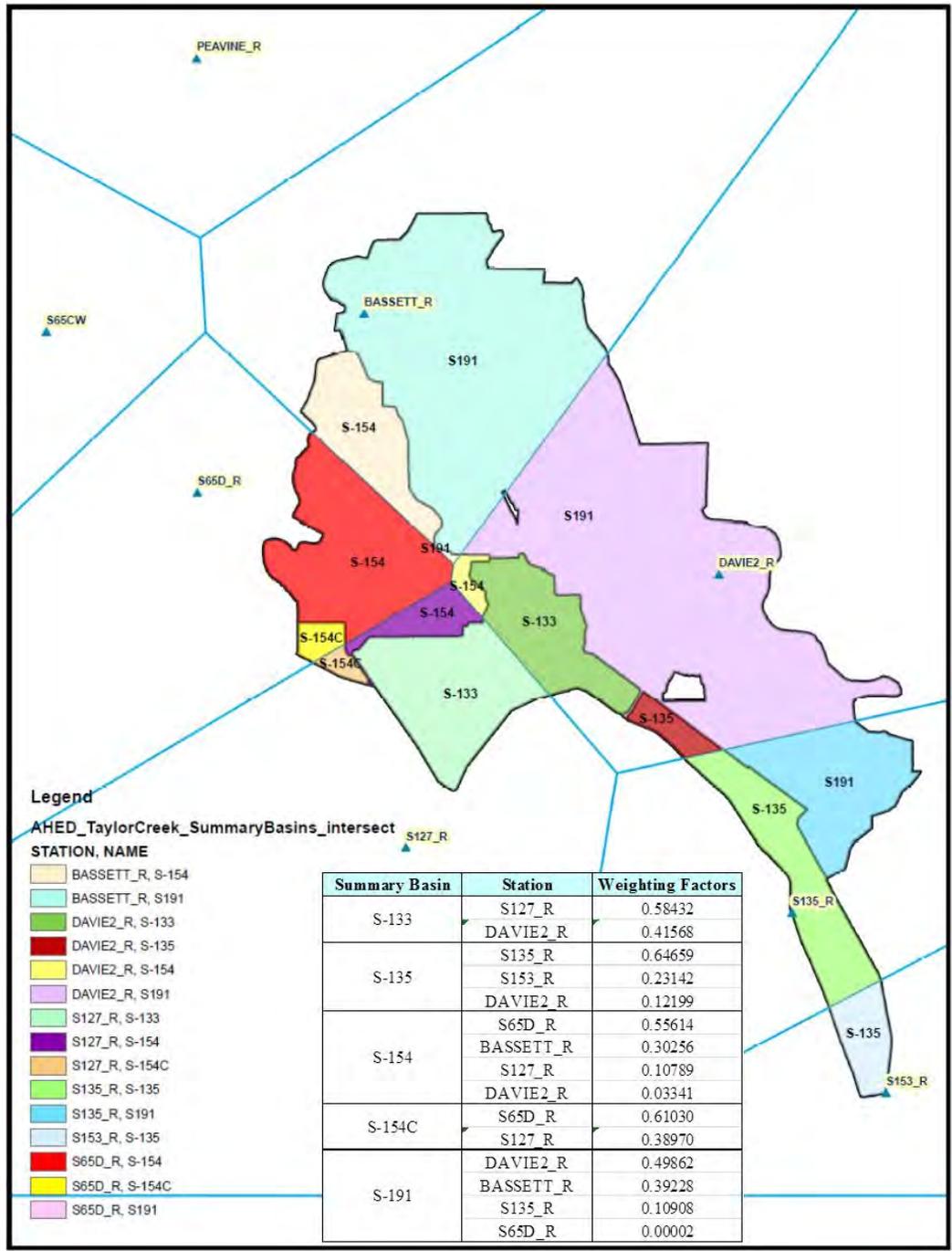


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1675 Figure 3-2. Schematic of Taylor Creek-Nubbin Slough Sub-watershed, summary basins
1676 and selected rainfall stations.



1677





1678 **3.1.1 S-133 Summary Basin**

1679
1680 The following sections present a description of the S-133 Summary Basin, a summary of
1681 historical flow and TP levels, the selection of a Base Period, an estimated range of load
1682 reductions attributable to collective source controls, and the derivation of the resulting
1683 performance measure.

1684 **3.1.1.1 Background**

1685
1686 The 25,626-acre S-133 Summary Basin discharges into Lake Okeechobee through pump
1687 station S-133. Annual flow and TP data for discharges from the S-133 Summary Basin into
1688 Lake Okeechobee are summarized in **Table 3-2**. For the development of the performance
1689 measure methodology, a Base Period of WY1977-1986 was selected for the following
1690 reasons.

- 1691 ➤ it represents a period with minimal implementation of source controls. With the
- 1692 selection of the Base Period to precede significant source control implementation, no
- 1693 additional calculation is necessary in the performance measure methodology to
- 1694 account for source control implementation.
- 1695 ➤ basin water management operations were similar to current operating conditions
- 1696 affecting nutrient loading,
- 1697 ➤ it represents a period of relatively constant land use practices,
- 1698 ➤ reliable water quality and hydrologic data are available which captures a
- 1699 representative range of hydrologic variability, and
- 1700 ➤ a strong correlation exists between annual TP loads and rainfall, allowing for a
- 1701 performance measure methodology that explicitly incorporates hydrologic variability.
- 1702

1703 The Base Period is compared to the historical period of record and WY2001-2010 in **Table**
1704 **3-3**. This comparison is provided to identify the differences between the Base Period annual
1705 rainfall, flows and TP levels compared to the entire period of record and compared to a





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1706 recent ten-year period. The implementation of source controls in a basin subsequent to the
1707 Base Period should result in lower levels of TP when compared against both the period of
1708 record and recent ten-year period.

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1711

Table 3-2. Summary of historical data for S-133.

Table with 10 columns: Water Year, Flow AF, TP Load mt, FWM TP Conc µg/L, Rainfall inches, Unit Area Runoff in/yr, Unit Area Load lbs/ac, Rainfall Characteristics (Kurtosis K, Coef. Of Var. CV, Skewness S). Rows include years from 1977 to 2010, and summary statistics like Minimum, Average, Maximum, Std. Dev., Skewness, and Median.

1712





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Table 3-3. Comparison of Base Period with period of record and WY2001-2010 data for S-133.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1977-2010					
Annual Minimum	0	0.000	132	22.76	0.00
Annual Average	20,549	7.630	301	44.49	0.66
Annual Median	15,996	5.866	305	44.75	0.50
Annual Maximum	59,383	23.346	566	63.58	2.01
Base Period WY1977-1986					
Annual Minimum	0	0.000	230	33.01	0.00
Annual Average	22,651	10.364	371	45.13	0.89
Annual Median	17,403	7.366	341	46.54	0.63
Annual Maximum	59,383	23.346	566	63.58	2.01
Difference between Period of Record and Base Period					
Annual Minimum	0	0.000	-98	-10.25	0.00
Annual Average	-2,101	-2.733	-70	-0.64	-0.24
Annual Median	-1,407	-1.501	-36	-1.79	-0.13
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	N/A	N/A	-43%	-31%	N/A
Annual Average	-9%	-26%	-19%	-1%	-26%
Annual Median	-8%	-20%	-11%	-4%	-20%
Annual Maximum	0%	0%	0%	0%	0%
WY2001-2010					
Annual Minimum	0	0.000	200	22.76	0.00
Annual Average	15,546	6.782	354	38.41	0.58
Annual Median	13,952	5.638	339	39.30	0.49
Annual Maximum	46,255	21.068	539	48.00	1.81
Difference between WY2001-2010 and Base Period					
Annual Minimum	0	0.000	-30	-10.25	0.00
Annual Average	-7,105	-3.581	-17	-6.72	-0.31
Annual Median	-3,451	-1.728	-2	-7.25	-0.15
Annual Maximum	-13,128	-2.278	-27	-15.58	-0.20
Annual Minimum	N/A	N/A	-13%	-31%	N/A
Annual Average	-31%	-35%	-5%	-15%	-35%
Annual Median	-20%	-23%	-1%	-16%	-23%
Annual Maximum	-22%	-10%	-5%	-25%	-10%

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3.1.1.2 Performance Measure Methodology

Based on the evaluation of individual land use source control effectiveness ranges described in Section 2.6, the overall range of TP load reduction that could be accomplished through collective source controls within the basin was estimated, and a load reduction target of 25 percent was determined to be reasonable and appropriate. Details are provided in Appendix D and in Attachment 1.

An Annual Load Target and an Annual Load Limit were derived from the Base Period data using a 25 percent load reduction. The Annual Load Target and Annual Load Limit will be calculated according to the following equations and explanation:

$$\text{Target} = -200.98003 + 19.638 X + 29.41568 P + 30.52657 C$$

Explained Variance = 79.1%, Standard Error of Regression = 3.885 mt

Predictors (X and C) are calculated from the first two moments (m₁, m₂) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

$$m_1 = \text{Sum} [r_i] / 12$$

$$m_2 = \text{Sum} [r_i - m_1]^2 / 12$$

$$X = \ln (12 m_1)$$

$$C = [(12/11) m_2]^{0.5} / m_1$$

$$\text{Limit} = \text{Target} + 1.43976 \text{ SE}$$

SE = standard error of the Target for May-April interval

$$\text{SE} = 3.88541 [1 + 1/10 + 3.01635 (X-X_m)^2 + 4.00198 (P-P_m)^2 + 10.51972 (C-C_m)^2 + 0.38068 (X-X_m) (P-P_m) + 2.9188 (X-X_m) (C-C_m) + 8.67534 (P-P_m) (C-C_m)]^{0.5}$$

Where:

X = the natural logarithm of the 12-month total rainfall (ln[inches])





1745 P = the natural logarithm of the rainfall for the previous water year (ln[inches])

1746 C = coefficient of variation calculated from 12 monthly rainfall totals

1747 X_m = average value of the predictor in base period = 3.79116

1748 P_m = average value of the predictor in base period = 3.77727

1749 C_m = average value of the predictor in base period = 0.75970

1750

1751 In general, the use of the previous year’s rainfall as a predictor variable was avoided due to
1752 concerns of collinearity between rainfall and the previous year’s rainfall⁸. Consistent with
1753 the guidance of Section 2.6, collinearity was checked for the Target equation above, and
1754 determined to be not a problem, in that there was no statistically significant correlation
1755 between annual rainfall and prior year’s rainfall.

1756

1757 The first and second predictors (X and P) indicate that load increases with total annual
1758 rainfall and total annual previous year’s rainfall. The third predictor (C) indicates that the
1759 load resulting from a given annual rainfall is higher when the distribution of monthly
1760 rainfall has higher variability. For a given annual rainfall, the lowest load occurs when
1761 rainfall is evenly distributed across months and the highest load occurs when all of the rain
1762 falls in one month. Real cases fall in between.

1763

1764 A comparison of the scaled loads, i.e., the observed Base Period loads reduced by the
1765 recommended 25 percent load reduction, at S-133 and the resulting Targets and Limits for
1766 the Base Period are presented in **Figure 3-3**. Annual TP loads at S-133, adjusted to account
1767 for regional projects (if applicable), will be evaluated against the performance measure
1768 described above.

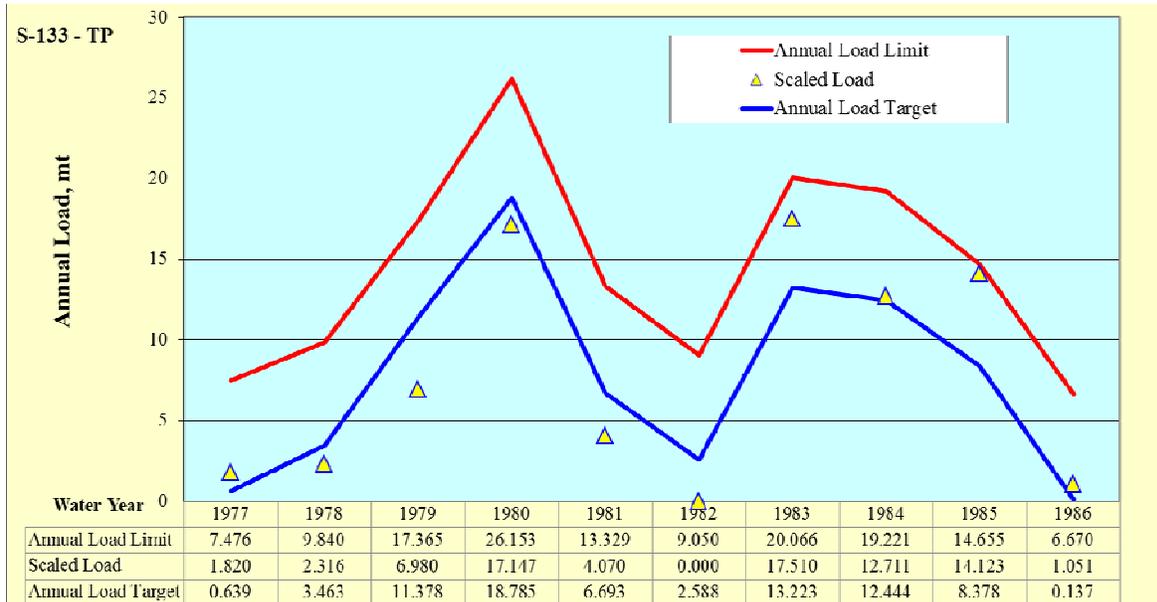
1769

⁸ In the case of the S-133 Summary Basin, the highest adjusted R² for a regression equation that did not contain prior year as a predictor variable was only 23 percent.





1770 **Figure 3-3. Comparison of scaled annual loads to the Annual Load Targets and Limits**
1771 **for the S-133 Summary Basin.**
1772



1773 **Suspension of Performance Determination.** The performance determination will be
 1774 suspended due to rainfall conditions if the observed annual TP load, adjusted for regional
 1775 projects (if present), at S-133 exceeds the Annual Load Target and the adjusted rainfall falls
 1776 outside the range of adjusted rainfall values for the Base Period (30.03 – 77.63 inches), as
 1777 derived below. Rainfall conditions will be assessed by calculating an adjusted rainfall
 1778 amount which reflects the cumulative effect of the predictor variables of the Annual Load
 1779 Target equation. The adjusted rainfall is the rainfall that would produce the equivalent
 1780 annual load using the Annual Load Target equation by setting the value of P and C to their
 1781 mean values for the calibration period.
 1782

1783
 1784
 1785
$$\text{Adjusted Rainfall} = \exp [X + 1.49790 (P - 3.77727) + 1.55446 (C - 0.75970)]$$

 1786

1787 The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the
 1788 rainfall conditions observed during the WY1977-2010 period of record are summarized in





1789 **Table 3-4.** The annual performance determination process will account for regional projects,
1790 as applicable, and is presented in the flowchart in **Figure 1-2.**

1791
1792 **Table 3-4. Estimates of Annual Load Targets and Limits for the historical period of**
1793 **record for the S-133 Summary Basin (Base Period: WY1977-1986).**

1794

Water Year	Observed Load, mt	Observed Rain, in	CV	Target Load, mt	Limit Load, mt	Adjusted Rain, in
1977	2.427	41.00	0.980	0.639	7.476	30.81
1978	3.088	46.56	0.648	3.463	9.839	35.58
1979	9.306	47.05	0.778	11.378	17.364	53.24
1980	22.864	53.41	0.929	18.785	26.153	77.63
1981	5.426	34.60	0.690	6.693	13.328	41.94
1982	0.000	48.32	0.759	2.588	9.049	34.03
1983	23.346	63.58	0.609	13.223	20.066	58.48
1984	16.948	46.52	0.520	12.444	19.221	56.21
1985	18.829	37.24	0.831	8.378	14.654	45.70
1986	1.401	33.01	0.853	0.137	6.670	30.03
1987	4.766	51.29	0.782	3.077	9.753	34.89
1988	6.694	40.62	0.636	7.003	13.234	42.61
1989	6.584	47.14	0.835	9.141	15.157	47.50
1990	0.000	40.33	0.668	5.357	11.486	39.18
1991	0.123	52.50	0.805	10.129	16.307	49.96
1992	8.363	44.59	0.775	13.764	20.049	60.11
1993	19.526	52.87	1.028	20.028	28.211	82.70
1994	2.874	42.53	0.455	3.273	10.687	35.23
1995	9.083	55.72	0.430	1.413	9.821	32.05
1996	11.927	60.01	0.851	23.667	31.584	99.54
1997	1.694	44.53	0.777	17.731	24.706	73.57
1998	6.474	53.54	0.429	1.950	10.104	32.94
1999	2.350	42.93	0.992	20.220	28.557	83.51
2000	7.506	48.73	0.960	15.235	22.255	64.79
2001	0.000	22.76	1.006	5.417	14.862	39.30
2002	5.878	38.50	1.028	-5.983	1.980	21.99
2003	5.853	44.91	0.922	9.268	15.570	47.81
2004	5.423	38.89	0.739	5.385	11.411	39.24
2005	21.068	42.10	1.080	13.119	20.773	58.17
2006	17.829	48.00	0.859	11.281	17.456	52.97
2007	0.000	28.27	1.065	11.031	19.977	52.30
2008	0.000	39.70	0.690	-9.321	-0.929	18.55
2009	10.728	34.04	1.414	19.748	32.019	81.53
2010	1.045	46.88	0.717	0.231	6.987	30.18

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Note: Shaded water years indicate the performance determination would have been suspended due to anomalous rainfall coupled with the observed load being greater than the Load Target.



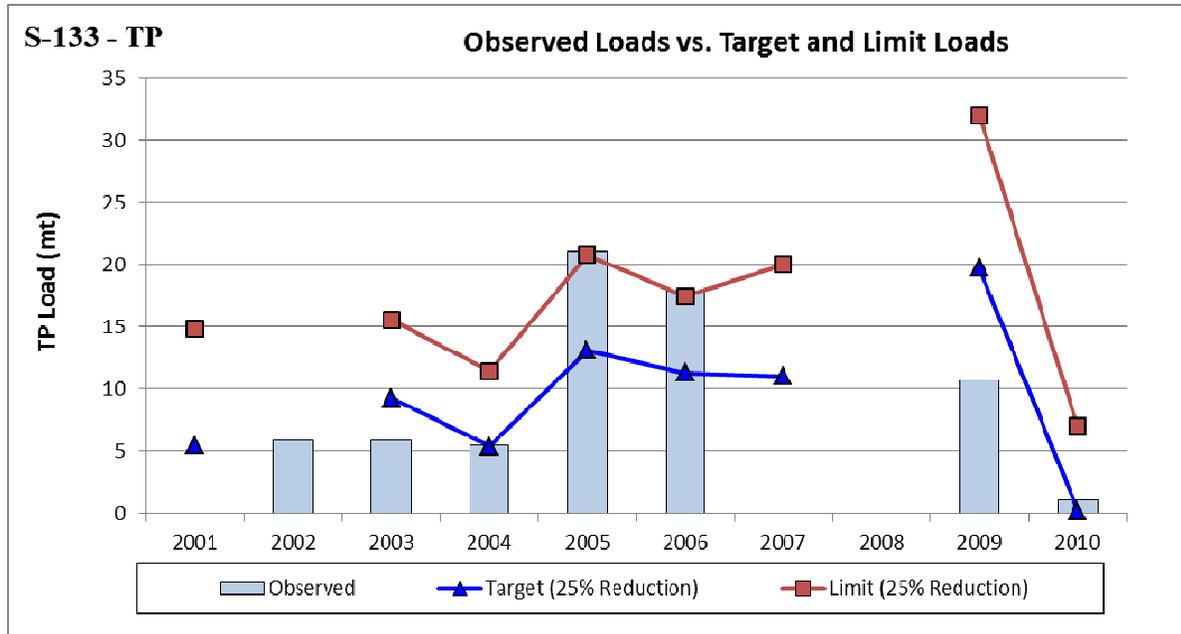


1798 **Comparison to WY2001-2010.** A comparison of the loads observed during WY2001-2010
1799 to the Annual Load Targets and Limits is presented in **Figure 3-4**.

1800

1801 **Figure 3-4. Comparison of WY2001-2010 observed loads to the Annual Load Targets**
1802 **and Limits for the S-133 Summary Basin.**

1803



1804
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Note: The performance determination for WY2002 and WY2008) would have been suspended due to the adjusted rainfall being below the minimum value during the Base Period coupled with the observed load being greater than the Load Target.

1809 **Exceedance Frequency Analysis.** As shown in **Figure 3-3**, although the scaled observed
1810 loads fall above the Annual Load Target roughly half the time (five out of nine years, or 55
1811 percent), three of these exceedances occur in successive years. In accordance with the
1812 proposed performance determination process discussed in Section 2.6, three successive years
1813 when the observed load exceeds the Annual Load Target would prevent the basin from
1814 meeting its performance measure. In the case of the scaled Base Period data, this is an
1815 example of a Type I error⁹, or “false positive” - when the performance method suggests a

⁹ The Type I error rate is the probability that the performance measure methodology will reject the null hypothesis (i.e., a determination that the TP load does not meet the performance measure) when in reality the





1816 lack of compliance when the basin’s load actually achieves the long-term reduction goals.
 1817 While this occurrence is not common, it is statistically possible. The use of a three-year
 1818 cycle for the Annual Load Target is consistent with the District’s Chapter 40E-63 F.A.C., and
 1819 has a theoretical Type I error (i.e., false positive) rate of 12.5 percent. Using the approach
 1820 described in Section 2.6, an approximation of the cumulative exceedance frequency for the
 1821 determination methodology was estimated using a Monte Carlo approach based on the annual
 1822 rainfall and the annual TP loads of the Base Period (**Table 3-5**). Because the TP loads and
 1823 rainfall statistics from the Base Period do not perfectly describe normal distributions (e.g.,
 1824 the medians are generally less than the means), the methodology includes conditional
 1825 probabilities, and because the random number generator is imperfect, the exceedance
 1826 frequencies deviate from the theoretical values shown in the second column. However, the
 1827 results are determined to be reasonable and defensible since the cumulative exceedance
 1828 frequency is less than the theoretical value of approximately 17.5 percent.

1829

1830 **Table 3-5. Exceedance frequencies for the proposed determination methodology for the**
 1831 **S-133 Summary Basin.**
 1832

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Rain _{adj} is outside the range and Load > Annual Load Target	<20%	12.1%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	8.8%
Step 4. Load > Annual Load Limit?	<10%	1.8%
Cumulative Exceedance Frequency	<17.5%	10.1%

1833
1834

null hypothesis is true – the annual load meets the performance measure, and is therefore also known as the false positive rate.





1835 **3.1.2 S-135 Summary Basin**

1836
1837 The following sections present a description of the S-135 Summary Basin and a summary of
1838 historical flow and TP levels.

1839 **3.1.2.1 Background**

1840
1841 The 17,756-acre S-135 Summary Basin discharges into Lake Okeechobee through pump
1842 station S-135. Annual flow and TP data for discharges from the S-135 Summary Basin into
1843 Lake Okeechobee are summarized in **Table 3-6**.

1844

1845 **3.1.2.2 Performance Measure Methodology**

1846
1847 Since this summary basin has historically contributed a small percentage of the annual Lake
1848 Okeechobee total phosphorus load (approximately one percent), no performance metric will
1849 be assigned to this area. However, the water quality from this basin will be assessed annually
1850 to determine if there is an increasing trend.

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1863 Table 3-6. Summary of historical data for S-135 for the WY 1977-2010 period of record.
1864

Table with 10 columns: Water Year, Flow AF, TP Load mt, FWM TP Conc µg/L, Rainfall inches, Unit Area Runoff in/yr, Unit Area Load lbs/ac, Kurtosis K, Coef. Of Var. CV, Skewness S. Rows include years 1977-2010 and summary statistics (Minimum, Average, Maximum, Std. Dev., Skewness, Median).

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1871 **3.1.3 S-154 Summary Basin**

1872
1873 The following sections present a description of the S-154 Summary Basin, a summary of
1874 historical flow and TP levels, the selection of a Base Period, an estimated range of load
1875 reductions attributable to collective source controls, and the derivation of the resulting
1876 performance measure.

1877
1878 **3.1.3.1 Background**

1879
1880 The 31,815-acre S-154 Summary Basin discharges into Lake Okeechobee through S-154.
1881 Annual flow and TP data for discharges from the S-154 Summary Basin into Lake
1882 Okeechobee are summarized in **Table 3-7**. For the development of the performance measure
1883 methodology, a Base Period of WY1977-1984 was selected for the following reasons:

- 1884 ➤ it represents a period with minimal implementation of source controls. With the
1885 selection of the Base Period to precede significant source control implementation, no
1886 additional calculation is necessary in the performance measure methodology to
1887 account for prior source control implementation.
- 1888 ➤ basin water management operations were similar to current operating conditions
1889 affecting nutrient loading,
- 1890 ➤ it represents a period of relatively constant land use practices,
- 1891 ➤ it traversed a wide range of hydrologic conditions (wet and dry years),
- 1892 ○ Monthly and annual flow for Water Year 1983 (May 1982 – April 1983) were
1893 higher than during the other years, however, no individual month was
1894 identified as a potential outlier. Similarly, the TP concentrations for WY1983
1895 were relatively high, yet no outliers were detected. The combination of high
1896 flows and high concentrations resulted in relatively high monthly loads for
1897 this period as well.





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1900

Table 3-7. Summary of historical data for S-154.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics		
							Kurtosis K	Coef. Of Var. CV	Skewness S
1977	6,185	1.093	143	37.82	2.33	0.08	1.024	0.935	1.173
1978	10,946	6.453	478	39.21	4.13	0.45	-1.299	0.599	0.194
1979	47,160	25.106	432	46.19	17.79	1.74	2.016	0.774	1.323
1980	44,896	37.800	683	52.55	16.93	2.62	3.975	0.956	1.871
1981	4,659	2.977	518	30.06	1.76	0.21	0.955	0.890	1.091
1982	5,605	6.663	964	42.01	2.11	0.46	-0.949	0.812	0.426
1983	116,218	149.667	1,044	56.20	43.84	10.37	-0.872	0.572	0.422
1984	8,521	9.880	940	42.03	3.21	0.68	-0.290	0.574	0.519
1985	19,319	23.612	991	36.13	7.29	1.64	4.210	0.954	1.618
1986	14,142	12.701	728	32.18	5.33	0.88	-1.141	0.660	0.455
1987	39,927	53.714	1,091	45.90	15.06	3.72	-1.080	0.659	0.185
1988	30,730	42.574	1,123	48.99	11.59	2.95	0.950	0.609	0.534
1989	7,786	7.786	811	42.13	2.94	0.54	-0.482	0.631	0.231
1990	19,243	23.787	1,002	42.20	7.26	1.65	-0.345	0.809	0.603
1991	10,958	14.526	1,075	52.89	4.13	1.01	-0.735	0.670	0.385
1992	23,280	24.308	847	46.11	8.78	1.68	0.018	0.873	0.925
1993	26,185	25.192	780	48.63	9.88	1.75	2.736	0.967	1.421
1994	4,301	2.089	394	41.23	1.62	0.14	-0.961	0.403	-0.571
1995	36,619	23.949	530	56.25	13.81	1.66	-0.536	0.524	0.851
1996	19,328	26.028	1,092	52.38	7.29	1.80	-1.451	0.782	0.343
1997	437	0.351	651	37.01	0.16	0.02	-1.068	0.599	0.023
1998	48,869	43.391	720	55.98	18.43	3.01	0.106	0.420	-0.873
1999	7,917	7.621	780	32.78	2.99	0.53	0.271	0.741	0.712
2000	79,204	82.860	848	55.01	29.87	5.74	7.101	1.147	2.337
2001	173	0.116	544	27.22	0.07	0.01	0.050	1.129	0.912
2002	22,411	24.815	898	42.46	8.45	1.72	-1.373	0.851	0.562
2003	13,165	8.244	508	41.92	4.97	0.57	1.287	0.589	1.200
2004	27,033	17.816	534	40.91	10.20	1.23	0.630	0.737	0.933
2005	56,536	65.602	941	49.61	21.32	4.55	0.233	1.014	1.024
2006	49,216	36.142	595	47.72	18.56	2.50	2.634	1.016	1.477
2007	547	0.323	479	21.59	0.21	0.02	-0.892	0.988	0.822
2008	91	0.025	223	34.74	0.03	0.00	-0.397	0.675	0.371
2009	37,837	40.845	875	42.72	14.27	2.83	2.638	1.192	1.635
2010	13,119	10.123	626	54.80	4.95	0.70	-1.047	0.665	0.028
Minimum	91	0.025	143	21.59	0.03	0.00	-1.451	0.403	-0.873
Average	25,075	25.241	816	43.40	9.46	1.75	0.468	0.777	0.740
Maximum	116,218	149.667	1,123	56.25	43.84	10.37	7.101	1.192	2.337
Std. Dev.	25,002	29.601	257	8.77	9.43	2.05	1.924	0.204	0.663
Skewness	1.817	2.588	-0.341	-0.424	1.817	2.59	1.690	0.241	0.019
Median	19,281	20.714	754	42.33	7.27	1.44	-0.136	0.758	0.658

1901
1902

➤ reliable water quality and hydrologic data are available, and





1903 ➤ a strong correlation exists between annual TP loads and rainfall, allowing for a
1904 performance measure methodology that explicitly incorporates hydrologic variability.
1905 The Base Period is compared to the historical period of record and WY2001-2010 in **Table**
1906 **3-8.**

1907 **Table 3-8. Comparison of Base Period with period of record data for S-154.**
1908

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1977-2010					
Annual Minimum	91	0.025	143	21.59	0.00
Annual Average	25,075	25.241	816	43.40	1.75
Annual Median	19,281	20.714	754	42.33	1.44
Annual Maximum	116,218	149.667	1,123	56.25	10.37
Base Period WY1977-1984					
Annual Minimum	4,659	1.093	143	30.06	0.08
Annual Average	30,524	29.955	796	43.26	2.08
Annual Median	9,734	8.272	601	42.02	0.57
Annual Maximum	116,218	149.667	1,044	56.20	10.37
Difference between Period of Record and Base Period					
Annual Minimum	-4,568	-1.068	0	-8.47	-0.07
Annual Average	-5,448	-4.714	20	0.14	-0.33
Annual Median	9,548	12.443	154	0.31	0.86
Annual Maximum	0	0.000	79	0.05	0.00
Annual Minimum	-98%	-98%	0%	-28%	-98%
Annual Average	-18%	-16%	3%	0%	-16%
Annual Median	98%	150%	26%	1%	150%
Annual Maximum	0%	0%	8%	0%	0%
WY2001-2010					
Annual Minimum	91	0.025	223	21.59	0.00
Annual Average	22,013	20.405	751	40.37	1.41
Annual Median	17,788	13.970	570	42.19	0.97
Annual Maximum	56,536	65.602	941	54.80	4.55
Difference between WY2001-2010 and Base Period					
Annual Minimum	-4,568	-1.068	80	-8.47	-0.07
Annual Average	-8,511	-9.550	-44	-2.89	-0.66
Annual Median	8,055	5.698	-31	0.17	0.39
Annual Maximum	-59,682	-84.065	-103	-1.40	-5.83
Annual Minimum	-98%	-98%	56%	-28%	-98%
Annual Average	-28%	-32%	-6%	-7%	-32%
Annual Median	83%	69%	-5%	0%	69%
Annual Maximum	-51%	-56%	-10%	-2%	-56%

1909





3.1.3.2 Performance Measure Methodology

Based on the evaluation of individual land use source control effectiveness ranges described in Section 2.6, the overall range of TP load reduction that could be accomplished through collective source controls within the basin was estimated, and a load reduction target of 35 percent was determined to be reasonable and appropriate. Details are provided in Appendix D and in Attachment 1.

An Annual Load Target and an Annual Load Limit were derived from the Base Period data using a 35 percent load reduction. The Annual Load Target and Annual Load Limit will be calculated according to the following equations and explanation:

Target = exp (-5.20573 + 0.16556 X)

Explained Variance = 80.1%, Standard Error of Regression¹⁰ = 0.74134

Predictor X is calculated from the first moment (m₁) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

m₁ = Sum [r_i] / 12

X = 12 m₁

Limit = Target * exp (1.43976 SE)

SE = standard error of the predicted ln(Load) for May-April interval

SE = 0.74134 [1 + 1/8 + (X-X_m)² / 485.64409]^{0.5}

Where:

X = the 12-month total rainfall (inches)

X_m = average value of the predictor in base period = 43.2588 inches

¹⁰ The standard error of the regression equation is expressed in the same units as the transformed load, i.e., ln(metric tons).





1936

1937 The predictor X indicates that the load increases exponentially with total annual rainfall. A
1938 comparison of the scaled loads and the resulting Targets and Limits for the Base Period are
1939 presented in **Figure 3-5**. Annual TP loads at S-154, adjusted to account for regional
1940 projects (if applicable), will be evaluated against the performance measure described above.

1941

1942 **Suspension of Performance Determination.** The performance determination will be
1943 suspended due to rainfall conditions if the observed annual TP load, adjusted for regional
1944 projects (if present), at S-154 exceeds the Annual Load Target and the rainfall falls outside
1945 the range of rainfall values for the Base Period (30.06 – 56.20 inches). The calculated
1946 Annual Load Targets and Annual Load Limits for the rainfall conditions observed during the
1947 WY1977-2010 period of record are summarized in **Table 3-9**.

1948

1949 The annual performance determination process will account for regional projects, as
1950 applicable, and is presented in the flowchart in **Figure 1-2**.

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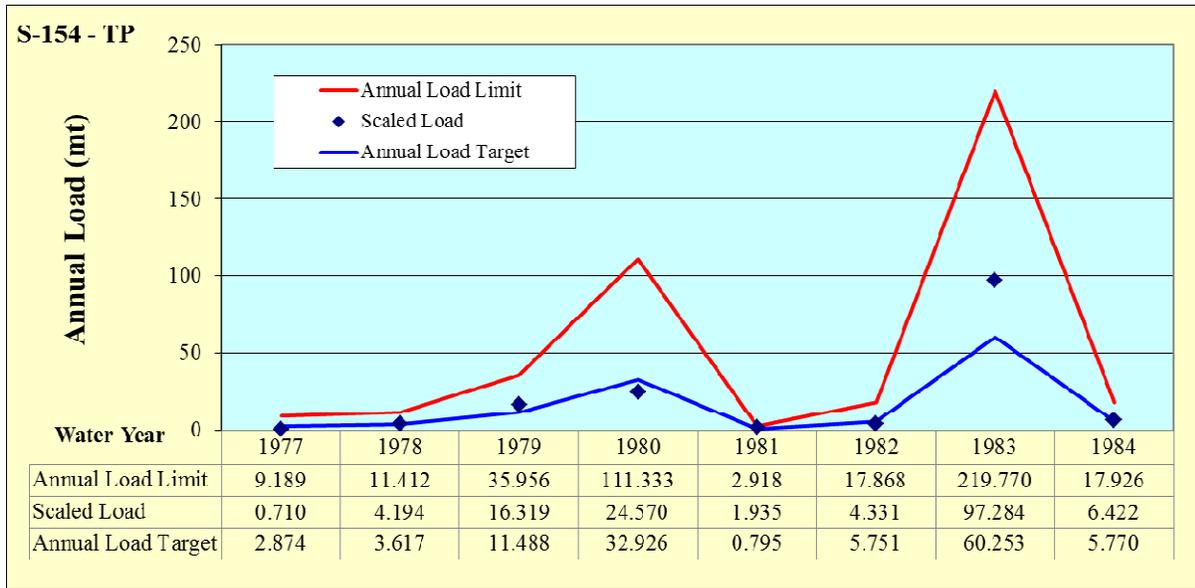
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Figure 3-5. Comparison of scaled annual loads with the Annual Load Targets and Limits for the S-154 Summary Basin.



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Table 3-9. Estimates of Annual Load Targets and Limits for the historical period of record for the S-154 Summary Basin (Base Period: WY1977-1984).

Water Year	Observed Load, mt	Rain in	Target Load, mt	Limit Load, mt
1977	1.093	37.82	2.874	9.189
1978	6.453	39.21	3.617	11.412
1979	25.106	46.19	11.488	35.956
1980	37.800	52.55	32.926	111.332
1981	2.977	30.06	0.795	2.918
1982	6.663	42.01	5.751	17.868
1983	149.667	56.20	60.252	219.768
1984	9.880	42.03	5.770	17.926
1985	23.612	36.13	2.172	7.095
1986	12.701	32.18	1.130	3.954
1987	53.714	45.90	10.950	34.213
1988	42.574	48.99	18.263	58.587
1989	7.786	42.13	5.866	18.221
1990	23.787	42.20	5.934	18.431
1991	14.526	52.89	34.832	118.509
1992	24.308	46.11	11.337	35.466
1993	25.192	48.63	17.206	54.975
1994	2.089	41.23	5.054	15.745
1995	23.949	56.25	60.753	221.856
1996	26.028	52.38	32.012	107.917
1997	0.351	37.01	2.513	8.112
1998	43.391	55.98	58.097	210.824
1999	7.621	32.78	1.248	4.314
2000	82.860	55.01	49.478	175.677
2001	0.116	27.22	0.497	1.961
2002	24.815	42.46	6.195	19.232
2003	8.244	41.92	5.665	17.608
2004	17.816	40.91	4.793	14.954
2005	65.602	49.61	20.237	65.410
2006	36.142	47.72	14.800	46.860
2007	0.323	21.59	0.196	0.916
2008	0.025	34.74	1.726	5.758
2009	40.845	42.72	6.468	20.070
2010	10.123	54.80	47.787	168.906

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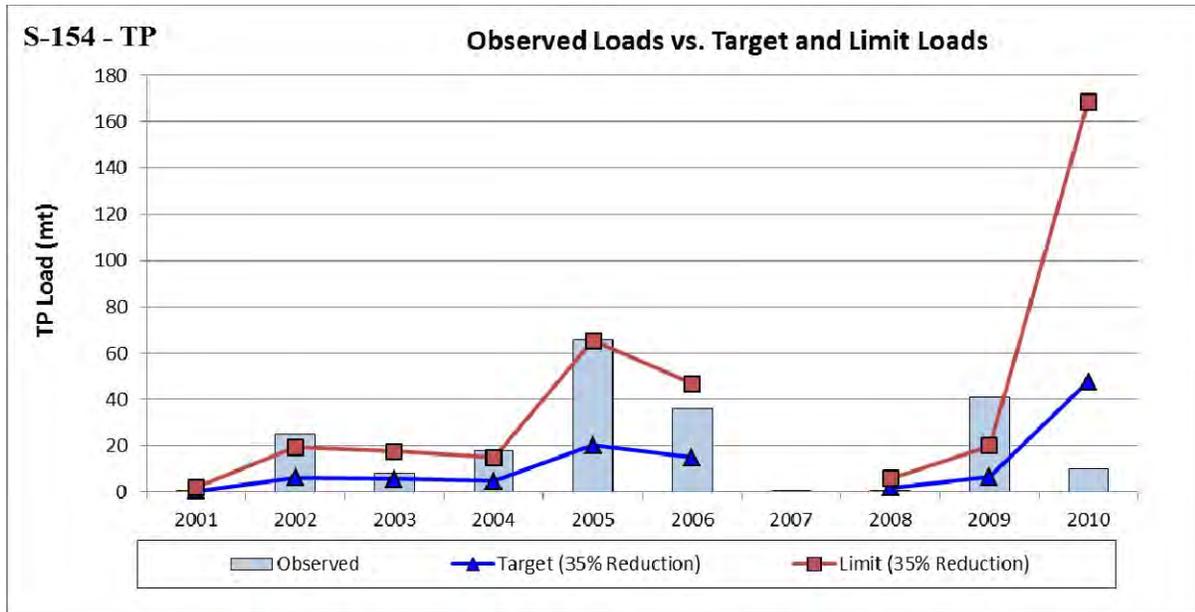
Note: Shaded water years indicate the performance determination would have been suspended due to anomalous rainfall coupled with the observed load being greater than the Load Target.





1987 **Comparison to WY2001-2010.** A comparison of the loads observed during WY2001-2010
1988 to the Annual Load Targets and Limits is presented in **Figure 3-6**.

1989
1990 **Figure 3-6. Comparison of WY2001-2010 observed loads to the Annual Load Targets**
1991 **and Limits for the S-154 Summary Basin.**
1992



1993
1994 Note: The performance determination for WY2007 would have been suspended due to rainfall below the
1995 minimum value during the Base Period coupled with the observed load being greater than the Load Target.
1996

1997 **Exceedance Frequency Analysis.** Using the approach described in Section 2.6, an
1998 approximation of the cumulative exceedance frequency for the determination methodology
1999 was estimated using a Monte Carlo approach based on the annual rainfall and the annual TP
2000 loads of the Base Period (**Table 3-10**). Because the TP loads and rainfall statistics from the
2001 Base Period do not perfectly describe normal distributions (e.g., the medians are generally
2002 less than the means), the methodology includes conditional probabilities, and because the
2003 random number generator is imperfect, the exceedance frequencies deviate from the
2004 theoretical values shown in the second column. However, the results are determined to be





2005 reasonable and defensible since the cumulative exceedance frequency is less than the
2006 theoretical value of approximately 17.5 percent.

2007

2008 **Table 3-10. Exceedance frequencies for the proposed determination methodology for**
2009 **the S-154 Summary Basin.**

2010

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Radj is outside the range and Load > Annual Load Target	<20%	5.6%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	11.0%
Step 4. Load > Annual Load Limit?	<10%	4.0%
Cumulative Exceedance Frequency	<17.5%	13.9%

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2027 **3.1.4 S-154C Summary Basin**

2028
2029 The following sections present a description of the S-154C Summary Basin and a summary
2030 of historical flow and TP levels.

2031

2032 **3.1.4.1 Background**

2033 The S-154C Summary Basin consists of 2,134 acres of predominantly improved pasture. A
2034 single discharge structure (S-154C) located in the southeast corner of the basin conveys
2035 stormwater runoff from the basin into Lake Okeechobee approximately 3 miles downstream
2036 of S-65E and approximately 5 miles upstream of the State Road 78 bridge over the
2037 Kissimmee River. Flow and TP data collection began at S-154C in July 2008. Monthly
2038 summaries are provided in **Table 3-11** for a portion WY2009 and WY2010.

2039

2040 **3.1.4.2 Performance Measure Methodology**

2041
2042 Since this summary basin has historically contributed a small percentage of the annual Lake
2043 Okeechobee total phosphorus load (less than one percent), no performance metric will be
2044 assigned to this area. However, the water quality from the basin will be assessed annually to
2045 determine if there is an increasing trend.

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Table 3-11. Summary of historical flow and TP data for S-154C.

Month	Flow AF	TP Load kg	TP Conc µg/L
200807	277	200	585
200808	1,588	2,546	1,300
200809	697	563	655
200810	385	156	328
200811	123	57	376
200812	119	51	347
200901	44	18	332
200902	0	0	
200903	0	0	
200904	0	0	
200905	0	0	
200906	274	88	260
200907	446	230	418
200908	115	75	529
200909	91	59	526
200910	81	37	370
200911	65	24	299
200912	1	0	
201001	20	13	527
201002	110	81	597
201003	872	754	701
201004	317	295	754
<i>Average</i>	<i>256</i>	<i>239</i>	<i>524</i>
<i>Flow-weighted mean TP Conc.</i>			<i>756</i>
<i>Geometric mean TP Conc.</i>			<i>481</i>
<i>Median</i>	<i>113</i>	<i>58</i>	<i>526</i>
<i>Std Dev</i>	<i>378</i>	<i>550</i>	<i>250</i>

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2066 **3.1.5 S-191 Summary Basin**

2067
2068 The following sections present a description of the S-191 Summary Basin, a summary of
2069 historical flow and TP levels, the selection of a Base Period, an estimated range of load
2070 reductions attributable to collective source controls, and the derivation of the resulting
2071 performance measure.

2072 **3.1.5.1 Background**

2073
2074 The 119,402-acre S-191 Summary Basin discharges into Lake Okeechobee through S-191.
2075 Annual flow and TP data observed at S-191 are summarized in **Table 3-12**. For the
2076 development of the performance measure methodology, a Base Period of WY1977-1988 was
2077 selected for the following reasons:

- 2078 ➤ it represents a period with minimal implementation of source controls. With the
2079 selection of the Base Period to precede significant source control implementation, no
2080 additional calculation is necessary in the performance measure methodology to
2081 account for prior source control implementation.
- 2082 ➤ basin water management operations were similar to current operating conditions
2083 affecting nutrient loading, with the exception of recent regional projects. The
2084 proposed performance measure methodology accounts for the influence of these
2085 regional projects on basin loads.
- 2086 ➤ it represents a period of relatively constant land use practices,
- 2087 ➤ it traversed a wide range of hydrologic conditions (wet and dry years),
 - 2088 ○ Monthly and annual flow for Water Year 1980 (May 1979 – April 1979) were
2089 relatively higher than during the other years due to tropical storm activity.
2090 The TP concentrations for WY1980 were also relatively high, yet no outliers
2091 were detected. The combination of high flows and high concentrations
2092 resulted in relatively high monthly loads for this period as well.





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- 2093 ➤ reliable water quality and hydrologic data are available, and
- 2094 ➤ a very strong correlation exists between annual TP loads and rainfall, allowing for a
- 2095 performance measure methodology that explicitly incorporates hydrologic variability.

2096

2097

2098

Table 3-12. Summary of historical data for S-191.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics		
							Kurtosis K	Coef. Of Var. CV	Skewness S
1977	157,712	185.092	951	44.62	15.85	3.42	-0.399	0.836	0.736
1978	123,421	156.780	1,030	48.24	12.40	2.89	-0.487	0.557	0.561
1979	147,602	176.433	969	51.94	14.83	3.26	0.161	0.628	0.772
1980	195,007	239.196	994	54.82	19.60	4.42	5.312	1.038	2.104
1981	44,844	51.039	923	35.01	4.51	0.94	3.245	0.817	1.379
1982	107,623	183.556	1,383	45.02	10.82	3.39	-0.318	0.853	0.668
1983	206,721	204.033	800	63.58	20.78	3.77	-0.464	0.536	0.544
1984	77,818	78.301	816	44.54	7.82	1.45	-1.004	0.555	0.135
1985	51,376	66.775	1,054	36.55	5.16	1.23	2.362	0.850	1.178
1986	78,395	85.978	889	35.74	7.88	1.59	0.665	0.757	0.938
1987	139,706	142.242	825	44.10	14.04	2.63	-0.375	0.795	0.794
1988	61,889	57.785	757	41.09	6.22	1.07	-0.340	0.592	0.145
1989	47,010	42.844	739	40.23	4.72	0.79	-1.151	0.686	0.298
1990	61,061	63.274	840	46.43	6.14	1.17	0.482	0.893	0.916
1991	121,462	100.327	670	48.43	12.21	1.85	-1.668	0.640	-0.140
1992	76,465	52.372	555	48.97	7.68	0.97	-1.308	0.784	0.513
1993	158,297	127.422	653	59.51	15.91	2.35	3.033	0.944	1.529
1994	38,590	20.648	434	45.01	3.88	0.38	-0.771	0.415	-0.165
1995	173,986	120.673	562	56.64	17.49	2.23	-0.332	0.520	0.425
1996	169,688	144.982	693	60.78	17.05	2.68	-1.499	0.838	0.314
1997	34,195	20.554	487	42.78	3.44	0.38	-1.145	0.678	0.451
1998	126,309	85.797	551	53.69	12.69	1.58	-0.804	0.490	-0.393
1999	61,962	48.313	632	31.08	6.23	0.89	-0.532	0.706	0.711
2000	150,747	143.699	773	55.00	15.15	2.65	5.709	1.173	2.158
2001	13,557	11.290	675	25.52	1.36	0.21	-0.694	1.096	0.850
2002	87,642	77.970	721	47.49	8.81	1.44	7.429	1.178	2.424
2003	85,497	74.273	704	47.65	8.59	1.37	0.767	0.748	1.109
2004	89,666	71.207	644	37.94	9.01	1.31	1.022	0.816	1.185
2005	167,369	148.557	720	48.22	16.82	2.74	1.499	1.047	1.390
2006	187,800	143.248	618	51.80	18.87	2.64	1.510	1.008	1.228
2007	17,850	13.564	616	30.26	1.79	0.25	0.637	1.031	1.161
2008	23,960	15.683	531	37.56	2.41	0.29	-0.689	0.690	0.358
2009	98,634	77.643	638	33.55	9.91	1.43	5.621	1.214	2.106
2010	52,899	30.585	469	48.36	5.32	0.56	-1.358	0.680	0.022
Minimum	13,557	11.290	434	25.52	1.36	0.21	-1.668	0.415	-0.393
Average	101,081	95.945	770	45.36	10.16	1.77	0.709	0.797	0.835
Maximum	206,721	239.196	1,383	63.58	20.78	4.42	7.429	1.214	2.424
Std. Dev.	55,813	60.831	198	9.05	5.61	1.12	2.328	0.211	0.690
Skewness	0.240	0.507	1.038	-0.111	0.240	0.51	1.521	0.306	0.557
Median	88,654	78.136	712	45.73	8.91	1.44	-0.336	0.790	0.754

2099





2100 The Base Period is compared to the historical period of record and WY2001-2010 in **Table**
2101 **3-13**. The median WY2001-2010 annual load was approximately 51 percent lower than the
2102 Base Period, reflecting the effectiveness of source controls already implemented in this basin.

2103

2104 **Table 3-13. Comparison of Base Period with period of record data for S-191.**

2105

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1977-2010					
Annual Minimum	13,557	11.290	434	25.52	0.21
Annual Average	101,081	95.945	770	45.36	1.77
Annual Median	88,654	78.136	712	45.73	1.44
Annual Maximum	206,721	239.196	1,383	63.58	4.42
Base Period WY1977-1988					
Annual Minimum	44,844	51.039	757	35.01	0.94
Annual Average	116,010	135.601	948	45.44	2.50
Annual Median	115,522	149.511	937	44.58	2.76
Annual Maximum	206,721	239.196	1,383	63.58	4.42
Difference between Period of Record and Base Period					
Annual Minimum	-31,287	-39.749	-323	-9.49	-0.73
Annual Average	-14,928	-39.656	-178	-0.08	-0.73
Annual Median	-26,868	-71.376	-225	1.15	-1.32
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	-70%	-78%	-43%	-27%	-78%
Annual Average	-13%	-29%	-19%	0%	-29%
Annual Median	-23%	-48%	-24%	3%	-48%
Annual Maximum	0%	0%	0%	0%	0%
WY2001-2010					
Annual Minimum	13,557	11.290	469	25.52	0.21
Annual Average	82,487	66.402	653	40.84	1.23
Annual Median	86,570	72.740	641	42.72	1.34
Annual Maximum	187,800	148.557	721	51.80	2.74
Difference between WY2001-2010 and Base Period					
Annual Minimum	-31,287	-39.749	-288	-9.49	-0.73
Annual Average	-33,522	-69.199	-295	-4.60	-1.28
Annual Median	-28,953	-76.771	-296	-1.86	-1.42
Annual Maximum	-18,921	-90.639	-662	-11.78	-1.67
Annual Minimum	-70%	-78%	-38%	-27%	-78%
Annual Average	-29%	-51%	-31%	-10%	-51%
Annual Median	-25%	-51%	-32%	-4%	-51%
Annual Maximum	-9%	-38%	-48%	-19%	-38%

2106





3.1.5.2 Performance Measure Methodology

Based on the evaluation of individual land use source control effectiveness ranges described in Section 2.6, the overall range of TP load reduction that could be accomplished through collective source controls within the basin was estimated, and a load reduction target of 40 percent was determined to be reasonable and appropriate. Details are provided in Appendix D and in Attachment 1.

An Annual Load Target and an Annual Load Limit were derived from the Base Period data using a 40 percent load reduction. The Annual Load Target and Annual Load Limit will be calculated according to the following equations and explanation:

$$\text{Target} = -692.35612 + 210.9038 X + 84.89757 C$$

Explained Variance = 89.4%, Standard Error of Regression = 13.995 mt

Predictors (X and C) are calculated from the first two moments (m₁, m₂) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

$$m_1 = \text{Sum} [r_i] / 12$$

$$m_2 = \text{Sum} [r_i - m_1]^2 / 12$$

$$X = \ln (12 m_1)$$

$$C = \ln \{ [(12/11) m_2]^{0.5} / m_1 \}$$

$$\text{Limit} = \text{Target} + 1.38303 \text{ SE}$$

SE = standard error of the Target for May-April interval

$$\text{SE} = 13.99487 [1 + 1/12 + 3.1233 (X-X_m)^2 + 2.11893 (C-C_m)^2 + 1.54068 (X-X_m) (C-C_m)]^{0.5}$$

Where:

X = the natural logarithm of the 12-month total rainfall (ln(inches))





2134 C = is the natural logarithm of the coefficient of variation calculated from 12
2135 monthly rainfall totals

2136 X_m = average value of the predictor in base period = 3.80143

2137 C_m = average value of the predictor in base period = -0.33003

2138

2139 The first predictor (X) indicates that load increases with total annual rainfall. The second
2140 predictor (C) indicates that the load resulting from a given annual rainfall is higher when
2141 the distribution of monthly rainfall has higher variability. For a given annual rainfall, the
2142 lowest load occurs when rainfall is evenly distributed across months and the highest load
2143 occurs when all of the rain falls in one month. Real cases fall in between.

2144

2145 A comparison of the scaled loads and the resulting Targets and Limits for the Base Period
2146 is presented in **Figure 3-7**. Annual TP loads at S-191, adjusted to account for regional
2147 projects, will be evaluated against the performance measure described above.

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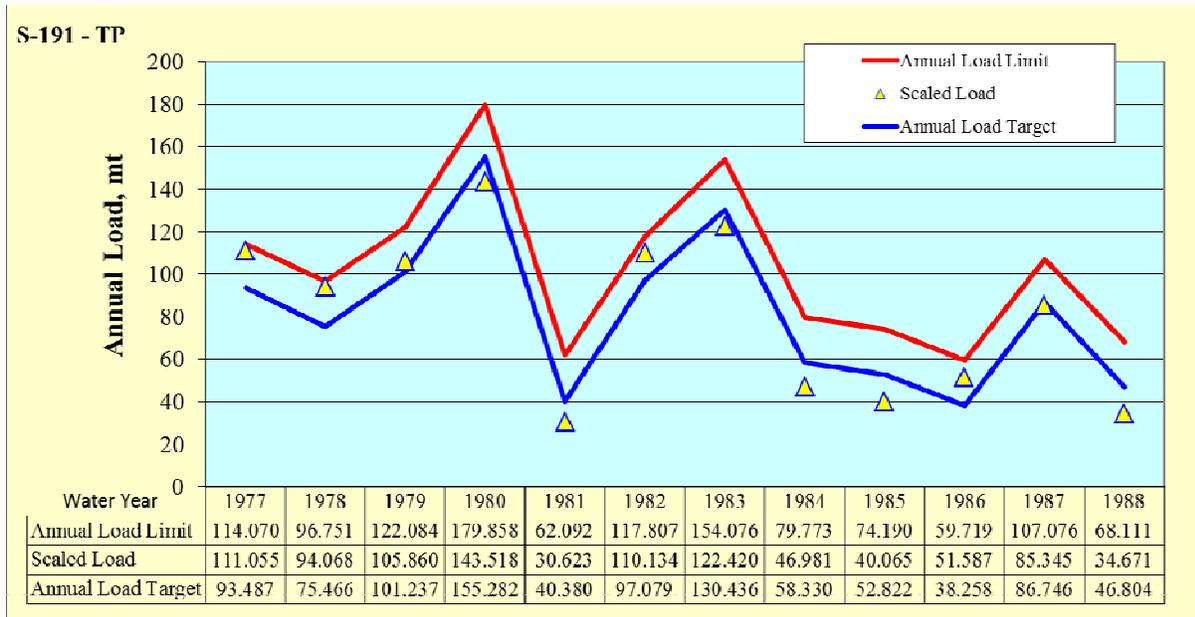
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Figure 3-7. Comparison of scaled annual loads with the Annual Load Targets and Limits for the S-191 Summary Basin.



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2166 **Suspension of Performance Determination.** The performance determination will be
 2167 suspended due to rainfall conditions if the observed annual TP load, adjusted for regional
 2168 projects, at S-191 exceeds the Annual Load Target and the adjusted rainfall falls outside the
 2169 range of adjusted rainfall values for the Base Period (36.49 – 63.56 inches), as derived
 2170 below. Rainfall conditions will be assessed by calculating an adjusted rainfall amount which
 2171 reflects the cumulative effect of the predictor variables that make up the Annual Load Target
 2172 equation. The adjusted rainfall is the rainfall that would produce the equivalent annual load
 2173 using the Annual Load Target equation by setting the value of C to its mean value for the
 2174 calibration period.

2175

2176 Adjusted Rainfall = exp [X + 0.40254 (C + 0.33003)]

2177





2178 The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the
2179 WY1977-2010 period of record are summarized in **Table 3-14**. The annual performance
2180 determination process will account for regional projects, as applicable, and is presented in the
2181 flowchart in **Figure 1-2**.

2182
2183 **Table 3-14. Estimates of annual Load Targets and Limits for the historical period of**
2184 **record for the S-191 Summary Basin (Base Period: WY1977-1988).**
2185

Water Year	Observed Load, mt	Observed Rain, in	CV	Target Load, mt	Limit Load, mt	Adjusted Rain, in
1977	185.092	44.62	0.836	93.487	114.070	47.41
1978	156.780	48.24	0.557	75.466	96.751	43.53
1979	176.433	51.94	0.628	101.237	122.084	49.19
1980	239.196	54.82	1.038	155.281	179.857	63.56
1981	51.039	35.01	0.817	40.381	62.092	36.86
1982	183.556	45.02	0.853	97.079	117.807	48.23
1983	204.033	63.58	0.536	130.436	154.076	56.49
1984	78.301	44.54	0.555	58.330	79.772	40.13
1985	66.775	36.55	0.850	52.822	74.191	39.10
1986	85.978	35.74	0.757	38.258	59.719	36.49
1987	142.242	44.10	0.795	86.746	107.075	45.92
1988	57.785	41.09	0.592	46.805	68.112	38.00
1989	42.844	40.23	0.686	54.856	75.443	39.48
1990	63.274	46.43	0.893	107.473	128.670	50.67
1991	100.327	48.43	0.640	88.087	108.545	46.22
1992	52.372	48.97	0.784	107.655	128.288	50.71
1993	127.422	59.51	0.944	164.535	189.119	66.41
1994	20.648	45.01	0.415	35.865	61.238	36.08
1995	120.673	56.64	0.520	103.486	126.067	49.72
1996	144.982	60.78	0.838	158.876	182.561	64.65
1997	20.554	42.78	0.678	66.822	87.132	41.78
1998	85.797	53.69	0.490	87.160	109.984	46.01
1999	48.313	31.08	0.706	2.872	26.656	30.85
2000	143.699	55.00	1.173	166.352	192.883	66.98
2001	11.290	25.52	1.096	-1.359	26.565	30.24
2002	77.970	47.49	1.178	135.750	160.657	57.93
2003	74.273	47.65	0.748	97.901	118.226	48.42
2004	71.207	37.94	0.816	57.228	78.169	39.93
2005	148.557	48.22	1.047	128.959	152.211	56.10
2006	143.248	51.80	1.008	140.840	164.291	59.35
2007	13.564	30.26	1.031	29.381	54.018	34.99
2008	15.683	37.56	0.690	40.866	62.017	36.94
2009	77.643	33.55	1.214	65.020	90.197	41.43
2010	30.585	48.36	0.680	92.929	113.247	47.29

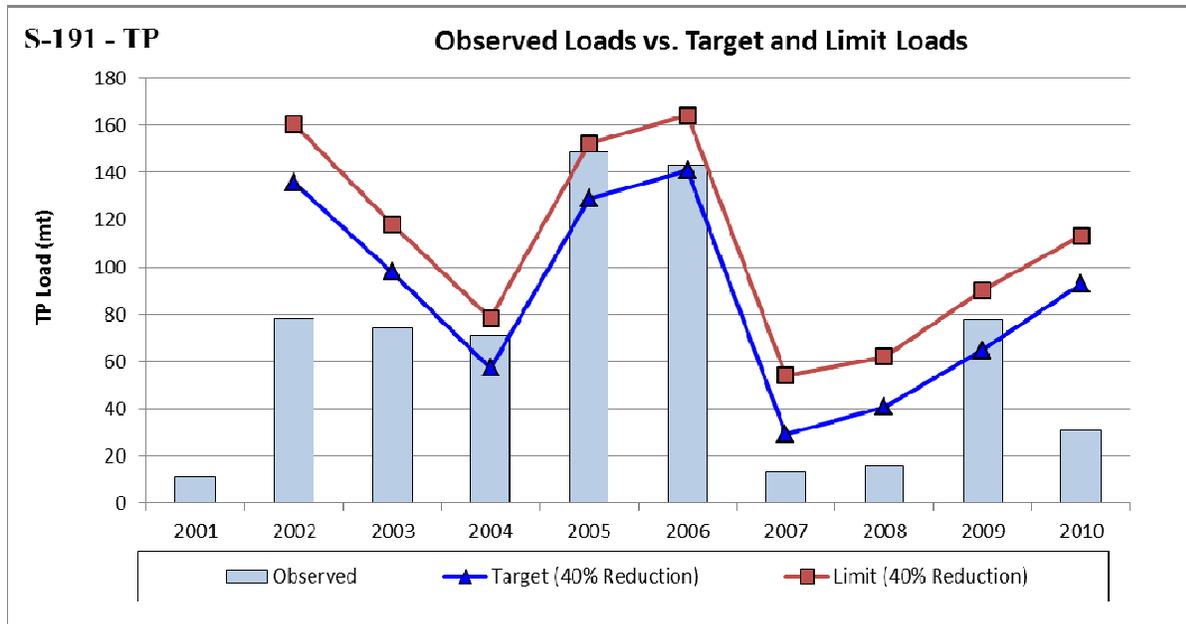
2186
2187 Note: Shaded water years indicate the performance determination would have been suspended due to
2188 anomalous rainfall coupled with the observed load being greater than the Load Target.





2189 **Comparison to WY2001-2010.** A comparison of the loads observed during WY2001-2010
2190 to the Annual Load Targets and Limits is presented in **Figure 3-8**.

2191 **Figure 3-8. Comparison of WY2001-2010 observed loads to the Annual Load Targets**
2192 **and Limits for the S-191 Summary Basin.**
2193
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2195
2196 Note: The performance determination for WY2001 would have been suspended due to adjusted rainfall below
2197 the minimum value during the Base Period coupled with the observed load being greater than the Load Target.
2198

2199 **Exceedance Frequency Analysis.** Using the approach described in Section 2.6, an
2200 approximation of the cumulative exceedance frequency for the determination methodology
2201 was estimated using a Monte Carlo approach based on the annual rainfall and the annual TP
2202 loads of the Base Period (**Table 3-15**). Because the TP loads and rainfall statistics from the
2203 Base Period do not perfectly describe normal distributions (e.g., the medians are generally
2204 less than the means), the methodology includes conditional probabilities, and because the
2205 random number generator is imperfect, the exceedance frequencies deviate from the
2206 theoretical values shown in the second column. However, the results are determined to be





2207 reasonable and defensible since the cumulative exceedance frequency is less than the
2208 theoretical value of approximately 17.5 percent.

2209

2210 **Table 3-15. Exceedance frequencies for the proposed determination methodology for**
2211 **the S-191 Summary Basin.**
2212

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Rain _{adj} is outside the range and Load > Annual Load Target	<20%	8.0%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	10.2%
Step 4. Load > Annual Load Limit?	<10%	4.2%
Cumulative Exceedance Frequency	<17.5%	13.4%

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2228 **3.2 Lower Kissimmee Sub-watershed**

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2230 The following sections present a description of the Lower Kissimmee Sub-watershed, a
2231 summary of historical flow and TP levels, the selection of a Base Period, an estimated range
2232 of load reductions attributable to collective source controls, and the derivation of the
2233 resulting performance measure.

2234 **3.2.1.1 Background**

2235

2236 The Upper and Lower Kissimmee Sub-watersheds comprise the Kissimmee River Basin,
2237 which includes most of the area that drains into Lake Okeechobee from the north and
2238 northwest through the Kissimmee River (C-38 canal). The 429,188-acre Lower Kissimmee
2239 Sub-watershed includes the tributary watersheds of the Kissimmee River that lie between the
2240 outlet from Lake Kissimmee and the inlet to Lake Okeechobee. The S-65 sub-basins (S-65A,
2241 S-65BC, S-65D, and S-65E) are located along the length of the C-38 canal and form four
2242 pools (**Figure 3-9**). Structure S-65B was removed as a part of the first phase of Kissimmee
2243 River Restoration Project and reduced the number of pools from five to four. Water levels in
2244 each of the pools are regulated according to interim regulation schedules. Monitoring stations
2245 are located at each S-65 structure (at the downstream boundary of each sub-basin) and at
2246 station S-65, which is at the outlet from Lake Kissimmee to the Kissimmee River. The S-65
2247 structures are gated spillways and locks that are operated to enhance the natural resources of
2248 the river floodplain and to provide flood protection within their respective sub-basins and the
2249 Upper Kissimmee River Basin. Discharge monitoring locations are shown in **Figure 3-9** and
2250 listed in **Tables C-1** and **C-2**.

2251

2252 District staff identified the rainfall stations considered to be representative of the Lower
2253 Kissimmee Sub-watershed for the period WY1976-2010. Rainfall stations are shown in
2254 **Figure 3-10** with their associated Thiessen polygons and weighting factors. In order to
2255 separate discharges originating in the upstream Upper Kissimmee Sub-watershed, pass-





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2256 through loads are estimated by comparing daily discharges from S-65 to the flows at the
2257 outlet structure S-65E (Appendix A).

2258 **Figure 3-9. Lower Kissimmee Sub-watershed boundary and discharge monitoring**
2259 **locations.**



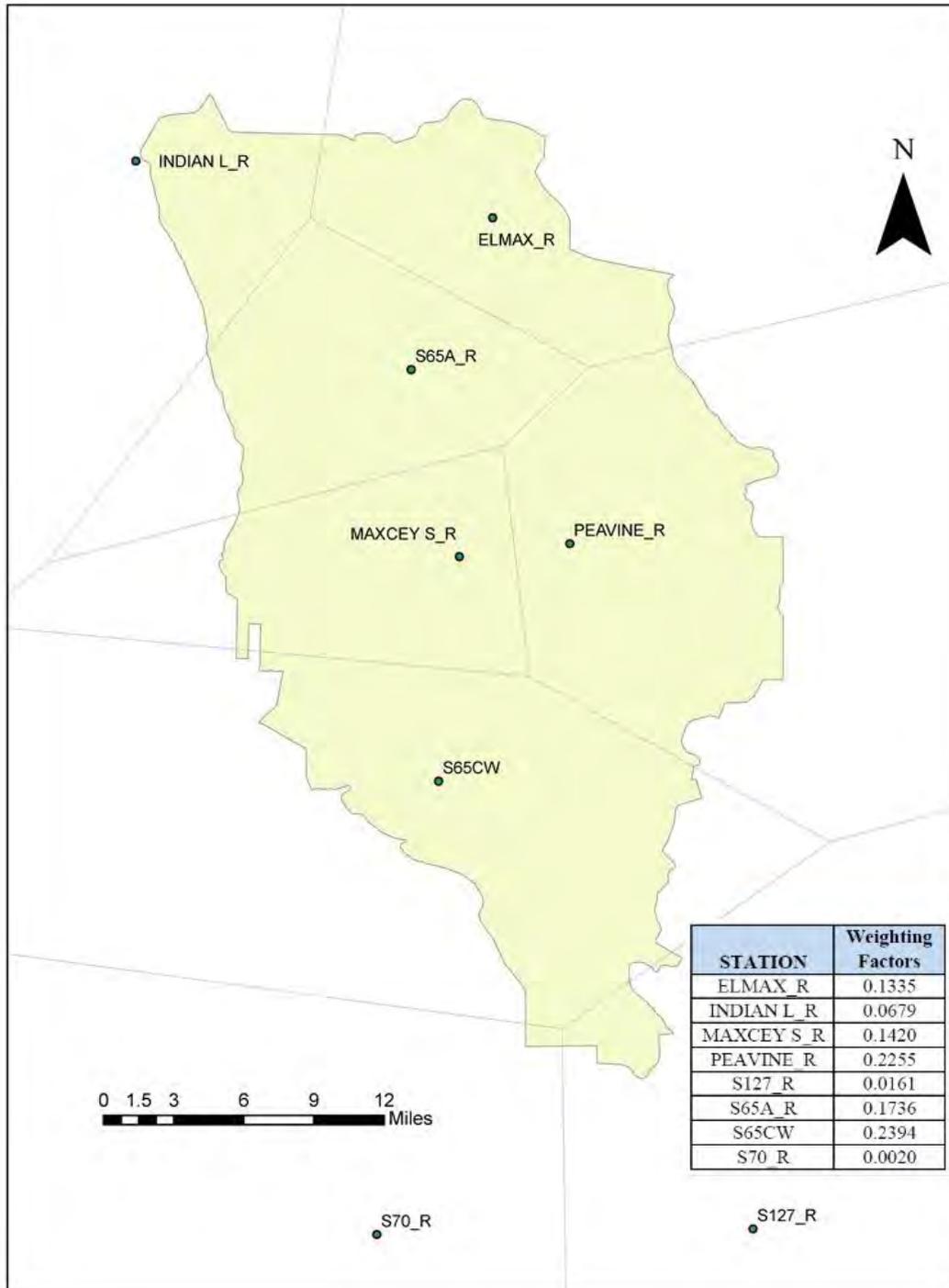
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Figure 3-10. Schematic of Lower Kissimmee Sub-watershed and the selected rainfall stations.



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2264 Annual flow and TP data for discharges from the Lower Kissimmee Sub-watershed into Lake
2265 Okeechobee are summarized in **Table 3-16**. For the development of the performance
2266 measure methodology, a Base Period of WY1977-1990 was selected for the following
2267 reasons:

- 2268 ➤ it represents a period with minimal implementation of source controls. With the
2269 selection of the Base Period to precede significant source control implementation, no
2270 additional calculation is necessary in the performance measure methodology to
2271 account for prior source control implementation.
- 2272 ➤ it represents a period of relatively constant land use practices,
- 2273 ➤ it traversed a wide range of hydrologic conditions (wet and dry years),
 - 2274 ○ Monthly and annual flow and TP levels for Water Year 1980 (May 1979 –
2275 April 1979) were relatively higher than during the other years due to tropical
2276 storm activity.
- 2277 ➤ reliable water quality and hydrologic data are available, and
- 2278 ➤ a strong correlation exists between annual TP loads and rainfall, allowing for a
2279 performance measure methodology that explicitly incorporates hydrologic variability.

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2281 The Base Period is compared to the historical period of record and WY2001-2010 in **Table**
2282 **3-17**.

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Table 3-16. Summary of historical data for the Lower Kissimmee Sub-watershed.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics		
							Kurtosis K	Coef. Of Var. CV	Skewness S
1977	413,364	60.731	119	51.72	11.56	0.31	-1.733	0.884	0.476
1978	242,506	29.763	99	47.79	6.78	0.15	-0.497	0.553	-0.033
1979	679,833	146.321	174	59.10	19.01	0.75	0.847	0.737	1.071
1980	631,914	157.288	202	55.96	17.67	0.81	1.053	0.807	1.307
1981	91,591	19.994	177	39.33	2.56	0.10	-0.276	0.707	0.336
1982	99,717	31.589	257	45.05	2.79	0.16	-1.290	0.675	0.261
1983	851,549	197.316	188	61.84	23.81	1.01	-1.535	0.526	-0.038
1984	80,459	37.387	377	43.25	2.25	0.19	-0.057	0.565	0.572
1985	211,885	79.258	303	41.71	5.92	0.41	-0.999	0.747	0.405
1986	136,112	43.588	260	43.05	3.81	0.22	-0.594	0.794	0.910
1987	244,506	100.068	332	47.04	6.84	0.51	2.710	0.748	1.275
1988	372,249	129.497	282	55.94	10.41	0.67	0.243	0.649	0.512
1989	100,602	34.449	278	43.14	2.81	0.18	0.232	0.577	0.809
1990	122,723	51.390	339	47.96	3.43	0.26	-0.944	0.648	0.238
1991	257,169	73.414	231	51.37	7.19	0.38	-0.201	0.616	0.297
1992	341,430	118.047	280	52.11	9.55	0.61	1.545	0.831	1.171
1993	353,751	87.536	201	62.62	9.89	0.45	1.678	0.825	1.365
1994	110,516	15.485	114	49.07	3.09	0.08	-0.777	0.469	0.192
1995	555,041	138.797	203	67.55	15.52	0.71	-1.149	0.481	0.581
1996	470,881	71.604	123	56.39	13.17	0.37	-0.235	0.806	0.719
1997	160,921	8.174	41	47.24	4.50	0.04	-0.542	0.735	0.824
1998	683,024	178.028	211	82.31	19.10	0.91	-0.764	0.377	-0.438
1999	223,967	44.198	160	47.91	6.26	0.23	0.543	0.918	1.174
2000	425,118	148.916	284	60.11	11.89	0.76	-1.359	0.788	0.425
2001	54,838	10.543	156	39.14	1.53	0.05	-0.288	1.109	0.884
2002	419,512	68.369	132	47.01	11.73	0.35	-1.355	0.762	0.476
2003	593,953	116.200	159	63.32	16.61	0.60	0.262	0.745	0.873
2004	608,979	104.848	140	50.31	17.03	0.54	0.282	0.838	1.053
2005	526,704	47.038	72	59.74	14.73	0.24	2.161	0.913	1.430
2006	651,415	26.793	33	61.15	18.21	0.14	-1.427	0.770	0.156
2007	86,663	24.679	231	32.72	2.42	0.13	-0.551	0.906	0.961
2008	75,414	16.480	177	44.16	2.11	0.08	2.482	0.712	1.140
2009	434,150	120.876	226	44.53	12.14	0.62	0.631	1.274	1.404
2010	243,614	43.948	146	54.00	6.81	0.23	-1.842	0.630	-0.117
Minimum	54,838	8.174	33	32.72	1.53	0.04	-1.842	0.377	-0.438
Average	339,884	75.959	181	51.64	9.50	0.39	-0.110	0.739	0.667
Maximum	851,549	197.316	377	82.31	23.81	1.01	2.710	1.274	1.430
Std. Dev.	222,855	52.862	84	9.77	6.23	0.27	1.203	0.177	0.488
Skewness	0.478	0.630	0.096	0.852	0.478	0.63	0.771	0.648	-0.227
Median	299,300	64.550	195	49.69	8.37	0.33	-0.282	0.746	0.650

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Table 3-17. Comparison of Base Period with period of record data for Lower Kissimmee Sub-watershed.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1977-2010					
Annual Minimum	54,838	8.174	33	32.72	0.04
Annual Average	339,884	75.959	181	51.64	0.39
Annual Median	299,300	64.550	195	49.69	0.33
Annual Maximum	851,549	197.316	377	82.31	1.01
Base Period WY1977-1990					
Annual Minimum	80,459	19.994	99	39.33	0.10
Annual Average	305,644	79.903	212	48.78	0.41
Annual Median	227,196	56.061	259	47.42	0.29
Annual Maximum	851,549	197.316	377	61.84	1.01
Difference between Period of Record and Base Period					
Annual Minimum	-25,621	-11.820	-66	-6.61	-0.06
Annual Average	34,241	-3.944	-31	2.86	-0.02
Annual Median	72,104	8.489	-64	2.28	0.04
Annual Maximum	0	0.000	0	20.47	0.00
Annual Minimum	-32%	-59%	-67%	-17%	-59%
Annual Average	11%	-5%	-15%	6%	-5%
Annual Median	32%	15%	-25%	5%	15%
Annual Maximum	0%	0%	0%	33%	0%
WY2001-2010					
Annual Minimum	54,838	10.543	33	32.72	0.05
Annual Average	369,524	57.977	127	49.61	0.30
Annual Median	426,831	45.493	151	48.66	0.23
Annual Maximum	651,415	120.876	231	63.32	0.62
Difference between WY2001-2010 and Base Period					
Annual Minimum	-25,621	-9.451	-66	-6.61	-0.05
Annual Average	63,881	-21.925	-85	0.83	-0.11
Annual Median	199,636	-10.568	-108	1.25	-0.05
Annual Maximum	-200,134	-76.440	-146	1.48	-0.39
Annual Minimum	-32%	-47%	-67%	-17%	-47%
Annual Average	21%	-27%	-40%	2%	-27%
Annual Median	88%	-19%	-42%	3%	-19%
Annual Maximum	-24%	-39%	-39%	2%	-39%

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2311 **3.2.1.2 Performance Measure Methodology**

2312
2313 Based on the evaluation of individual land use source control effectiveness ranges described
2314 in Section 2.6, the overall range of TP load reduction that could be accomplished through
2315 collective source controls within the basin was estimated, and a load reduction target of 30
2316 percent was determined to be reasonable and appropriate. Details are provided in Appendix
2317 D and in Attachment 1.

2318
2319 An Annual Load Target and an Annual Load Limit were derived from the Base Period data
2320 using a 30 percent load reduction. The Annual Load Target and Annual Load Limit for the
2321 Lower Kissimmee Sub-watershed will be calculated according to the following
2322 equations and explanation:

2323
2324 Target = $[-8.42963 + 0.31747 X]^2$
2325 Explained Variance = 75.1%, Standard Error of Regression¹¹ = 1.33557
2326 Predictor X is calculated from the first moment (m_1) of the 12 monthly rainfall
2327 totals (r_i , $i=1$ to 12, inches) for the Evaluation Year:

2328 $m_1 = \text{Sum} [r_i] / 12$

2329 $X = 12 m_1$

2330 Limit = $[\text{sqrt}(\text{Target}) + (1.35622 \text{ SE})]^2$

2331 SE = standard error of the predicted sqrt(Load) for May-April
2332 interval

2333 $\text{SE} = 1.33557 [1 + 1/14 + (X-X_m)^2 / 641.63129]^{0.5}$

2334 Where:

2335 X = the 12-month total rainfall (inches)

2336 X_m = average value of the predictor in base period = 48.7771 inches

¹¹ The standard error of the regression equation is expressed in the same units as the transformed load, i.e., sqrt(metric tons).





2337

2338 The predictor X indicates that load increases with total annual rainfall.

2339

2340 A comparison of the scaled loads and the resulting Targets and Limits for the Base Period
2341 are presented in **Figure 3-11**. Annual TP loads at S-65E, adjusted to account for pass-
2342 through loads as described in Appendix A and regional projects (if applicable), will be
2343 evaluated against the performance measure described above.

2344

2345 **Suspension of Performance Determination.** The performance determination will be
2346 suspended due to rainfall conditions if the observed annual TP load for the sub-watershed,
2347 adjusted for regional projects (if present), exceeds the Annual Load Target and the rainfall
2348 falls outside the range of observed rainfall values for the Base Period (39.33 – 61.84 inches).
2349 The calculated Annual Load Targets and Annual Load Limits for the rainfall conditions
2350 observed during the WY1977-2010 period of record are summarized in **Table 3-18**.

2351

2352 The annual performance determination process will account for pass-through loads and
2353 regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

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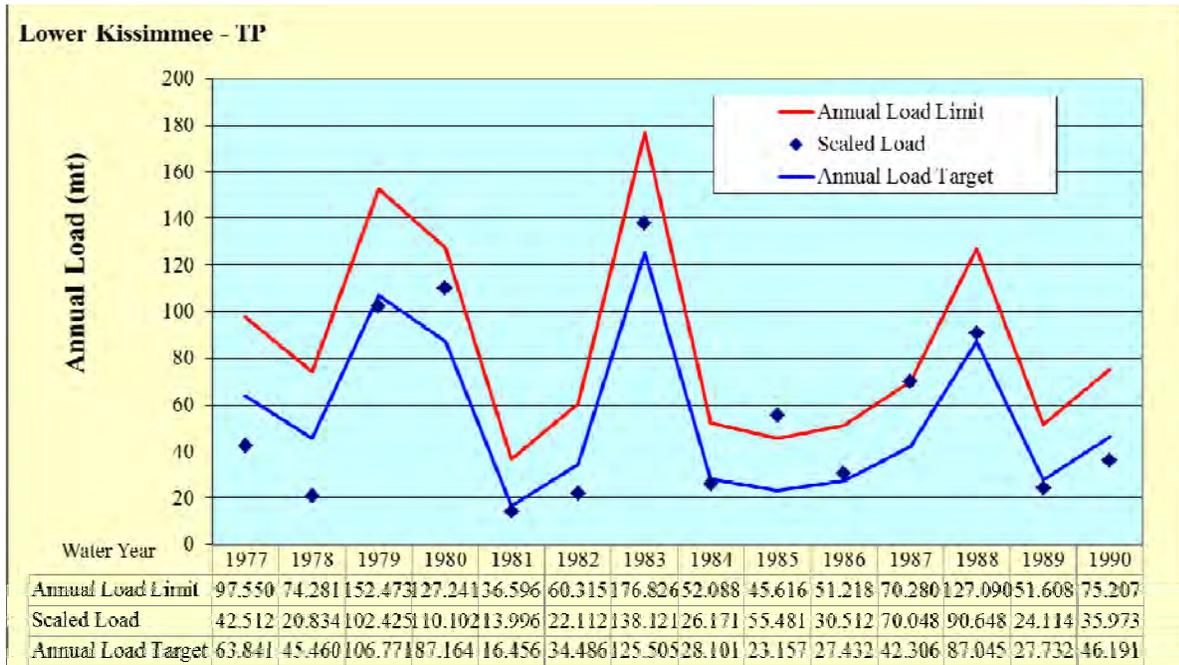
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Figure 3-11. Comparison of scaled annual loads with the Annual Load Targets and Limits for the Lower Kissimmee Sub-watershed.



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Table 3-18. Estimates of annual Load Targets and Limits for the historical period of record for the Lower Kissimmee Sub-watershed (Base Period: WY1977-1984).

Water Year	Observed Load, mt	Rain inches	Target Load, mt	Limit Load, mt
1977	60.731	51.72	63.841	97.550
1978	29.763	47.79	45.460	74.281
1979	146.321	59.10	106.771	152.473
1980	157.288	55.96	87.164	127.241
1981	19.994	39.33	16.456	36.596
1982	31.589	45.05	34.486	60.315
1983	197.316	61.84	125.505	176.826
1984	37.387	43.25	28.101	52.088
1985	79.258	41.71	23.157	45.616
1986	43.588	43.05	27.432	51.218
1987	100.068	47.04	42.306	70.280
1988	129.497	55.94	87.045	127.090
1989	34.449	43.14	27.732	51.608
1990	51.390	47.96	46.191	75.207
1991	73.414	51.37	62.078	95.316
1992	118.047	52.11	65.835	100.077
1993	87.536	62.62	131.114	184.163
1994	15.485	49.07	51.105	81.429
1995	138.797	67.55	169.407	234.751
1996	71.604	56.39	89.731	130.530
1997	8.174	47.24	43.136	71.333
1998	178.028	82.31	313.345	430.371
1999	44.198	47.91	45.975	74.934
2000	148.916	60.11	113.500	161.193
2001	10.543	39.14	15.970	35.926
2002	68.369	47.01	42.182	70.123
2003	116.200	63.32	136.253	190.902
2004	104.848	50.31	56.888	88.746
2005	47.038	59.74	111.011	157.964
2006	26.793	61.15	120.644	170.485
2007	24.679	32.72	3.834	17.278
2008	16.480	44.16	31.248	56.156
2009	120.876	44.53	32.575	57.863
2010	43.948	54.00	75.932	112.904

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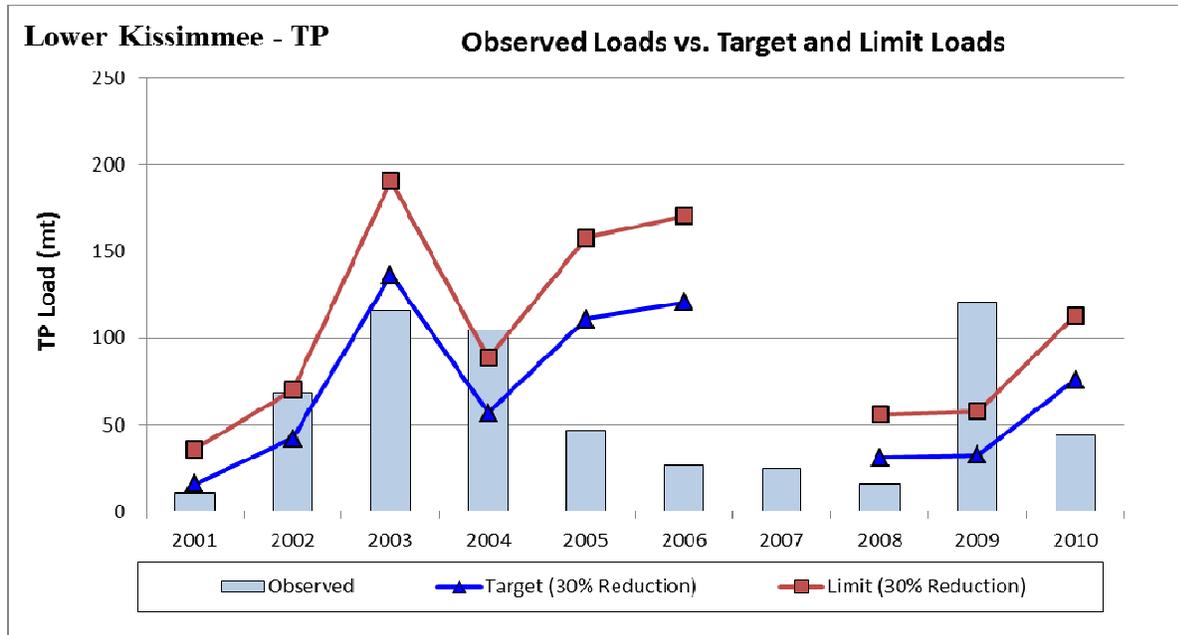
Note: Shaded water years indicate the performance determination would have been suspended due to anomalous rainfall coupled with the observed load being greater than the Load Target.





2391 **Comparison to WY2001-2010.** A comparison of the loads observed during WY2001-2010
2392 to the Annual Load Targets and Limits is presented in **Figure 3-12.**

2393
2394 **Figure 3-12. Comparison of WY2001-2010 observed loads to the Annual Load Targets**
2395 **and Limits for the Lower Kissimmee Sub-watershed.**
2396



2397
2398 Note: The performance determination for WY2007 would have been suspended due to rainfall below the
2399 minimum value during the Base Period coupled with the observed load being greater than the Load Target.
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2402 **Exceedance Frequency Analysis.** As shown in **Figure 3-11**, although the scaled observed
2403 loads fall above the Annual Load Targets exactly half the time (seven out of fourteen years),
2404 the scaled observed load for WY1985 exceeded the calculated Annual Load Limit. In
2405 accordance with the proposed performance determination process discussed in Section 2.6,
2406 having the observed load exceed the Annual Load Limit would prevent the basin from
2407 meeting its performance measure for that year. In the case of the scaled Base Period data,





2408 this is an example of a Type I error¹², or “false positive” - when the performance method
 2409 suggests a lack of compliance when the basin’s load actually achieves the long-term
 2410 reduction goals. While this occurrence is not common, it is statistically possible. The use of
 2411 the upper 90 percent confidence limit for the Annual Load Limit is consistent with the
 2412 District’s Chapter 40E-63 F.A.C., and has a theoretical Type I error (i.e., false positive) rate
 2413 of approximately ten percent. Using the approach described in Section 2.6, an approximation
 2414 of the cumulative exceedance frequency for the determination methodology was estimated
 2415 using a Monte Carlo approach based on the annual rainfall and the annual TP loads of the
 2416 Base Period (**Table 3-19**). Because the TP loads and rainfall statistics from the Base Period
 2417 do not perfectly describe normal distributions (e.g., the medians are generally less than the
 2418 means), the methodology includes conditional probabilities, and because the random number
 2419 generator is imperfect, the exceedance frequencies deviate from the theoretical values shown
 2420 in the second column. However, the results are determined to be reasonable and defensible
 2421 since the cumulative exceedance frequency is less than the theoretical value of approximately
 2422 17.5 percent.

2423

2424 **Table 3-19. Exceedance frequencies for the proposed determination methodology for**
 2425 **the Lower Kissimmee Sub-watershed.**

2426

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Rain is outside the range and Load > Annual Load Target	<20%	5.9%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	11.1%
Step 4. Load > Annual Load Limit?	<10%	6.3%
Cumulative Exceedance Frequency	<17.5%	15.6%

2427

¹² The Type I error rate is the probability that the performance measure methodology will reject the null hypothesis (i.e., a determination that the TP load does not meet the performance measure) when in reality the null hypothesis is true – the annual load meets the performance measure, and is therefore also known as the false positive rate.





2428 **3.3 East Lake Okeechobee Sub-watershed**

2429
2430 The C-44 Hydrologic Unit and the L-8 Summary Basin, collectively referred to as the East
2431 Lake Okeechobee Sub-watershed, drain into Lake Okeechobee from the east. The C-44
2432 Canal discharges into Lake Okeechobee through the navigation lock S-308, and also
2433 discharges to the St Lucie Canal and estuary to the east through spillway S-80. The L-8
2434 Canal discharges into Lake Okeechobee through gated Culvert 10A, and also discharges to
2435 the southeast through numerous water control structures. In total, the East Lake Okeechobee
2436 Sub-watershed comprises 239,013 acres located east of Lake Okeechobee (**Figure 3-13**).

2437 The following sections describe the derivation of the performance measure methodologies
2438 for the basins within the East Lake Okeechobee Sub-watershed.

2439 **3.3.1 C-44 Hydrologic Unit**

2440
2441 The C-44 Hydrologic Unit is composed of 132,572 acres located in Martin County. Inflows
2442 enter the basin from Lake Okeechobee via S-308. Outflows from the C-44 Hydrologic Unit
2443 are discharged in two directions: to Lake Okeechobee at S-308 (when lake stages are at, or
2444 below 14.5 feet, NGVD), and to the St Lucie Estuary at S-80. Flow and TP monitoring sites
2445 are identified in **Tables C-1** and **C-2**. The performance measure methodology for the C-44
2446 Hydrologic Unit was developed by HDR Engineering, Inc. (HDR 2011c) and is summarized
2447 herein. It is based on flows and TP loads resulting from rainfall and runoff from the C-44
2448 Hydrologic Unit and accounts for pass-through flows and loads from Lake Okeechobee. The
2449 performance measure methodology is based on the total discharges from the basin to Lake
2450 Okeechobee and the St. Lucie Estuary. A few refinements were made to the performance
2451 measure methodology developed by HDR, including

- 2452 1. As part of a general review of load reductions across the entire Lake Okeechobee
2453 Watershed, District staff rounded the load reduction for the C-44 Hydrologic Unit
2454 from 33 percent to 35 percent in recognition of inherent uncertainty (see Section 2.6).



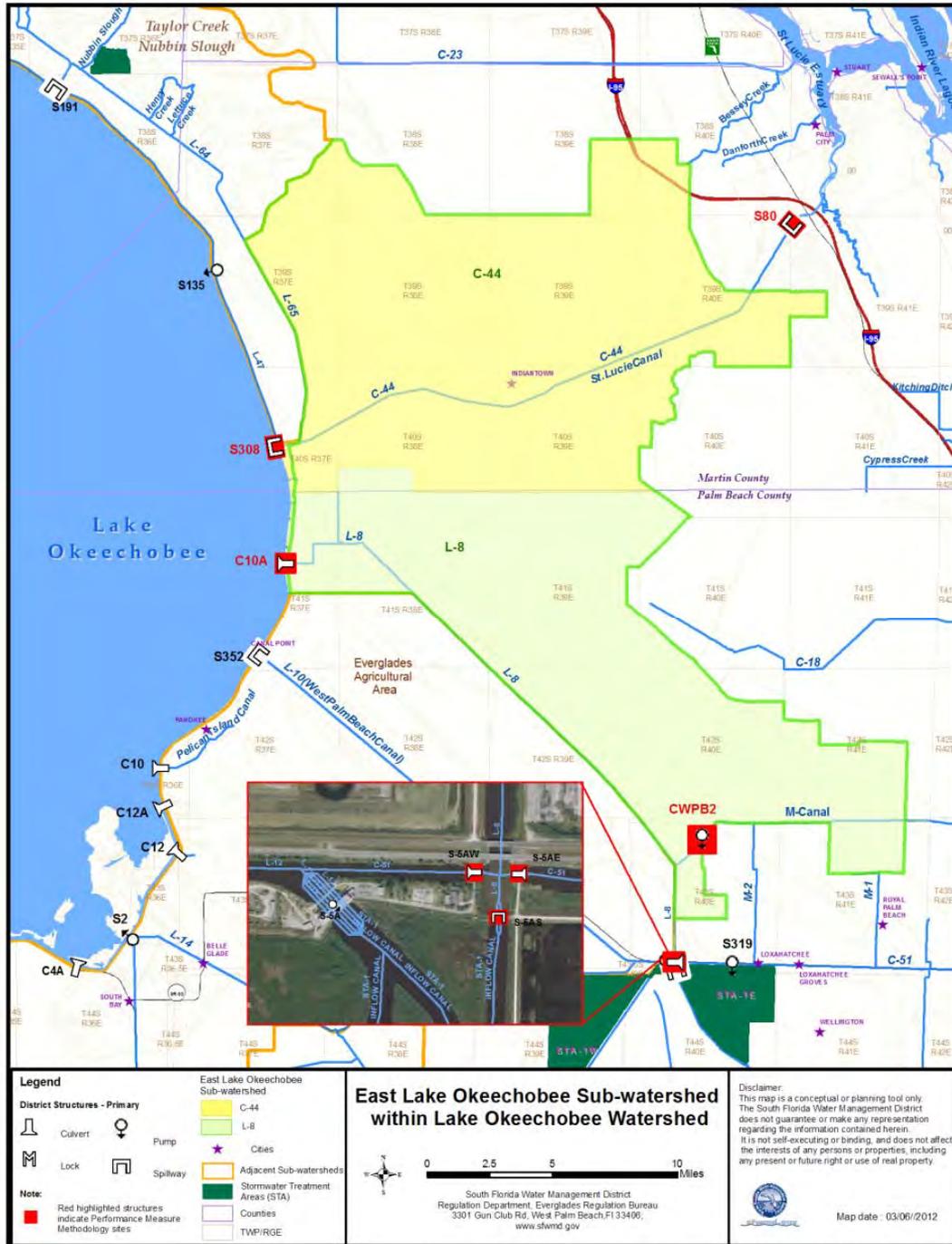


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Figure 3-13. East Lake Okeechobee Sub-watershed boundary and discharge monitoring locations.



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- 2458 2. A different protocol for significant digits was utilized in the Lake Okeechobee
- 2459 Watershed compared to the protocols used in the St. Lucie River Watershed, and this
- 2460 resulted in slight refinements to the regression equation coefficients.
- 2461 3. The rainfall data were revised for the C-44 Hydrologic Unit.
- 2462 4. A minor refinement was made to the C-44 Hydrologic Unit boundary to add
- 2463 approximately 2,850 acres of contributing area from Basin 8.

2464

2465 As a result of these refinements, the performance measure was slightly revised from that

2466 found in the HDR final report (HDR 2011c).

2467

2468 **3.3.1.1 Background**

2469 Basin flows and loads from the C-44 Hydrologic Unit, adjusted for pass-through flows and

2470 loads discharged from Lake Okeechobee, were calculated using algorithms provided in

2471 Appendix A. **Table 3-20** provides a summary of the historical flow, load, and rainfall data

2472 for the C-44 Hydrologic Unit for the period of record WY1982-2010. The pass-through

2473 calculations for WY1998 yielded negative TP load and concentration, reflecting a decrease in

2474 TP concentrations as the pass-through flows transited the basin. District staff identified four

2475 rainfall stations considered to be representative of the C-44 Hydrologic Unit. Weighting

2476 factors, based on the Thiessen polygon areas for each rainfall station, were used to calculate

2477 daily basin rainfall values. **Figure 3-14** presents a schematic of the Thiessen polygon areas

2478 represented by each of the rainfall stations. For the development of the performance measure

2479 methodology, a base period of WY2000-2010 was selected for the following reasons (HDR

2480 2011c).

- 2482 • Basin water management operations during the Base Period (WY2000-2010)
- 2483 were similar to current operating conditions (represented by WY2001-2010).
- 2484 • It provides a strong relationship between rainfall and nutrient load,





- 2485 • Some level of source control implementation occurred, but no affects were
- 2486 observed in the basin’s nutrient load levels.
- 2487 • Flow and nutrient concentration data are available and monitoring is ongoing,
- 2488 • No significant trends were identified for the monthly or annual data, and
- 2489 • Rainfall patterns during this period are reasonably representative of long-term
- 2490 conditions.

Table 3-20. Summary of historical data for the C-44 Hydrologic Unit.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics		
							Kurtosis K	Coef. Of Var. CV	Skewness S
1981				37.17			0.326	0.708	0.830
1982	33,047	5.929	145	51.15	2.99	0.10	1.913	0.917	1.413
1983	200,611	37.047	150	70.12	18.16	0.62	-0.839	0.491	0.138
1984	216,426	28.397	106	58.90	19.59	0.47	-0.732	0.630	0.360
1985	192,015	51.046	216	47.82	17.38	0.85	-0.771	0.704	-0.004
1986	231,135	54.573	191	46.55	20.92	0.91	0.826	0.797	0.933
1987	157,737	41.639	214	50.89	14.28	0.69	3.789	0.859	1.622
1988	283,537	51.434	147	48.34	25.66	0.86	-0.706	0.580	0.143
1989	280,212	52.858	153	40.56	25.36	0.88	-0.944	0.724	0.310
1990	245,572	43.126	142	45.17	22.23	0.72	-0.369	0.774	0.808
1991	148,999	27.331	149	54.32	13.49	0.45	-0.722	0.626	0.265
1992	209,544	38.721	150	41.83	18.97	0.64	-0.819	0.601	0.359
1993	359,996	72.273	163	68.22	32.59	1.20	0.742	0.792	0.962
1994	177,180	29.672	136	57.09	16.04	0.49	-0.100	0.470	0.086
1995	439,087	83.710	155	67.89	39.74	1.39	-1.129	0.472	0.209
1996	307,569	71.564	189	70.58	27.84	1.19	-0.165	0.993	0.891
1997	129,269	19.529	122	47.22	11.70	0.32	-1.053	0.497	0.311
1998	157,244	-20.791	-107	57.74	14.23	-0.35	-0.642	0.463	-0.241
1999	148,623	27.924	152	45.45	13.45	0.46	0.431	0.844	1.129
2000	218,672	54.759	203	50.95	19.79	0.91	-0.418	0.795	0.727
2001	106,872	18.805	143	33.53	9.67	0.31	-1.050	0.913	0.619
2002	140,276	52.861	306	52.48	12.70	0.88	-0.608	0.795	0.738
2003	131,019	35.645	221	46.68	11.86	0.59	0.161	0.722	0.991
2004	200,497	69.692	282	40.07	18.15	1.16	0.910	0.865	1.247
2005	207,987	83.848	327	54.20	18.83	1.39	3.895	1.160	1.834
2006	370,613	121.520	266	59.63	33.55	2.02	1.091	0.921	1.096
2007	58,545	14.779	205	30.41	5.30	0.25	-0.764	0.825	0.728
2008	189,664	74.924	320	57.53	17.17	1.25	-1.420	0.535	0.176
2009	118,819	52.596	359	44.41	10.76	0.87	2.324	1.034	1.441
2010	136,617	37.478	222	44.84	12.37	0.62	-0.691	0.545	0.085
Minimum	33,047	5.929	106	30.41	2.99	0.10	-1.420	0.470	-0.004
Average	201,434	48.346	195	50.96	18.23	0.80	0.099	0.746	0.701
Maximum	439,087	121.520	359	70.58	39.74	2.02	3.895	1.160	1.834
Std. Dev.	92,060	25.167	68	10.24	8.33	0.42	1.407	0.182	0.517
Skewness	0.710	0.836	0.963	0.299	0.710	0.84	1.558	0.187	0.480
Median	196,256	47.086	176	49.62	17.76	0.78	-0.513	0.783	0.728

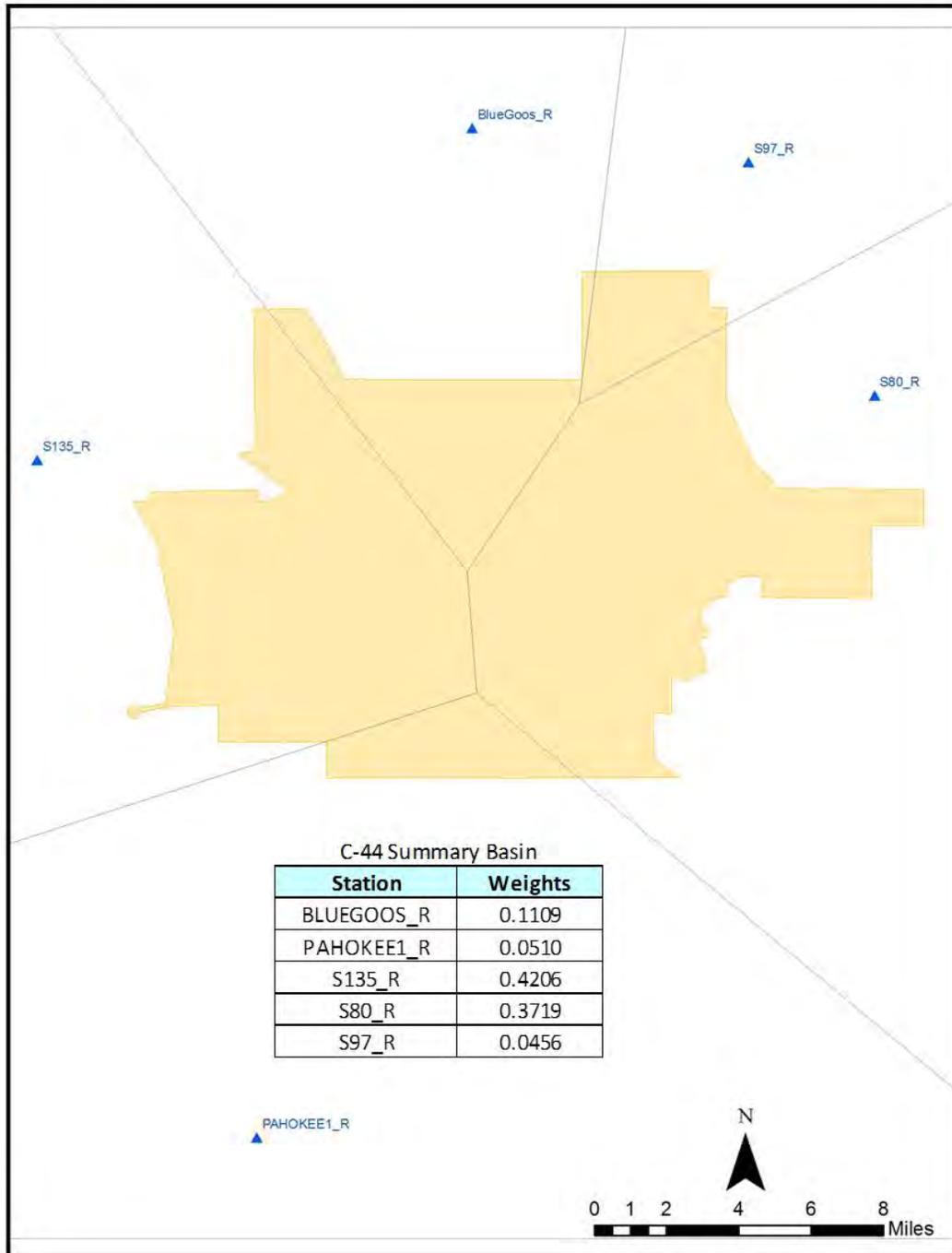
- Notes:
1. Summary statistics exclude WY1998 due to negative TP levels.
 2. Slight differences in values presented in HDR (2011c) are due to different protocol for significant digits, revised rainfall data, and a different estimate of basin area.

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2496 Figure 3-14. Schematic of the C-44 Hydrologic Unit and the selected rainfall stations.



2497





2498 Table 3-21 compares rainfall, flow, and TP data for the WY 2000-2010 base period with the
2499 WY1982-2010 period of record and the recent WY2001-2010 period.

2500

2501 **Table 3-21. Comparison of base period with period of record data for the C-44**
2502 **Hydrologic Unit.**

2503

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1982-2010					
Annual Minimum	33,047	5.929	106	30.41	0.10
Annual Average	201,434	48.346	195	50.96	0.80
Annual Median	196,256	47.086	176	49.62	0.78
Annual Maximum	439,087	121.520	359	70.58	2.02
Base Period WY2000-2010					
Annual Minimum	58,545	14.779	143	30.41	0.25
Annual Average	170,871	56.082	266	46.79	0.93
Annual Median	140,276	52.861	266	46.68	0.88
Annual Maximum	370,613	121.520	359	59.63	2.02
Difference between Period of Record and Base Period					
Annual Minimum	-25,498	-8.850	-37	0.00	-0.15
Annual Average	30,563	-7.737	-72	4.16	-0.13
Annual Median	55,980	-5.775	-90	2.94	-0.10
Annual Maximum	68,474	0.000	0	10.95	0.00
Annual Minimum	-44%	-60%	-26%	0%	-60%
Annual Average	18%	-14%	-27%	9%	-14%
Annual Median	40%	-11%	-34%	6%	-11%
Annual Maximum	18%	0%	0%	18%	0%
WY2001-2010					
Annual Minimum	58,545	14.779	143	30.41	0.25
Annual Average	166,091	56.215	274	46.38	0.93
Annual Median	138,447	52.729	274	45.76	0.88
Annual Maximum	370,613	121.520	359	59.63	2.02
Difference between WY2001-2010 and Base Period					
Annual Minimum	0	0.000	0	0.00	0.00
Annual Average	-4,780	0.132	8	-0.42	0.00
Annual Median	-1,830	-0.133	8	-0.92	0.00
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	0%	0%	0%	0%	0%
Annual Average	-3%	0%	3%	-1%	0%
Annual Median	-1%	0%	3%	-2%	0%
Annual Maximum	0%	0%	0%	0%	0%

2504





2505 **3.3.1.2 Performance Measure Methodology**

2506
2507 Based on the evaluation of individual land use source control effectiveness ranges described
2508 in Section 2.6, the overall range of TP load reduction that could be accomplished through
2509 collective source controls within the basin was estimated, and a load reduction target of 35
2510 percent was determined to be reasonable and appropriate. Details are provided in Appendix
2511 D and in the *Data Analysis and Performance Measure Development for the St. Lucie River*
2512 *Watershed Source Control Program* (HDR 2011c).

2513
2514 An Annual Load Target and an Annual Load Limit were derived from the Base Period data
2515 using a 35 percent load reduction. The Annual Load Target and Annual Load Limit and
2516 adjusted rainfall for the C-44 Hydrologic Unit will be calculated according to the
2517 following equations and explanation.

2518
2519 Target = exp [-6.33102 + 2.47876 X + 0.32418 S]

2520 Explained Variance = 83.9%, Standard Error of Regression¹³ = 0.28227

2521 Predictors (X and S) are calculated from the first three moments (m₁,
2522 m₂, m₃) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the
2523 Evaluation Year:

2524 $m_1 = \text{Sum} [r_i] / 12$

2525 $m_2 = \text{Sum} [r_i - m_1]^2 / 12$

2526 $m_3 = \text{Sum} [r_i - m_1]^3 / 12$

2527 $X = \ln (12 m_1)$

2528 $S = (12/11) m_3 / m_2^{1.5}$

2529
¹³ The standard error of the regression equation is expressed in the same units as the transformed load, i.e., ln(metric tons).





2530 Limit = Target * exp (1.39682 SE)

2531 SE = standard error of the predicted ln(Load) for May-April
2532 interval

2533
$$SE = 0.28227 [1 + 1/11 + 2.17743 (X-X_m)^2 + 0.37715 (S-S_m)^2 -$$

2534
$$0.19128 (X-X_m) (S-S_m)]^{0.5}$$

2535
2536 Where:

2537 X = natural logarithm of the 12-month total rainfall (ln(inches))

2538 X_m = average value of the predictor in base period = 3.82565

2539 S = is the skewness of the annual rainfall calculated from 12 monthly rainfall
2540 totals

2541 S_m = average value of the predictor in base period = 0.88018

2542
2543 The first predictor (X) indicates that load increases exponentially with total annual rainfall.
2544 The second predictor (S) indicates that the load resulting from a given annual rainfall is
2545 higher when the distribution of monthly rainfall has higher skewness. For a given annual
2546 rainfall, the lowest load occurs when rainfall is evenly distributed across months and the
2547 highest load occurs when all of the rain falls in one month. Real cases fall in between.

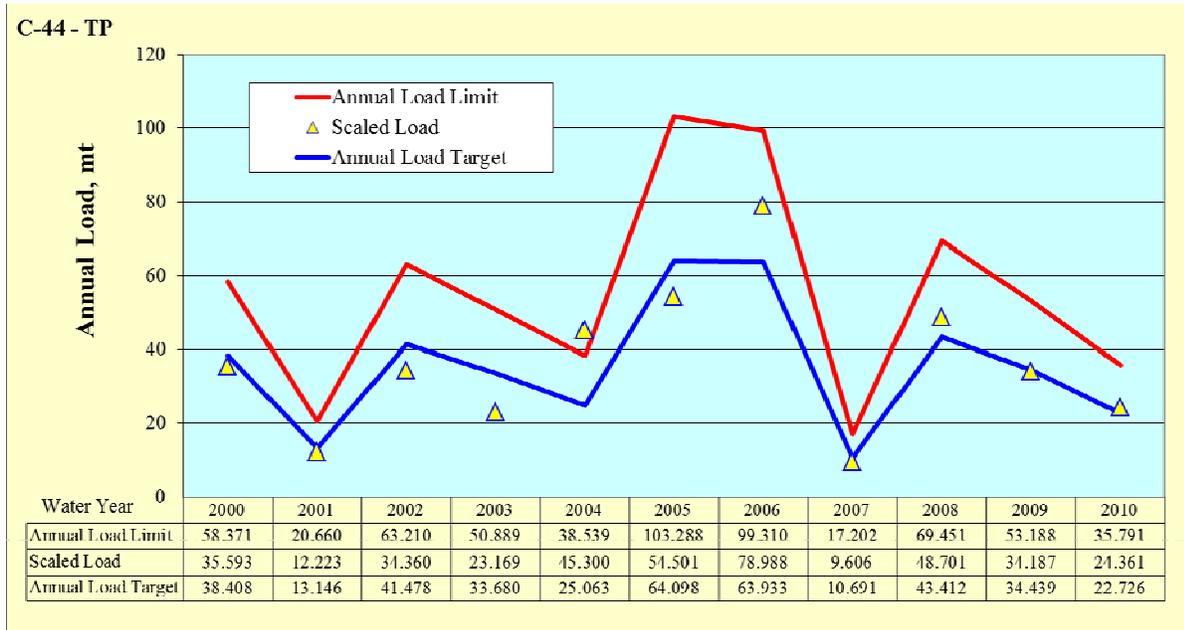
2548
2549 A comparison of the scaled loads and the resulting Targets and Limits for the Base Period
2550 are presented in **Figure 3-15**. The combined annual TP loads at S-308 and S-80, adjusted
2551 to account for pass-through loads as described in Appendix A and regional projects (if
2552 applicable), will be evaluated against the performance measure described above.

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2557 **Figure 3-15. Comparison of scaled annual TP loads with the Annual Load Targets and**
2558 **Limits for the C-44 Hydrologic Unit.**
2559



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2563 **Suspension of Performance Determination:** The performance determination will be
2564 suspended due to rainfall conditions if the observed annual TP load, adjusted for regional
2565 projects (if present), from the basin exceeds the Annual Load Target and the adjusted rainfall
2566 falls outside the range of adjusted rainfall values for the Base Period (29.81 to 61.40 inches),
2567 as derived below. Rainfall conditions will be assessed by calculating an adjusted rainfall
2568 amount which reflects the cumulative effect of the two variables that comprise the Load
2569 Target equation: Rain and S:

2570
2571 Adjusted Rainfall = equivalent rainfall for mean S variable (inches)

2572
2573 $Rain_{adj} = \exp[\ln(Rain) + 0.13078 (S - 0.88018)]$

2574





2575 **Table 3-22** shows the calculated adjusted rainfall values, Annual Load Targets and Annual
2576 Load Limits for the period of record.

2577
2578 The annual performance determination process will account for pass-through loads and
2579 regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

2580
2581 **Comparison to WY2001-2010.** A comparison of the loads observed during WY2001-2010
2582 to the Annual Load Targets and Limits is presented in **Figure 3-16**.

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Technical Support Document
Lake Okeechobee Watershed Performance Measures

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Table 3-22. Annual adjusted rainfall for the period of record for the C-44 Hydrologic Unit (Base Period: WY2000-2010).

Water Year	Observed Load, mt	Observed Rain, in	Skewness	Target Load, mt	Limit Load, mt	Adjusted Rain, in
1982	5.929	51.15	1.413	48.442	74.781	54.84
1983	37.047	70.12	0.138	70.032	118.007	63.63
1984	28.397	58.90	0.360	48.848	77.286	55.03
1985	51.046	47.82	-0.004	25.897	41.268	42.60
1986	54.573	46.55	0.933	32.825	49.563	46.87
1987	41.639	50.89	1.622	51.188	80.342	56.07
1988	51.434	48.34	0.143	27.899	43.805	43.90
1989	52.858	40.56	0.310	19.063	29.535	37.65
1990	43.126	45.17	0.808	29.255	44.181	44.75
1991	27.331	54.32	0.265	38.755	60.919	50.12
1992	38.721	41.83	0.359	20.907	32.216	39.07
1993	72.273	68.22	0.962	85.455	136.943	68.95
1994	29.672	57.09	0.086	41.368	66.685	51.46
1995	83.710	67.89	0.209	66.146	109.698	62.18
1996	71.564	70.58	0.891	90.856	147.130	70.68
1997	19.529	47.22	0.311	27.798	42.954	43.83
1998	-20.791	57.74	-0.241	38.266	64.273	49.86
1999	27.924	45.45	1.129	32.965	49.986	46.95
2000	54.759	50.95	0.727	38.408	58.371	49.94
2001	18.805	33.53	0.619	13.146	20.660	32.40
2002	52.861	52.48	0.738	41.478	63.210	51.51
2003	35.645	46.68	0.991	33.680	50.889	47.36
2004	69.692	40.07	1.247	25.063	38.539	42.04
2005	83.848	54.20	1.834	64.098	103.288	61.40
2006	121.520	59.63	1.096	63.933	99.310	61.34
2007	14.779	30.41	0.728	10.691	17.202	29.81
2008	74.924	57.53	0.176	43.412	69.451	52.47
2009	52.596	44.41	1.441	34.439	53.188	47.79
2010	37.478	44.84	0.085	22.726	35.791	40.41

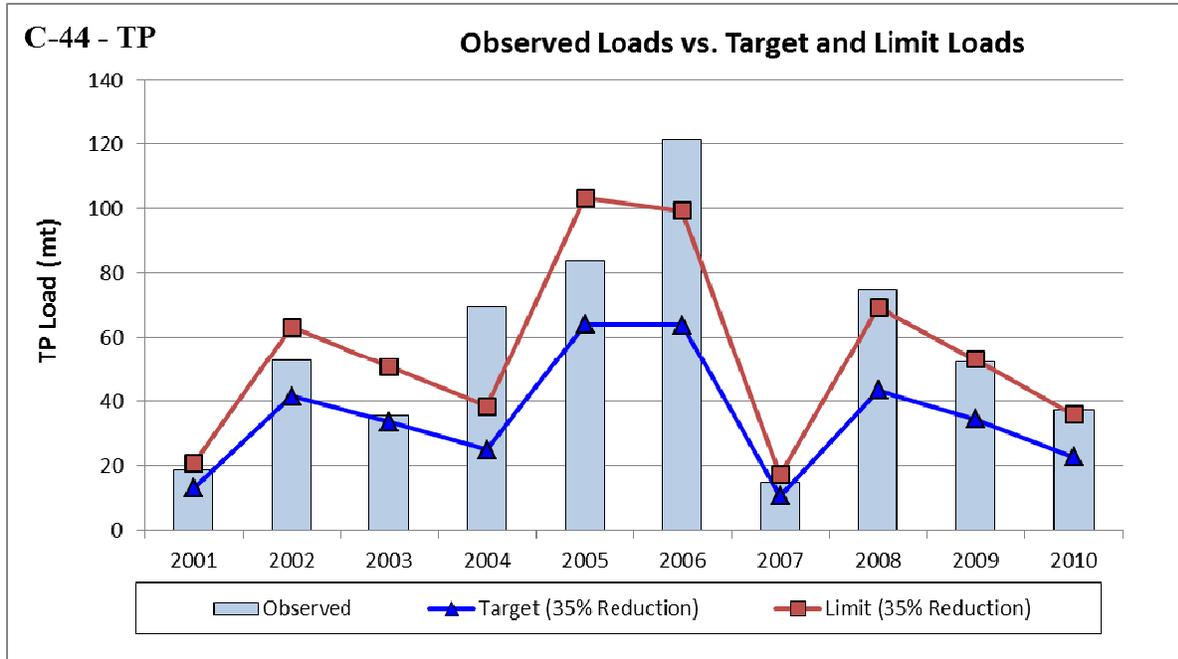
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Note: Shaded water years indicate the performance determination would have been suspended due to anomalous rainfall coupled with the observed load being greater than the Load Target.





2621 **Figure 3-16. Comparison of WY2001-2010 observed loads to the Annual Load Targets**
2622 **and Limits for the C-44 Hydrologic Unit.**
2623



2624
2625 Note: The Base Period extended from WY2000-2010.
2626

2627 **Exceedance Frequency Analysis.** As shown in **Figure 3-15**, although the scaled observed
2628 loads fall above the Annual Load Targets less than half the time (three out of eleven years, or
2629 33 percent), the scaled observed load for WY2004 exceeded the calculated Annual Load
2630 Limit. In accordance with the proposed performance determination process discussed in
2631 Section 2.6, having the observed load exceed the Annual Load Limit would prevent the basin
2632 from meeting its performance measure for that year. In the case of the scaled Base Period
2633 data, this is an example of a Type I error¹⁴, or “false positive” - when the performance
2634 method suggests a lack of compliance when the basin’s load actually achieves the long-term
2635 reduction goals. While this occurrence is not common, it is statistically possible. The use of

¹⁴ The Type I error rate is the probability that the performance measure methodology will reject the null hypothesis (i.e., a determination that the TP load does not meet the performance measure) when in reality the null hypothesis is true – the annual load meets the performance measure, and is therefore also known as the false positive rate.





2636 the upper 90 percent confidence limit for the Annual Load Limit is consistent with the
 2637 District’s Chapter 40E-63 F.A.C., and has a theoretical Type I error (i.e., false positive) rate
 2638 of approximately ten percent. Using the approach described in Section 2.6, an approximation
 2639 of the cumulative exceedance frequency for the determination methodology was estimated
 2640 using a Monte Carlo approach based on the annual rainfall and the annual TP loads of the
 2641 Base Period (**Table 3-23**). Because the TP loads and rainfall statistics from the Base Period
 2642 do not perfectly describe normal distributions (e.g., the medians are generally less than the
 2643 means), the methodology includes conditional probabilities, and because the random number
 2644 generator is imperfect, the exceedance frequencies deviate from the theoretical values shown
 2645 in the second column. However, the results were determined to be reasonable and defensible
 2646 since the cumulative exceedance frequency is less than the theoretical value of approximately
 2647 17.5 percent.

2648
 2649 **Table 3-23. Exceedance frequencies for the proposed performance measure**
 2650 **methodology for the C-44 Hydrologic Unit.**
 2651

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Rain _{adj} is outside the range and Load > Annual Load Target	<20%	5.9%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	10.9%
Step 4. Load > Annual Load Limit?	<10%	4.1%
Cumulative Exceedance Frequency	<17.5%	13.8%

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2657 **3.3.2 L-8 Summary Basin**

2658
2659 The following sections present a description of the L-8 Summary Basin, a summary of
2660 historical flow and TP levels, the selection of a Base Period, an estimated range of load
2661 reductions attributable to collective source controls, and the derivation of the resulting
2662 performance measure.

2663 **3.3.2.1 Background**

2664
2665 The L-8 Summary Basin is located within the East Lake Okeechobee Sub-watershed and
2666 comprises 106,440 acres located east of Lake Okeechobee (**Figure 3-13**). A summary of the
2667 L-8 Summary Basin water control structures is presented in **Table 3-24 and Figure 3-17**;
2668 their locations are provided in **Figure 3-13**. The L-8 Summary Basin discharges stormwater
2669 runoff and other flows to multiple receiving waters:

- 2670 ➤ To Lake Okeechobee at Lake Culvert 10A (C-10A)

2671 The purpose of this structure is to provide irrigation releases from Lake
2672 Okeechobee to the agricultural lands along the L-8 Canal and to afford gravity
2673 drainage of that canal into Lake Okeechobee during flood periods, when the
2674 lake is lower than the canal (reference: SFWMD structure manual). During
2675 periods of water supply deliveries and regulatory releases from Lake
2676 Okeechobee, the flap gates at C-10A are raised and water flows into the L-8
2677 Canal.

- 2678 ➤ To the City of West Palm Beach’s Water Catchment Area through their Control
2679 Pump Station No. 2.

- 2680 ○ Flow data for this station is only available beginning May 1994, hence the
2681 historical data analysis for the L-8 Summary Basin began at this point in time.





2682

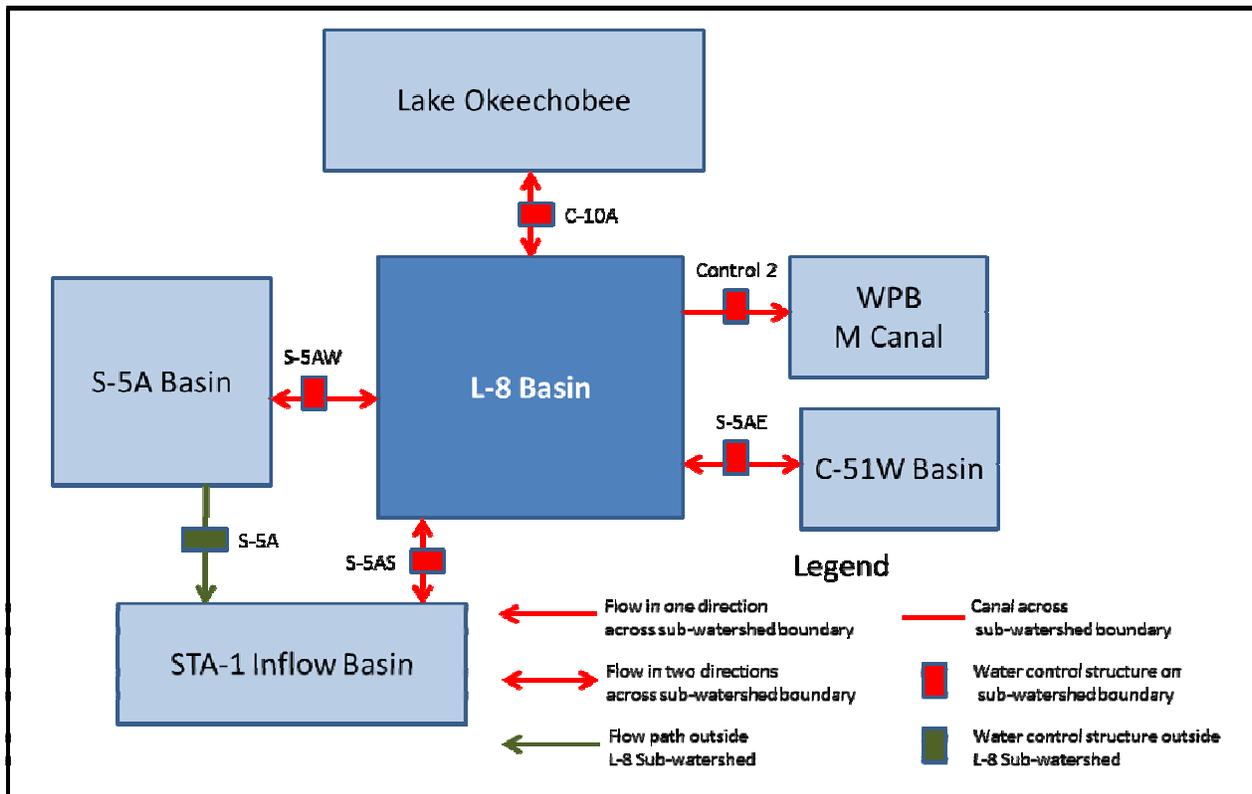
Table 3-24. L-8 Summary Basin inflow and outflow structures.

Structure	Inflow/Outflow	Discharges From	Discharges To
C-10A	Both	L-8 to Lake	Lake to L-8
S-5AS	Both	Prior to June 1999: L-8 to WCA-1; After June 1999: L-8 to STA-1 Inflow Basin	Prior to June 1999: WCA-1 to L-8; After June 1999: STA-1 Inflow Basin to L-8
S-5AE	Both	L-8 to C-51 W Canal	C-51 W Canal to L-8
S-5AW	Both	L-8 to West Palm Beach Canal in EAA	WPB Canal to L-8
Control 2	Out	L-8 Canal	M-1 Canal

2683

2684

Figure 3-17. Flow diagram for the L-8 Summary Basin



2685





- 2686 ➤ To Water Conservation Area 1 (WCA1) through S-5AS,
- 2687 ➤ To the West Palm Beach Canal Basin (also known as the S-5A Basin), part of the
- 2688 Everglades Agricultural Area (EAA) through S-5AW, and
- 2689 ➤ To C-51 West Basin through S-5AE.

2690 The L-8 Summary Basin receives inflows from multiple sources:

- 2691 ➤ from Lake Okeechobee at C-10A;
- 2692 ➤ from WCA-1 at S-5AS;
- 2693 ➤ from the C-51 West Basin at S-5AE, and
- 2694 ➤ from the West Palm Beach Canal Basin in the EAA at S-5AW.

2695 Basin flows and loads from the L-8 Summary Basin, adjusted for pass-through flows and

2696 loads, were calculated using algorithms provided in Appendix A.

2697 District staff identified four rainfall stations considered to be representative of the L-8

2698 Summary Basin. Weighting factors, based on the Thiessen polygon areas for each rainfall

2699 station, were used to calculate daily basin rainfall values. **Figure 3-18** presents a schematic

2700 of the Thiessen polygon areas represented by each of the rainfall stations.

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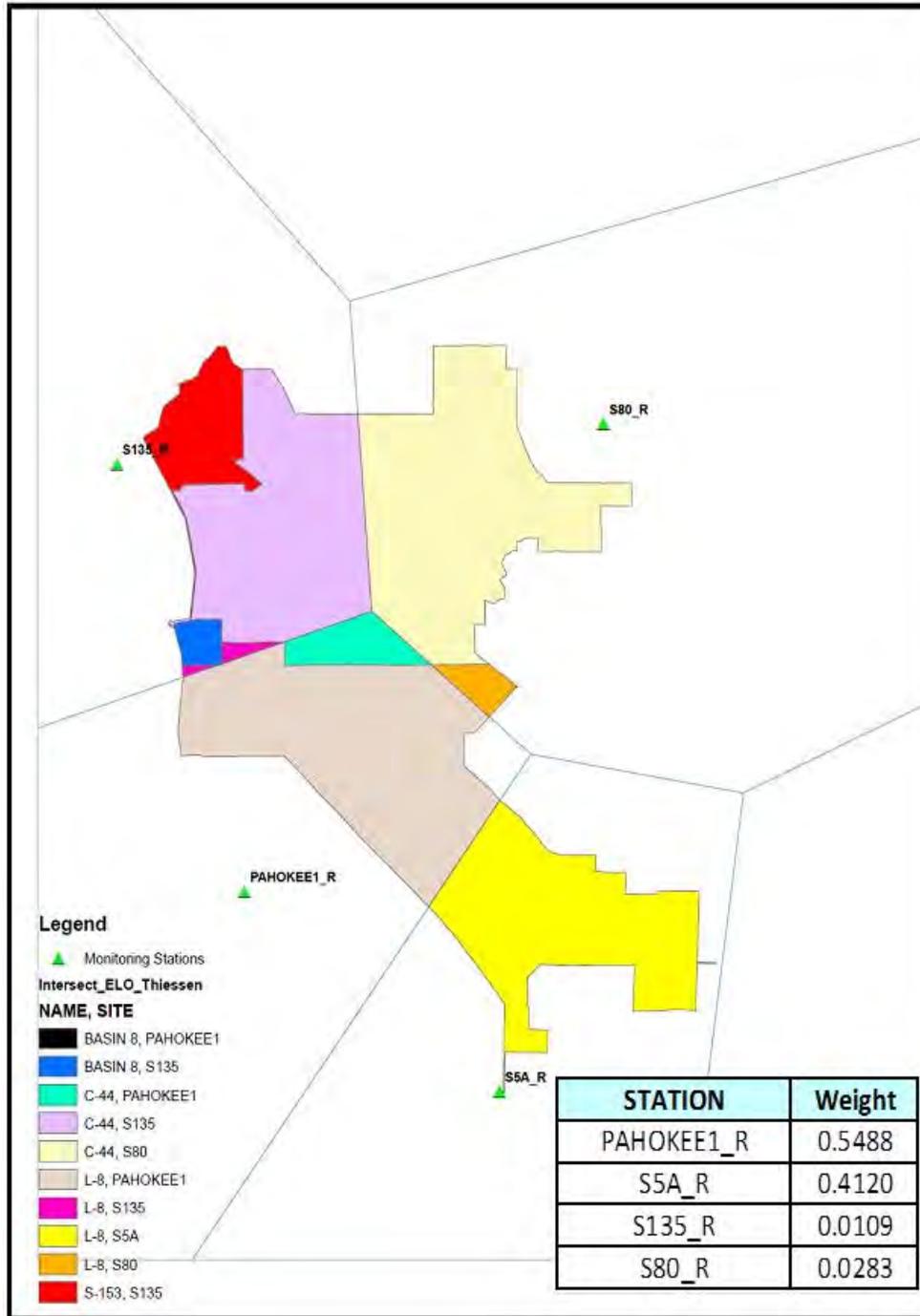
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2706

Figure 3-18. Schematic of L-8 Summary Basin and the selected rainfall stations.



2707





2708 Annual flow and TP data for discharges from the L-8 Summary Basin are summarized in
2709 **Table 3-25**. For the development of the performance measure methodology, a Base Period
2710 of WY1995-2003 was selected for the following reasons.

- 2711 ➤ it represents a period with minimal implementation of source controls. With the
2712 selection of the Base Period to precede significant source control implementation, no
2713 additional calculation is necessary in the performance measure methodology to
2714 account for prior source control implementation,
- 2715 ➤ basin water management operations were similar to current operating conditions
2716 affecting nutrient loading.
- 2717 ➤ it represents a period of relatively constant land use practices,
- 2718 ➤ it traversed a wide range of hydrologic conditions (wet and dry years),
- 2719 ➤ reliable water quality and hydrologic data are available, and
- 2720 ➤ a strong correlation exists between annual TP loads and rainfall, allowing for a
2721 performance measure methodology that explicitly incorporates hydrologic variability.

2722 The Base Period is compared to the historical period of record and WY2001-2010 in **Table**
2723 **3-26**.
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Table 3-25. Summary of historical data for the L-8 Summary Basin.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Area acres	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics		
								Kurtosis K	Coef. Of Var. CV	Skewness S
1995	346,189	34.383	81	73.63	106,440	39.03	0.71	-1.834	0.545	-0.162
1996	231,284	20.855	73	54.83	106,440	26.07	0.43	-0.205	0.895	0.886
1997	116,731	8.544	59	53.36	106,440	13.16	0.18	-0.811	0.575	0.276
1998	219,254	19.086	71	62.11	106,440	24.72	0.40	-0.704	0.517	0.020
1999	147,738	13.232	73	42.28	106,440	16.66	0.27	0.466	0.856	1.207
2000	174,897	13.195	61	60.17	106,440	19.72	0.27	1.795	0.789	1.251
2001	102,466	17.134	136	37.65	106,440	11.55	0.35	-1.452	0.933	0.451
2002	181,863	17.979	80	54.39	106,440	20.50	0.37	-1.735	0.715	0.345
2003	104,544	5.220	40	50.27	106,440	11.79	0.11	0.104	0.653	0.737
2004	136,930	2.587	15	49.95	106,440	15.44	0.05	1.061	0.825	1.058
2005	139,143	9.533	56	56.45	106,440	15.69	0.20	2.534	1.014	1.532
2006	99,927	3.319	27	43.33	106,440	11.27	0.07	-1.595	0.698	-0.096
2007	64,844	6.907	86	36.98	106,440	7.31	0.14	-0.684	1.030	0.823
2008	164,628	14.918	73	44.39	106,440	18.56	0.31	-1.266	0.605	0.340
2009	151,572	8.705	47	46.48	106,440	17.09	0.18	1.865	1.107	1.367
2010	97,433	11.686	97	63.89	106,440	10.98	0.24	-1.462	0.578	0.082
Minimum	64,844	2.587	15	36.98	106,440	7.31	0.05	-1.834	0.517	-0.162
Average	154,965	12.955	68	51.89	106,440	17.47	0.27	-0.245	0.771	0.632
Maximum	346,189	34.383	136	73.63	106,440	39.03	0.71	2.534	1.107	1.532
Std. Dev.	68,117	7.973	28	10.03	0	7.68	0.17	1.413	0.188	0.549
Skewness	1.519	1.183	0.418	0.414		1.519	1.18	0.735	0.311	0.124
Median	143,441	12.441	72	51.82	106,440	16.17	0.26	-0.694	0.752	0.594

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Table 3-26. Comparison of Base Period with period of record data and WY2001-2010 for the L-8 Summary Basin.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1995-2010					
Annual Minimum	64,844	2.587	15	36.98	0.05
Annual Average	154,965	12.955	68	51.89	0.27
Annual Median	143,441	12.441	72	51.82	0.26
Annual Maximum	346,189	34.383	136	73.63	0.71
Base Period WY1995-2003					
Annual Minimum	102,466	5.220	40	37.65	0.11
Annual Average	180,552	16.625	75	54.30	0.34
Annual Median	174,897	17.134	73	54.39	0.35
Annual Maximum	346,189	34.383	136	73.63	0.71
Difference between Period of Record and Base Period					
Annual Minimum	-37,622	-2.633	-25	-0.67	-0.05
Annual Average	-25,587	-3.670	-7	-2.41	-0.08
Annual Median	-31,457	-4.694	-1	-2.58	-0.10
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	-37%	-50%	-63%	-2%	-50%
Annual Average	-14%	-22%	-9%	-4%	-22%
Annual Median	-18%	-27%	-1%	-5%	-27%
Annual Maximum	0%	0%	0%	0%	0%
WY2001-2010					
Annual Minimum	64,844	2.587	15	36.98	0.05
Annual Average	124,335	9.799	64	48.38	0.20
Annual Median	120,737	9.119	65	48.22	0.19
Annual Maximum	181,863	17.979	136	63.89	0.37
Difference between WY2001-2010 and Base Period					
Annual Minimum	-37,622	-2.633	-25	-0.67	-0.05
Annual Average	-56,217	-6.827	-11	-5.92	-0.14
Annual Median	-54,160	-8.015	-9	-6.18	-0.17
Annual Maximum	-164,326	-16.404	0	-9.74	-0.34
Annual Minimum	-37%	-50%	-63%	-2%	-50%
Annual Average	-31%	-41%	-14%	-11%	-41%
Annual Median	-31%	-47%	-12%	-11%	-47%
Annual Maximum	-47%	-48%	0%	-13%	-48%

2763





3.3.2.2 Performance Measure Methodology

Based on the evaluation of individual land use source control effectiveness ranges described in Section 2.6, the overall range of TP load reduction that could be accomplished through collective source controls within the basin was estimated, and a load reduction target of 20 percent was determined to be reasonable and appropriate. Details are provided in Appendix D and in Attachment 1.

An Annual Load Target and an Annual Load Limit were derived from the Base Period data using a 20 percent load reduction. The Annual Load Target and Annual Load Limit for the L-8 Summary Basin will be calculated according to the following equations and explanation.

$$\text{Target} = (-5.06793 + 0.08241 X - 1.54007 S + 6.93876 C)^2$$

$$\text{Explained Variance} = 84.1\%, \text{ Standard Error of Regression}^{15} = 0.46154$$

Predictors (X, C, S) are calculated from the first three moments (m₁, m₂, m₃) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

$$m_1 = \text{Sum} [r_i] / 12$$

$$m_2 = \text{Sum} [r_i - m_1]^2 / 12$$

$$m_3 = \text{Sum} [r_i - m_1]^3 / 12$$

$$X = (12 m_1)$$

$$C = [(12/11) m_2]^{0.5} / m_1$$

$$S = (12/11) m_3 / m_2^{1.5}$$

¹⁵ The standard error of the regression equation is expressed in the same units as the transformed load, i.e., sqrt(metric tons).





2789 Limit = [sqrt(Target) + (1.47588 SE)]²

2790 SE = standard error of the predicted sqrt(Load) for May-April interval

2791 SE = 0.46154 [1 + 1/9 + 0.00211 (X-X_m)² + 0.98133 (S-S_m)² +

2792 14.63127 (C-C_m)² - 0.0005 (X-X_m) (S-S_m) +

2793 0.19976 (X-X_m) (C-C_m) - 4.37464 (S-S_m) (C-C_m)]^{0.5}

2794 Where:

2795 X = the 12-month total rainfall (inches)

2796 C = coefficient of variation calculated from 12 monthly rainfall totals

2797 S = skewness coefficient calculated from 12 monthly rainfall totals

2798 X_m = average value of the predictor in calibration period = 54.2989

2799 C_m = average value of the predictor in calibration period = 0.71978

2800 S_m = average value of the predictor in calibration period = 0.55678

2801

2802 The first predictor (X) indicates that load increases with total annual rainfall. The second
2803 and third predictors (C and S) indicate that the load resulting from a given annual
2804 rainfall is higher when the distribution of monthly rainfall has higher variability or lower
2805 skewness. For a given annual rainfall, the lowest load occurs when rainfall is evenly
2806 distributed across months and the highest load occurs when all of the rain falls in one
2807 month. Real cases fall in between.

2808

2809 A comparison of the scaled loads and the resulting Targets and Limits for the Base Period
2810 are presented in **Figure 3-19**. Annual TP loads at S-5AE, S-5AS, S-5AW, WPB2 and C-
2811 10A, adjusted to account for pass-through loads as described in Appendix A and regional
2812 projects (if applicable), will be evaluated against the performance measure described above.

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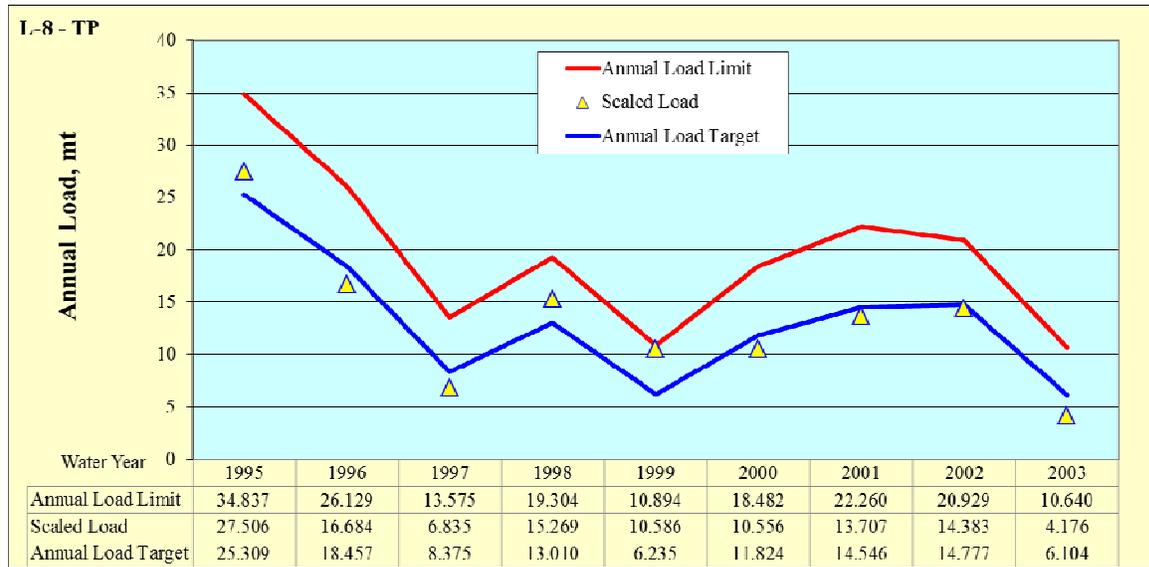
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2817 **Figure 3-19. Comparison of scaled observed loads with the Annual Load Targets and**
2818 **Limits for the L-8 Summary Basin.**
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2822 **Suspension of Performance Determination.** The performance determination will be
2823 suspended due to rainfall conditions if the observed annual TP load, adjusted for regional
2824 projects (if present), from the basin exceeds the Annual Load Target and the adjusted rainfall
2825 falls outside the range of adjusted rainfall values for the Base Period (41.28 to 72.35 inches),
2826 as derived below. Rainfall conditions will be assessed by calculating an adjusted rainfall
2827 amount which reflects the cumulative effect of the predictor variables that make up the
2828 Annual Load Target equation. The adjusted rainfall is the rainfall that would produce the
2829 equivalent annual load using the Annual Load Target equation by setting the value of S and
2830 C to its mean value for the calibration period.

2831
2832 Adjusted Rainfall = equivalent rainfall for mean C and S variables (inches)

2833
2834 Adjusted Rainfall = $X - 18.68862 (S - 0.55678) + 84.20099 (C - 0.71978)$

2835





2836 The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the
2837 WY1995-2010 period of record are summarized in **Table 3-27**.

2838
2839 The annual performance determination process will account for pass-through loads and
2840 regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

2841
2842 **Comparison to WY2001-2010.** A comparison of the WY2001-2010 observed loads to the
2843 Annual Load Targets and Limits is presented in **Figure 3-20**.

2844
2845 **Exceedance Frequency Analysis.** Using the approach described in Section 2.6, an
2846 approximation of the cumulative exceedance frequency for the determination methodology
2847 was estimated using a Monte Carlo approach based on the annual rainfall and the annual TP
2848 loads of the Base Period (**Table 3-28**). Because the TP loads and rainfall statistics from the
2849 Base Period do not perfectly describe normal distributions (e.g., the medians are generally
2850 less than the means), the methodology includes conditional probabilities, and because the
2851 random number generator is imperfect, the exceedance frequencies deviate from the
2852 theoretical values shown in the second column. However, the results are determined to be
2853 reasonable and defensible since the cumulative exceedance frequency is less than the
2854 theoretical value of approximately 17.5 percent.

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Table 3-27. Annual adjusted rainfall for the historical period of record for the L-8 Summary Basin (Base Period: WY1995-2003).

Water Year	Observed Load, mt	Observed Rain, in	Target Load, mt	Limit Load, mt	Adjusted Rain, in
1995	34.383	73.63	25.309	34.837	72.35
1996	20.855	54.83	18.457	26.129	63.43
1997	8.544	53.36	8.375	13.575	46.42
1998	19.086	62.11	13.010	19.304	55.07
1999	13.232	42.28	6.235	10.894	41.60
2000	13.195	60.17	11.824	18.482	53.02
2001	17.134	37.65	14.546	22.260	57.58
2002	17.979	54.39	14.777	20.929	57.95
2003	5.220	50.27	6.104	10.640	41.28
2004	2.587	49.95	9.881	15.221	49.44
2005	9.533	56.45	18.151	27.759	63.00
2006	3.319	43.33	12.207	19.366	53.70
2007	6.907	36.98	14.891	22.756	58.13
2008	14.918	44.39	5.128	9.897	38.78
2009	8.705	46.48	18.821	28.370	63.94
2010	11.686	63.89	16.658	23.475	60.82

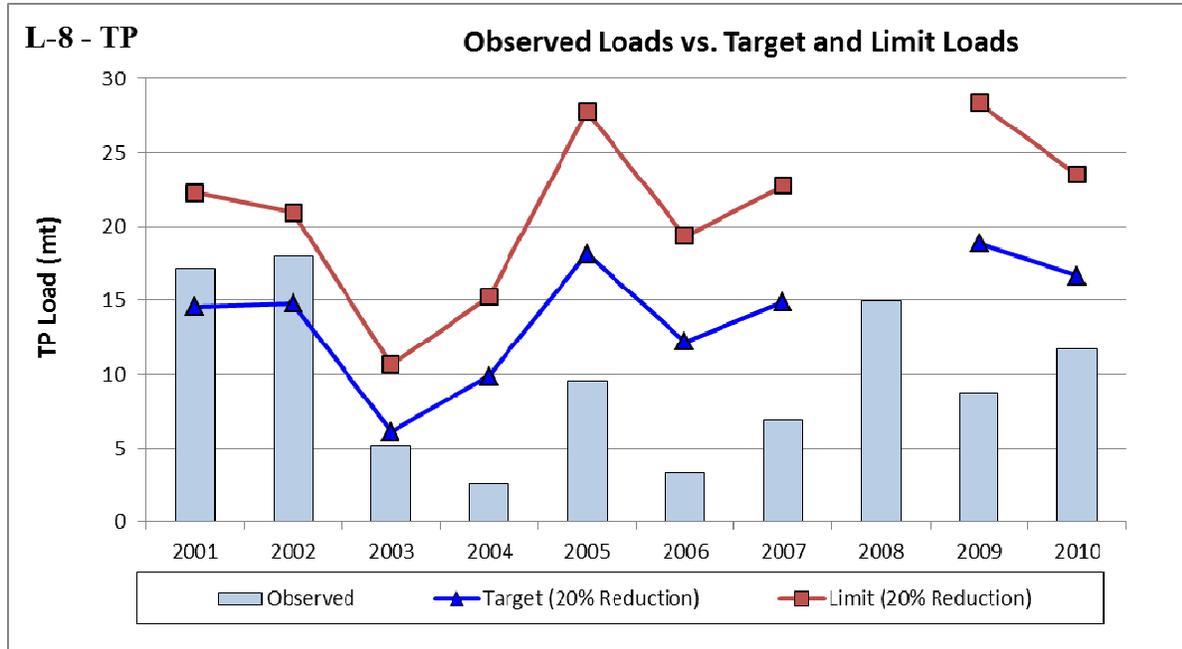
Note: Shaded water years indicate the performance determination would have been suspended due to anomalous rainfall coupled with the observed load being greater than the Annual Load Target.

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2884 **Figure 3-20. Comparison of WY2001-2010 observed loads to the Annual Load Targets**
 2885 **and Limits for the L-8 Summary Basin.**
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2887 Notes: 1. The performance determination for WY2008 would have been suspended due to rainfall below the
 2888 minimum value during the Base Period coupled with the observed load being greater than the Load Target.
 2889 2. The Base Period extended from WY1995-2003.
 2890

2891 **Table 3-28. Exceedance frequencies for the proposed determination methodology for**
 2892 **the L-8 Summary Basin.**
 2893
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 2895

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Rain _{adj} is outside the range and Load > Annual Load Target	<20%	16.2%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	7.1%
Step 4. Load > Annual Load Limit?	<10%	1.2%
Cumulative Exceedance Frequency	<17.5%	8.0%



2897 **3.4 Indian Prairie Sub-watershed**

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2899 The following sections present a description of the sub-watershed, a summary of historical
2900 flow and TP levels, the selection of a Base Period, an estimated range of load reductions
2901 attributable to collective source controls, and the derivation of the resulting performance
2902 measure.

2903 **3.4.1.1 Background**

2904

2905 The Indian Prairie Sub-watershed occupies 276,577 acres lying between Lakes Istokpoga and
2906 Okeechobee (**Figure 3-21**). It is bordered on the west by the Fisheating Creek and Lake
2907 Istokpoga Sub-watersheds and on the east by the Lower Kissimmee and Taylor Creek-
2908 Nubbin Slough Sub-watersheds. Three primary canals convey water through the sub-
2909 watershed, C-41 (Harney Pond Canal), C-40 (Indian Prairie Canal), and C-41A. Discharges
2910 are made from Lake Istokpoga through S-68 into C-41A and are then conveyed through one
2911 of three routes:

- 2912 • C-41A discharges at S-84 into C-38 downstream of S-65E,
- 2913 • C-40 discharges at S-72 into Lake Okeechobee, and
- 2914 • C-41 discharges at S-71 into Lake Okeechobee.

2915

2916 **Table 3-29** and **Figure 3-22** identifies the inflow and outflow structures that move water
2917 across the sub-watershed borders. Four minor structures (HP-7, Inflow-1, Inflow-2 and
2918 Inflow-3) are located along the east and west banks of the C-41 Canal downstream of S-71,
2919 although flow and water quality are not monitored at these structures. Flow and water
2920 quality monitoring was initiated downstream of these structures in the C-41 Canal at a
2921 location known as C41H78, but the first year of reported TP load data was not available until
2922 WY2010. Because insufficient data were available, these minor structures were excluded
2923 from the derivation of the performance measure for the Indian Prairie Sub-watershed.





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Table 3-29. Indian Prairie Sub-watershed inflow and outflow structures.

Station	Inflow/Outflow	Discharges From	Discharges To
G-33	Out	Paradise Run	Lake Okeechobee via C-38
G-34/L-59E	Out	L-59	Lake Okeechobee via C-38
G-207	In	Lake Okeechobee	C-41
G-208	In	Lake Okeechobee	C-40
L-59W	Out	C-59	Lake Okeechobee via C-40
L-60E	Out	L-60	Lake Okeechobee via C-40
L-60W	Out	L-60	Lake Okeechobee via C-41
L-61 E	Out	L-61	Lake Okeechobee via C-41
S-68	In	Lake Istokpoga	C-41A
S-71	Out	C-41	Lake Okeechobee via C-41
S-72	Out	C-40	Lake Okeechobee via C-40
S-84	Out	C-41A	Lake Okeechobee via C-38
S-127	Out	S-127 Basin	Lake Okeechobee
S-129	Out	S-129 Basin	Lake Okeechobee
S-131	Out	S-131 Basin	Lake Okeechobee

Note: flow and TP monitoring sites are identified in **Tables C-1** and **C-2**.

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2933 There are no structures downstream of the L-61, L-60, and L-59 outlets; so their discharges
2934 flow directly to Lake Okeechobee. Water quality data at G-207, G-208 and G-33 are not
2935 collected. Therefore, flows and loads at these structures are not used in the performance
2936 measure methodology. It is not anticipated that this omission will significantly affect the
2937 annual performance determination. G-207 and G-208 only pump supplemental water supply
2938 into the sub-watershed during drought conditions and the volume and quality of stormwater
2939 runoff should not be significantly affected. After a review of the S-129 spillway data, it was
2940 determined that the negative flows were questionable, and therefore, they were omitted from
2941 the analyses.

2942 District staff identified rainfall stations considered to be representative of the Indian Prairie
2943 Sub-watershed for the period WY1989-2010. A schematic of the sub-watershed with the
2944 various rain stations is presented in **Figure 3-23**. Monthly rainfall data and weighting factors

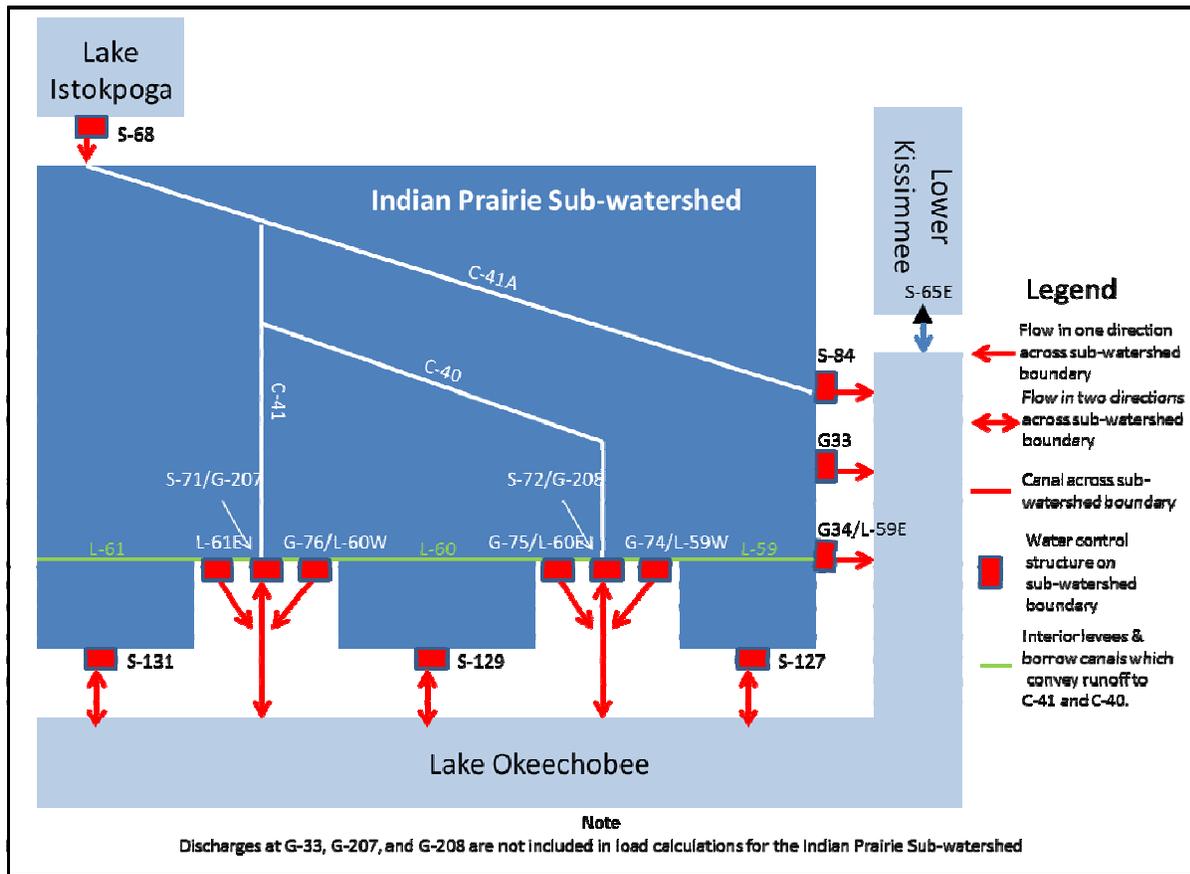




2945 for the rainfall stations for each basin were developed and provided by the District.
2946 Weighting factors are shown in **Figure 3-23**. Missing daily data were filled in with values of
2947 an adjacent station.

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Figure 3-22. Flow diagram for Indian Prairie Sub-watershed.



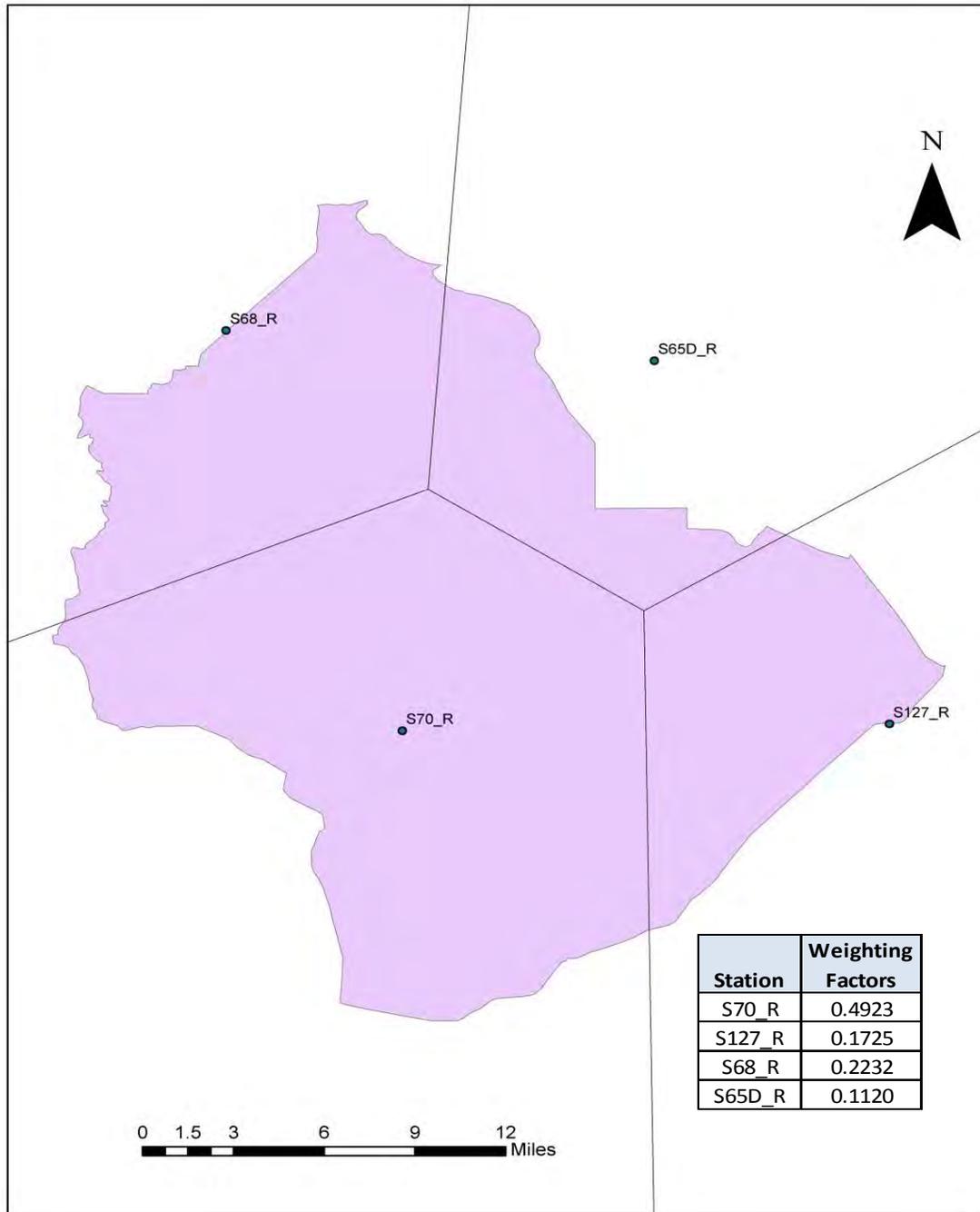
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Figure 3-23. Schematic of Indian Prairie Sub-watershed and the selected rainfall stations.



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2959 The performance measure methodology is based on flows and TP loads resulting from
2960 rainfall and runoff from the Indian Prairie Sub-watershed. Basin flows and loads, adjusted
2961 for pass-through flows and loads discharged from external sources, were calculated using
2962 algorithms provided in Appendix A. Annual flow and TP data for discharges from the
2963 Indian Prairie Sub-watershed into Lake Okeechobee are summarized in **Table 3-30**.

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Table 3-30. Summary of historical data for the Indian Prairie Sub-watershed.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics		
							Kurtosis K	Coef. Of Var. CV	Skewness S
1989	107,966	27.851	209	40.18	4.68	0.22	-1.686	0.705	0.252
1990	202,940	55.363	221	40.56	8.81	0.44	0.385	0.816	0.985
1991	174,913	71.071	329	49.86	7.59	0.57	0.069	0.746	0.772
1992	214,626	67.635	255	46.49	9.31	0.54	0.512	0.749	0.756
1993	187,848	90.336	390	47.18	8.15	0.72	3.195	0.888	1.604
1994	74,500	23.478	255	37.70	3.23	0.19	-1.133	0.540	0.443
1995	312,342	76.579	199	49.45	13.55	0.61	-0.500	0.524	0.980
1996	350,771	119.585	276	47.60	15.22	0.95	-1.044	0.802	0.478
1997	100,752	29.220	235	37.40	4.37	0.23	0.445	0.846	0.929
1998	363,576	86.631	193	54.87	15.77	0.69	0.190	0.471	-0.985
1999	180,128	65.140	293	42.68	7.82	0.52	-0.418	0.908	0.963
2000	283,700	68.956	197	37.09	12.31	0.55	7.950	1.171	2.528
2001	59,726	14.763	200	26.90	2.59	0.12	-0.943	1.078	0.791
2002	215,063	114.458	431	30.24	9.33	0.91	-0.801	1.001	0.678
2003	341,652	155.802	370	43.78	14.82	1.24	3.817	0.686	1.550
2004	256,333	95.566	302	36.24	11.12	0.76	-1.418	0.691	0.165
2005	389,025	178.081	371	37.99	16.88	1.42	0.169	0.964	1.016
2006	373,094	69.216	150	38.07	16.19	0.55	2.241	0.906	1.254
2007	112,267	52.797	381	28.31	4.87	0.42	0.516	1.127	1.216
2008	58,630	20.593	285	38.01	2.54	0.16	2.393	0.771	1.232
2009	280,338	166.168	481	40.21	12.16	1.32	0.096	1.211	1.174
2010	269,223	107.779	325	52.95	11.68	0.86	-1.029	0.704	0.317
Minimum	58,630	14.763	150	26.90	2.54	0.12	-1.686	0.471	-0.985
Average	223,155	79.867	290	41.08	9.68	0.64	0.591	0.832	0.868
Maximum	389,025	178.081	481	54.87	16.88	1.42	7.950	1.211	2.528
Std. Dev.	107,026	46.310	88	7.47	4.64	0.37	2.206	0.204	0.666
Skewness	-0.059	0.623	0.491	-0.040	-0.059	0.62	2.035	0.182	-0.316
Median	214,845	70.144	281	40.20	9.32	0.56	0.133	0.809	0.946

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2974 A Base Period of WY1989-2001 was selected for the development of the performance
2975 measure methodology. This period was selected for the following reasons:

2976

2977 ➤ it represents a period with minimal implementation of source controls. With the
2978 selection of the Base Period to precede significant source control implementation, no
2979 additional calculation is necessary in the performance measure methodology to
2980 account for prior source control implementation,

2981 ➤ basin water management operations were similar to current operating conditions
2982 affecting nutrient loading,

2983 ➤ it traversed a wide range of hydrologic conditions (wet and dry years),

2984 ➤ reliable water quality and hydrologic data are available, and

2985 ➤ a very strong correlation exists between annual TP loads and rainfall, allowing for a
2986 performance measure methodology that explicitly incorporates hydrologic variability.

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2988 The Base Period is compared to the historical period of record and WY2001-2010 in **Table**
2989 **3-31.**

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Table 3-31. Comparison of Base Period with period of record and WY2001-2010 data for the Indian Prairie Sub-watershed.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1989-2010					
Annual Minimum	58,630	14.763	150	26.90	0.12
Annual Average	223,155	79.867	290	41.08	0.64
Annual Median	214,845	70.144	281	40.20	0.56
Annual Maximum	389,025	178.081	481	54.87	1.42
Base Period WY1989-2001					
Annual Minimum	59,726	14.763	193	26.90	0.12
Annual Average	201,061	61.278	247	42.92	0.49
Annual Median	187,848	67.635	235	42.68	0.54
Annual Maximum	363,576	119.585	390	54.87	0.95
Difference between Period of Record and Base Period					
Annual Minimum	-1,096	0.000	-43	0.00	0.00
Annual Average	22,095	18.589	43	-1.84	0.15
Annual Median	26,997	2.508	46	-2.49	0.02
Annual Maximum	25,449	58.496	91	0.00	0.47
Annual Minimum	-2%	0%	-22%	0%	0%
Annual Average	11%	30%	17%	-4%	30%
Annual Median	14%	4%	19%	-6%	4%
Annual Maximum	7%	49%	23%	0%	49%
WY2001-2010					
Annual Minimum	58,630	14.763	150	26.90	0.12
Annual Average	235,535	97.522	336	37.27	0.78
Annual Median	262,778	101.673	348	38.00	0.81
Annual Maximum	389,025	178.081	481	52.95	1.42
Difference between WY2001-2010 and Base Period					
Annual Minimum	-1,096	0.000	-43	0.00	0.00
Annual Average	34,474	36.245	89	-5.65	0.29
Annual Median	74,930	34.038	113	-4.68	0.27
Annual Maximum	25,449	58.496	91	-1.92	0.47
Annual Minimum	-2%	0%	-22%	0%	0%
Annual Average	17%	59%	36%	-13%	59%
Annual Median	40%	50%	48%	-11%	50%
Annual Maximum	7%	49%	23%	-3%	49%

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3.4.2 Performance Measure Methodology

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3009
3010 Based on the evaluation of individual land use source control effectiveness ranges described
3011 in Section 2.6, the overall range of TP load reduction that could be accomplished through
3012 collective source controls within the basin was estimated, and a load reduction target of 30
3013 percent was determined to be reasonable and appropriate. Details are provided in Appendix
3014 D and in Attachment 1.

3015
3016 An Annual Load Target and an Annual Load Limit were derived from the Base Period data
3017 using a 30 percent load reduction. The Annual Load Target and Annual Load Limit for the
3018 Indian Prairie Sub-watershed will be calculated according to the following equations and
3019 explanation:

3020
3021 Target = exp (-12.83843 + 4.02124 X + 1.76267 C)

3022 Explained Variance = 91.1%, Standard Error of Regression¹⁶ = 0.20346

3023 Predictors (X and C) are calculated from the first two moments (m₁,
3024 m₂) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation
3025 Year:

3026 $m_1 = \text{Sum} [r_i] / 12$

3027 $m_2 = \text{Sum} [r_i - m_1]^2 / 12$

3028 $X = \ln (12 m_1)$

3029 $C = [(12/11) m_2]^{0.5} / m_1$

3030
3031 Limit = Target * exp (1.37218 SE)

¹⁶ The standard error of the regression equation is expressed in the same units as the transformed load, i.e., ln(metric tons).





3032 SE = standard error of the predicted ln(Load) for May-April
3033 interval

3034
$$SE = 0.20346 [1 + 1/13 + 3.91995 (X-X_m)^2 + 3.19741 (C-C_m)^2 +$$

3035
$$4.34342 (X-X_m) (C-C_m)]^{0.5}$$

3036 Where:

3037 X = the natural logarithm of the 12-month total rainfall (ln(inches))

3038 C = is the coefficient of variation calculated from 12 monthly rainfall totals

3039 X_m = average value of the predictor in base period = 3.74445

3040 C_m = average value of the predictor in base period = 0.78800

3041

3042 The first predictor (X) indicates that load increases with total annual rainfall. The second
3043 predictor (C) indicates that the load resulting from a given annual rainfall is higher when
3044 the distribution of monthly rainfall has higher variability. For a given annual rainfall, the
3045 lowest load occurs when rainfall is evenly distributed across months and the highest load
3046 occurs when all of the rain falls in one month. Real cases fall in between.

3047

3048 A comparison of the scaled loads and the resulting Targets and Limits for the Base Period
3049 is presented in **Figure 3-24**. Annual TP loads at the sub-watershed outlet structures,
3050 adjusted to account for pass-through loads as described in Appendix A, will be evaluated
3051 against the performance measure described above.

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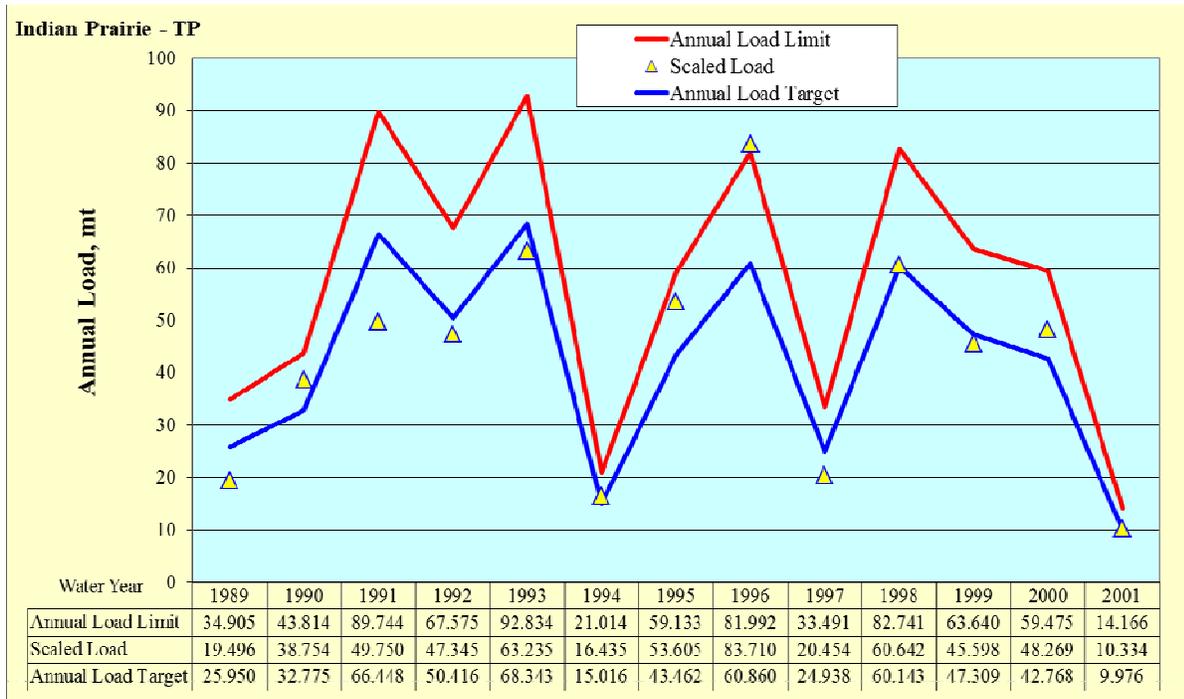
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Figure 3-24. Comparison of scaled annual loads with the Annual Load Targets and Limits for the Indian Prairie Sub-watershed.



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3064 **Suspension of Performance Determination.** The performance determination will be
 3065 suspended due to rainfall conditions if the observed annual TP load, adjusted for regional
 3066 projects (if present), from the sub-watershed exceeds the Annual Load Target and the
 3067 adjusted rainfall falls outside the range of adjusted rainfall values for the Base Period (30.55
 3068 – 49.29 inches), as derived below. Rainfall conditions will be assessed by calculating an
 3069 adjusted rainfall amount which reflects the cumulative effect of the predictor variables of the
 3070 Annual Load Target equation. The adjusted rainfall is the rainfall that would produce the
 3071 equivalent annual load using the Annual Load Target equation by setting the value of C to its
 3072 mean value for the calibration period.

3073

3074 Adjusted Rainfall = $\exp [X + 0.43834 (C - 0.788)]$





3075 The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the
3076 WY1989-2010 period of record are summarized in **Table 3-32**.

3077
3078 The annual performance determination process will account for pass-through loads and
3079 regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

3080
3081 **Table 3-32. Annual adjusted rainfall, Annual Load Targets and Limits for the period of**
3082 **record for the Indian Prairie Sub-watershed (Base Period: WY1989-2001).**
3083

Water Year	Observed Load, mt	Observed Rain, in	Ln(Rain)	CV	Target Load, mt	Limit Load, mt	Adjusted Rain, in
1989	27.851	40.18	3.69337	0.705	25.950	34.905	38.74
1990	55.363	40.56	3.70278	0.816	32.775	43.814	41.06
1991	71.071	49.86	3.90922	0.746	66.448	89.745	48.95
1992	67.635	46.49	3.83924	0.749	50.415	67.574	45.70
1993	90.336	47.18	3.85397	0.888	68.343	92.834	49.29
1994	23.478	37.70	3.62966	0.54	15.016	21.013	33.82
1995	76.579	49.45	3.90096	0.524	43.463	59.134	44.05
1996	119.585	47.60	3.86283	0.802	60.861	81.993	47.89
1997	29.220	37.40	3.62167	0.846	24.938	33.492	38.36
1998	86.631	54.87	4.00497	0.471	60.142	82.740	47.75
1999	65.140	42.68	3.75373	0.908	47.309	63.639	44.99
2000	68.956	37.09	3.61335	1.171	42.767	59.473	43.87
2001	14.763	26.90	3.29213	1.078	9.976	14.167	30.55
2002	114.458	30.24	3.40917	1.001	13.944	19.293	33.20
2003	155.802	43.78	3.77918	0.686	35.436	47.488	41.87
2004	95.566	36.24	3.59016	0.691	16.718	22.886	34.73
2005	178.081	37.99	3.63732	0.964	32.698	44.048	41.04
2006	69.216	38.07	3.63943	0.906	29.771	39.956	40.09
2007	52.797	28.31	3.34322	1.127	13.356	18.768	32.85
2008	20.593	38.01	3.63785	0.771	23.318	31.376	37.73
2009	166.168	40.21	3.69412	1.211	63.502	90.062	48.40
2010	107.779	52.95	3.96935	0.704	78.585	106.912	51.04

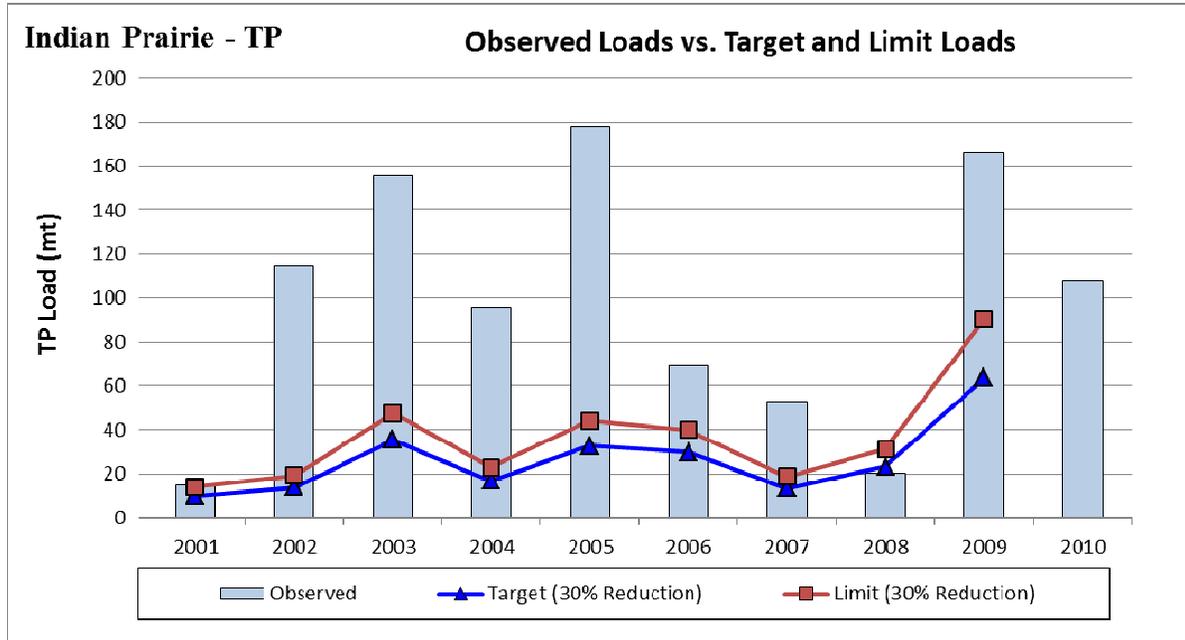
3084
3085 Note: Shaded water years indicate the performance determination would have been suspended due to
3086 anomalous rainfall coupled with the observed load being greater than the Annual Load Target.

3087
3088
3089 **Comparison to WY2001-2010.** A comparison of the WY2001-2010 observed loads to the
3090 Annual Load Targets and Limits is presented in **Figure 3-25**.





3091 **Figure 3-25. Comparison of WY2001-2010 observed loads with the Annual Load**
3092 **Targets and Limits for the Indian Prairie Sub-watershed.**
3093



3094 Notes: 1. The performance determination for WY2010 would have been suspended due to adjusted rainfall
3095 above the maximum value during the Base Period coupled with the observed load being greater than the Load
3096 Target.
3097
3098 2. The Base Period extended from WY1989-2001.
3099

3100 **Exceedance Frequency Analysis.** As shown in **Figure 3-24**, although the scaled observed
3101 loads fall above the Annual Load Targets less than half the time (five out of thirteen years, or
3102 38 percent), the scaled observed load for WY1996 exceeded the calculated Annual Load
3103 Limit. In accordance with the proposed performance determination process discussed in
3104 Section 2.6, having the observed load exceed the Annual Load Limit would prevent the basin
3105 from meeting its performance measure for that year. In the case of the scaled Base Period
3106 data, this is an example of a Type I error¹⁷, or “false positive” - when the performance
3107 method suggests a lack of compliance when the basin’s load actually achieves the long-term

¹⁷ The Type I error rate is the probability that the performance measure methodology will reject the null hypothesis (i.e., a determination that the TP load does not meet the performance measure) when in reality the null hypothesis is true – the annual load meets the performance measure, and is therefore also known as the false positive rate.





3108 reduction goals. While this occurrence is not common, it is statistically possible. The use of
 3109 the upper 90 percent confidence limit for the Annual Load Limit is consistent with the
 3110 District’s Chapter 40E-63 F.A.C., and has a theoretical Type I error (i.e., false positive) rate
 3111 of approximately ten percent. Using the approach described in Section 2.6, an approximation
 3112 of the cumulative exceedance frequency for the determination methodology was estimated
 3113 using a Monte Carlo approach based on the annual rainfall and the annual TP loads of the
 3114 Base Period (**Table 3-33**). Because the TP loads and rainfall statistics from the Base Period
 3115 do not perfectly describe normal distributions (e.g., the medians are generally less than the
 3116 means), the methodology includes conditional probabilities, and because the random number
 3117 generator is imperfect, the exceedance frequencies deviate from the theoretical values shown
 3118 in the second column. However, the results are determined to be reasonable and defensible
 3119 since the cumulative exceedance frequency is less than the theoretical value of approximately
 3120 17.5 percent.

3121

3122 **Table 3-33. Exceedance frequencies for the proposed determination methodology for**
 3123 **the Indian Prairie Sub-watershed.**

3124

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Adj. Rain is outside the range and Load > Annual Load Target	<20%	10.5%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	9.3%
Step 4. Load > Annual Load Limit?	<10%	4.4%
Cumulative Exceedance Frequency	<17.5%	12.5%

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3128 ***3.5 Fisheating Creek-Nicodemus Slough Sub-watershed***

3129
3130 The Fisheating Creek-Nicodemus Slough Sub-watershed comprises 318,042 acres located
3131 directly west of Lake Okeechobee (**Figure 3-26**). The sub-watershed contains two summary
3132 basins that discharge to the lake in close proximity: the Fisheating Creek (FECR) Summary
3133 Basin and the Nicodemus Slough Summary Basin. Flow and TP monitoring sites are
3134 identified in **Tables C-1** and **C-2**.

3135
3136 District staff identified the rainfall stations considered to be representative of the Fisheating
3137 Creek-Nicodemus Slough Sub-watershed and summary basins for the period WY1976-2010.
3138 A schematic of the sub-watershed with the various rain stations is presented in **Figure 3-27**.
3139 Monthly rainfall data and weighting factors for the rainfall stations for each summary basin
3140 were developed and provided by the District. Weighting factors are shown in **Figure 3-27**.
3141 Missing daily data were filled in with values of an adjacent station.

3142 The following sections describe the derivation of the performance measure methodologies
3143 for the summary basins within the Fisheating Creek-Nicodemus Slough Sub-watershed.

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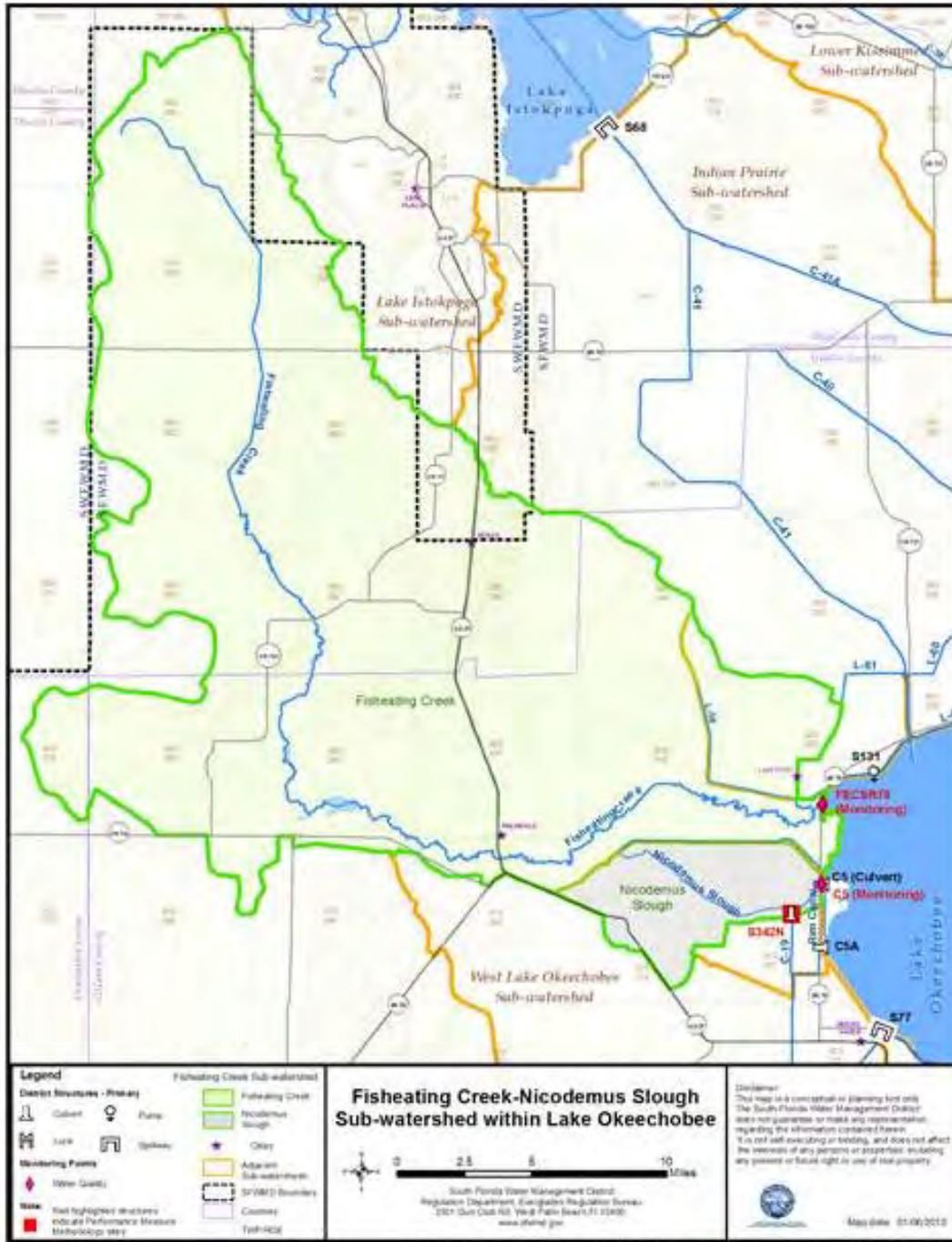


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Figure 3-26. Fisheating Creek-Nicodemus Slough Sub-watershed boundary and discharge monitoring locations.

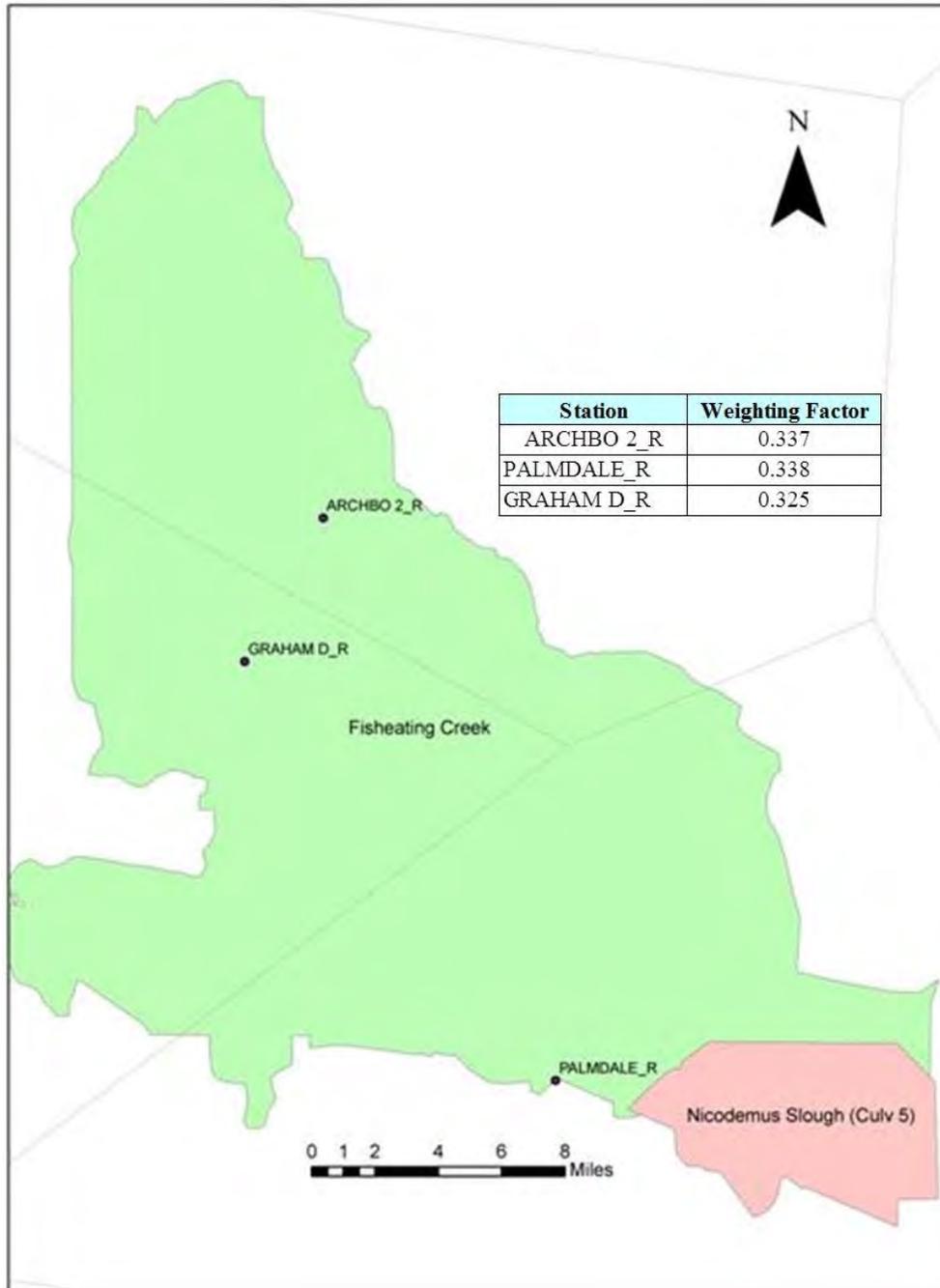


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3163 Figure 3-27. Schematic of Fisheating Creek-Nicodemus Slough Sub-watershed and the
3164 selected rainfall stations.
3165



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3167 **3.5.1 Fisheating Creek Summary Basin**

3168
3169 The Fisheating Creek Summary Basin comprises 298,713 acres and is the only basin in the
3170 Lake Okeechobee Watershed with an uncontrolled “natural” discharge, i.e., Fisheating Creek
3171 (SFWMD 2008). Fisheating Creek originates in western Highlands County and flows south
3172 through Cypress Swamp and into Glades County with an average gradient of 0.5 foot per
3173 mile (SFWMD 2011a). From central Glades County, water leaves the creek channel and
3174 flows east through Cowbone Marsh into Lake Okeechobee. Levees have been constructed
3175 roughly parallel to Fisheating Creek near its outlet to the lake.
3176

3177 **3.5.1.1 Background**

3178
3179 Annual flow and TP data for discharges from the Fisheating Creek Summary Basin, as
3180 monitored at the SR 78 bridge near Lakeport, are summarized in **Table 3-34**. For the
3181 development of the performance measure methodology, a Base Period of WY1998-2008 was
3182 selected for the following reasons.

- 3183 ➤ it represents a period with minimal implementation of source controls. With the
3184 selection of the Base Period to precede significant source control implementation, no
3185 additional calculation is necessary in the performance measure methodology to
3186 account for prior source control implementation.
- 3187 ➤ basin water management operations were similar to current operating conditions
3188 affecting nutrient loading, in that the basin has remained unregulated (e.g., no water
3189 control structures exist to regulate flows) from the selected base period to present,
- 3190 ➤ it represents a period of relatively constant land use practices,
- 3191 ➤ it traversed a wide range of hydrologic conditions (wet and dry years),
- 3192 ➤ reliable water quality and hydrologic data are available, and
- 3193 ➤ a strong correlation exists between annual TP loads and rainfall, allowing for a
3194 performance measure methodology that explicitly incorporates hydrologic variability.





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3195 The Base Period is compared to the historical period of record and WY2001-2010 in Table
3196 3-35.

3197

3198 **Table 3-34. Summary of historical data for the Fisheating Creek Summary Basin.**

3199

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics		
							Kurtosis K	Coef. Of Var. CV	Skewness S
1998	535,316	129.919	197	67.22	21.50	0.96	0.270	0.527	-0.132
1999	183,933	45.813	202	44.68	7.39	0.34	-0.685	0.789	0.648
2000	237,576	49.094	168	62.08	9.54	0.36	-0.131	0.958	0.991
2001	13,727	2.719	161	33.31	0.55	0.02	0.597	0.980	0.959
2002	329,509	135.612	334	54.36	13.24	1.00	-0.290	0.946	0.914
2003	409,394	103.714	205	78.23	16.45	0.77	0.345	0.744	0.851
2004	359,710	67.618	152	53.67	14.45	0.50	-0.804	0.818	0.598
2005	391,353	137.727	285	60.14	15.72	1.02	1.116	0.934	1.233
2006	385,019	77.389	163	47.89	15.47	0.57	0.067	1.053	0.993
2007	163,419	64.542	320	43.14	6.56	0.48	7.454	1.489	2.491
2008	41,528	11.236	219	42.21	1.67	0.08	0.142	0.746	0.935
2009	222,597	77.283	281	40.01	8.94	0.57	-0.181	1.161	1.158
2010	197,349	77.137	317	52.29	7.93	0.57	-1.111	0.691	0.307
Minimum	13,727	2.719	152	33.31	0.55	0.02	-1.111	0.527	-0.132
Average	266,956	75.369	229	52.25	10.72	0.56	0.522	0.910	0.919
Maximum	535,316	137.727	334	78.23	21.50	1.02	7.454	1.489	2.491
Std. Dev.	151,236	43.244	67	12.36	6.08	0.32	2.166	0.242	0.599
Skewness	-0.085	-0.057	0.399	0.597	-0.085	-0.06	3.133	0.938	1.142
Median	237,576	77.137	205	52.29	9.54	0.57	0.067	0.934	0.935

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Table 3-35. Comparison of Base Period with period of record and WY2001-2010 data for the Fisheating Creek Summary Basin.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1998-2010					
Annual Minimum	13,727	2.719	152	33.31	0.02
Annual Average	266,956	75.369	229	52.25	0.56
Annual Median	237,576	77.137	205	52.29	0.57
Annual Maximum	535,316	137.727	334	78.23	1.02
Base Period WY1998-2008					
Annual Minimum	13,727	2.719	152	33.31	0.02
Annual Average	277,317	75.035	219	53.36	0.55
Annual Median	329,509	67.618	202	53.67	0.50
Annual Maximum	535,316	137.727	334	78.23	1.02
Difference between Period of Record and Base Period					
Annual Minimum	0	0.000	0	0.00	0.00
Annual Average	-10,361	0.335	10	-1.11	0.00
Annual Median	-91,933	9.519	3	-1.38	0.07
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	0%	0%	0%	0%	0%
Annual Average	-4%	0%	4%	-2%	0%
Annual Median	-28%	14%	1%	-3%	14%
Annual Maximum	0%	0%	0%	0%	0%
WY2001-2010					
Annual Minimum	13,727	2.719	152	33.31	0.02
Annual Average	251,361	75.498	243	50.53	0.56
Annual Median	276,053	77.210	250	50.09	0.57
Annual Maximum	409,394	137.727	334	78.23	1.02
Difference between WY2001-2010 and Base Period					
Annual Minimum	0	0.000	0	0.00	0.00
Annual Average	-25,956	0.463	24	-2.83	0.00
Annual Median	-53,456	9.592	48	-3.58	0.07
Annual Maximum	-125,922	0.000	0	0.00	0.00
Annual Minimum	0%	0%	0%	0%	0%
Annual Average	-9%	1%	11%	-5%	1%
Annual Median	-16%	14%	24%	-7%	14%
Annual Maximum	-24%	0%	0%	0%	0%

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3.5.1.2 Performance Measure Methodology

Based on the evaluation of individual land use source control effectiveness ranges described in Section 2.6, the overall range of TP load reduction that could be accomplished through collective source controls within the basin was estimated, and a load reduction target of 30 percent was determined to be reasonable and appropriate. Details are provided in Appendix D and in Attachment 1.

An Annual Load Target and an Annual Load Limit were derived from the Base Period data using a 30 percent load reduction. The Annual Load Target and Annual Load Limit for the Fisheating Creek Summary Basin will be calculated according to the following equations and explanation:

Target = -340.304899 + 99.44445 X

Explained Variance = 53.5%, Standard Error of Regression = 23.828 mt

Predictor X is calculated from the first moment (m₁) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation Year:

m₁ = Sum [r_i] / 12

X = ln (12 m₁)

Limit = Target + 1.38303 SE

SE = standard error of the Target for May-April interval

SE = 23.82794 [1 + 1/11 + (X-X_m)² / 0.59477]^{0.5}

Where:

X = the natural logarithm of the 12-month total rainfall (ln(inches))

X_m = average value of the predictor in base period = 3.95024

The predictor X indicates that load increases with total annual rainfall.





3251 A comparison of the scaled loads and the resulting Targets and Limits for the Base Period
3252 are presented in **Figure 3-28**. Annual TP loads monitored at the SR 78 bridge near Lakeport
3253 will be evaluated against the performance measure described above.

3254
3255 **Suspension of Performance Determination.** The performance determination will be
3256 suspended due to rainfall conditions if the observed annual TP load, adjusted for regional
3257 projects (if present), from the basin exceeds the Annual Load Target and the rainfall falls
3258 outside the range of rainfall values for the Base Period (33.31 – 78.23 inches). The
3259 calculated Annual Load Targets and Annual Load Limits for the rainfall conditions observed
3260 during the period of record are summarized in **Table 3-36**.

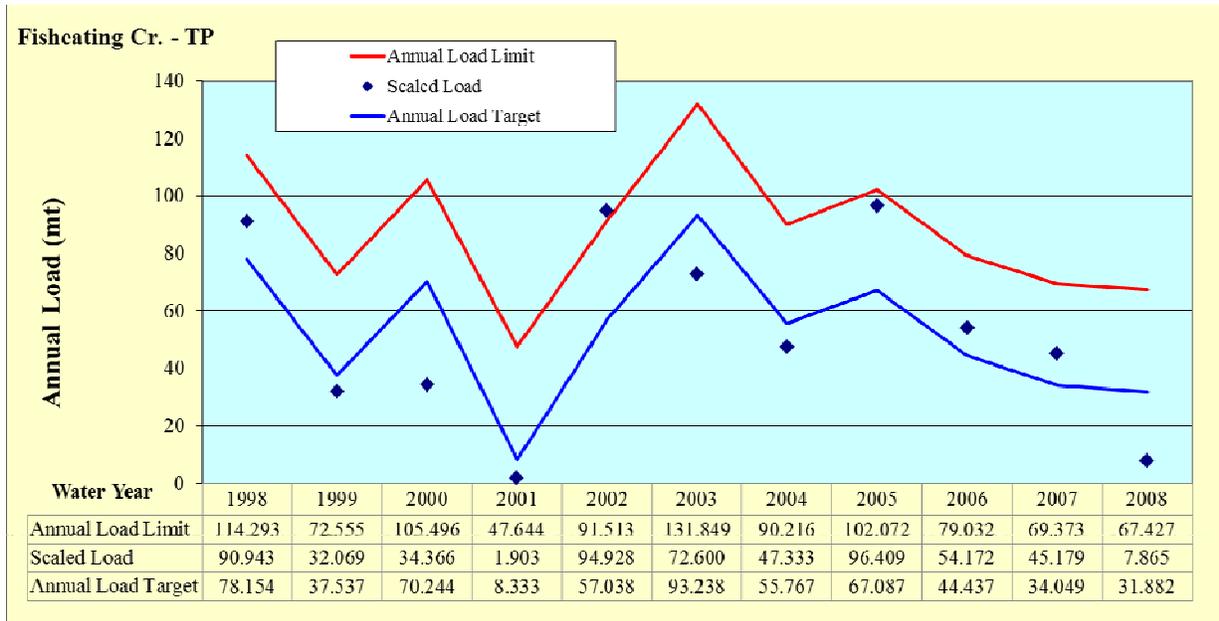
3261
3262 The annual performance determination process will account for regional projects, as
3263 applicable, and is presented in the flowchart in **Figure 1-2**.

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3286 **Figure 3-28. Comparison of scaled loads with the Annual Load Targets and Limits for**
 3287 **the Fisheating Creek Summary Basin.**
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3289 **Table 3-36. Estimates of annual Load Targets and Limits for the historical period of**
 3290 **record for the Lower Kissimmee Sub-watershed (Base Period: WY1998-2008).**
 3291
 3292
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Water Year	Observed Load, mt	ln(Rain) ln(inches)	Target Load, mt	Limit Load, mt
1998	129.919	4.20797	78.154	114.293
1999	45.813	3.79953	37.537	72.555
2000	49.094	4.12842	70.244	105.496
2001	2.719	3.50586	8.333	47.644
2002	135.612	3.99563	57.038	91.513
2003	103.714	4.35965	93.238	131.849
2004	67.618	3.98285	55.767	90.216
2005	137.727	4.09668	67.087	102.072
2006	77.389	3.86891	44.437	79.032
2007	64.542	3.76445	34.049	69.373
2008	11.236	3.74266	31.882	67.427
2009	77.283	3.68913	26.559	62.742
2010	77.137	3.95681	53.178	87.599

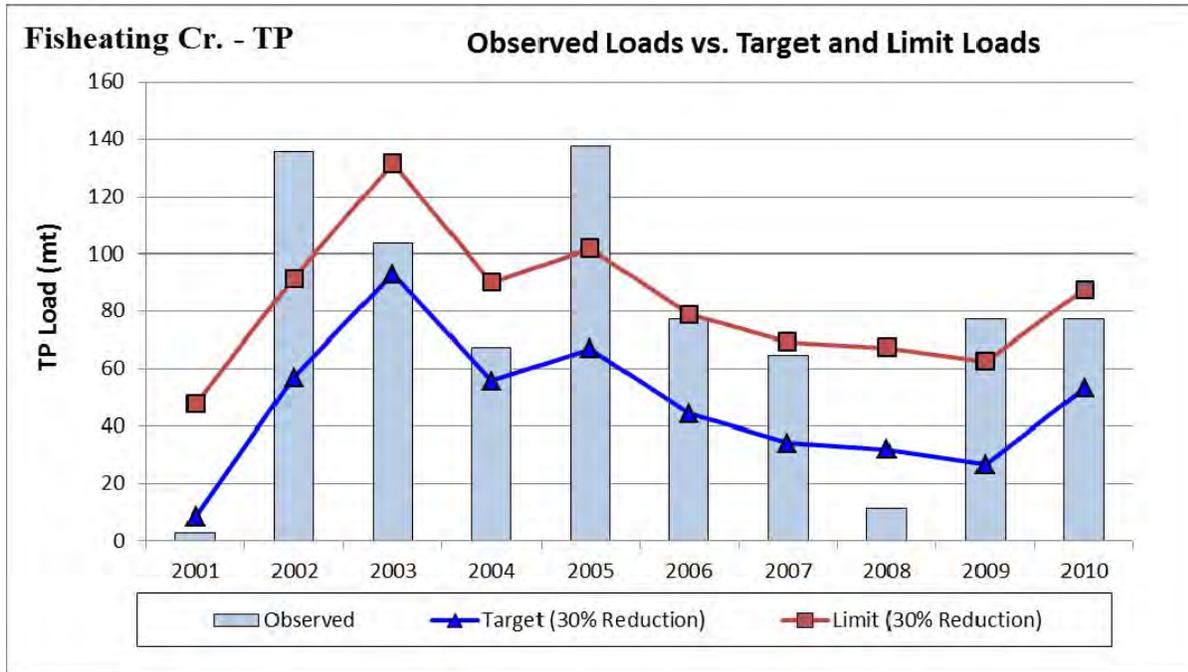
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3296 **Comparison to WY2001-2010.** A comparison of the WY2001-2010 observed loads to the
3297 Annual Load Targets and Limits is presented in **Figure 3-29**.

3298
3299 **Figure 3-29. Comparison of WY2001-2010 observed loads to the Annual Load Targets**
3300 **and Limits for the Fisheating Creek Summary Basin.**
3301



3302
3303 Note: The Base Period extended from WY1998-2008.

3304 **Exceedance Frequency Analysis.** As shown in **Figure 3-28**, although the scaled observed
3305 loads fall above the Annual Load Targets less than half the time (five out of eleven years, or
3306 45 percent), the scaled observed load for WY2002 exceeded the calculated Annual Load
3307 Limit. In accordance with the proposed performance determination process discussed in
3308 Section 2.6, having the observed load exceed the Annual Load Limit would prevent the basin
3309 from meeting its performance measure for that year. In the case of the scaled Base Period
3310 data, this is an example of a Type I error¹⁸, or “false positive” - when the performance
3311

¹⁸ The Type I error rate is the probability that the performance measure methodology will reject the null hypothesis (i.e., a determination that the TP load does not meet the performance measure) when in reality the





3312 method suggests a lack of compliance when the basin’s load actually achieves the long-term
 3313 reduction goals. While this occurrence is not common, it is statistically possible. The use of
 3314 the upper 90 percent confidence limit for the Annual Load Limit is consistent with the
 3315 District’s Chapter 40E-63 F.A.C., and has a theoretical Type I error (i.e., false positive) rate
 3316 of approximately ten percent. Using the approach described in Section 2.6, an approximation
 3317 of the cumulative exceedance frequency for the determination methodology was estimated
 3318 using a Monte Carlo approach based on the annual rainfall and the annual TP loads of the
 3319 Base Period (**Table 3-37**). Because the TP loads and rainfall statistics from the Base Period
 3320 do not perfectly describe normal distributions (e.g., the medians are generally less than the
 3321 means), the methodology includes conditional probabilities, and because the random number
 3322 generator is imperfect, the exceedance frequencies deviate from the theoretical values shown
 3323 in the second column. However, the results are determined to be reasonable and defensible
 3324 since the cumulative exceedance frequency is less than the theoretical value of approximately
 3325 17.5 percent.

3326

3327 **Table 3-37. Exceedance frequencies for the proposed determination methodology for**
 3328 **the Fisheating Creek Summary Basin.**
 3329

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Rain is outside the range and Load > Annual Load Target	<20%	4.0%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	11.6%
Step 4. Load > Annual Load Limit?	<10%	5.7%
Cumulative Exceedance Frequency	<17.5%	15.7%

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null hypothesis is true – the annual load meets the performance measure, and is therefore also known as the false positive rate.





3333 **3.5.2 Nicodemus Slough Summary Basin**

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The following sections present a description of the Nicodemus Slough Summary Basin and a summary of historical flow and TP levels.

3337 **3.5.2.1 Background**

3338

3339 The Nicodemus Slough Summary Basin comprises 19,329 acres located west of Lake
3340 Okeechobee and south of the Fisheating Creek Summary Basin. The connection to Lake
3341 Okeechobee is through control structure Culvert 5, located at the crossing of SR 78 and the
3342 levee LD-3. The purpose of Culvert 5 is to provide releases from Lake Okeechobee to the
3343 lower reaches of Nicodemus Slough and to afford gravity drainage of that slough into Lake
3344 Okeechobee during flood periods when the lake is lower than the slough. Reliable flow data
3345 for the Nicodemus Slough Summary Basin at Culvert 5 are available only from March 2008
3346 to the present. In that time, only four TP samples were collected on days with flow, hence
3347 there is insufficient flow and TP data available to adequately analyze alternative Base
3348 Periods for the basin. Another structure, S-342N, is located on the southern boundary of the
3349 basin, and minimal flow and TP data are available. Due to the lack of a long-term data set of
3350 sufficient quality, insufficient data were available for a complete historical data analysis.
3351 Monthly summaries are provided in **Table 3-38** for WY2009 and WY2010.

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3358 Table 3-38. Monthly summary of flow and TP data for the Nicodemus Slough Summary
3359 Basin.

Date	Flow AF	TP load kg	TP Conc µg/L	Rainfall inches
200805	0	0		0.520
200806	0	0		10.690
200807	1236	139	91	6.640
200808	10555	1199	92	12.730
200809	17	2	95	4.230
200810	0	0		3.530
200811	3	1	270	0.400
200812	0	0		1.540
200901	1	0	0	1.060
200902	0	0		0.190
200903	0	0		0.900
200904	7	2	232	0.990
200905	0	0		7.410
200906	269	109	328	10.270
200907	2006	176	71	10.930
200908	95	9	77	7.790
200909	63	6	77	3.350
200910	3	0	0	0.060
200911	0	0		0.810
200912	0	0		6.220
201001	3	0	0	1.950
201002	0	0		1.850
201003	301	46	124	8.030
201004	390	62	129	6.780

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3362 **3.5.2.2 Performance Measure Methodology**

3363 Since this summary basin has historically contributed a small percentage of the annual Lake
3364 Okeechobee total phosphorus load (less than one percent), no performance metric will be
3365 assigned to this area. However, the water quality from the basin will be assessed annually to
3366 determine if there is an increasing trend.
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3374 **3.6 Lake Istokpoga Sub-watershed**

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3376 The following sections present a description of the Lake Istokpoga Sub-watershed, a
3377 summary of historical flow and TP levels, the selection of Reference Periods, and the
3378 derivation of the resulting performance indicators for tributaries within the sub-watershed.

3379 **3.6.1 Background**

3380

3381 The Lake Istokpoga Sub-watershed comprises 394,203 acres located northeast of Lake
3382 Okeechobee (**Figure 3-30**). The Lake Istokpoga sub-watershed is located to the west and
3383 north (upstream) of Lake Istokpoga. Lake Istokpoga receives direct runoff from adjacent
3384 land areas and inflows from Josephine Creek and Arbuckle Creek. The primary outlet from
3385 Lake Istokpoga is through the S-68 structure¹⁹, which releases water through a series of
3386 canals southeastward to both Lake Okeechobee and the Kissimmee River. The location of S-
3387 68 is shown in **Figure 3-30**.

3388

3389 District staff identified the rainfall stations considered to be representative of the Lake
3390 Istokpoga Sub-watershed for the period WY1976-2010. A schematic of the sub-watershed
3391 with the various rain stations is presented in **Figure 3-31**. Monthly rainfall data and
3392 weighting factors for the rainfall stations were developed and provided by the District.
3393 Because of the nutrient attenuation effect of Lake Istokpoga, the nutrient loads discharged at
3394 S-68 may not be representative of stormwater runoff from within the sub-watershed, and thus
3395 the criteria for the establishment of a performance measure at S-68 were not met. Therefore,
3396 tributaries upstream of Lake Istokpoga were evaluated to see if there were sufficient data to
3397 develop performance measure methodologies in the individual tributaries.

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¹⁹ A secondary structure, G-85, is located along the Istokpoga Canal and historically has discharged minimal flow. This structure is operated very infrequently by manipulation of the flashboards; normally, all flashboards are in place (SFWMD Structure Books).



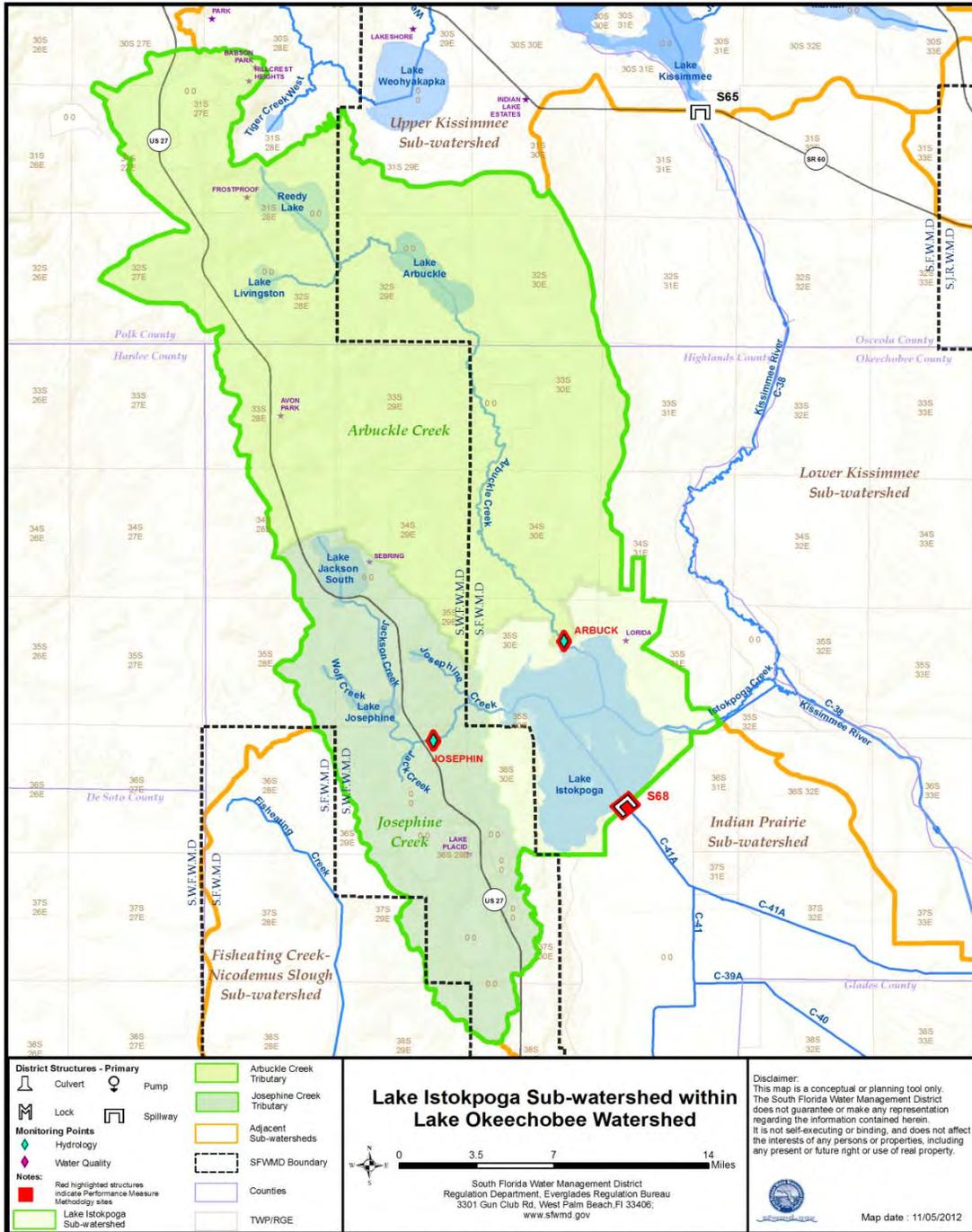


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Lake Okeechobee Watershed Performance Measures

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Figure 3-30. Lake Istokpoga Sub-watershed boundary and discharge monitoring locations (from SFWMD).



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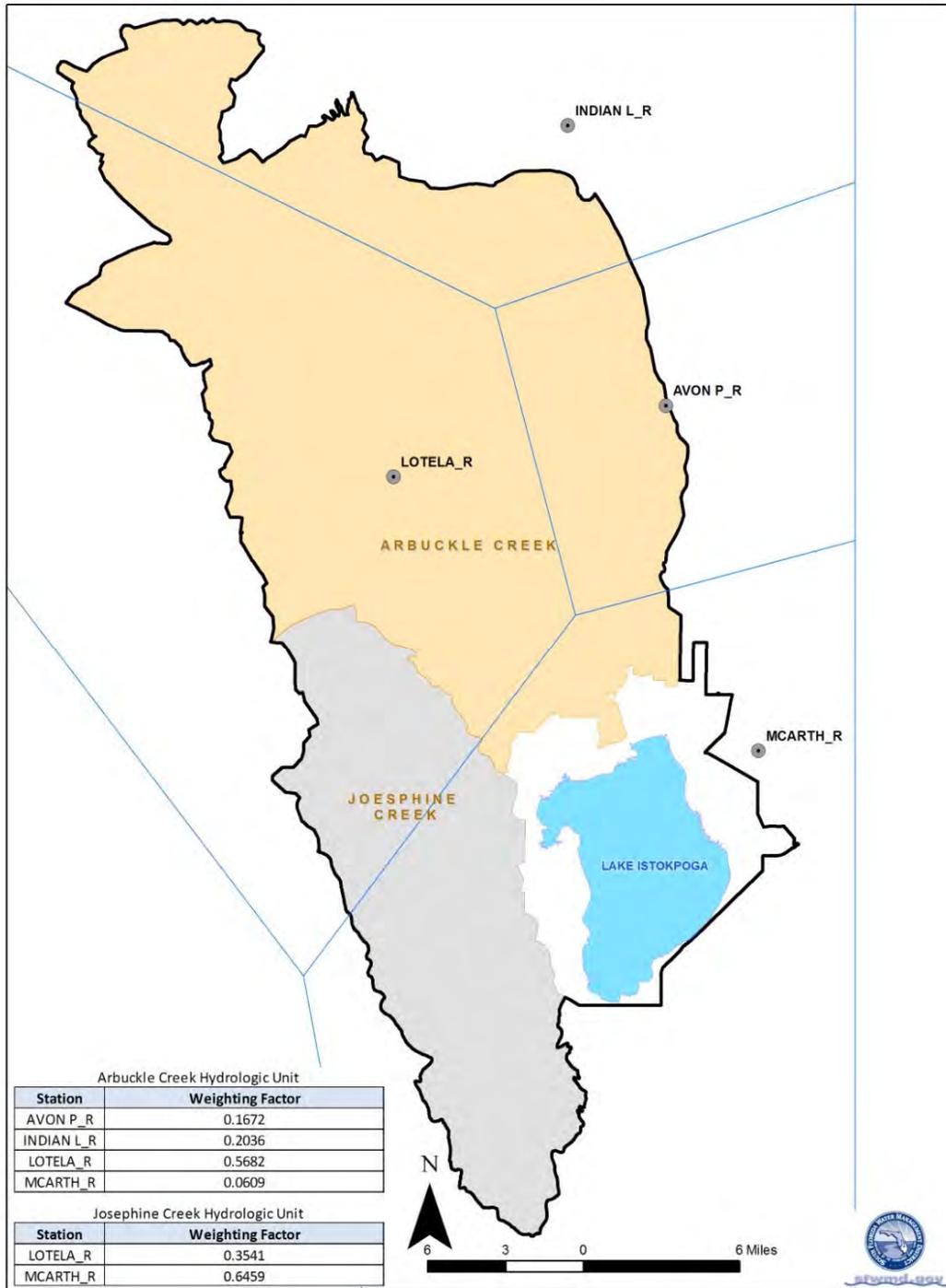
lurs/ulad.sfwmd.gov/DFSRoot/err_gis/data/projects/EVG/lok/rucks_LOK_PerformanceMeasures/LOK_LakeIstokpoga



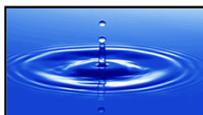


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Figure 3-31. Schematic of Lake Istokpoga Sub-watershed (from SFWMD).



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3404 Stormwater runoff from roughly eighty-six percent of the sub-watershed of the sub-
3405 watershed flows into Lake Istokpoga via Arbuckle Creek and Josephine Creek. The
3406 remaining portion of the sub-watershed is Lake Istokpoga itself and the surrounding land
3407 area that discharges into Lake Istokpoga via sheet flow and is not monitored. A review of
3408 available data identified monitoring sites located on two major tributaries upstream of Lake
3409 Istokpoga. These discharge monitoring locations are shown in **Figure 3-31** and are further
3410 described below:

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3412 1. One site is located on Arbuckle Creek (ARBUCK), which flows into Lake Istokpoga
3413 from the north. Arbuckle Creek has a tributary area of approximately 246,264 acres,
3414 or roughly sixty-three percent of the Lake Istokpoga Sub-watershed area. Flow data
3415 are recorded at a nearby USGS gauge (Arbuckle Creek near De Soto City, FL: ID no.
3416 02270500).

3417 2. One site is located on Josephine Creek (JOSEPHIN) (LI02362923), which flows into
3418 Lake Istokpoga. Shingle Creek has a tributary area of approximately 90,607 acres, or
3419 roughly twenty-three percent of the Lake Istokpoga Sub-watershed area. Flow data
3420 are recorded at a nearby USGS gauge (Josephine Creek near De Soto City, FL: ID no.
3421 02271500).

3422

3423 Both water quality and flow data were available for the tributaries in the Lake Istokpoga Sub-
3424 watershed. However, performance measures were not developed for these tributaries because
3425 the boundaries were not well defined. Instead, prediction equations for performance
3426 indicators are recommended for the upstream tributaries at Arbuckle Creek and Josephine
3427 Creek. The following section summarizes the performance indicators for Arbuckle Creek and
3428 Josephine Creek.

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3430 **3.6.1.1 Performance Measure Methodology**

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3432 **Site 1: Arbuckle Creek**

3433 Annual flow and TP data for discharges from the Arbuckle Creek Tributary are summarized
3434 in **Table 3-39**. For the development of the performance indicator, a Reference Period of
3435 WY1997-2007 was selected for the following reasons:

- 3436 ➤ it represents a period with minimal implementation of source controls. With the
3437 selection of the Reference Period to precede significant source control
3438 implementation, no additional calculation is necessary in the performance indicator
3439 to account for prior source control implementation,
- 3440 ➤ it represents a period of relatively constant land use practices,
- 3441 ➤ reliable water quality and hydrologic data are available, and
- 3442 ➤ a strong correlation exists between annual TP loads and rainfall, allowing for a
3443 performance indicator that explicitly incorporates hydrologic variability

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3445 The Reference Period is compared to the historical period of record and WY2001-2010 in
3446 **Table 3-40**.

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Table 3-39. Summary of historical data for ARBUCK, the outlet structure for the Arbuckle Creek Tributary for the WY 1992-2010 period of record.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Area acres	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics		
								Kurtosis K	Coef. Of Var. CV	Skewness S
1992	190,774	21.775	93	53.87	246,266	9.30	0.19	-0.193	0.852	0.829
1993	213,813	25.570	97	59.28	246,266	10.42	0.23	1.399	0.914	1.448
1994	73,471	9.051	100	43.87	246,266	3.58	0.08	-1.138	0.734	0.593
1995	255,078	25.216	80	60.60	246,266	12.43	0.23	3.421	0.765	1.822
1996	234,590	37.065	128	55.91	246,266	11.43	0.33	-0.762	0.765	0.556
1997	98,572	9.748	80	42.95	246,266	4.80	0.09	-1.440	0.644	-0.011
1998	515,250	87.642	138	77.45	246,266	25.11	0.78	0.053	0.436	-0.393
1999	165,150	30.417	149	45.41	246,266	8.05	0.27	0.749	0.954	1.261
2000	198,903	26.846	109	43.95	246,266	9.69	0.24	0.447	0.856	0.978
2001	35,771	4.264	97	40.71	246,266	1.74	0.04	-0.498	1.097	0.922
2002	292,832	38.802	107	53.88	246,266	14.27	0.35	-1.289	0.712	0.256
2003	293,748	58.961	163	58.37	246,266	14.31	0.53	-0.536	0.724	0.594
2004	261,554	90.876	282	52.55	246,266	12.74	0.81	-0.899	0.804	0.656
2005	257,547	69.319	218	53.04	246,266	12.55	0.62	0.991	0.871	1.134
2006	341,771	48.603	115	50.00	246,266	16.65	0.44	-0.269	0.882	0.682
2007	87,730	12.087	112	33.74	246,266	4.27	0.11	-0.901	0.784	0.825
2008	63,589	4.741	60	40.42	246,266	3.10	0.04	1.918	0.749	1.060
2009	161,959	38.276	192	39.80	246,266	7.89	0.34	2.784	1.057	1.599
2010	110,761	24.379	178	47.15	246,266	5.40	0.22	-1.805	0.664	-0.002
Minimum	35,771	4.264	60	33.74	246,266	1.74	0.04	-1.805	0.436	-0.393
Average	202,782	34.928	140	50.16	246,266	9.88	0.31	0.107	0.803	0.779
Maximum	515,250	90.876	282	77.45	246,266	25.11	0.81	3.421	1.097	1.822
Std. Dev.	116,298	25.944	55	10.01	0	5.67	0.23	1.448	0.150	0.564
Skewness	0.874	0.965	1.337	0.919	0.000	0.874	0.97	0.942	-0.196	-0.201
Median	198,903	26.846	112	50.00	246,266	9.69	0.24	-0.269	0.784	0.825

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Table 3-40. Comparison of the Reference Period with the period of record data for Arbuckle Creek.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Load lbs/ac
Period of Record - WY1992-2010					
Annual Minimum	35,771	4.264	60	33.74	0.04
Annual Average	202,782	34.928	140	50.16	0.31
Annual Median	198,903	26.846	112	50.00	0.24
Annual Maximum	515,250	90.876	282	77.45	0.81
Reference Period WY1997-2007					
Annual Minimum	35,771	4.264	80	33.74	0.04
Annual Average	231,712	43.415	152	50.19	0.39
Annual Median	257,547	38.802	115	50.00	0.35
Annual Maximum	515,250	90.876	282	77.45	0.81
Difference between Period of Record and Reference Period					
Annual Minimum	0	0.000	-20	0.00	0.000
Annual Average	-28,929	-8.487	-12	-0.03	-0.076
Annual Median	-58,644	-11.956	-3	0.00	-0.107
Annual Maximum	0	0.000	0	0.00	0.000
Annual Minimum	0%	0%	-25%	0%	0%
Annual Average	-12%	-20%	-8%	0%	-20%
Annual Median	-23%	-31%	-3%	0%	-31%
Annual Maximum	0%	0%	0%	0%	0%
WY2001-2010					
Annual Minimum	35,771	4.264	60	33.74	0.04
Annual Average	190,726	39.031	166	46.97	0.35
Annual Median	209,753	38.539	139	48.58	0.35
Annual Maximum	341,771	90.876	282	58.37	0.81
Difference between WY2001-2010 and Reference Period					
Annual Minimum	0	0.000	-20	0.00	0.00
Annual Average	-40,985	-4.384	14	-3.22	-0.04
Annual Median	-47,794	-0.263	24	-1.43	0.00
Annual Maximum	-173,479	0.000	0	-19.08	0.00
Annual Minimum	0%	0%	-25%	0%	0%
Annual Average	-18%	-10%	9%	-6%	-10%
Annual Median	-19%	-1%	21%	-3%	-1%
Annual Maximum	-34%	0%	0%	-25%	0%

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3477 Based on the fact that the annual median total phosphorus concentration for the period of
3478 record (112 µg/l) is below the Numeric Nutrient Criteria (120 µg/l) (Chapter 62-302,
3479 F.A.C.) it is recommended that no reduction goal be applied to tributary. An Annual Load
3480 Target and an Annual Load Limit for the Arbuckle Creek Tributary will be calculated
3481 according to the following equations and explanation:

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3483 Target = -406.10066 + 115.44341 X

3484 Explained Variance = 67.5 percent, Standard Error of Regression Equation = 18.275

3485 Predictor X is calculated from the first moment (m_1) of the 12 monthly rainfall totals
3486 (r_i , $i=1$ to 12, inches) for the Evaluation Year:

3487 $m_1 = \text{Sum} [r_i] / 12$

3488 $X = \ln (12 m_1)$

3489

3490 Limit = Target + 1.38303 SE

3491 SE = standard error of the Target for May-April interval

3492 $SE = 18.27506 [1 + 1/11 + (X-X_m)^2 / 0.46933]^{0.5}$

3493

3494 Where:

3495 X = the natural logarithm of the 12-month total rainfall (ln(inches))

3496 X_m = average value of the predictor in Reference Period = 3.89382

3497

3498 The predictor X indicates that load increases with total annual rainfall.

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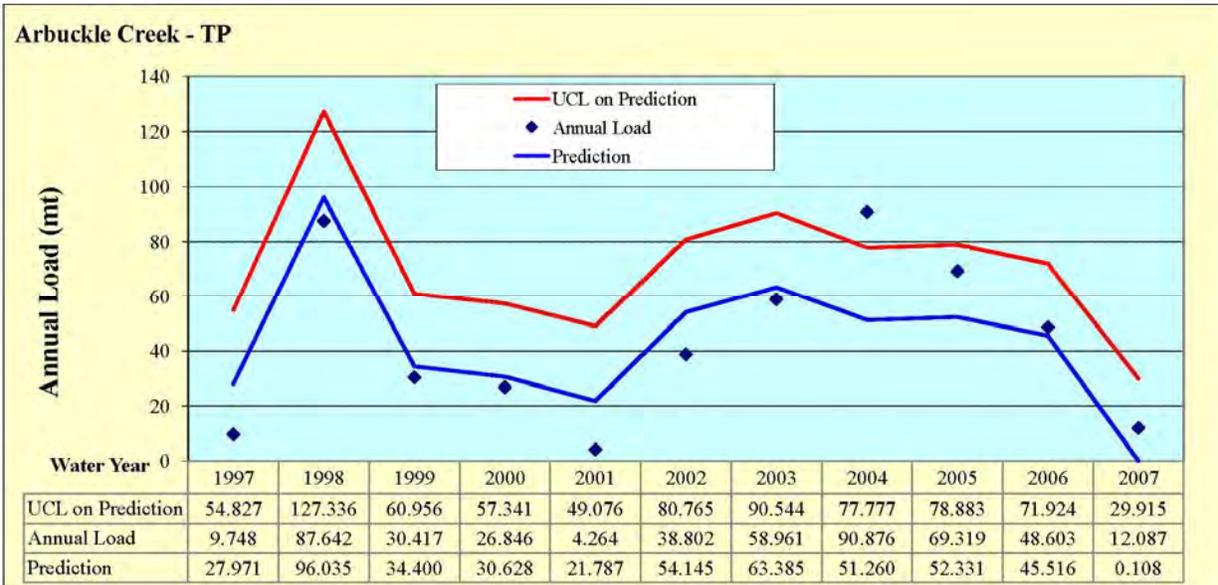
3500 A comparison of the observed loads and the resulting Targets and Limits for the Reference
3501 Period are presented in **Figure 3-32**. Annual TP loads at the tributary outlet monitoring
3502 location will be evaluated against the performance measure described above.

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3504 **Figure 3-32. Comparison of observed annual loads with the Annual Load Targets and**
3505 **Limits for the Arbuckle Creek Tributary.**
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3509 **Suspension of Performance Determination.** The performance determination will be
3510 suspended due to rainfall conditions if the observed annual TP load from the basin, adjusted
3511 for regional projects (if present), exceeds the Annual Load Target and the rainfall falls
3512 outside the range of rainfall values for the Reference Period (33.74 – 77.45 inches). The
3513 calculated Annual Load Targets and Annual Load Limits for the rainfall conditions observed
3514 during the period of record are summarized in **Table 3-41**.

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3516 The annual performance determination process will account for regional projects, as
3517 applicable, and is presented in the flowchart in **Figure 1-2**.

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3519 **Comparison to WY2001-2010.** A comparison of the WY2001-2010 observed loads to the
3520 Annual Load Targets and Limits is presented in **Figure 3-33**.

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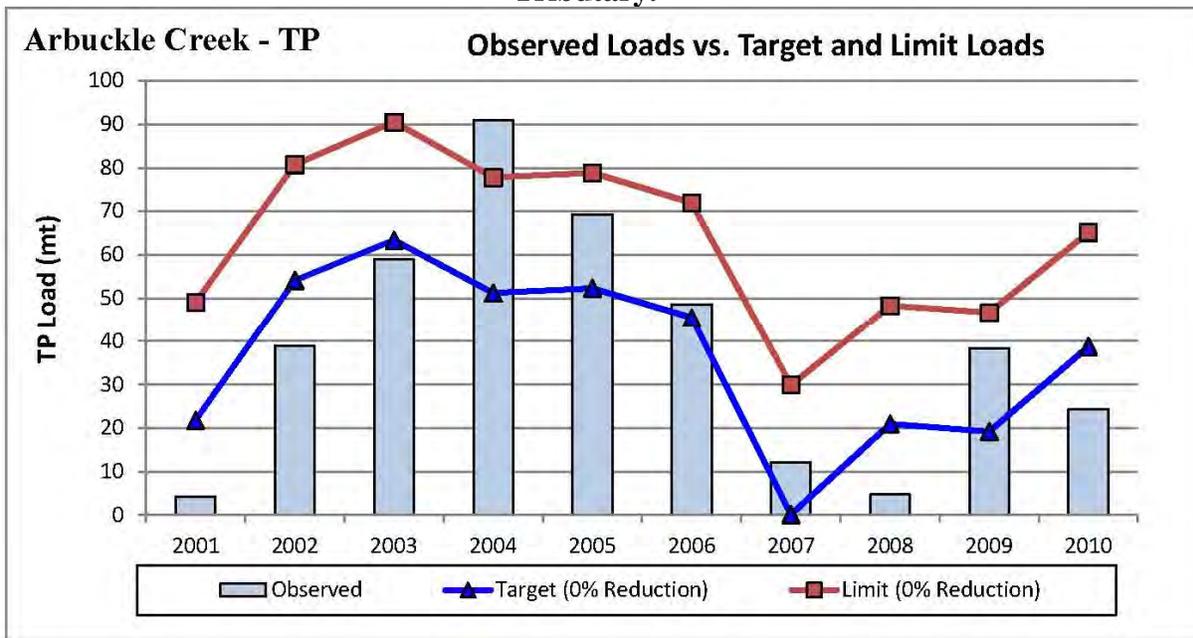
Table 3-41. Annual adjusted rainfall for the historical period of record for the Arbuckle Creek Tributary (Reference Period: WY1997-2007).

Water Year	Observed Load, mt	ln(Rain) ln(inches)	Target Load, mt	SE Load, mt	Limit Load, mt
1997	9.748	3.76004	27.971	19.418	54.827
1998	87.642	4.34963	96.035	22.632	127.336
1999	30.417	3.81573	34.400	19.201	60.956
2000	26.846	3.78305	30.628	19.315	57.341
2001	4.264	3.70647	21.787	19.731	49.076
2002	38.802	3.98676	54.145	19.248	80.765
2003	58.961	4.06680	63.385	19.638	90.544
2004	90.876	3.96177	51.260	19.174	77.777
2005	69.319	3.97105	52.331	19.199	78.883
2006	48.603	3.91202	45.516	19.094	71.924
2007	12.087	3.51868	0.108	21.552	29.915
2008	4.741	3.69932	20.961	19.780	48.318
2009	38.276	3.68387	19.178	19.892	46.690
2010	24.379	3.85333	38.741	19.118	65.182

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Figure 3-33. Comparison of WY2001-2010 loads with Reference Period loads and Annual Load Targets, adjusted for hydrologic variability, for the Boggy Creek Tributary.



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Note: The Reference Period extended from WY1997-2007.





3531 **Exceedance Frequency Analysis.** As shown in **Figure 3-32**, although the scaled observed
 3532 loads fall above the Annual Load Target less than half the time (four out of eleven years, or
 3533 36 percent), these exceedances occur in successive years. Using the approach described in
 3534 Section 2.6, an approximation of the cumulative exceedance frequency for the determination
 3535 methodology was estimated using a Monte Carlo approach based on the annual rainfall and
 3536 the annual TP loads of the Base Period (**Table 3-42**). Because the TP loads and rainfall
 3537 statistics from the Base Period do not perfectly describe normal distributions (e.g., the
 3538 medians are generally less than the means), the methodology includes conditional
 3539 probabilities, and because the random number generator is imperfect, the exceedance
 3540 frequencies deviate from the theoretical values shown in the second column. However, the
 3541 results are determined to be reasonable and defensible since the cumulative exceedance
 3542 frequency is less than the theoretical value of approximately 17.5 percent.

3543

3544 **Table 3-42. Exceedance frequencies for the proposed determination methodology for**
 3545 **the Arbuckle Creek basin.**
 3546

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Rain is outside the range and Load > Annual Load Target	<20%	2.8%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	12.1%
Step 4. Load > Annual Load Limit?	<10%	5.7%
Cumulative Exceedance Frequency	<17.5%	16.1%

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3550 **Site 2: Josephine Creek**

3551 Annual flow and TP data for discharges from the Josephine Creek Tributary are summarized
 3552 in **Table 3-43**. For the development of the performance indicator, a Reference Period of
 3553 WY1997-2004 was selected for the following reasons:





- 3554 ➤ it represents a period with minimal implementation of source controls. With the
- 3555 selection of the Reference Period to precede significant source control
- 3556 implementation, no additional calculation is necessary in the performance indicator
- 3557 to account for prior source control implementation,
- 3558 ➤ it represents a period of relatively constant land use practices,
- 3559 ➤ reliable water quality and hydrologic data are available, and
- 3560 ➤ a strong correlation exists between annual TP loads and rainfall, allowing for a
- 3561 performance indicator that explicitly incorporates hydrologic variability

3562
3563 The Reference Period is compared to the historical period of record and WY2001-2010 in
3564 **Table 3-44.**

3565
3566 **Table 3-43. Summary of historical data for JOSEPHIN, the outlet structure for the**
3567 **Josephine Creek Tributary for the WY 1997-2010 period of record.**
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Water Year	Flow AF	Load mt	FWM Conc, µg/L	Rainfall inches	Unit Area Runoff, inches	Unit Area Load, lbs/ac	Rainfall Characteristics		
							Kurtosis	Coef. Of Var.	Skewness
1997	18,073	0.887	40	41.67	2.39	0.02	-1.595	0.660	0.030
1998	84,407	7.435	71	77.63	11.18	0.18	0.506	0.376	-0.519
1999	36,978	2.349	51	42.72	4.90	0.06	-0.583	1.009	1.038
2000	40,666	2.869	57	54.65	5.39	0.07	-0.927	0.904	0.722
2001	6,852	0.360	43	36.85	0.91	0.01	-1.084	1.143	0.818
2002	47,295	3.139	54	51.20	6.26	0.08	-1.453	0.771	0.309
2003	79,216	5.525	57	62.30	10.49	0.13	-1.497	0.633	0.322
2004	67,107	4.453	54	52.75	8.89	0.11	-0.215	0.721	0.519
2005	83,943	6.323	61	53.51	11.12	0.15	2.431	0.913	1.474
2006	102,465	5.271	42	45.88	13.57	0.13	0.748	0.854	0.840
2007	21,561	1.374	52	29.68	2.86	0.03	-0.284	0.753	0.869
2008	20,122	1.272	51	42.77	2.66	0.03	-0.360	0.630	0.270
2009	71,127	4.639	53	40.19	9.42	0.11	2.746	1.193	1.692
2010	38,864	2.477	52	49.22	5.15	0.06	-1.349	0.690	0.396
Minimum	6,852	0.360	40	29.68	0.91	0.01	-1.595	0.376	-0.519
Average	51,334	3.455	53	48.64	6.80	0.08	-0.208	0.804	0.627
Maximum	102,465	7.435	71	77.63	13.57	0.18	2.746	1.193	1.692
Std. Dev.	29,906	2.183	8	11.79	3.96	0.05	1.387	0.218	0.570
Median	43,981	3.004	53	47.55	5.82	0.07	-0.472	0.762	0.621
Skewness	0.168	0.307	0.471	0.958	0.168	0.307	1.214	0.136	0.037

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Table 3-44. Comparison of the Reference Period with the period of record data for Josephine Creek.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Load lbs/ac
Period of Record - WY1997-2010					
Annual Minimum	6,852	0.360	40	36.85	0.01
Annual Average	51,334	3.455	55	52.66	0.08
Annual Median	43,981	3.004	53	53.13	0.07
Annual Maximum	102,465	7.435	71	77.63	0.18
Preliminary Reference Period WY1997-2004					
Annual Minimum	6,852	0.360	40	41.67	0.01
Annual Average	47,574	3.377	58	53.24	0.08
Annual Median	43,981	3.004	54	52.58	0.07
Annual Maximum	84,407	7.435	71	77.63	0.18
Difference between Period of Record and Reference Period					
Annual Minimum	0	0.000	0	-4.82	0.000
Annual Average	3,760	0.078	-3	-0.59	0.002
Annual Median	0	0.000	-2	0.55	0.000
Annual Maximum	18,058	0.000	0	0.00	0.000
Annual Minimum	0%	0%	0%	-12%	0%
Annual Average	8%	2%	-5%	-1%	2%
Annual Median	0%	0%	-3%	1%	0%
Annual Maximum	21%	0%	0%	0%	0%
WY2001-2010					
Annual Minimum	6,852	0.360	42	36.85	0.01
Annual Average	53,855	3.483	52	52.97	0.08
Annual Median	57,201	3.796	53	53.13	0.09
Annual Maximum	102,465	6.323	61	77.63	0.15
Difference between WY2001-2010 and Reference Period					
Annual Minimum	0	0.000	2	-4.82	0.00
Annual Average	6,281	0.106	-5	-0.28	0.00
Annual Median	13,221	0.792	-2	0.55	0.02
Annual Maximum	18,058	-1.112	-10	0.00	-0.03
Annual Minimum	0%	0%	5%	-12%	0%
Annual Average	13%	3%	-9%	-1%	3%
Annual Median	30%	26%	-3%	1%	26%
Annual Maximum	21%	-15%	-14%	0%	-15%

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3576 Based on the fact that the annual median total phosphorus concentration for the period of
3577 record (53 µg/l) is below the Numeric Nutrient Criteria (120 µg/l) (Chapter 62-302, F.A.C.),
3578 it is recommended that no reduction goal be applied to tributary. An Annual Load Target
3579 and an Annual Load Limit for the Josephine Creek Tributary will be calculated according to
3580 the following equations and explanation:

3581

3582 Target = -33.98677 + 9.49604 X

3583 Explained Variance = 92.7 percent, Standard Error of Regression Equation = 0.686

3584 Predictor X is calculated from the first moment (m_1) of the 12 monthly rainfall totals
3585 (r_i , $i=1$ to 12, inches) for the Evaluation Year:

3586 $m_1 = \text{Sum} [r_i] / 12$

3587 $X = \ln (12 m_1)$

3588

3589 Limit = Target + 1.43976 SE

3590 SE = standard error of the Target for May-April interval

3591 $SE = 0.68581 [1 + 1/8 + (X-X_m)^2 / 0.40023]^{0.5}$

3592

3593 Where:

3594 X = the natural logarithm of the 12-month total rainfall (ln(inches))

3595 X_m = average value of the predictor in Reference Period = 3.93468

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3597 The predictor X indicates that load increases with total annual rainfall.

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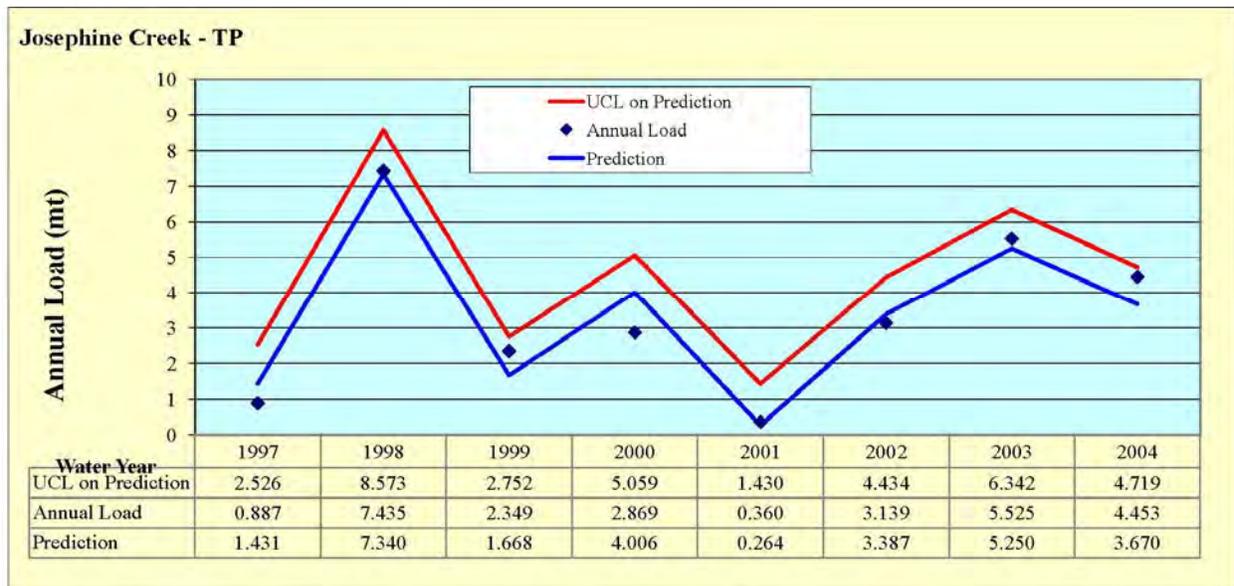
3599 A comparison of the observed loads and the resulting Targets and Limits for the Reference
3600 Period are presented in **Figure 3-34**. Annual TP loads at the tributary outlet monitoring
3601 location, will be evaluated against the performance measure described above.

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3603 **Figure 3-34. Comparison of observed annual loads with the Annual Load Targets and**
3604 **Limits for the Josephine Creek Tributary.**
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3608 **Suspension of Performance Determination.** The performance determination will be
3609 suspended due to rainfall conditions if the observed annual TP load from the basin, adjusted
3610 for regional projects (if present), exceeds the Annual Load Target and the rainfall falls
3611 outside the range of rainfall values for the Reference Period (36.85 – 77.63 inches). The
3612 calculated Annual Load Targets and Annual Load Limits for the rainfall conditions observed
3613 during the period of record are summarized in **Table 3-45**.

3614
3615 The annual performance determination process will account for regional projects, as
3616 applicable, and is presented in the flowchart in **Figure 1-2**.

3617
3618 **Comparison to WY2001-2010.** A comparison of the WY2001-2010 observed loads to the
3619 Annual Load Targets and Limits is presented in **Figure 3-35**.

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Table 3-45. Annual adjusted rainfall for the historical period of record for the Josephine Creek Tributary (Reference Period: WY1997-2004).

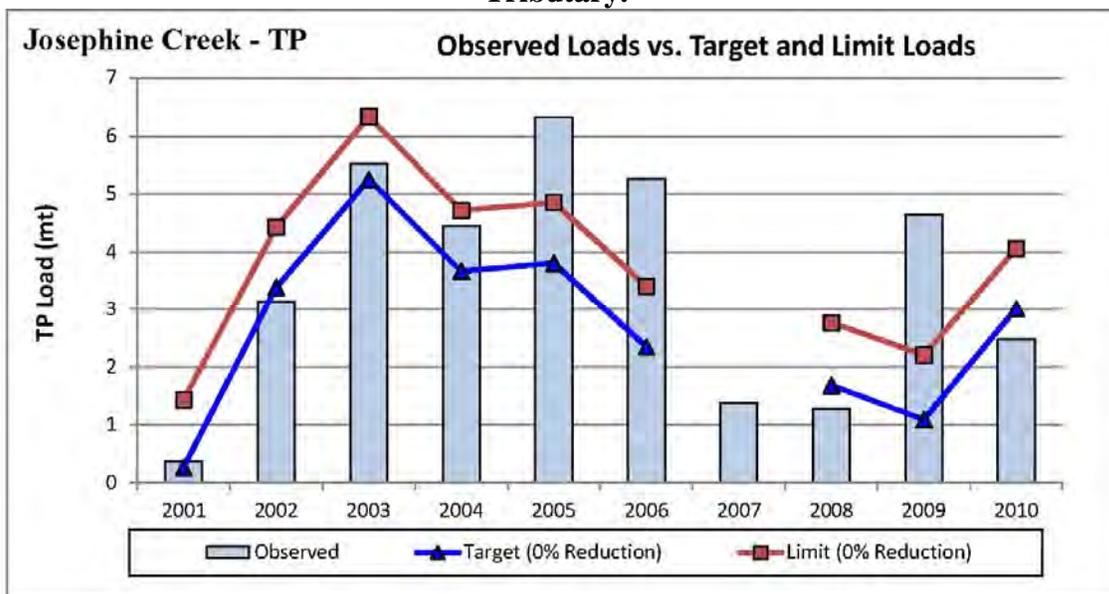
Water Year	Observed Load, mt	ln(Rain) ln(inches)	Target Load, mt	SE Load, mt	Limit Load, mt
1997	0.887	3.72978	1.431	0.761	2.526
1998	7.435	4.35195	7.340	0.857	8.573
1999	2.349	3.75467	1.668	0.753	2.752
2000	2.869	4.00095	4.006	0.731	5.059
2001	0.360	3.60686	0.264	0.810	1.430
2002	3.139	3.93574	3.387	0.727	4.434
2003	5.525	4.13196	5.250	0.758	6.342
2004	4.453	3.96556	3.670	0.728	4.719
2005	6.323	3.97987	3.806	0.729	4.856
2006	5.271	3.82603	2.345	0.737	3.406
2007	1.374	3.39047	-1.791	0.937	-0.442
2008	1.272	3.75584	1.679	0.753	2.763
2009	4.639	3.69362	1.088	0.773	2.201
2010	2.477	3.89630	3.013	0.729	4.062

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Note: Shaded water years indicate the performance determination would have been suspended due to anomalous rainfall coupled with the observed load being greater than the Load Target.

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Figure 3-35. Comparison of WY2001-2010 loads with Reference Period loads and Annual Load Targets, adjusted for hydrologic variability, for the Josephine Creek Tributary.



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Note: The Reference Period extended from WY1997-2004. The performance determination for WY2007 would have been suspended due to rainfall below the minimum value during the Reference Period coupled with the observed load being greater than the Load Target.





3634 **Exceedance Frequency Analysis.** Using the approach described in Section 2.6, an
 3635 approximation of the cumulative exceedance frequency for the determination methodology
 3636 was estimated using a Monte Carlo approach based on the annual rainfall and the annual TP
 3637 loads of the Base Period (**Table 3-46**). Because the TP loads and rainfall statistics from the
 3638 Base Period do not perfectly describe normal distributions (e.g., the medians are generally
 3639 less than the means), the methodology includes conditional probabilities, and because the
 3640 random number generator is imperfect, the exceedance frequencies deviate from the
 3641 theoretical values shown in the second column. However, the results are determined to be
 3642 reasonable and defensible since the cumulative exceedance frequency is less than the
 3643 theoretical value of approximately 17.5 percent.

3644

3645 **Table 3-46. Exceedance frequencies for the proposed determination methodology for**
 3646 **the Josephine Creek basin.**

3647

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Rain is outside the range and Load > Annual Load Target	<20%	6.0%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	10.9%
Step 4. Load > Annual Load Limit?	<10%	4.0%
Cumulative Exceedance Frequency	<17.5%	13.8%

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3657 **3.7 West Lake Okeechobee Sub-watershed**

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3659 The West Lake Okeechobee Sub-watershed is composed of 246,240 acres located along the
3660 west shore of Lake Okeechobee, south of Fisheating Creek and northeast of the South Lake
3661 Okeechobee Sub-watershed (**Figure 3-36**). The sub-watershed consists of two smaller
3662 hydrologic units, East Caloosahatchee and S-4/Industrial Canal. These two hydrologic units
3663 are referred to as summary basins in reference to the Lake Okeechobee Watershed, while
3664 they are referred to as sub-watersheds in the Caloosahatchee River Watershed. For the
3665 purposes of this report, both areas will simply be referred to as hydrologic units or basins.
3666 Flow and TP monitoring sites are identified in **Tables C-1** and **C-2**.

3667
3668 District staff identified five rainfall stations considered to be representative of the West Lake
3669 Okeechobee Sub-watershed. Monthly rainfall data and weighting factors for the rainfall
3670 stations for each basin were developed and provided by the District. All selected rainfall
3671 stations had periods of record that began no later than May 1976. The Thiessen Polygons
3672 and associated weighting factors used to calculate basin rainfall values are shown in **Figure**
3673 **3-37**.

3674
3675 The following sections describe the derivation of the performance measure methodologies
3676 for TP for the basins within the West Lake Okeechobee Sub-watershed. Performance
3677 measure(s) for nitrogen species will be addressed in a future document for the
3678 Caloosahatchee River Watershed.

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Technical Support Document
Lake Okeechobee Watershed Performance Measures

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Figure 3-36. West Lake Okeechobee Sub-watershed boundary and discharge monitoring locations.



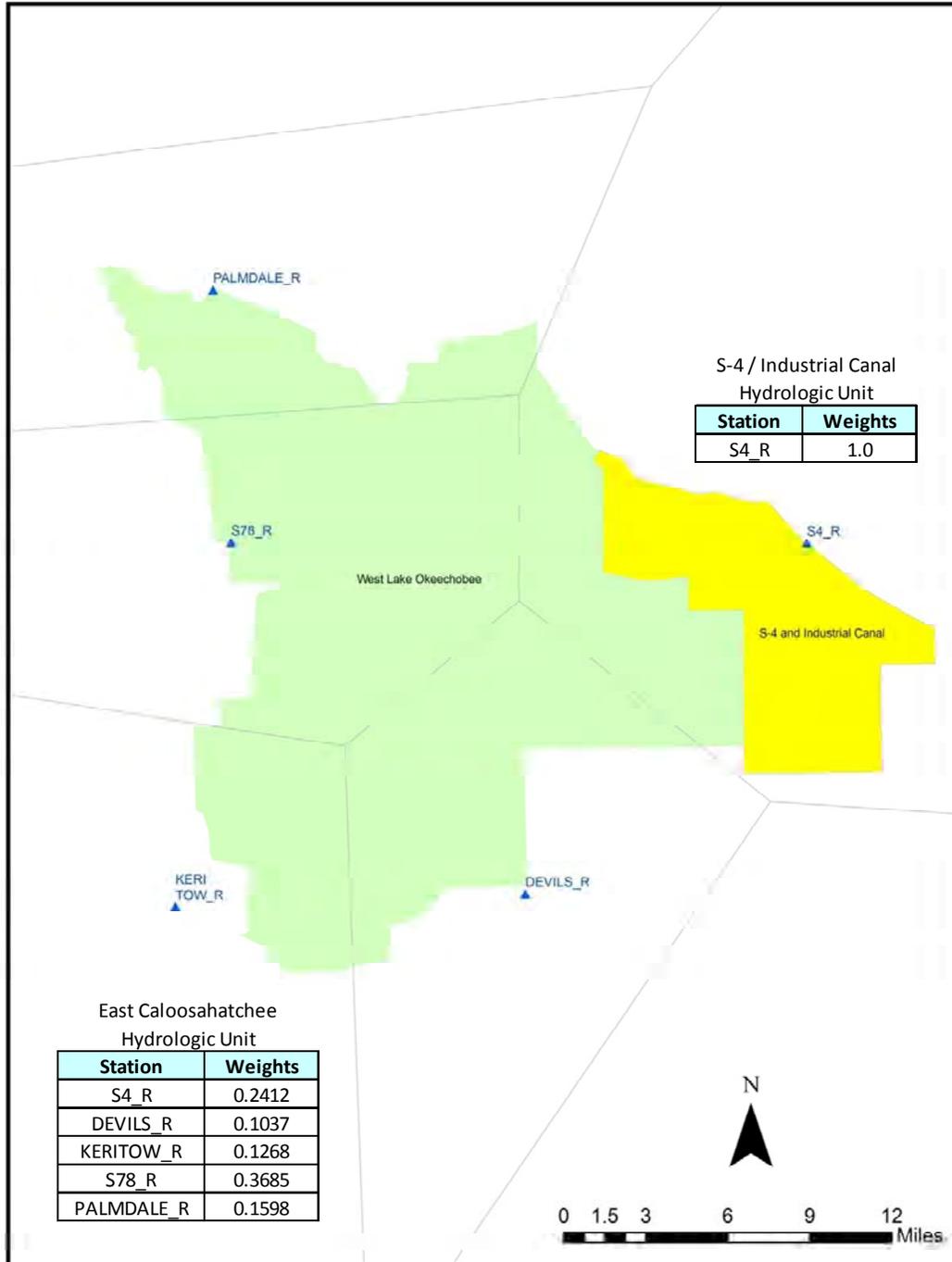
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Figure 3-37. Schematic of West Lake Okeechobee Sub-watershed, hydrologic units and selected rainfall stations.



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3691 **3.7.1 S-4/Industrial Canal Hydrologic Unit**
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3693 The S-4/Industrial Canal Hydrologic Unit is composed of 42,145 acres located along the west
3694 shore of Lake Okeechobee between the East Caloosahatchee Hydrologic Unit and the South
3695 Lake Okeechobee Sub-watershed. The S-4/Industrial Canal Hydrologic Unit contains two
3696 interconnected sub-basins: S-4 and Industrial Canal. The S-4/Industrial Canal Hydrologic
3697 Unit is also referred to as the S-4 Sub-watershed, e.g., in the Caloosahatchee River
3698 Watershed. S-169 is a culvert structure that discharges in both directions between the
3699 Industrial Canal Sub-basin and the S-4 Sub-basin. The S-4/Industrial Canal Hydrologic Unit
3700 has four primary structures on its borders with Lake Okeechobee, the East Caloosahatchee
3701 Hydrologic Unit, and the South Florida Conservancy District (SFCD) Unit 5 which is within
3702 the South Lake Okeechobee Sub-watershed (east of structure EPD-07) (**Figure 3-38**):

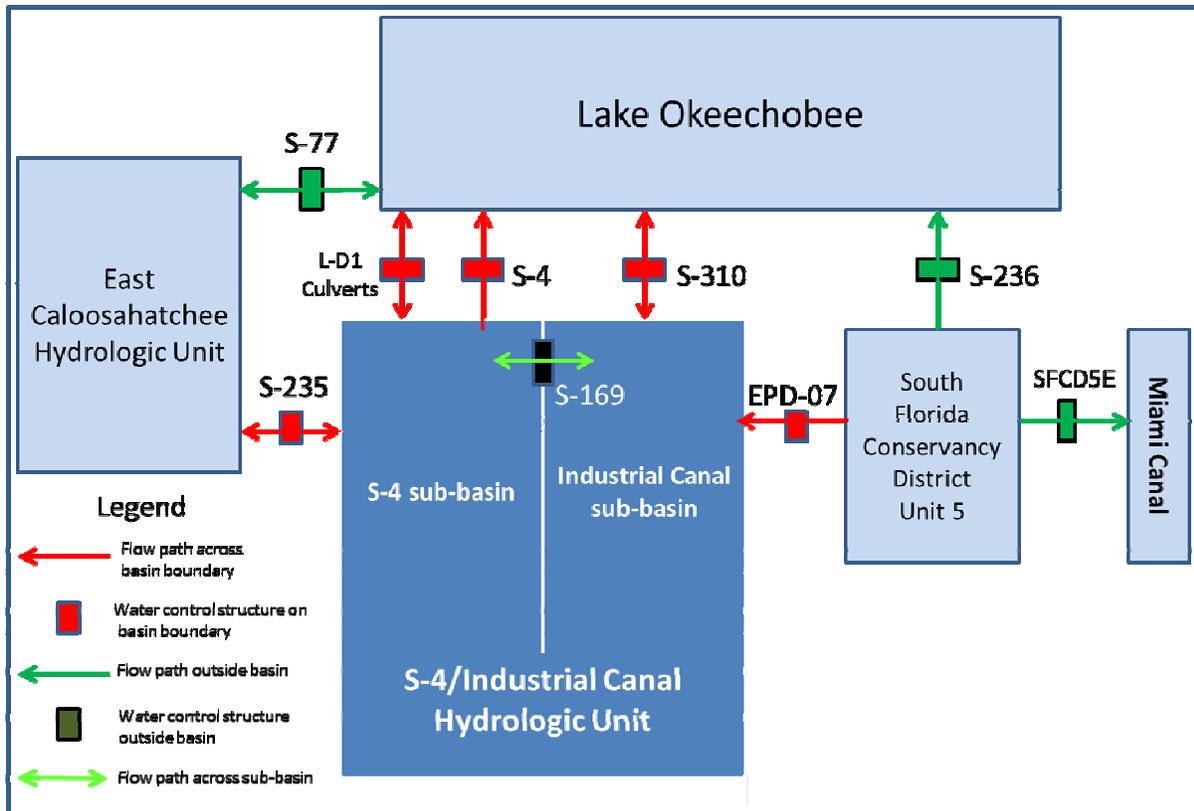
- 3703 • S-235 is a culvert that discharges in both directions between S-4/Industrial Canal
3704 Hydrologic Unit and the East Caloosahatchee Hydrologic Unit;
- 3705 • S-4 is a pump station that discharges from the S-4/Industrial Canal Hydrologic Unit
3706 to Lake Okeechobee;
- 3707 • S-310 is a boat lock that passes water in both directions between the S-4/Industrial
3708 Canal Hydrologic Unit and Lake Okeechobee when lake stages are below 15.5 feet,
3709 NGVD (the gate is closed when the lake stage is above 15.5 ft NGVD, from SFWMD
3710 Structure Books); and
- 3711 • EPD-07 is a pump station that discharges excess water from the SFCD Unit 5 in the
3712 South Lake Okeechobee Sub-watershed to Industrial Canal. In August 2005, new
3713 facilities became operational that enabled the diversion of a long-term average annual
3714 80 percent of the SFCD Unit 5 drainage away from Lake Okeechobee as required by
3715 the Everglades Forever Act (Burns & McDonnell, 2008).





3716 Other structures that discharge to and from the S-4/Industrial Canal Hydrologic Unit are the
 3717 LD-1 culverts (C-1, C-1A, and C-2 – discharge to/from Lake Okeechobee) and the Disston
 3718 Island Conservancy District Pump Station No. 3 (DICD#3 - discharges to/from the East
 3719 Caloosahatchee Hydrologic Unit). No discharge records are available for these structures
 3720 and it is assumed that the nutrient loads discharged from these structures are not significant.
 3721 Hence, these structures are not addressed in this performance measure.

3722 **Figure 3-38. S-4/Industrial Canal Hydrologic Unit Flow Schematic.**
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3729 **3.7.1.1 Background**

3730
3731 The performance measure methodology is based on flows and TP loads resulting from
3732 rainfall and runoff from the S-4/Industrial Canal Hydrologic Unit. Basin flows and loads,
3733 adjusted for pass-through flows and loads discharged from external sources, were calculated
3734 using algorithms provided in Appendix A. Annual basin flow and TP data for discharges
3735 from the S-4/Industrial Canal Hydrologic Unit for the WY1993-2010 period of record are
3736 summarized in **Table 3-47**.

3737

3738 **Table 3-47. Summary of historical data for the S-4/Industrial Canal Hydrologic Unit.**

3739

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics		
							Kurtosis K	Coef. Of Var. CV	Skewness S
1992				38.80			-0.934	0.534	0.308
1993	106,756	17.622	134	46.54	30.40	0.92	5.558	1.235	2.175
1994	71,896	7.485	84	33.83	20.47	0.39	-0.994	0.576	0.302
1995	101,775	23.532	187	58.12	28.98	1.23	1.402	0.620	1.328
1996	129,326	23.440	147	53.38	36.82	1.23	-0.552	0.864	0.763
1997	88,818	10.278	94	38.13	25.29	0.54	-0.733	0.801	0.566
1998	114,857	16.179	114	54.22	32.70	0.85	1.039	0.763	1.007
1999	78,842	20.649	212	34.48	22.45	1.08	1.398	1.225	1.449
2000	131,064	28.655	177	58.34	37.32	1.50	3.871	1.133	1.733
2001	36,636	6.888	152	34.30	10.43	0.36	-0.615	1.006	0.803
2002	47,396	11.258	193	43.78	13.50	0.59	-1.095	0.783	0.660
2003	94,857	20.933	179	42.96	27.01	1.10	1.878	0.923	1.586
2004	88,864	15.699	143	36.98	25.30	0.82	-0.432	0.696	0.239
2005	110,534	22.510	165	40.47	31.47	1.18	0.269	0.927	1.109
2006	113,392	30.280	216	48.63	32.29	1.58	-0.372	0.930	0.786
2007	25,621	6.906	219	24.83	7.30	0.36	-0.052	1.079	1.130
2008	15,712	4.519	233	36.52	4.47	0.24	-1.578	0.683	0.255
2009	48,116	16.153	272	30.54	13.70	0.84	0.181	1.128	1.064
2010	109,247	21.455	159	56.29	31.11	1.12	-1.709	0.679	-0.137
Minimum	15,712	4.519	84	24.83	4.47	0.24	-1.709	0.576	-0.137
Average	84,095	16.913	163	42.91	23.94	0.88	0.415	0.892	0.934
Maximum	131,064	30.280	272	58.34	37.32	1.58	5.558	1.235	2.175
Std. Dev.	35,596	7.697	49	10.13	10.14	0.40	1.887	0.208	0.588
Skewness	-0.618	-0.039	0.082	0.130	-0.618	-0.04	1.518	0.229	0.226
Median	91,861	16.901	171	41.72	26.16	0.88	-0.212	0.894	0.905

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3742 For the development of the performance measure methodology, a Base Period of WY1993-
3743 2001 was selected for the following reasons.





- 3744 ➤ It represents a period with minimal implementation of source controls. With the
3745 selection of the Base Period to precede significant source control implementation,
3746 no additional calculation is necessary in the performance measure methodology to
3747 account for prior source control implementation.
- 3748 ➤ Beginning in WY2006, discharges into the basin from the adjacent Ch. 298
3749 District have decreased by more than 80 percent, a result of the mandated
3750 diversion project. However, there has been no noticeable effect on the basin
3751 flows and TP loads, likely due to the pass-through algorithm used to account for
3752 these external inflows.
- 3753 ➤ It represents a period of relatively constant land use practices.
- 3754 ➤ It contained a reasonably wide range of hydrologic conditions.
- 3755 ➤ Reliable water quality and flow data are available
- 3756 ➤ A strong correlation exists between annual TP loads and rainfall, allowing for a
3757 performance measure methodology that explicitly incorporates hydrologic
3758 variability.

3759 The Base Period is compared to the historical period of record and WY2001-2010 in **Table**
3760 **3-48.**

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Table 3-48. Comparison of Base Period with period of record and WY2001-2010 data for the S-4/Industrial Canal Hydrologic Unit.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1993-2010					
Annual Minimum	15,712	4.519	84	24.83	0.24
Annual Average	84,095	16.913	163	42.91	0.88
Annual Median	91,861	16.901	171	41.72	0.88
Annual Maximum	131,064	30.280	272	58.34	1.58
Base Period WY1993-2001					
Annual Minimum	36,636	6.888	84	33.83	0.36
Annual Average	95,552	17.192	146	45.70	0.90
Annual Median	101,775	17.622	147	46.54	0.92
Annual Maximum	131,064	28.655	212	58.34	1.50
Difference between Period of Record and Base Period					
Annual Minimum	-20,924	-2.369	0	-9.00	-0.12
Annual Average	-11,457	-0.279	17	-2.80	-0.01
Annual Median	-9,915	-0.721	24	-4.83	-0.04
Annual Maximum	0	1.625	60	0.00	0.09
Annual Minimum	-57%	-34%	0%	-27%	-34%
Annual Average	-12%	-2%	12%	-6%	-2%
Annual Median	-10%	-4%	16%	-10%	-4%
Annual Maximum	0%	6%	28%	0%	6%
WY2001-2010					
Annual Minimum	15,712	4.519	143	24.83	0.24
Annual Average	69,038	15.660	184	39.53	0.82
Annual Median	68,490	15.926	186	38.73	0.83
Annual Maximum	113,392	30.280	272	56.29	1.58
Difference between WY2001-2010 and Base Period					
Annual Minimum	-20,924	-2.369	59	-9.00	-0.12
Annual Average	-26,515	-1.532	38	-6.17	-0.08
Annual Median	-33,285	-1.696	39	-7.82	-0.09
Annual Maximum	-17,672	1.625	60	-2.05	0.09
Annual Minimum	-57%	-34%	70%	-27%	-34%
Annual Average	-28%	-9%	26%	-14%	-9%
Annual Median	-33%	-10%	27%	-17%	-10%
Annual Maximum	-13%	6%	28%	-4%	6%

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3775 **3.7.1.2 Performance Measure Methodology**

3776
3777 Based on the evaluation of individual land use source control effectiveness ranges described
3778 in Section 2.6, the overall range of TP load reduction that could be accomplished through
3779 collective source controls within the basin was estimated, and a load reduction target of 30
3780 percent was determined to be reasonable and appropriate. Details are provided in Appendix
3781 D and in Attachment 1.

3782
3783 An Annual Load Target and an Annual Load Limit were derived from the Base Period data
3784 using a 30 percent load reduction. The Annual Load Target and Annual Load Limit will be
3785 calculated according to the following equations and explanation:

3786
3787 Target = $-14.62787 + 0.41452 X + 8.44621 C$
3788 Explained Variance = 76.2%, Standard Error of Regression = 3.026 mt

3789
3790 Predictors (X and C) are calculated from the first two moments (m_1, m_2) of
3791 the 12 monthly rainfall totals ($r_i, i=1$ to 12, inches) for the Evaluation Year:

3792 $m_1 = \text{Sum} [r_i] / 12$

3793 $m_2 = \text{Sum} [r_i - m_1]^2 / 12$

3794 $X = 12 m_1$

3795 $C = [(12/11) m_2]^{0.5} / m_1$

3796 Limit = Target + 1.43976 SE

3797 SE = standard error of the Target for May-April interval

3798 $SE = 3.02608 [1 + 1/9 + 0.00112 (X-X_m)^2 + 2.03794 (C-C_m)^2 +$
3799 $0.00884 (X-X_m) (C-C_m)]^{0.5}$

3800 Where:

3801 X = the 12-month total rainfall (inches)





3802 C = coefficient of variation calculated from 12 monthly rainfall totals

3803 X_m = average value of the predictor in base period = 45.704 inches

3804 C_m = average value of the predictor in base period = 0.91367

3805

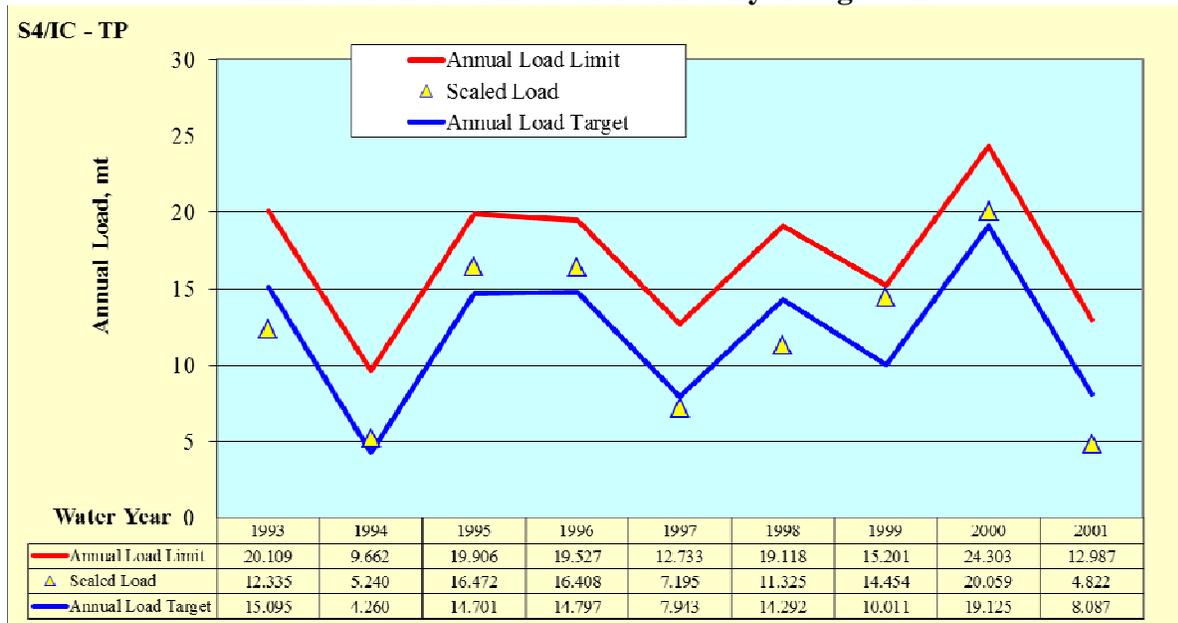
3806 The first predictor (X) indicates that load increases with total annual rainfall. The second
3807 predictor (C) indicates that the load resulting from a given annual rainfall is higher when
3808 the distribution of monthly rainfall has higher variability. For a given annual rainfall, the
3809 lowest load occurs when rainfall is evenly distributed across months and the highest load
3810 occurs when all of the rain falls in one month. Real cases are likely to fall in between.

3811

3812 A comparison of the scaled loads and the resulting Targets and Limits for the Base Period
3813 are presented in **Figure 3-39**. Annual TP loads at the sub-watershed outlet structures,
3814 adjusted to account for regional projects (as applicable) and pass-through loads as described
3815 in Appendix A, will be evaluated against the performance measure described above.

3816

3817 **Figure 3-39. Comparison of scaled annual loads with the Annual Load Targets and**
3818 **Limits for the S-4/Industrial Canal Hydrologic Unit.**



3819





3820 **Suspension of Performance Determination.** The performance determination will be
3821 suspended due to rainfall conditions if the observed annual TP load, adjusted for regional
3822 projects (if present), from the basin exceeds the Annual Load Target and the adjusted rainfall
3823 falls outside the range of adjusted rainfall values for the Base Period (26.95 – 62.81 inches),
3824 as derived below. Rainfall conditions will be assessed by calculating an adjusted rainfall
3825 amount which reflects the cumulative effect of the predictor variables of the Annual Load
3826 Target equation. The adjusted rainfall is the rainfall that would produce the equivalent
3827 annual load using the Annual Load Target equation by setting the value of C to its mean
3828 value for the calibration period.

3829

3830
$$\text{Adjusted Rain} = X + 20.37588 (C - 0.91367)$$

3831

3832 The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the
3833 WY1993-2010 period of record are summarized in **Table 3-49**.

3834

3835 The annual performance determination process will account for pass-through loads and
3836 regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

3837

3838 **Comparison to WY2001-2010.** A comparison of the WY2001-2010 observed loads to the
3839 Annual Load Targets and Limits is presented in **Figure 3-40**.

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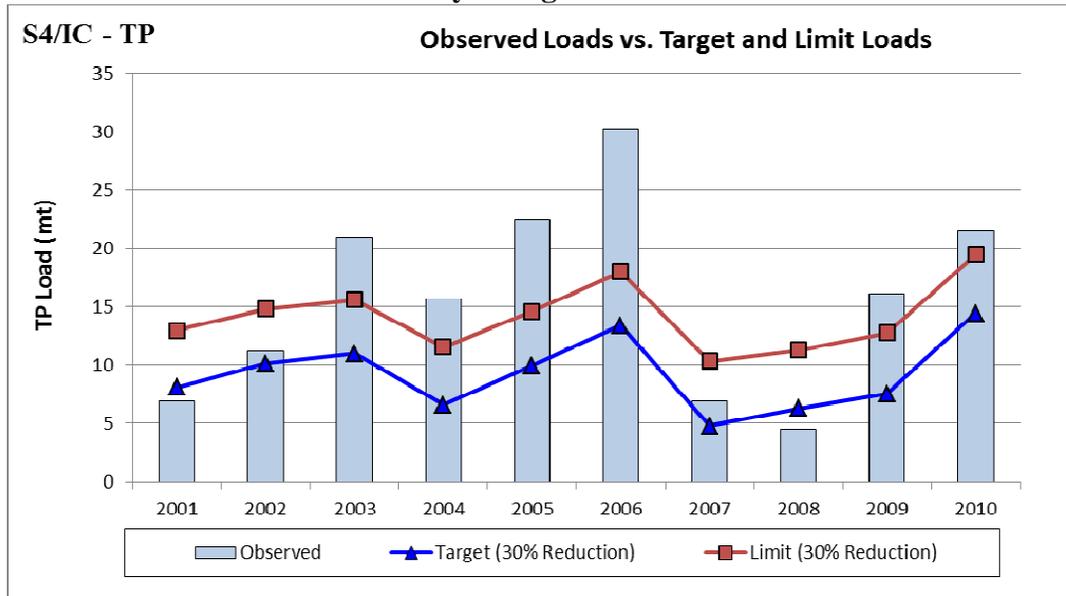
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Table 3-49. Annual adjusted rainfall for the historical period of record for the S-4/Industrial Canal Hydrologic Unit (Base Period: WY1993-2001).

Water Year	Observed Load, mt	Rain in	CV	Target Load, mt	Limit Load, mt	Adjusted Rain, in
1993	17.622	46.54	1.235	15.095	20.110	53.09
1994	7.485	33.83	0.576	4.260	9.661	26.95
1995	23.532	58.12	0.620	14.701	19.906	52.14
1996	23.440	53.38	0.864	14.797	19.527	52.37
1997	10.278	38.13	0.801	7.943	12.733	35.83
1998	16.179	54.22	0.763	14.292	19.119	51.15
1999	20.649	34.48	1.225	10.011	15.201	40.82
2000	28.655	58.34	1.133	19.125	24.303	62.81
2001	6.888	34.30	1.006	8.087	12.987	36.18
2002	11.258	43.78	0.783	10.133	14.810	41.12
2003	20.933	42.96	0.923	10.976	15.586	43.15
2004	15.699	36.98	0.696	6.580	11.566	32.54
2005	22.510	40.47	0.927	9.977	14.632	40.74
2006	30.280	48.63	0.930	13.385	17.999	48.96
2007	6.906	24.83	1.079	4.778	10.331	28.20
2008	4.519	36.52	0.683	6.279	11.309	31.82
2009	16.153	30.54	1.128	7.559	12.776	34.91
2010	21.455	56.29	0.679	14.440	19.459	51.51

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Figure 3-40. Comparison of WY2001-2010 loads with Base Period loads and Annual Load Targets, adjusted for hydrologic variability, for the S-4/Industrial Canal Hydrologic Unit.



Note: The Base Period extended from WY1993-2001.

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3858 **Exceedance Frequency Analysis.** As shown in **Figure 3-39**, although the scaled observed
3859 loads fall above the Annual Load Target roughly half the time (five out of nine years, or 55
3860 percent), three of these exceedances occur in successive years. In accordance with the
3861 proposed performance determination process discussed in Section 2.6, three successive years
3862 when the observed load exceeds the Annual Load Target would prevent the basin from
3863 meeting its performance measure. In the case of the scaled Base Period data, this is an
3864 example of a Type I error²⁰, or “false positive” - when the performance method suggests a
3865 lack of compliance when the basin’s load actually achieves the long-term reduction goals.
3866 The use of a three-year cycle for the Annual Load Target is consistent with the District’s
3867 Chapter 40E-63 F.A.C., and has a theoretical Type I error (i.e., false positive) rate of 12.5
3868 percent. Using the approach described in Section 2.6, an approximation of the cumulative
3869 exceedance frequency for the determination methodology was estimated using a Monte Carlo
3870 approach based on the annual rainfall and the annual TP loads of the Base Period (**Table 3-**
3871 **50**). Because the TP loads and rainfall statistics from the Base Period do not perfectly
3872 describe normal distributions (e.g., the medians are generally less than the means), the
3873 methodology includes conditional probabilities, and because the random number generator is
3874 imperfect, the exceedance frequencies deviate from the theoretical values shown in the
3875 second column. However, the results are determined to be reasonable and defensible since
3876 the cumulative exceedance frequency is less than the theoretical value of approximately 17.5
3877 percent.

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²⁰ The Type I error rate is the probability that the performance measure methodology will reject the null hypothesis (i.e., a determination that the TP load does not meet the performance measure) when in reality the null hypothesis is true – the annual load meets the performance measure, and is therefore also known as the false positive rate.





3884 **Table 3-50. Exceedance frequencies for the proposed determination methodology for**
3885 **the S-4/Industrial Canal Hydrologic Unit.**
3886

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Rain _{adj} is outside the range and Load > Annual Load Target	<20%	5.2%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	11.2%
Step 4. Load > Annual Load Limit?	<10%	3.0%
Cumulative Exceedance Frequency	<17.5%	13.4%

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3.7.2 East Caloosahatchee Hydrologic Unit

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The East Caloosahatchee Hydrologic Unit consists of 204,094 acres located adjacent to the west shoreline of Lake Okeechobee. It includes the area that drains to C-43 Canal between S-77 and S-78. Flows are discharged to and from Lake Okeechobee at S-77. Flows are also discharged to and from the S-4/Industrial Canal Hydrologic Unit at S-235. The East Caloosahatchee Hydrologic Unit is also referred to as the East Caloosahatchee Sub-watershed of the Caloosahatchee River Watershed²¹. The historical data analysis for the East Caloosahatchee Hydrologic Unit was prepared under a separate contract by HDR Engineering, Inc. (2011b) and is summarized herein.

There are five additional locations where flows cross the boundaries of the East Caloosahatchee Hydrologic Unit (**Figure 3-417**), as described below:

- Disston Island Conservancy District Pump No. 3 (DICD3) discharges in both directions to and from the S-4/Industrial Canal Hydrologic Unit,
- S-342N discharges from Nicodemus Slough,
- G-135 discharges from the L-1 Borrow Canal (Flaghole Drainage District) to C-43, and
- Canals 1, 2, and 3, with other tertiary canals, provide a connection with the West Caloosahatchee Sub-watershed (the area that drains to C-43 between S-78 and S-79).
- Culvert 5A discharges both directions to and from Lake Okeechobee.

The discharges at these locations are small and there are little or no flow or water quality data (HDR 2011b for DICD3, S-342N G-135, and Canals 1, 2, and 3. Culvert 5A data was evaluated by District staff and was assumed that the nutrient loads discharge from this

¹ Performance measure(s) for nitrogen species will be addressed in a future document for the Caloosahatchee River Watershed



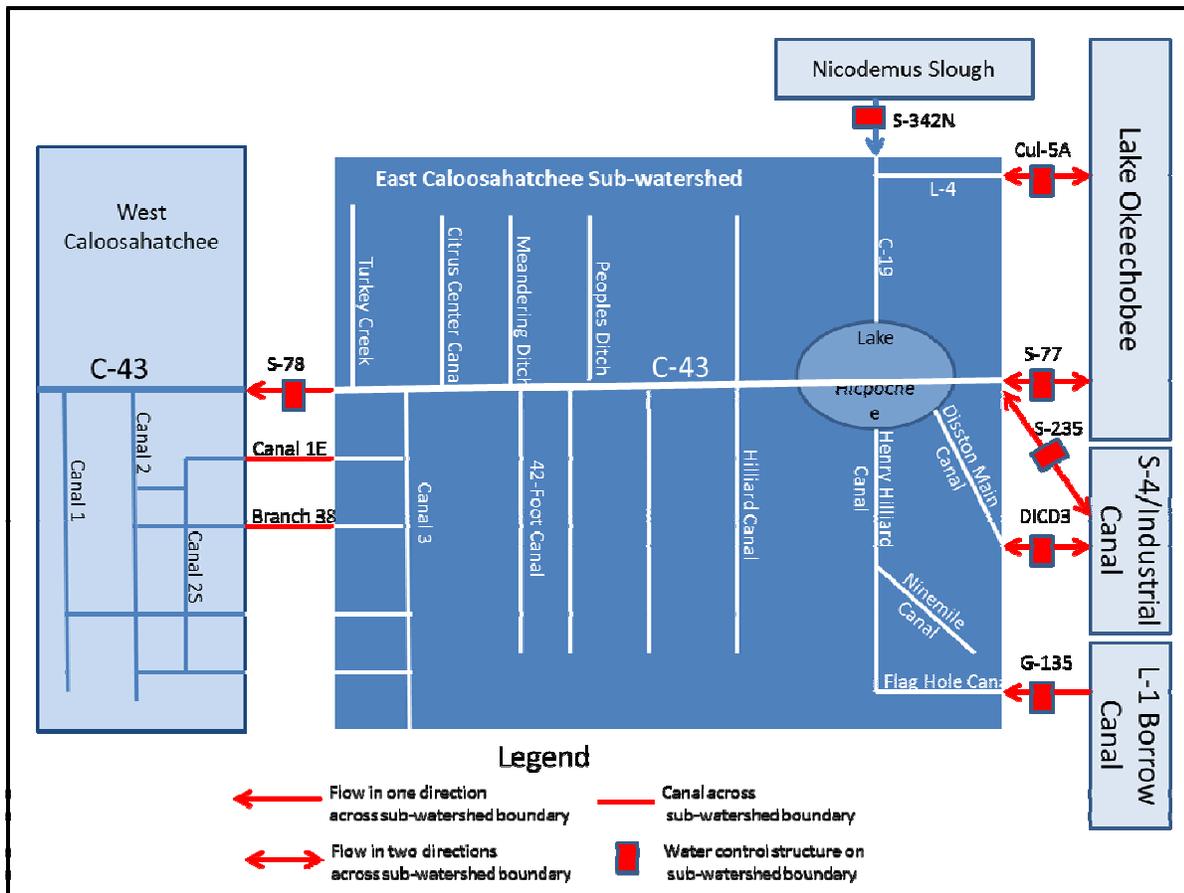


3938 structure was not significant). Hence, these flows and loads were not considered in this
3939 performance measure methodology.

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Figure 3-41. Flow diagram for East Caloosahatchee basin.



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3945 3.7.2.1 Background

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The performance measure methodology is based on flows and TP loads resulting from rainfall and runoff from the East Caloosahatchee Hydrologic Unit. Basin flows and loads, adjusted for pass through flows and loads discharged from external sources, were calculated





3950 using algorithms provided in Appendix A. Annual flow and TP data for discharges from the
3951 East Caloosahatchee Hydrologic Units are summarized in Table 3-51.

3952 Table 3-51. Summary of historical data for the East Caloosahatchee Hydrologic Unit.
3953
3954

Table with 10 columns: Water Year, Flow AF, TP Load mt, FWM TP Conc µg/L, Rainfall inches, Unit Area Runoff in/yr, Unit Area Load lbs/ac, Kurtosis K, Coef. Of Var. CV, Skewness S. Rows include years 1981-2010 and summary statistics (Minimum, Average, Maximum, Std. Dev., Skewness, Median).

3955 Note: The FWM TP concentration is calculated by dividing the annual TP load by the annual flow. In WY2001
3956 the observed load was negative due to more TP load entering the basin than leaving the basin, thus resulting in a
3957 negative TP concentration. Since the negative TP concentration is not physically possible, WY2001 data were
3958 excluded from the summary statistics.
3959

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3962 For the development of the performance measure methodology, a Base Period of WY1982-
3963 1990 was selected for the following reasons.

- 3964 ➤ it represents a period with minimal prior implementation of source controls. With the
3965 selection of the Base Period to precede significant source control implementation, no
3966 additional calculation is necessary in the performance measure methodology to
3967 account for prior source control implementation,
- 3968 ➤ it represents a period of relatively uniform water management,
- 3969 ➤ it traversed several hydrologic conditions (wet and dry years),
- 3970 ➤ reliable water quality and hydrologic data are available, and
- 3971 ➤ a strong correlation exists between annual TP loads and rainfall, allowing for a
3972 performance measure methodology that explicitly incorporates hydrologic variability.

3973

3974 The Base Period is compared to the historical period of record and WY2001-2010 in **Table**
3975 **3-52**.

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Table 3-52. Comparison of Base Period with period of record and WY2001-2010 data for the East Caloosahatchee Hydrologic Unit.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1982-2010					
Annual Minimum	89,153	7.725	21	37.94	0.08
Annual Average	270,704	60.864	182	52.75	0.66
Annual Median	251,487	59.209	180	52.58	0.64
Annual Maximum	588,703	191.161	335	72.47	2.06
Base Period WY1982-1990					
Annual Minimum	89,153	23.185	90	42.29	0.25
Annual Average	245,818	66.000	218	50.69	0.71
Annual Median	211,215	54.939	195	47.99	0.59
Annual Maximum	588,703	191.161	335	72.47	2.06
Difference between Period of Record and Base Period					
Annual Minimum	0	-15.460	-69	-4.35	-0.17
Annual Average	24,887	-5.136	-35	2.07	-0.06
Annual Median	40,272	4.270	-16	4.59	0.05
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	0%	-67%	-77%	-10%	-67%
Annual Average	10%	-8%	-16%	4%	-8%
Annual Median	19%	8%	-8%	10%	8%
Annual Maximum	0%	0%	0%	0%	0%
WY2002-2010					
Annual Minimum	108,808	7.725	21	37.94	0.08
Annual Average	316,672	66.119	169	53.35	0.71
Annual Median	300,291	71.866	179	54.29	0.78
Annual Maximum	575,220	101.832	291	63.32	1.10
Difference between WY2002-2010 and Base Period					
Annual Minimum	19,655	-15.460	-69	-4.35	-0.17
Annual Average	70,854	0.119	-48	2.66	0.00
Annual Median	89,076	16.927	-16	6.30	0.18
Annual Maximum	-13,483	-89.329	-44	-9.15	-0.96
Annual Minimum	22%	-67%	-77%	-10%	-67%
Annual Average	29%	0%	-22%	5%	0%
Annual Median	42%	31%	-8%	13%	31%
Annual Maximum	-2%	-47%	-13%	-13%	-47%

Note: WY2001 was excluded due to negative TP Load, TP Concentration, and Unit Area Load.

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4002 **3.7.2.2 Performance Measure Methodology**

4003
4004 Based on the evaluation of individual land use source control effectiveness ranges described
4005 in Section 2.6, the overall range of TP load reduction that could be accomplished through
4006 collective source controls within the basin was estimated, and a load reduction target of 30
4007 percent was determined to be reasonable and appropriate. Details are provided in Appendix
4008 D and in Attachment 1.

4009
4010 An Annual Load Target and an Annual Load Limit were derived from the Base Period data
4011 using a 30 percent load reduction. The Annual Load Target and Annual Load Limit will be
4012 calculated according to the following equations and explanation:

4013
4014 Target = -136.788 + 3.61027 Rain
4015 Explained Variance = 72.6% , Standard Error of Regression = 21.79613 mtons
4016
4017 Predictor X is calculated from the first moment (m_1) of the 12 monthly rainfall totals (r_i , $i=1$
4018 to 12, inches) for the Evaluation Year:

4019
$$m_1 = \text{Sum} [r_1] / 12$$

4020
$$X = 12 m_1$$

4021
$$\text{Limit} = \text{Target} + 1.41492 \text{ SE}$$

4022 SE = standard error of the Target for May-April interval

4023
$$\text{SE} = 21.79613 [1 + 1/9 + (X-X_m)^2 / 675.50602]^{0.5}$$

4024 Where:

4025 X = the 12-month total rainfall (inches)

4026 X_m = average value of the predictor in base period = 50.686 inches

4027
4028 The predictor X indicates that load increases with total annual rainfall.

4029



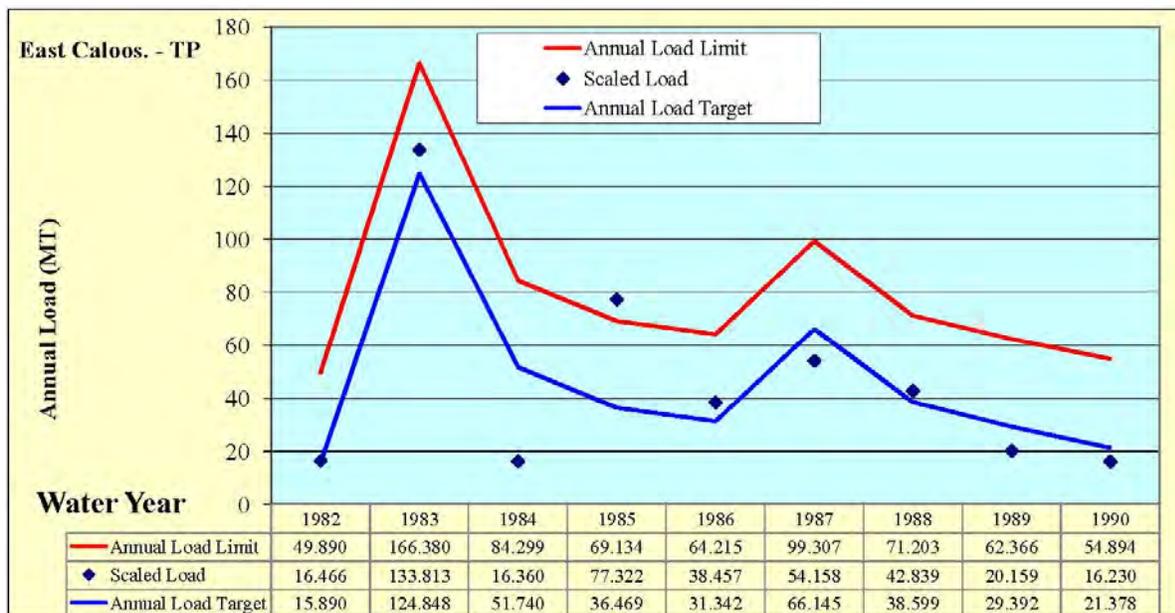


4030 A comparison of the scaled loads and the resulting Targets and Limits for the Base Period are
4031 presented in **Figure 3-42**. Annual TP loads at the hydrologic unit outlet structures, adjusted
4032 to account for regional projects (as applicable) and pass-through loads as described in
4033 Appendix A, will be evaluated against the performance measure described above.

4034

4035 **Figure 3-42. Comparison of scaled annual loads with the Annual Load Targets and**
4036 **Limits for the East Caloosahatchee Hydrologic Unit.**

4037



4038

4039

4040 **Suspension of Performance Determination.** The performance determination will be
4041 suspended due to rainfall conditions if the observed annual TP load, adjusted for regional
4042 projects (if present), from the basin exceeds the Annual Load Target and the rainfall falls
4043 outside the range of rainfall values for the Base Period (42.29 – 72.47 inches). The calculated
4044 Annual Load Targets and Annual Load Limits for the rainfall conditions observed during the
4045 WY1982-2010 period of record are summarized in **Table 3-53**. The annual performance
4046 determination process will account for pass-through loads and regional projects, as
4047 applicable, and is presented in the flowchart **Figure 1-2**.





4048 **Comparison to WY2001-2010.** A comparison of the WY2001-2010 observed loads to the
4049 Annual Load Targets and Limits is presented in **Figure 3-43**.

4050

4051 **Table 3-53. Annual adjusted rainfall for the historical period of record for the East**
4052 **Caloosahatchee Hydrologic Unit (Base Period: WY1982-1990).**
4053

Water Year	Observed Load, mt	Rain inches	Target Load, mt	Limit Load, mt
1982	23.523	42.29	15.890	49.890
1983	191.161	72.47	124.848	166.380
1984	23.371	52.22	51.740	84.299
1985	110.460	47.99	36.469	69.134
1986	54.939	46.57	31.342	64.215
1987	77.368	56.21	66.145	99.307
1988	61.198	48.58	38.599	71.203
1989	28.798	46.03	29.392	62.366
1990	23.185	43.81	21.378	54.894
1991	35.224	52.85	54.015	86.624
1992	63.448	59.68	78.673	112.888
1993	68.616	52.67	53.365	85.958
1994	37.434	47.73	35.530	68.227
1995	61.030	57.57	71.055	104.574
1996	64.927	57.42	70.513	103.989
1997	21.435	47.75	35.602	68.296
1998	57.387	62.17	87.662	122.911
1999	52.252	42.46	16.504	50.445
2000	53.363	60.47	81.525	116.044
2001	-3.251	34.44	-12.451	25.343
2002	71.866	54.89	61.379	94.268
2003	101.832	61.45	85.063	119.990
2004	92.878	54.29	59.213	92.001
2005	7.725	52.49	52.715	85.293
2006	93.518	57.97	72.499	106.137
2007	54.034	37.94	0.185	36.039
2008	18.112	51.49	49.105	81.627
2009	89.044	46.30	30.367	63.289
2010	66.063	63.32	91.814	127.612

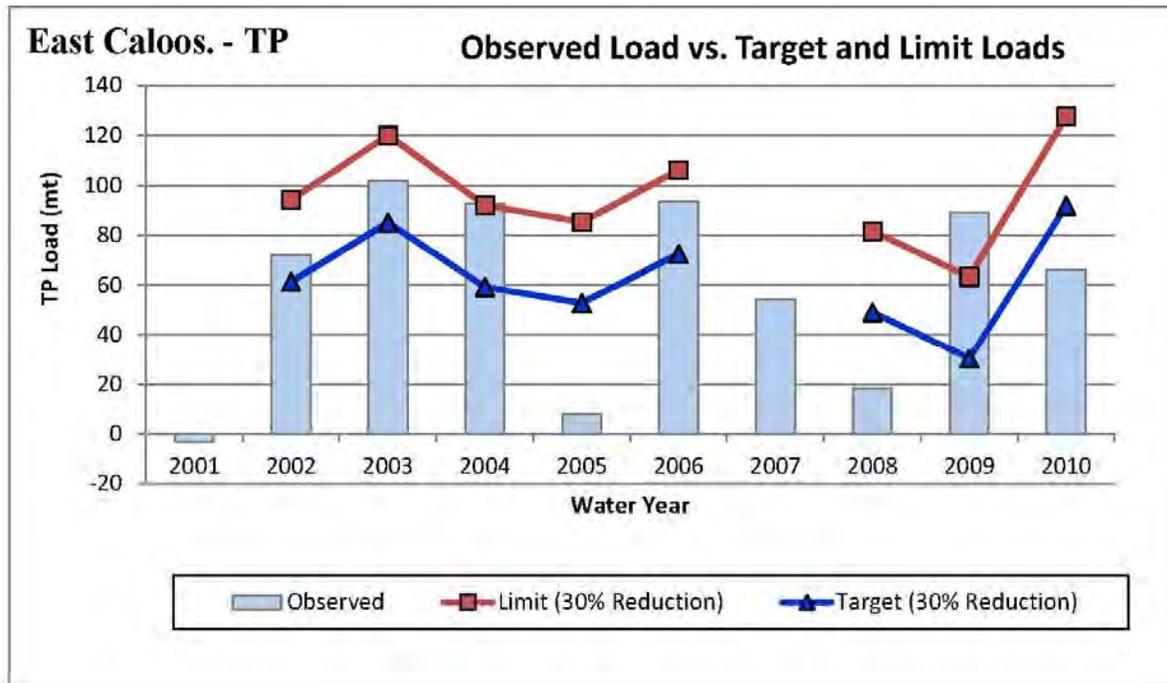
4054

4055 Note: Shaded water years indicate the performance determination would have been suspended due to anomalous
4056 rainfall coupled with the observed load being greater than the Load Target.
4057
4058





4059 **Figure 3-43. Comparison of WY2001-2010 loads with Base Period loads and Annual**
4060 **Load Targets, adjusted for hydrologic variability, for the East Caloosahatchee**
4061 **Hydrologic Unit.**
4062



4063
4064 Note: The performance determination for WY2001 and WY2007 would have been suspended due to rainfall
4065 below the minimum value during the Base Period coupled with the observed load being greater than the Load
4066 Target.
4067

4068 **Exceedance Frequency Analysis.** As shown in **Figure 3-42**, although the scaled observed
4069 loads fall above the Annual Load Target roughly half the time (five out of nine years, or 55
4070 percent), only the scaled observed load for WY 1985 exceeded the calculated Annual Load
4071 Limit during the base period. In accordance with the proposed performance determination
4072 process discussed in Section 2.6, having the observed load exceed the Annual Load Limit
4073 would prevent the basin from meeting its performance measure for that year. In the case of
4074 the scaled Base Period data, this is an example of a Type I error¹⁹, or “false positive” – when
4075 the performance method suggests a lack of compliance when the basin’s load actually
4076 achieves the long-term reduction goals. While this occurrence is not common, it is





4077 statistically possible. The use of the upper 90 percent confidence limit for the Annual Load is
 4078 consistent with the District’s Chapter 40E-63 F.A.C., and has a theoretical Type I error (i.e.,
 4079 false positive) rate of approximately ten percent. Using the approach described in Section
 4080 2.6, an approximation of the cumulative exceedance frequency for the determination
 4081 methodology was estimated using a Monte Carlo approach based on the annual rainfall and
 4082 the annual TP load of the Base Period (**Table 3-54**). Because the TP loads and rainfall
 4083 statistics from the Base Period do not perfectly describe normal distributions (e.g., the
 4084 medians are generally less than the means), the methodology includes conditional
 4085 probabilities, and because the random number generator is imperfect, the exceedance
 4086 frequencies deviate from the theoretical values shown in the second column. However, the
 4087 results are determined to be reasonable and defensible since the cumulative exceedance
 4088 frequency is less than the theoretical value of approximately 17.5 percent.

4089
 4090 **Table 3-54. Exceedance frequencies for the proposed determination methodology for**
 4091 **the East Caloosahatchee Hydrologic Unit.**
 4092

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Radj is outside the range and Load > Annual Load Target	<20%	9.2%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	9.9%
Step 4. Load > Annual Load Limit?	<10%	4.3%
Cumulative Exceedance Frequency	<17.5%	13.1%

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4097 **3.8 Upper Kissimmee Sub-watershed**

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4099 The following sections present a description of the Upper Kissimmee Sub-watershed, a
4100 summary of historical flow and TP levels, the selection of Reference Periods, and the
4101 derivation of the resulting performance indicators for tributaries within the sub-watershed.

4102 **3.8.1 Background**

4103
4104 The Upper Kissimmee Sub-watershed is the headwaters of the Kissimmee-Okeechobee-
4105 Everglades hydrologic system, and consists of 1,028,421 acres occupying portions of Lake,
4106 Orange, Osceola, and Polk Counties (**Figure 3-44**). The sub-watershed is composed of a
4107 large number of lakes connected by canals, creeks, and streams. Currently, canals connect
4108 all of the primary lakes to form the “Upper Kissimmee Chain of Lakes”. Reedy Creek,
4109 Shingle Creek, and Boggy Creek are the largest tributaries in the sub-watershed. Lakes
4110 Kissimmee, Hatchineha, and Cypress are located at the downstream portion of the sub-
4111 watershed. Outflows from the Upper Kissimmee Sub-watershed are discharged to the Lower
4112 Kissimmee Sub-watershed via S-65.

4113
4114 District staff identified the rainfall stations considered to be representative of the Upper
4115 Kissimmee Sub-watershed for the period WY1976-2010. A schematic of the sub-watershed
4116 with the various rain stations is presented in **Figure 3-45** and **Figure 3-46B** (**Figure 3-45** is
4117 for WY 1976-2007 and **Figure 3-46** is for WY 2008 – Present). Monthly rainfall data and
4118 weighting factors for the rainfall stations were developed and provided by the District.
4119 Because of the nutrient attenuation effect of Lake Kissimmee, the nutrient loads discharged
4120 at S-65 may not be representative of stormwater runoff from within the sub-watershed, and
4121 thus the criteria for the establishment of a performance measure at S-65 were not met.
4122 Therefore, tributaries upstream of Lake Kissimmee were evaluated to see if there were
4123 sufficient data to develop performance measure methodologies in the individual tributaries.



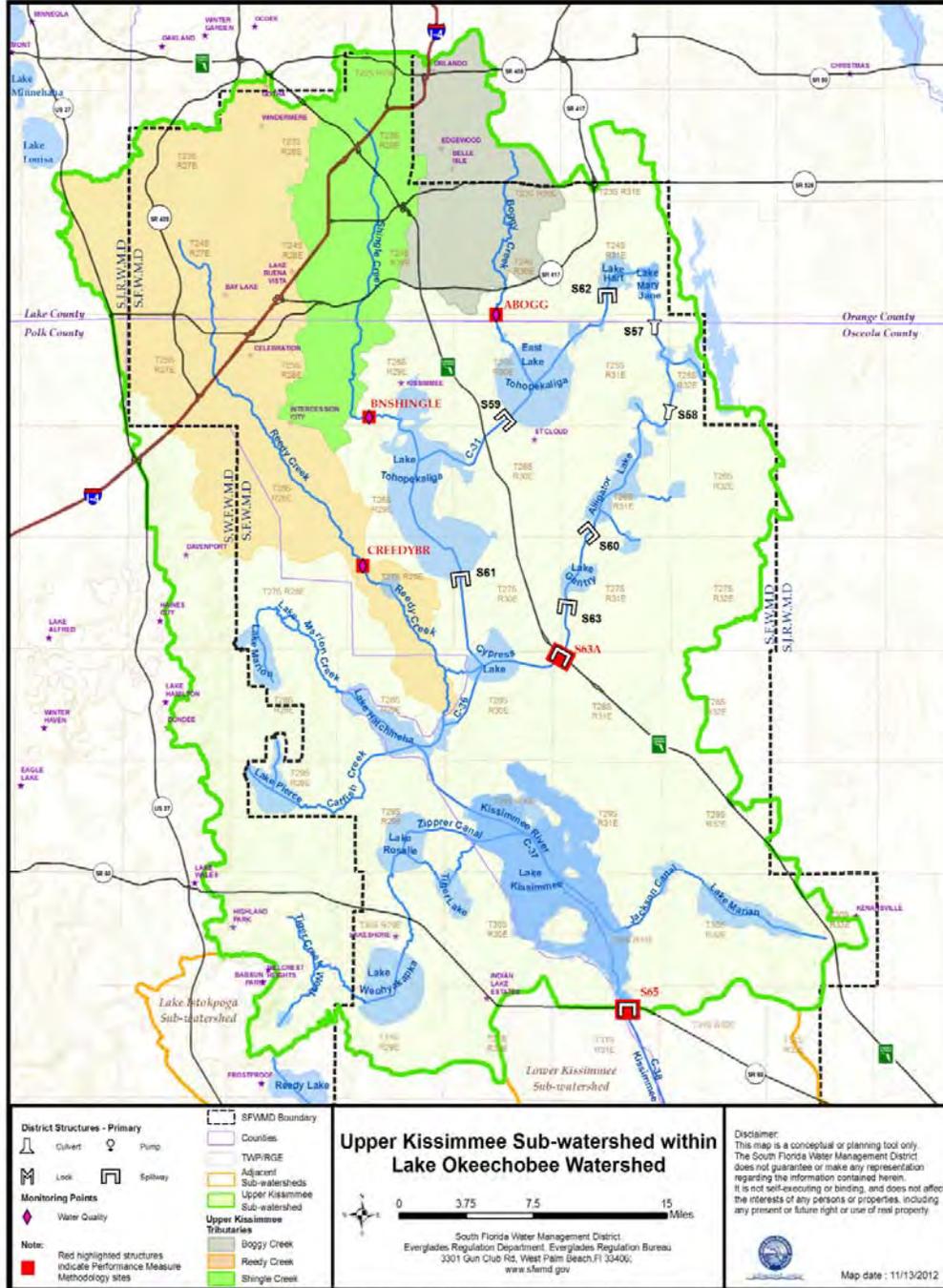


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Technical Support Document
Lake Okeechobee Watershed Performance Measures

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Figure 3-44. Upper Kissimmee Sub-watershed boundary and discharge monitoring locations (from SFWMD).



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kursulid.sfwmd.gov/DFS/rooteer_gis/data/projects/EV/Gloic/Rucks_LOR_PerformanceMeasures/LOK_UpperKissimmee_DrainageBasins_20121113.mxd



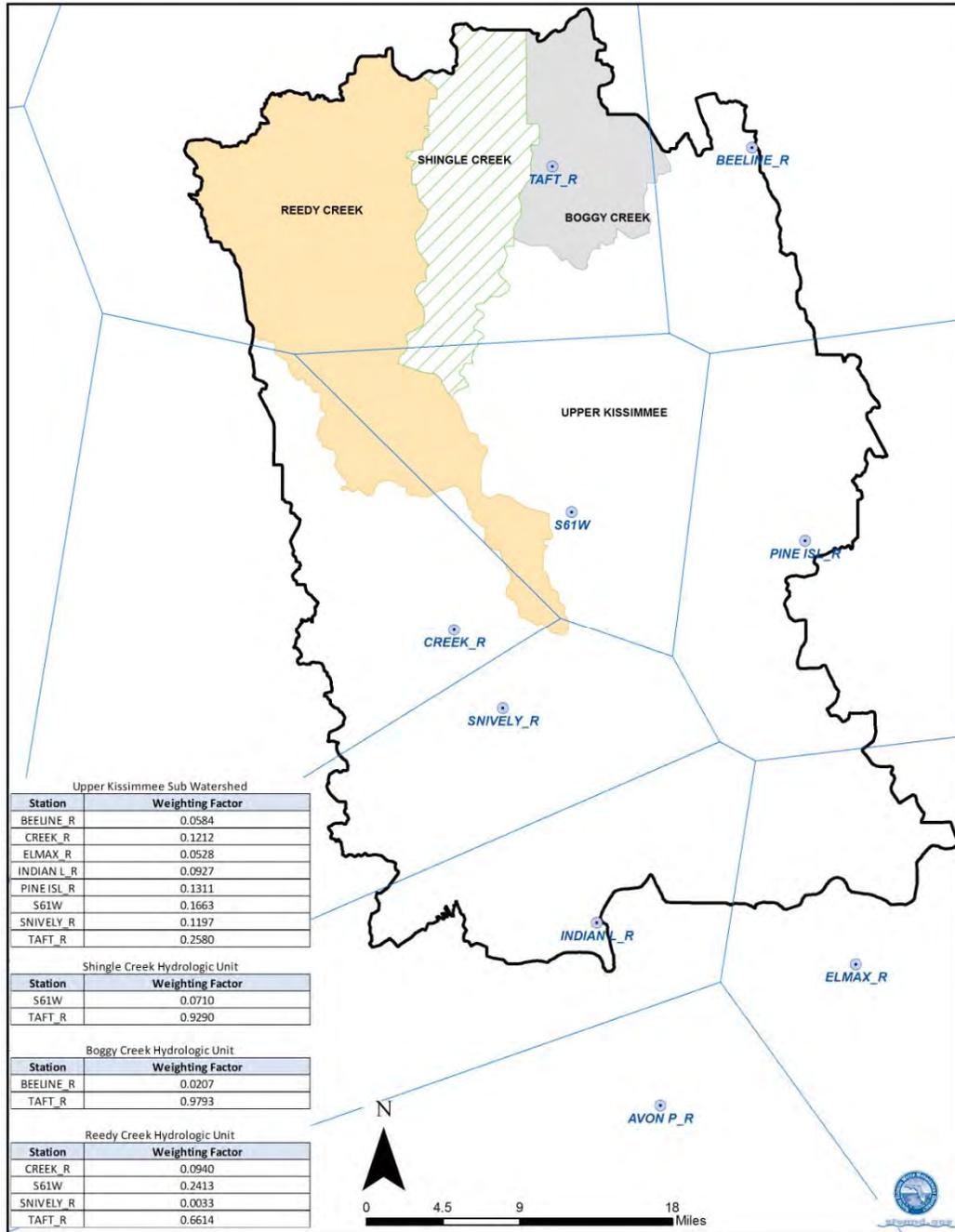


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Technical Support Document
Lake Okeechobee Watershed Performance Measures

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Figure 3-45. Schematic of Upper Kissimmee Sub-watershed (WY76-07) (from SFWMD).



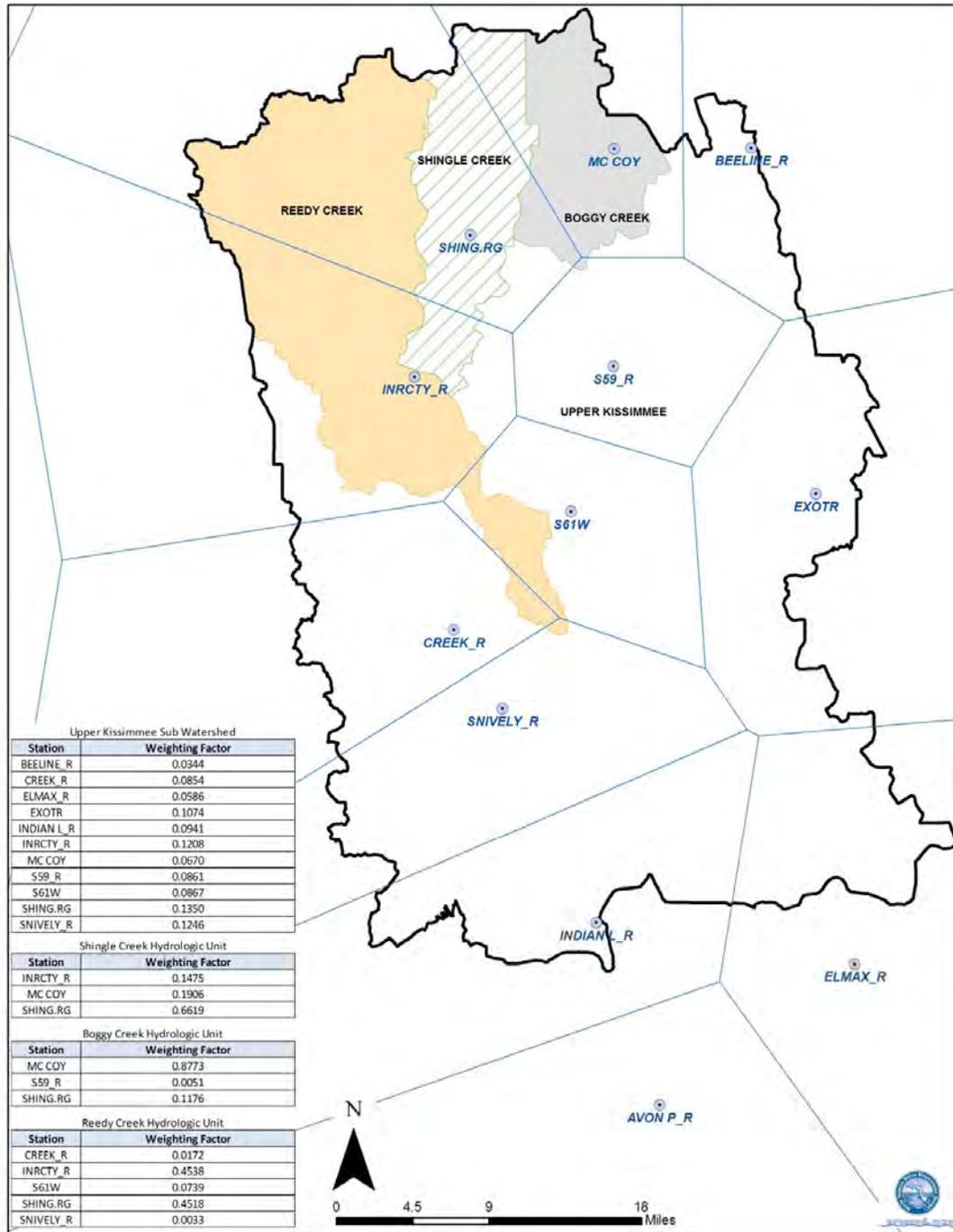
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Figure 3-46. Schematic of Upper Kissimmee Sub-watershed (WY08-Present) (from SFWMD).



4133





4134 Stormwater runoff from much of the sub-watershed flows directly into multiple lakes within
4135 the sub-watershed (i.e., the Upper Chain of Lakes) and the majority of inflow locations are
4136 not monitored. Review of available data identified monitoring sites located on only three
4137 major tributaries upstream of the Upper Chain of Lakes. These discharge monitoring
4138 locations are shown in **Figure 3-44** and are further described below. In addition to the three
4139 major tributaries, there was another structure (S-63A) where both flow and water quality data
4140 are available (also shown in **Figure 3-44**). The S-63A structure is located on C-34, just
4141 upstream of Cypress Lake. These four areas are described below:

4142

4143 3. One site is located on Boggy Creek (ABOGG), which flows into East Lake
4144 Tohopekaliga. Monitoring has been conducted at that site for approximately 30
4145 years. Boggy Creek has a tributary area of approximately 52,415 acres, or roughly
4146 five percent of the Upper Kissimmee Sub-watershed area. Flow data are recorded at
4147 a nearby USGS gauge (Boggy Creek near Taft, FL: ID no. 02262900).

4148 4. One site is located on Shingle Creek (BNSHINGLE), which flows into Lake
4149 Tohopekaliga. Monitoring has been conducted at that site for approximately 30
4150 years. Shingle Creek has a tributary area of approximately 68,153 acres, or roughly
4151 seven percent of the Upper Kissimmee Sub-watershed area. Flow data are recorded at
4152 a nearby USGS gauge (Shingle Creek at Campbell, FL: ID no. 02264495).

4153 5. One site is located on Reedy Creek (CREEDYBR), which flows into Cypress Lake
4154 and Lake Hatchineha downstream of Lake Tohopekaliga. Reedy Creek has a
4155 tributary area of approximately 172,116 acres, or roughly seventeen percent of the
4156 Upper Kissimmee Sub-watershed area. Water quality monitoring has been conducted
4157 at that site for approximately 26 years; however, this site is not located at the
4158 discharge point from the tributary. Therefore, CREEDYBR does not represent the
4159 entire Reedy Creek Tributary. Also, there is not a nearby flow station. The nearest
4160 USGS station for flow monitoring is located approximately 10 river miles upstream
4161 and would not be adequate to estimate load with TP data collected at this water





4162 quality monitoring site. However, it is recommended that monitoring be continued at
4163 this site so that in the future it can be determined if there is an increasing trend.

4164 6. One site is located on C-34 (S-63A) just upstream of Cypress Lake. Water quality
4165 monitoring was initiated in WY2008, thus there is not sufficient water quality or flow
4166 data to provide a complete historical data analysis. It is recommended that
4167 monitoring be continued at this site so that in the future it can be determined if there
4168 is an increasing trend.

4169

4170 Both water quality and flow data are available for the Boggy Creek and Shingle Creek
4171 tributaries. However, performance measures were not developed for these tributaries because
4172 the boundaries were not well defined. Instead, prediction equations for performance
4173 indicators are recommended for the upstream tributaries at Boggy Creek and Shingle Creek.
4174 Available data were deemed not adequate to establish performance indicators for the Reedy
4175 Creek and S-63A basins. However, the water quality from these areas will be assessed
4176 annually to determine if there is an increasing trend. It is also recommended that in the
4177 remaining portion of the Upper Kissimmee Sub-watershed that bi-weekly grab monitoring
4178 for total phosphorus be conducted at key locations and assessed annually to determine if
4179 there is an increasing trend.

4180

4181 The following section summarizes the performance indicators for Boggy Creek and Shingle
4182 Creek.

4183 ***3.8.1.1 Performance Measure Methodology***

4184

4185 **Site 1: Boggy Creek**

4186 Annual flow and TP data for discharges from the Boggy Creek Tributary are summarized in
4187 **Table 3-55**. For the development of the performance indicator, a Reference Period of
4188 WY2001-2008 was selected for the following reasons:





- 4189 ➤ it represents a period with minimal implementation of source controls. With the
- 4190 selection of the Reference Period to precede significant source control
- 4191 implementation, no additional calculation is necessary in the performance indicator
- 4192 to account for prior source control implementation,
- 4193 ➤ it represents a period of relatively constant land use practices,
- 4194 ➤ reliable water quality and hydrologic data are available, and
- 4195 ➤ a strong correlation exists between annual TP loads and rainfall, allowing for a
- 4196 performance indicator that explicitly incorporates hydrologic variability

4198 The Reference Period is compared to the historical period of record and WY2001-2010 in
4199 **Table 3-56.**

4200
4201 **Table 3-55. Summary of historical data for ABOGG, the outlet structure for the Boggy**
4202 **Creek Tributary for the WY 2001-2010 period of record.**
4203

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Area acres	Unit Area Runoff in/yr	Unit Area Load lbs/ac	Rainfall Characteristics		
								Kurtosis K	Coef. Of Var. CV	Skewness S
2001	14,705	0.684	38	33.11	52,415	3.37	0.03	-0.987	0.890	0.696
2002	81,072	6.074	61	52.17	52,415	18.56	0.26	4.552	1.149	1.858
2003	114,393	9.034	64	78.11	52,415	26.19	0.38	-0.027	0.625	0.654
2004	70,089	3.961	46	54.94	52,415	16.05	0.17	2.017	0.919	1.359
2005	112,478	8.865	64	66.09	52,415	25.75	0.37	-1.434	0.849	0.655
2006	94,911	6.318	54	58.21	52,415	21.73	0.27	2.057	1.230	1.480
2007	22,714	0.832	30	37.94	52,415	5.20	0.03	-0.503	0.773	0.921
2008	37,085	1.507	33	45.58	52,415	8.49	0.06	3.993	0.762	1.492
2009	56,235	3.239	47	42.66	52,415	12.87	0.14	0.016	0.962	1.076
2010	88,570	3.760	34	69.45	52,415	20.28	0.16	3.080	0.604	1.370
Minimum	14,705	0.684	30	33.11	52,415	3.37	0.03	-1.434	0.604	0.654
Average	69,225	4.427	52	53.83	52,415	15.85	0.19	1.276	0.876	1.156
Maximum	114,393	9.034	64	78.11	52,415	26.19	0.38	4.552	1.230	1.858
Std. Dev.	35,627	3.069	13	14.46	0	8.16	0.13	2.146	0.203	0.418
Skewness	-0.305	0.339	0.113	0.239	0.000	-0.305	0.34	0.289	0.441	0.138
Median	75,581	3.861	47	53.56	52,415	17.30	0.16	1.017	0.870	1.218

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Table 3-56. Comparison of the Reference Period with the period of record data for Boggy Creek.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	UAL lbs/ac
Period of Record - WY2001-2010					
Annual Minimum	14,705	0.684	30	33.11	0.03
Annual Average	69,225	4.427	52	53.83	0.19
Annual Median	75,581	3.861	47	53.56	0.16
Annual Maximum	114,393	9.034	64	78.11	0.38
Preliminary Reference Period WY2001-2008					
Annual Minimum	14,705	0.684	30	33.11	0.03
Annual Average	68,431	4.659	55	53.27	0.20
Annual Median	75,581	5.018	50	53.56	0.21
Annual Maximum	114,393	9.034	64	78.11	0.38
Difference between Period of Record and Reference Period					
Annual Minimum	0	0.000	0	0.00	0.000
Annual Average	794	-0.232	-3	0.56	-0.010
Annual Median	0	-1.157	-4	0.00	-0.049
Annual Maximum	0	0.000	0	0.00	0.000
Annual Minimum	0%	0%	0%	0%	0%
Annual Average	1%	-5%	-6%	1%	-5%
Annual Median	0%	-23%	-7%	0%	-23%
Annual Maximum	0%	0%	0%	0%	0%
Preliminary Reference Period WY2001-2008					
Annual Minimum	14,705	0.684	30	33.11	0.03
Annual Average	68,431	4.659	55	53.27	0.20
Annual Median	75,581	5.018	50	53.56	0.21
Annual Maximum	114,393	9.034	64	78.11	0.38
WY2001-2010					
Annual Minimum	14,705	0.684	30	33.11	0.03
Annual Average	69,225	4.427	52	53.83	0.19
Annual Median	75,581	3.861	47	53.56	0.16
Annual Maximum	114,393	9.034	64	78.11	0.38
Difference between WY2001-2010 and Reference Period					
Annual Minimum	0	0.000	0	0.00	0.00
Annual Average	794	-0.232	-3	0.56	-0.01
Annual Median	0	-1.157	-4	0.00	-0.05
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	0%	0%	0%	0%	0%
Annual Average	1%	-5%	-6%	1%	-5%
Annual Median	0%	-23%	-7%	0%	-23%
Annual Maximum	0%	0%	0%	0%	0%

4212





4213 Based on the fact that the annual median total phosphorus concentration for the period of
4214 record (47 µg/l) is below the Numeric Nutrient Criteria (120 µg/l for TP) (Chapter 62-302,
4215 F.A.C.), it is recommended that no reduction goal be applied to tributary. An Annual Load
4216 Target and an Annual Load Limit for the Boggy Creek Tributary will be calculated
4217 according to the following equations and explanation:

4218

4219 Target = (-2.39491 + 0.05939 X + 1.35719 C)²

4220 Explained Variance = 98.0 percent, Standard Error of Regression Equation = 0.2072

4221 Predictors (X and C) are calculated from the first two moments (m₁,
4222 m₂) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation
4223 Year:

4224 m₁ = Sum [r_i] / 12

4225 m₂ = Sum [r_i - m₁]² / 12

4226 X = 12 m₁

4227 C = [(12/11) m₂]^{0.5} / m₁

4228

4229 Limit = [sqrt (Target) + (1.47588 SE)]²

4230 SE = standard error of the predicted sqrt (Load) for May-April interval

4231 SE = 0.20722 [1 + 1/8 + 0.0007 (X-X_m)² + 3.58103 (C-C_m)² + 0.0135 (X-X_m) (C-
4232 C_m)]^{0.5}

4233

4234 Where:

4235 X = the 12-month total rainfall (inches)

4236 C = coefficient of variation calculated from 12 monthly rainfall totals

4237 X_m = average value of the predictor in reference period = 53.269 inches

4238 C_m = average value of the predictor in reference period = 0.89963

4239





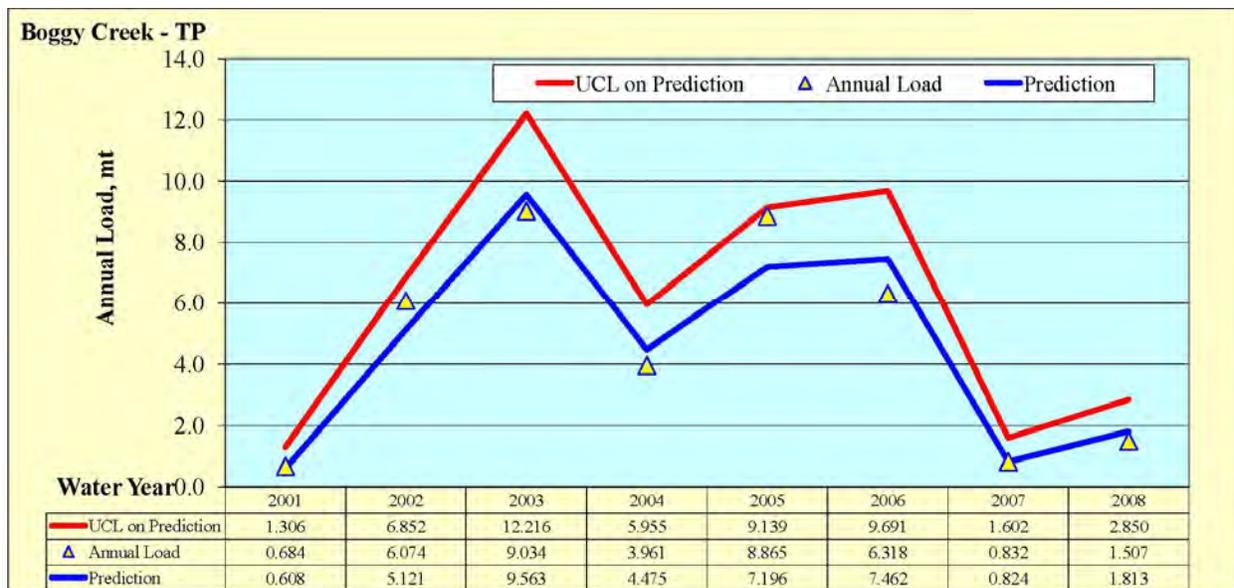
4240 The first predictor (X) indicates that load increases with total annual rainfall. The second
 4241 predictor (C) indicates that the load resulting from a given annual rainfall is higher when
 4242 the distribution of monthly rainfall has higher variability. For a given annual rainfall, the
 4243 lowest load occurs when rainfall is evenly distributed across months and the highest load
 4244 occurs when all of the rain falls in one month. Real cases are likely to fall in between.

4245
 4246 A comparison of the observed loads and the resulting Targets and Limits for the Reference
 4247 Period are presented in **Figure 3-47**. Annual TP loads at the tributary outlet monitoring
 4248 location, adjusted to account for regional projects (as applicable) and pass-through loads as
 4249 described in Appendix A, will be evaluated against the performance measure described
 4250 above.

4251

4252 **Figure 3-47. Comparison of observed annual loads with the Annual Load Targets and**
 4253 **Limits for the Boggy Creek Tributary.**

4254



4255

4256





4257 **Suspension of Performance Determination.** The performance determination will be
4258 suspended due to rainfall conditions if the observed annual TP load from the basin, adjusted
4259 for regional projects (if present), exceeds the Annual Load Target and the adjusted rainfall
4260 falls outside the range of adjusted rainfall values for the Reference Period (32.89 – 71.83
4261 inches), as derived below. Rainfall conditions will be assessed by calculating an adjusted
4262 rainfall amount which reflects the cumulative effect of the predictor variables of the Annual
4263 Load Target equation. The adjusted rainfall is the rainfall that would produce the equivalent
4264 annual load using the Annual Load Target equation by setting the value of C to its mean
4265 value for the calibration period.

4266

4267
$$\text{Adjusted Rain} = X + 22.85216 (C - 0.89963)$$

4268

4269 The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the
4270 WY2001-2010 period of record are summarized in **Table 3-57**.

4271

4272 The annual performance determination process will account for pass-through loads and
4273 regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

4274

4275 **Comparison to WY2001-2010.** A comparison of the WY2001-2010 observed loads to the
4276 Annual Load Targets and Limits is presented in **Figure 3-48**.

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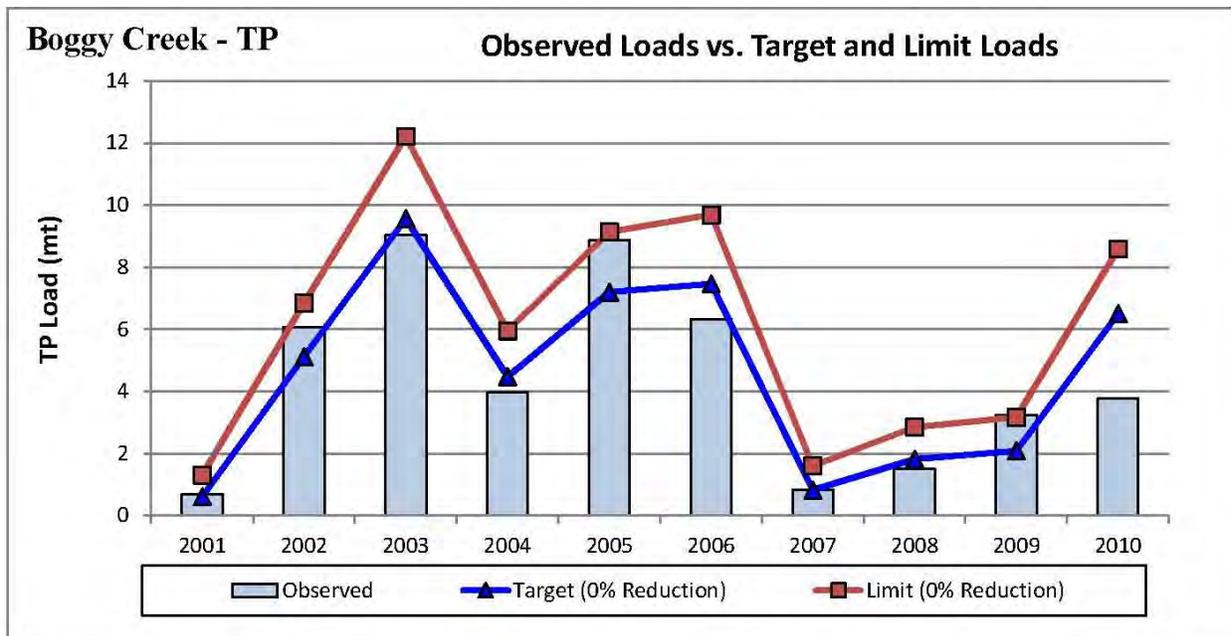
Table 3-57. Annual adjusted rainfall for the historical period of record for the Boggy Creek Tributary (Reference Period: WY2001-2008).

Water Year	Observed Load, mt	Rain in	CV	Target Load, mt	Limit Load, mt	Adjusted Rain, in
2001	0.684	33.11	0.890	0.608	1.307	32.89
2002	6.074	52.17	1.149	5.121	6.852	57.87
2003	9.034	78.11	0.625	9.563	12.216	71.83
2004	3.961	54.94	0.919	4.475	5.955	55.38
2005	8.865	66.09	0.849	7.196	9.139	64.93
2006	6.318	58.21	1.230	7.462	9.691	65.76
2007	0.832	37.94	0.773	0.824	1.603	35.05
2008	1.507	45.58	0.762	1.813	2.850	42.43
2009	3.239	42.66	0.962	2.086	3.170	44.09
2010	3.760	69.45	0.604	6.500	8.591	62.69

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Figure 3-48. Comparison of WY2001-2010 loads with Reference Period loads and Annual Load Targets, adjusted for hydrologic variability, for the Boggy Creek Tributary.



4293
4294

Note: The Reference Period extended from WY2001-2008.





4295 **Exceedance Frequency Analysis.** Using the approach described in Section 2.6, an
 4296 approximation of the cumulative exceedance frequency for the determination methodology
 4297 was estimated using a Monte Carlo approach based on the annual rainfall and the annual TP
 4298 loads of the Base Period (**Table 3-58**). Because the TP loads and rainfall statistics from the
 4299 Base Period do not perfectly describe normal distributions (e.g., the medians are generally
 4300 less than the means), the methodology includes conditional probabilities, and because the
 4301 random number generator is imperfect, the exceedance frequencies deviate from the
 4302 theoretical values shown in the second column. However, the results are determined to be
 4303 reasonable and defensible since the cumulative exceedance frequency is less than the
 4304 theoretical value of approximately 17.5 percent.

4305
 4306 **Table 3-58. Exceedance frequencies for the proposed determination methodology for**
 4307 **the Boggy Creek basin.**
 4308

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Rain _{adj} is outside the range and Load > Annual Load Target	<20%	9.9%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	9.7%
Step 4. Load > Annual Load Limit?	<10%	1.9%
Cumulative Exceedance Frequency	<17.5%	10.9%

4309
 4310
 4311





4312 **Site 2: Shingle Creek**

4313 Annual flow and TP data for discharges from the Shingle Creek Tributary are summarized
4314 in **Table 3-59**. For the development of the performance indicator, a Reference Period of
4315 WY1999-2007 was selected for the following reasons:

- 4316 ➤ it represents a period with minimal implementation of source controls. With the
- 4317 selection of the Reference Period to precede significant source control
- 4318 implementation, no additional calculation is necessary in the performance indicator
- 4319 to account for prior source control implementation,
- 4320 ➤ it represents a period of relatively constant land use practices,
- 4321 ➤ reliable water quality and hydrologic data are available, and
- 4322 ➤ a strong correlation exists between annual TP loads and rainfall, allowing for a
- 4323 performance indicator that explicitly incorporates hydrologic variability

4324
4325 The Reference Period is compared to the historical period of record and WY2001-2010 in
4326 **Table 3-60**.

4327
4328 **Table 3-59. Summary of historical data for BNSHINGLE, the outlet structure for the**
4329 **Shingle Creek Tributary for the WY 1999-2010 period of record.**
4330

Water Year	Flow AF	Load mt	FWM Conc, µg/L	Rainfall inches	Unit Area Runoff, inches	Unit Area Load, lbs/ac	Kurtosis K	Coef. Of Var. CV	Skewness S
1999	80,049	6.522	66	40.77	14.09	0.21	1.881	0.974	1.495
2000	95,791	8.870	75	49.97	16.87	0.29	4.365	1.057	1.875
2001	43,203	4.345	82	33.59	7.61	0.14	-0.960	0.897	0.696
2002	143,879	17.484	99	51.94	25.33	0.57	4.200	1.127	1.793
2003	300,377	39.935	108	76.98	52.89	1.29	-0.036	0.625	0.680
2004	214,290	21.736	82	53.90	37.73	0.70	1.913	0.907	1.324
2005	319,611	35.119	89	64.88	56.28	1.14	-1.344	0.851	0.685
2006	184,112	17.421	77	57.80	32.42	0.56	2.337	1.229	1.530
2007	87,421	7.388	69	37.45	15.39	0.24	-0.604	0.766	0.903
2008	132,363	10.956	67	43.71	23.31	0.35	5.591	0.754	1.888
2009	95,280	10.724	91	36.42	16.78	0.35	2.629	0.942	1.551
2010	231,653	18.445	65	75.82	40.79	0.60	0.617	0.641	0.817
Minimum	43,203	4.345	65	33.59	7.61	0.14	-1.344	0.625	0.680
Average	160,669	16.579	84	51.94	28.29	0.54	1.716	0.898	1.270
Maximum	319,611	39.935	108	76.98	56.28	1.29	5.591	1.229	1.888
Std. Dev.	89,684	11.207	14	14.73	15.79	0.36	2.250	0.185	0.484
Median	138,121	14.189	80	50.96	24.32	0.46	1.897	0.902	1.410
Skewness	0.627	1.147	0.660	0.574	0.63	1.15	0.251	0.184	-0.080

4331





4332
4333
4334

Table 3-60. Comparison of the Reference Period with the period of record data for Shingle Creek.

Metric	Flow AF	TP Load mt	TP Conc µg/L	Rainfall inches	Unit Area Load, lbs/ac
Period of Record - WY1999-2010					
Annual Minimum	43,203	4.345	65	33.59	0.14
Annual Average	160,669	16.579	84	51.94	0.54
Annual Median	138,121	14.189	80	50.96	0.46
Annual Maximum	319,611	39.935	108	76.98	1.29
Reference Period WY1999-2007					
Annual Minimum	43,203	4.345	66	33.59	0.14
Annual Average	163,193	17.647	88	51.92	0.57
Annual Median	143,879	17.421	82	51.94	0.56
Annual Maximum	319,611	39.935	108	76.98	1.29
Difference between Period of Record and Reference Period					
Annual Minimum	0	0.000	-1	0.00	0.00
Annual Average	-2,523	-1.068	-4	0.02	-0.03
Annual Median	-5,758	-3.233	-3	-0.98	-0.10
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	0%	0%	-2%	0%	0%
Annual Average	-2%	-6%	-5%	0%	-6%
Annual Median	-4%	-19%	-3%	-2%	-19%
Annual Maximum	0%	0%	0%	0%	0%
WY2001-2010					
Annual Minimum	43,203	4.345	65	33.59	0.14
Annual Average	175,219	18.355	85	53.25	0.59
Annual Median	163,996	17.453	82	52.92	0.56
Annual Maximum	319,611	39.935	108	76.98	1.29
Difference between WY2001-2010 and Reference Period					
Annual Minimum	0	0.000	-1	0.00	0.00
Annual Average	12,026	0.709	-3	1.33	0.02
Annual Median	20,117	0.032	0	0.98	0.00
Annual Maximum	0	0.000	0	0.00	0.00
Annual Minimum	0%	0%	-2%	0%	0%
Annual Average	7%	4%	-3%	3%	4%
Annual Median	14%	0%	0%	2%	0%
Annual Maximum	0%	0%	0%	0%	0%

4335
4336





4337 Based on the fact that the annual median total phosphorus concentration for the period of
4338 record (80 µg/l) is below the Numeric Nutrient Criteria (120 µg/l) (Chapter 62-302, F.A.C.),
4339 it is recommended that no reduction goal be applied to tributary. An Annual Load Target
4340 and an Annual Load Limit for the Shingle Creek Tributary will be calculated according to
4341 the following equations and explanation:

4342

4343 Target = -140.82331 + 43.29617 X + 9.1697 S

4344 Explained Variance = 96.9 percent, Standard Error of Regression Equation = 2.5823

4345 Predictors (X and S) are calculated from the first two moments (m₁, m₂,
4346 m₃) of the 12 monthly rainfall totals (r_i, i=1 to 12, inches) for the Evaluation
4347 Year:

4348 $m_1 = \text{Sum} [r_i] / 12$

4349 $m_2 = \text{Sum} [r_i - m_1]^2 / 12$

4350 $m_3 = \text{Sum} [r_i - m_1]^3 / 12$

4351 $X = 12 m_1$

4352 $S = (12/11) m_3 / m_2^{1.5}$

4353

4354 Limit = Target + 1.440 SE

4355 SE = standard error of the Target for May-April interval

4356 $SE = 2.58225 [1 + 1/9 + 1.7741 (X-X_m)^2 + 0.52978 (S-S_m)^2 + 0.10178 (X-X_m) (S-S_m)]^{0.5}$

4358

4359 Where:

4360 X = natural logarithm of the 12-month total rainfall (ln(inches))

4361 S = is the skewness of the annual rainfall calculated from 12 monthly rainfall totals

4362 X_m = average value of the predictor in reference period = 3.919





4363 S_m = average value of the predictor in reference period = 1.22011

4364

4365 The first predictor (X) indicates that load increases exponentially with total annual rainfall.

4366 The second predictor (S) indicates that the load resulting from a given annual rainfall is

4367 higher when the distribution of monthly rainfall has higher skewness. For a given annual

4368 rainfall, the lowest load occurs when rainfall is evenly distributed across months and the

4369 highest load occurs when all of the rain falls in one month. Real cases fall in between.

4370

4371 A comparison of the observed loads and the resulting Targets and Limits for the Reference

4372 Period are presented in **Figure 3-49**. Annual TP loads at the tributary outlet monitoring

4373 location, adjusted to account for regional projects (as applicable) and pass-through loads as

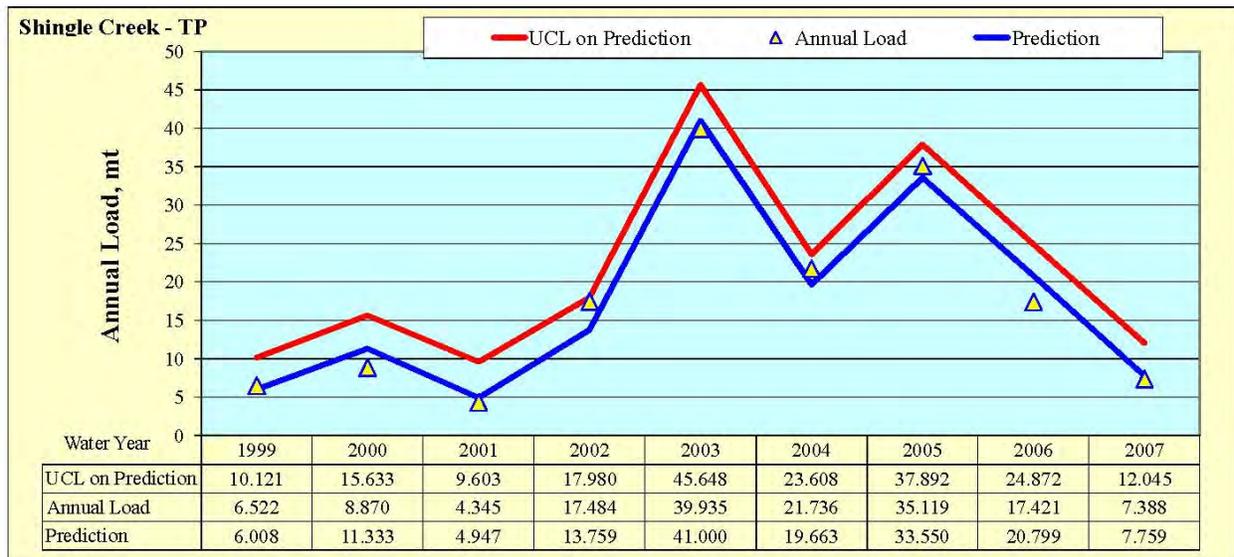
4374 described in Appendix A, will be evaluated against the performance measure described

4375 above.

4376

4377 **Figure 3-49. Comparison of observed annual loads with the Annual Load Targets and**
4378 **Limits for the Shingle Creek Tributary.**

4379



4380





4381 **Suspension of Performance Determination.** The performance determination will be
 4382 suspended due to rainfall conditions if the observed annual TP load from the basin, adjusted
 4383 for regional projects (if present), exceeds the Annual Load Target and the adjusted rainfall
 4384 falls outside the range of adjusted rainfall values for the Reference Period (37.53 – 86.31
 4385 inches), as derived below. Rainfall conditions will be assessed by calculating an adjusted
 4386 rainfall amount which reflects the cumulative effect of the two variables that comprise the
 4387 Load Target equation: Rain and S:

4388

4389 Adjusted Rainfall = equivalent rainfall for mean S variable (inches)

4390

4391 Adjusted Rain = $\exp[X - 0.21179(S - 1.22011)]$

4392

4393 The calculated adjusted rainfall values, Annual Load Targets and Annual Load Limits for the
 4394 WY1983-2010 period of record are summarized in **Table 3-61**.

4395

4396 The annual performance determination process will account for pass-through loads and
 4397 regional projects, as applicable, and is presented in the flowchart in **Figure 1-2**.

4398

4399 **Comparison to WY2001-2010.** A comparison of the WY2001-2010 observed loads to the
 4400 Annual Load Targets and Limits is presented in **Figure 3-50**.

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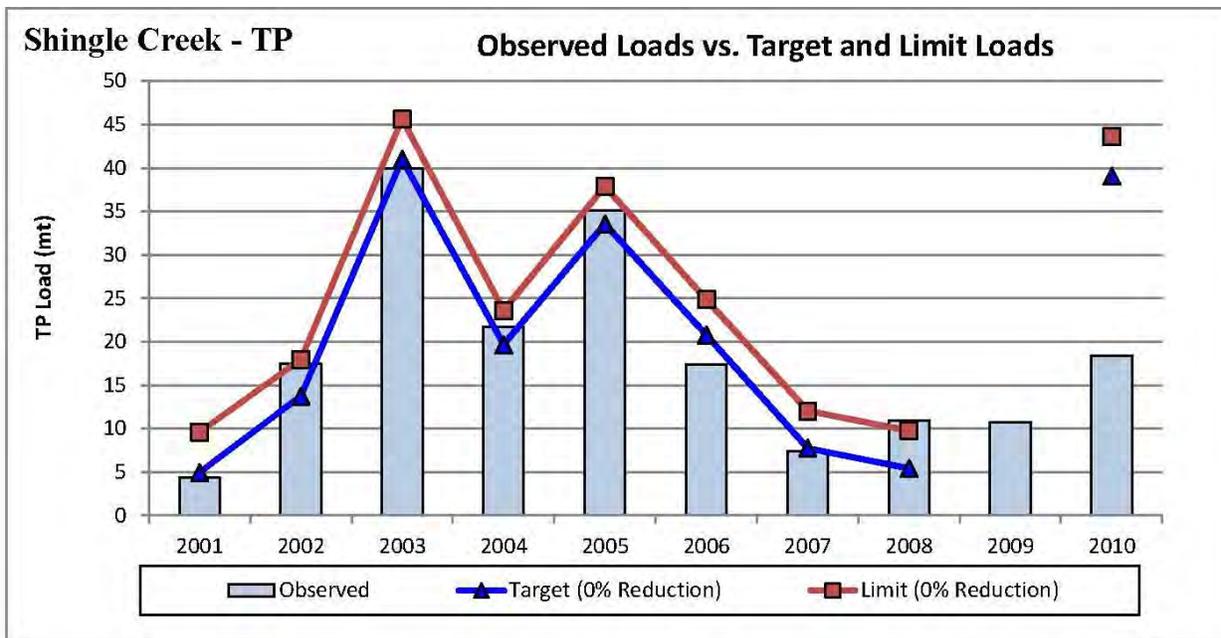


4408 **Table 3-61. Annual adjusted rainfall for the historical period of record for the Shingle**
 4409 **Creek Tributary (Reference Period: WY2001-2008).**
 4410

Water Year	Observed Load, mt	Ln(rain)	S	Target Load, mt	SE Load, mt	Limit Load, mt	Adjusted Rain, in
1999	6.522	3.70795	1.495	6.008	2.857	10.121	38.46
2000	8.870	3.91142	1.875	11.333	2.987	15.633	43.50
2001	4.345	3.51423	0.696	4.947	3.234	9.603	37.53
2002	17.484	3.95009	1.793	13.759	2.931	17.980	46.01
2003	39.935	4.34355	0.680	41.000	3.228	45.648	86.31
2004	21.736	3.98713	1.324	19.663	2.740	23.608	52.73
2005	35.119	4.17254	0.685	33.550	3.015	37.892	72.67
2006	17.421	4.05699	1.530	20.799	2.829	24.872	54.13
2007	7.388	3.62301	0.903	7.759	2.977	12.045	40.05
2008	10.956	3.77758	1.888	5.419	3.026	9.776	37.94
2009	10.724	3.59512	1.551	0.609	2.993	4.919	33.96
2010	18.445	4.32836	0.817	39.086	3.140	43.607	82.58

4411
 4412 Note: Shaded water years indicate the performance determination would have been suspended due to anomalous
 4413 rainfall coupled with the observed load being greater than the Load Target.
 4414

4415 **Figure 3-50. Comparison of WY2001-2010 loads with Reference Period loads and**
 4416 **Annual Load Targets, adjusted for hydrologic variability, for the Shingle Creek**
 4417 **Tributary.**
 4418



4419
 4420 Note: The Reference Period extended from WY2001-2007. The performance determination for WY2009
 4421 would have been suspended due to rainfall below the minimum value during the Reference Period coupled with
 4422 the observed load being greater than the Load Target.





4423 **Exceedance Frequency Analysis.** Using the approach described in Section 2.6, an
 4424 approximation of the cumulative exceedance frequency for the determination methodology
 4425 was estimated using a Monte Carlo approach based on the annual rainfall and the annual TP
 4426 loads of the Base Period (**Table 3-62**). Because the TP loads and rainfall statistics from the
 4427 Base Period do not perfectly describe normal distributions (e.g., the medians are generally
 4428 less than the means), the methodology includes conditional probabilities, and because the
 4429 random number generator is imperfect, the exceedance frequencies deviate from the
 4430 theoretical values shown in the second column. However, the results are determined to be
 4431 reasonable and defensible since the cumulative exceedance frequency is less than the
 4432 theoretical value of approximately 17.5 percent.

4433

4434 **Table 3-62. Exceedance frequencies for the proposed determination methodology for**
 4435 **the Shingle Creek basin.**

4436

Component of Performance Assessment	Theoretical Exceedance Frequency	Method Exceedance Frequency
Step 1. Load > Annual Load Target?	50%	50%
Step 2. Suspend assessment if Radj is outside the range and Load > Annual Load Target	<20%	6.2%
Step 3. Load > Annual Load Target for 3 consecutive years?	<12.5%	10.8%
Step 4. Load > Annual Load Limit?	<10%	3.0%
Cumulative Exceedance Frequency	<17.5%	13.0%

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4446 **3.9 South Lake Okeechobee Sub-watershed**

4447
4448 The South Lake Okeechobee Sub-watershed contains the northern Everglades Agricultural
4449 Area (EAA) including those portions of four special drainage districts established through
4450 Chapter 298 of the Florida Statutes historically discharging to Lake Okeechobee. In addition,
4451 Closter Farms, also known as 715 Farms and referenced as Agricultural Lease No. 3420 in
4452 the Everglades Forever Act (Chapter 473.4592, F.S.), is located within the South Lake
4453 Okeechobee Sub-watershed and historically discharged to the lake. These basins and
4454 structures discharging to Lake Okeechobee are presented in **Table 3-63** and **Figure 3-51**.

4455
4456 **Table 3-63. South Lake Okeechobee Sub-Watershed basins and Lake discharge**
4457 **structures.**
4458

Basin Name	Structures discharging to Lake Okeechobee
Everglades Agricultural Area (EAA)	S2, S3, S352
East Beach Water Control District (EBWCD)	Culvert 10
East Shore Water Control District (ESWCD)	Culvert 12
South Shore Drainage District (SSDD)	Culvert 4A
South Florida Conservancy District (SFCD)	S-236
Closter Farms	Culvert 12A

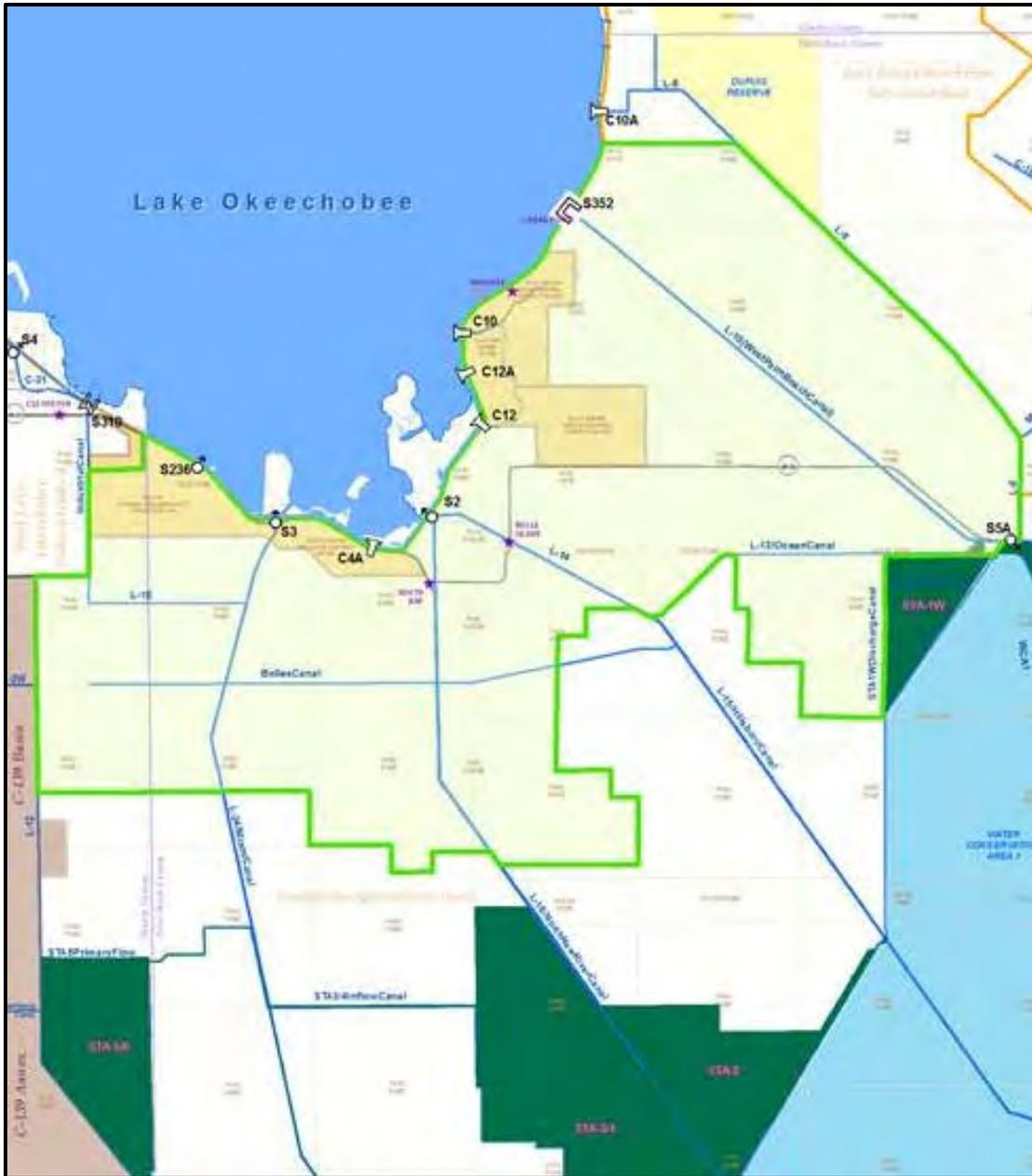
4459 Because of the critical importance of the Kissimmee-Lake Okeechobee-Everglades
4460 ecosystem, many programs work in concert to protect the water resources of the region as a
4461 whole. The performance measure methodologies summarized herein for the South Lake
4462 Okeechobee Sub-watershed complement the other regulatory programs designed to support
4463 achievement of the Lake Okeechobee TP TMDL of 140 metric tons per year (mt/yr), as
4464 defined in Chapter 62-304.700, F.A.C. Section 2.4 describes the relationship between the
4465 TMDL program and the performance measure methodologies developed for Chapters 40E-61
4466 and 40E-63 F.A.C. The relationship between the 2011 LOPP planning level estimates and





4467 the performance measure methodologies summarized in this document is also described in
4468 Section 2.4.

4469 **Figure 3-51. South Lake Okeechobee Sub-watershed boundary and monitoring**
4470 **locations for structures that discharge into Lake Okeechobee.**
4471



4472





4473 The EAA Basin discharges to both Lake Okeechobee and, at times, to the Everglades
4474 Protection Area, although the primary receiving bodies for the southern discharges are the
4475 Everglades Stormwater Treatment Areas. The existing performance measure methodology
4476 for the collective source control programs within the EAA Basin is described in Chapter 40E-
4477 63 F.A.C. and encompasses cumulative basin runoff loads, regardless of the direction of
4478 discharge. The following sections summarize the historical annual flow, TP and rainfall data,
4479 a summary of the existing performance methodology for the EAA Basin and a summary of
4480 the proposed performance measure methodologies for the Chapter 298 Districts.

4481 ***3.9.1 Summary of the Historic Data and Existing Performance***
4482 ***Measure Methodology for the EAA Basin***
4483

4484 The EAA Basin covers approximately 500,000 acres located south of Lake Okeechobee
4485 within eastern Hendry and western Palm Beach counties, an area of approximately 1,122
4486 square miles of highly productive agricultural land comprised of rich organic peat or muck
4487 soils (SFWMD 2011b). The area is considered to be one of Florida's most important
4488 agricultural regions, with approximately 77 percent of the EAA devoted to agricultural
4489 production. The major crops in the EAA Basin include sugar cane, vegetables, and sod, with
4490 secondary crops in rice and citrus.

4491

4492 ***3.9.1.1 EAA Basin Background***
4493

4494 The goal of the Everglades Regulatory Program in the EAA Basin under Chapter 40E-63
4495 F.A.C. is to reduce the TP loads discharged from the basin by 25 percent. The EAA
4496 regulated area is defined by multiple hydrologic drainage sub-basins. EAA Basin runoff load
4497 is based upon the total discharge load less pass-through computed inflows from other areas.
4498 Although the boundaries of these sub-basins remain static, the acreage contributing flow and





4499 used in the rule-adopted compliance model for determining EAA Basin TP load varies from
4500 year to year as regional projects are constructed.

4501 **3.9.1.2 EAA Basin Historical Data**

4502

4503 The District conducts EAA basin-level monitoring at all inflow and outflow structures to be
4504 used for assessing compliance with the source control program performance measure
4505 methodology. Annual observed runoff TP load from the EAA Basin for primary compliance
4506 includes both inflow and outflow structures from the EAA at which TP concentrations and
4507 flows are measured. EAA Basin runoff loads are estimated after first calculating pass-
4508 through loads from other sources. Specific details are provided in the Draft Technical
4509 Support Document for Chapter 40E-63, F.A.C. (SFWMD 1992).

4510

4511 A summary of the annual rainfall, total flows (i.e., basin runoff plus pass-through), and total
4512 TP levels for the EAA is presented in **Table 3-64** and **Figure 3-52**. A downward trend in
4513 EAA flow volume and TP load in the direction of the lake is evident. This operational change
4514 has resulted in a greater percentage of the discharge being directed to the STAs for treatment
4515 and lowering the amount of discharge to the Lake Okeechobee, however, this diversion does
4516 not contribute to meeting the total runoff load reduction requirements.

4517

4518





4519
4520

Table 3-64. Annual summary of total discharges from the EAA Basin.

Water Year	Rainfall inches	Total (1) Flow from EAA Basin			Total (1) TP Loads from EAA Basin			TP Concentrations	
		Total AF	To Lake AF	Percent to Lake	Total kg	To Lake kg	Percent to Lake	Total µg/L	To Lake µg/L
1980	53.50	1,217,485	121,763	10%	172,102	26,560	15%	115	177
1981	35.05	609,935	6,916	1%	90,503	1,250	1%	120	146
1982	46.65	830,700	435,530	52%	235,235	107,824	46%	230	201
1983	64.35	2,053,263	365,911	18%	520,894	74,996	14%	206	166
1984	49.83	1,258,721	61,174	5%	240,896	20,129	8%	155	267
1985	39.70	1,156,918	74,015	6%	260,503	28,426	11%	183	311
1986	51.15	1,174,455	272,057	23%	211,732	66,555	31%	146	198
1987	51.97	1,337,859	14,327	1%	279,160	4,356	2%	169	247
1988	43.43	914,909	11,790	1%	166,176	2,595	2%	147	178
1989	39.68	1,000,027	2,037	0%	218,289	682	0%	177	271
1990	40.14	966,874	131,261	14%	168,724	44,116	26%	141	272
1991	50.37	699,690	53,102	8%	172,568	20,485	12%	200	313
1992	47.61	1,123,912	9,703	1%	126,689	2,786	2%	91	233
1993	61.69	2,719,477	46,937	2%	411,485	8,918	2%	123	154
1994	50.45	1,057,001	4,546	0%	138,484	567	0%	106	101
1995	67.01	2,340,460	74,955	3%	340,763	18,820	6%	118	204
1996	56.86	1,824,342	67,336	4%	246,022	12,467	5%	109	150
1997	52.02	1,204,192	12,924	1%	147,757	1,866	1%	99	117
1998	56.12	1,465,369	15,615	1%	188,813	3,320	2%	104	172
1999	43.42	1,251,036	68,358	5%	182,610	21,566	12%	118	256
2000	57.51	1,623,541	46,785	3%	250,974	12,118	5%	125	210
2001	37.28	811,773	43,771	5%	109,043	10,392	10%	109	192
2002	49.14	1,306,561	343,221	26%	127,072	42,187	33%	79	100
2003	45.55	1,668,000	2,839	0%	209,482	617	0%	102	176
2004	46.76	1,280,414	465	0%	129,176	131	0%	82	228
2005	50.98	2,131,470	22,054	1%	278,050	3,691	1%	106	136
2006	50.08	1,292,920	12,323	1%	218,231	2,767	1%	137	182
2007	37.23	844,300	4,225	1%	175,601	744	0%	169	143
2008	46.95	655,894	4,108	1%	103,703	622	1%	128	123
2009	43.72	1,028,954	38,774	4%	165,371	8,093	5%	130	169
2010	61.88	1,290,235	17,082	1%	213,556	4,018	2%	134	191
POR Minimum	35.05	609,935	465	0%	90,503	131	0%	79	100
POR Average	49.29	1,294,861	76,965	6%	209,666	17,860	9%	131	188
POR Maximum	67.01	2,719,477	435,530	52%	520,894	107,824	46%	230	313
Base Period					WY1980-1988				
BP Minimum	35.05	609,935	6,916	1%	90,503	1,250	1%	115	146
BP Average	48.40	1,172,694	151,498	13%	241,911	36,966	15%	167	198
BP Maximum	64.35	2,053,263	435,530	52%	520,894	107,824	46%	230	311

Notes:

(1) Total includes flow-through from adjacent areas

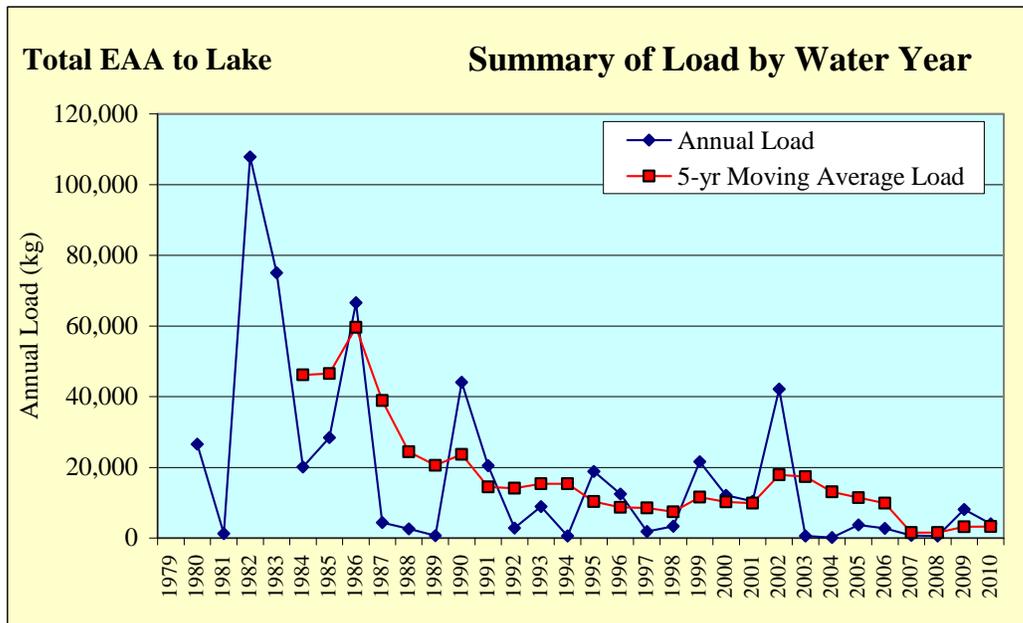
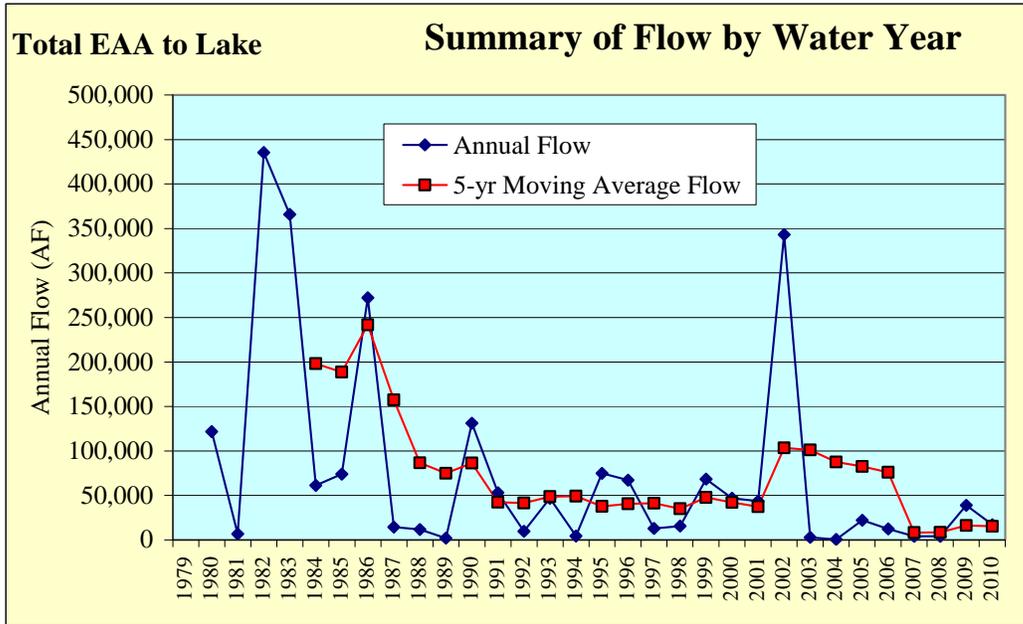
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Figure 3-52. Annual summary of total discharges from the EAA Basin to Lake Okeechobee.



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4528 **3.9.1.3 EAA Basin Existing Performance Measure Summary**

4529
4530 To evaluate compliance with the EAA basin-level TP load reduction requirements, the
4531 District annually evaluates BMP performance consistent with Chapter 40E-63 F.A.C. The
4532 EAA Basin must demonstrate a 25 percent reduction in load annually compared to the pre-
4533 BMP base period. Phosphorus load reduction calculations are conducted and reported
4534 annually. These calculations are made using an adjustment for the hydrologic variability
4535 associated with rainfall and surface water discharges over time. These adjusted equations,
4536 calibrated to the WY1980–WY1988 base period (May 1, 1979 through April 30, 1988),
4537 attempt to predict what the average annual TP load would have been for the EAA Basin if the
4538 current water year’s rainfall amount and monthly distribution had occurred during the base
4539 period.

4540
4541 Compliance with EAA Basin performance goal is based on mathematical equations and
4542 methodology outlined in Chapter 40E-63, F.A.C. The target load is based upon a 25 percent
4543 reduction in loading as well as accounting for a reduction in the EAA Basin area by a factor
4544 equal to the current acreage divided by the baseline acreage. The performance determination
4545 is suspended if the adjusted rainfall for the Evaluation Year exceeds 63.76 inches and the
4546 basin load is above the target. Compliance is determined by comparing the observed runoff
4547 TP loads for the Evaluation Year, adjusted for pass-through loads, to the target loads from
4548 the base period.

4549
4550 The EAA Basin has been in compliance with the Everglades Regulatory Program of BMPs
4551 since the first compliance year, WY1996. Since the program’s initiation, the EAA’s average
4552 annual percentage load reduction is greater than 50 percent.

4553





4554 **3.9.2 Summary of the Chapter 298 Districts Historic Data and**
4555 **Proposed Performance Measure Methodologies**

4556 The South Lake Okeechobee Sub-watershed contains four special drainage districts
4557 established through Chapter 298 of the Florida Statutes and Closter Farms, all located along
4558 the southern rim of Lake Okeechobee. In addition to discharging to the lake, the EBWCD,
4559 SSDD and SFCD also historically discharged stormwater into the surrounding canals of the
4560 EAA. Funded from agricultural privilege taxes and other sources, infrastructure
4561 improvements were completed between 2001 and 2005 to allow diversion of the lake
4562 discharges to the primary canal system of the EAA operated by the District:
4563

- 4564
- 4565 ➤ EBWCD: diversion works completed July 2001
- 4566 ➤ ESWCD: diversion works completed December 2001
- 4567 ➤ Closter Farms: diversion works completed December 2001
- 4568 ➤ SSDD: diversion works completed July 2004
- 4569 ➤ SFCD: diversion works completed June 2005

4570

4571 These basins are herein collectively referred to as the “Chapter 298 Districts”. Performance
4572 measure methodologies for these basins will evaluate levels in each basin’s combined
4573 discharge to Lake Okeechobee and the diversion works to the EAA. These methodologies are
4574 summarized herein and detailed within the *Draft – Performance Measure Methodology for*
4575 *the Chapter 298 Districts and Closter Farms* (Goforth et al. 2013)²².

²² The performance measure methodologies for the Ch. 298 Districts were developed under a different contract than the Lake Okeechobee Watershed performance measure methodologies, resulting in slight differences in data presentation, e.g., the period of record extended through WY2012 for the Ch. 298 Districts.





4577 **3.9.2.1 Background**

4578

4579 Consistent with the Long-Term Plan for the Southern Everglades and the District’s strategies
4580 for water quality restoration, the District administers a nutrient source control program within
4581 the Everglades Agricultural Area (EAA). The purpose of the nutrient source control program
4582 is to reduce nutrient loading from stormwater runoff to EAA canals, and ultimately to the
4583 District’s stormwater treatment areas (STAs). Critical to meeting the nutrient reduction goals
4584 of the nutrient source control program, are best management practices (BMPs) which are
4585 implemented by stakeholders within the EAA, and are designed to reduce nutrient loading to
4586 stormwater runoff before its ultimate discharge to the District’s STAs.

4587

4588 Performance measures quantify nutrient source control performance by establishing annual
4589 targets and limits for total phosphorus (TP) load. Performance measures have been
4590 developed for the EAA Chapter 298 Districts (East Beach Water Control District, East Shore
4591 Water Control District, South Florida Conservancy District, South Shore Water Control
4592 District, and the Closter Farms (**Figure 3-53**)) areas which historically discharged to Lake
4593 Okeechobee and were therefore excluded from the EAA Basin performance measures under
4594 Chapter 40E-63, F.A.C. Since the Closter basin discharges to the East Shore Water Control
4595 District (ESWCD) basin through the Closter diversion structure, with limited monitoring at
4596 that structure, Closter and ESWCD have been combined into a single basin for the purpose of
4597 the performance measure development. The resulting four basins discharge to different EAA
4598 canals (West Palm Beach, Hillsboro, North New River, and Miami), and ultimately to
4599 different STAs, therefore in developing performance measures, historic (base period) water
4600 quality and hydrologic monitoring data has been analyzed separately for each of the four
4601 basins.

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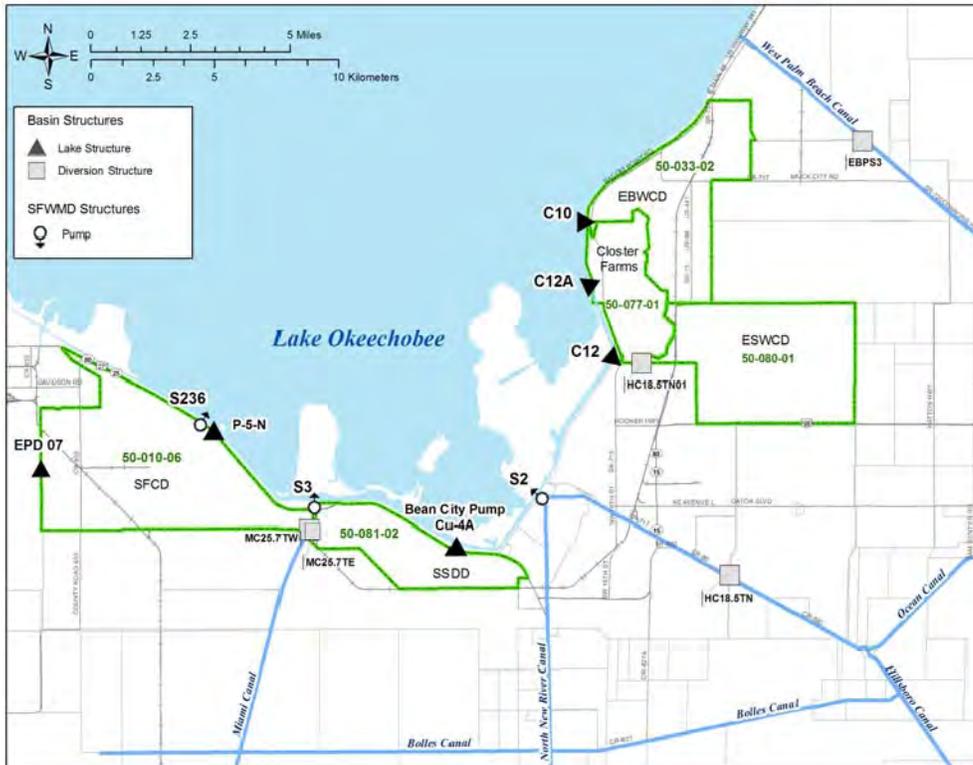


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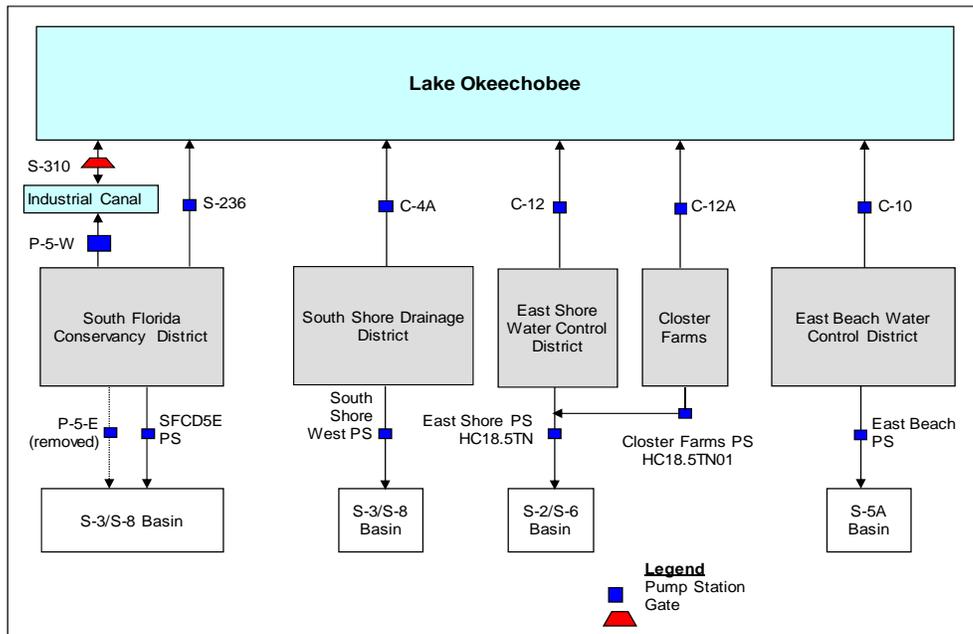
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Figure 3-53. Ch. 298 District basins map and flow schematic.



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4610 The following is a description of the general approach used to develop performance measures
4611 for the EAA Chapter 298 Districts basins.

4612

4613 **3.9.2.2 Historical Data Analysis**

4614

4615 A summary of the annual rainfall, total flows, and total TP levels for the Chapter 298
4616 Districts is presented in **Tables 3-66, 3-68, 3-70 and 3-72.**

4617

4618 Historical data analysis through Water Year 2012 (WY2012) was performed for each of the
4619 EAA Chapter 298 District basins. The analysis included the following.

- 4620 • analysis of flows and TP loads resulting from rainfall and runoff from each basin; and
- 4621 • identification of representative rainfall monitoring stations and use of the Thiessen
4622 polygon weighting method to estimate basin rainfall; and
- 4623 • identification of an appropriate base period for each basin. The base period serves as
4624 the benchmark of historical observed data on which performance measures are based.
4625 Base periods should include sufficient concentration and flow data to adequately
4626 represent TP levels through a wide range of hydrologic conditions and be
4627 representative of current operating conditions affecting TP loadings. Base periods
4628 should also have reasonable correlation between rainfall and nutrient loads, should
4629 precede the full implementation of collective source control measures, and meet other
4630 statistical criteria.

4631

4632 Based on statistical analysis of base period water quality and hydrologic data, two equations,
4633 prediction (target) and upper confidence limit (limit) for annual TP load discharged, as a
4634 function of annual rainfall have been developed for each of the four basins. These equations
4635 provide TP load targets and TP load limits for discharges from each basin for a given year as
4636 a function of that given year's annual rainfall, as long as that given year's annual rainfall is
4637 within a statistically determined range based on base period data. The prediction and upper





4638 confidence limit equations provide predictions and limits for TP load based on a 25 percent
4639 reduction, and can be modified to predict an alternative TP load reduction goal. The
4640 equations so modified for a given load reduction, provide a metric for determining whether
4641 each individual basin is achieving that load reduction goal.

4642 **3.9.2.3 Performance Measure Methodologies**

4643
4644 The general approach used to develop load based performance measures is described below
4645 with summaries of the proposed phosphorus source control performance measure
4646 methodologies. In order to quantify the performance of nutrient reduction source controls,
4647 the performance measures and performance indicators establish annual TP targets for the
4648 basins regardless of the receiving waterbody. Thus, loads are included for all structures that
4649 serve a basin although they may not discharge directly into the lake. Thus, the source
4650 control program participants with property in a basin that can discharge to multiple
4651 watersheds will have one goal to achieve rather than multiple goals. Requirements for the
4652 Chapter 298 District basins to divert 80% of historic flow and load discharges to Lake
4653 Okeechobee are currently specified in their respective Environmental Resource Permits and
4654 are not a topic of this document.

4655
4656 A total of over one hundred alternative regression equations were examined for each
4657 drainage basin.

- 4658 • Fifty-four (54) regression equations correlating annual load with annual rainfall and
4659 monthly rainfall characteristics (coefficient of variation, skewness and kurtosis) were
4660 evaluated.
- 4661 • Fifty-four (54) regression equations correlating annual concentration with annual
4662 rainfall and monthly rainfall characteristics (coefficient of variation, skewness and
4663 kurtosis) were evaluated.





- 4664 • Multiple statistical selection factors were analyzed in selecting the recommended
4665 regression equation for each basin. These included strength of correlation, statistical
4666 significance of regression coefficients, standard error of the regression equation,
4667 variance of residuals, co-linearity of predictor variables, presence of outliers,
4668 presence of temporal trends during the base period, and presence of over-
4669 parameterization.
- 4670 • In the case of the South Shore Drainage District, the base period is not characterized
4671 by a strong relationship between rainfall and TP load. An attempt to improve the
4672 correlation by using an independent variable to represent seepage from Lake
4673 Okeechobee successfully improved the predictive capability for flows, however, this
4674 did not improve the predictive capability for TP loads. For this basin, an alternative
4675 method of establishing annual predictions and UCL is recommended. The annual
4676 predicted value would be set equal to the base period average (arithmetic mean).

4677

4678 **Annual Performance Determination**

4679

4680 TP loads discharged at each of the EAA Chapter 298 District basins discharge structures will
4681 be assessed on an annual basis against the Annual Load Target and the Annual Load Limit
4682 (Figure 1-2). Tables 3-65, 3-67, 3-69, and 3-71 present summaries of the equations for
4683 calculating the annual load targets, limits, and minimum and maximum rainfall values used
4684 to establish a rainfall range for TP load based performance measures for the EAA Chapter
4685 298 District basins. Figures 3-54 – 3-57 provide comparisons of the scaled load data with the
4686 proposed targets and limits for the base periods for each of the basins. Tables 3-66, 3-68, 3-
4687 70, and 3-72 present summaries of historic discharges for the period of record for each of the
4688 basins.

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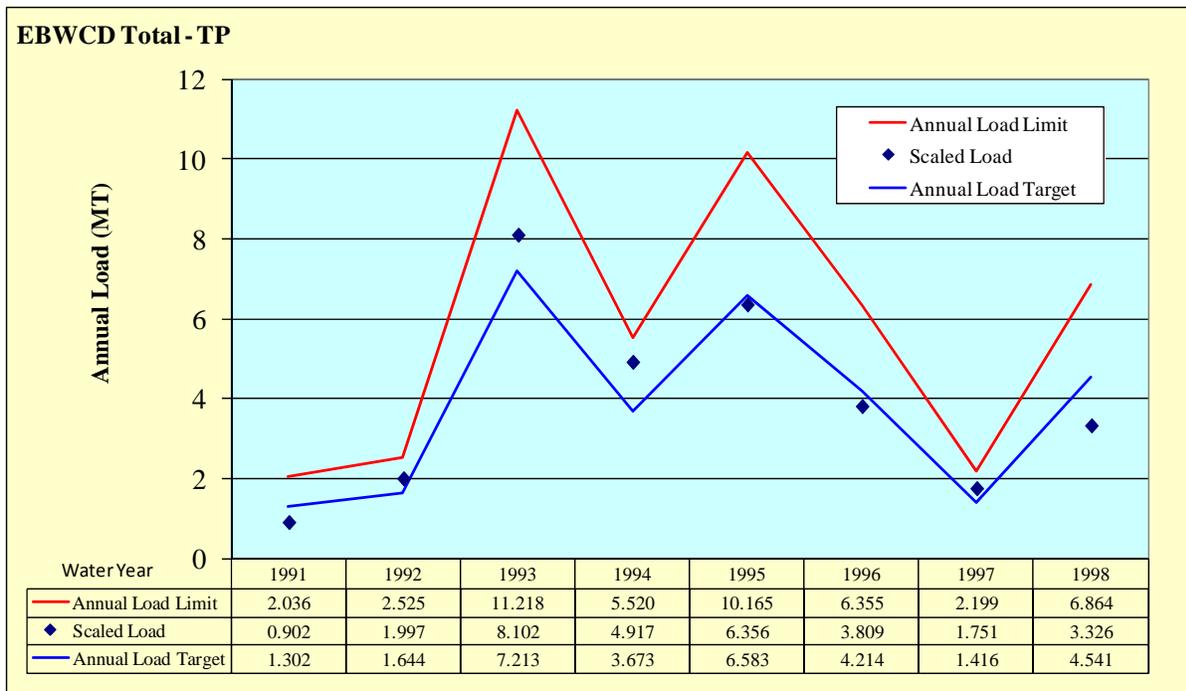
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Table 3-65. East Beach Water Control District TP Load Performance Measure.

Base Period Median Annual Load mt	Explained Variance R ²	Recommended Source Control Reduction	Base Period Rainfall	
			Minimum inches	Maximum inches
4.757	89%	25%	45.71	68.05
Target = exp[-16.17942 + 4.30194 ln(Rain)]				
Limit = Target* exp(0.38288 sqrt[1.125 + (ln(Rain) - 4.02892) ² / 0.17904])				

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Figure 3-54. Comparison of the scaled Base Period annual TP loads with the Annual Targets and Limits for the EBWCD based on a 25% load reduction.



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Table 3-66. Summary of historical discharges from EBWCD.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Area acres	Unit Area Runoff in/yr	Unit Area Load lbs/ac
1990				34.81			
1991	4,357	1.203	224	45.71	6,542	7.99	0.41
1992	4,970	2.663	434	48.26	6,542	9.12	0.90
1993	15,558	10.804	563	68.05	6,542	28.54	3.64
1994	16,827	6.553	316	58.17	6,542	30.87	2.21
1995	19,909	8.475	345	66.62	6,542	36.52	2.86
1996	15,969	5.079	258	60.06	6,542	29.29	1.71
1997	8,226	2.335	230	46.61	6,542	15.09	0.79
1998	16,595	4.434	217	61.11	6,542	30.44	1.49
1999	20,284	10.587	423	40.58	6,542	37.21	3.57
2000	33,161	12.656	309	59.69	6,542	60.83	4.26
2001	6,074	1.318	176	35.74	6,542	11.14	0.44
2002	21,103	9.360	360	43.11	6,542	38.71	3.15
2003	20,419	8.022	318	52.51	6,542	37.45	2.70
2004	23,744	8.824	301	55.45	6,542	43.55	2.97
2005	28,216	15.033	432	65.31	6,542	51.76	5.07
2006	18,162	10.748	480	42.75	6,542	33.31	3.62
2007	12,438	5.588	364	42.39	6,542	22.82	1.88
2008	8,795	5.593	516	47.15	6,542	16.13	1.88
2009	16,046	12.811	647	48.96	6,542	29.43	4.32
2010	20,131	20.127	811	63.07	6,542	36.93	6.78
2011	10,640	5.717	436	41.61	6,542	19.52	1.93
2012	5,300	2.704	414	35.01	6,542	9.72	0.91
Minimum	4,357	1.203	176	35.01	6,542	7.99	0.41
Average	15,769	7.756	399	51.27	6,542	28.93	2.61
Maximum	33,161	20.127	811	68.05	6,542	60.83	6.78
Std. Dev.	7,649	4.803	151	10.19	0	14.03	1.62
Skewness	0.288	0.734	1.094	0.147		0.288	0.73
Median	16,321	7.288	362	48.61	6,542	29.94	2.46

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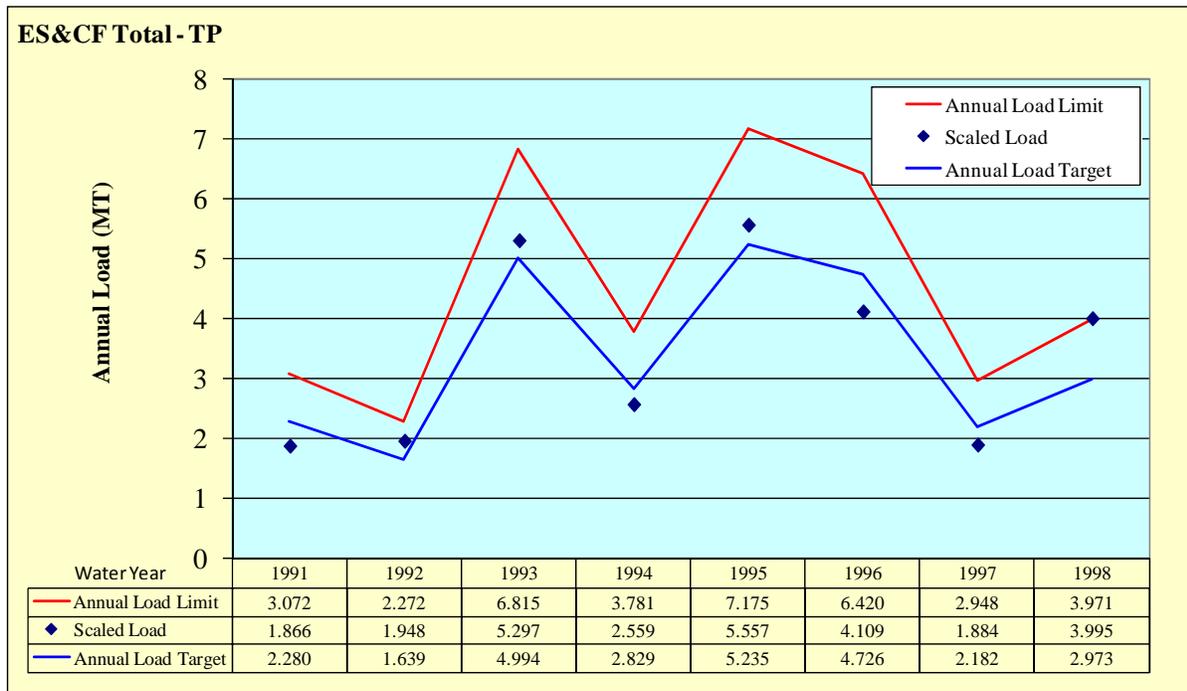
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Table 3-67. ESWCD and Closter TP Load Performance Measure.

Base Period Median Annual Load mt	Explained Variance R ²	Recommended Source Control Reduction	Base Period Rainfall	
			Minimum inches	Maximum inches
4.369	86%	25%	48.10	67.62
Target = exp[-12.71472 + 3.41017 ln(Rain)]				
Limit = Target* exp(0.27273 sqrt[1.125 + (ln(Rain) - 4.05997) ² / 0.11302])				

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Figure 3-55. Comparison of the scaled Base Period annual TP loads with the Annual Targets and Limits for the ESWCD & Closter based on a 25% load reduction.



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Table 3-68. Summary of historical discharges from ESWCD & Closter.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Area acres	Unit Area Runoff in/yr	Unit Area Load lbs/ac
1990				38.28			
1991	11,337	2.488	178	52.99	11,534	11.80	0.48
1992	13,429	2.597	157	48.10	11,534	13.97	0.50
1993	32,569	7.062	176	66.69	11,534	33.88	1.35
1994	18,486	3.412	150	56.45	11,534	19.23	0.65
1995	34,326	7.409	175	67.62	11,534	35.71	1.42
1996	31,269	5.479	142	65.62	11,534	32.53	1.05
1997	19,790	2.512	103	52.31	11,534	20.59	0.48
1998	26,377	5.326	164	57.28	11,534	27.44	1.02
1999	25,059	2.999	97	39.83	11,534	26.07	0.57
2000	45,171	7.328	132	60.95	11,534	47.00	1.40
2001	12,677	2.422	155	40.30	11,534	13.19	0.46
2002	21,685	2.884	108	45.44	11,534	22.56	0.55
2003	32,692	3.621	90	54.93	11,534	34.01	0.69
2004	30,282	3.025	81	51.88	11,534	31.51	0.58
2005	41,209	7.752	153	67.14	11,534	42.87	1.48
2006	30,343	7.433	199	51.81	11,534	31.57	1.42
2007	21,011	4.202	162	40.82	11,534	21.86	0.80
2008	14,603	3.129	174	48.50	11,534	15.19	0.60
2009	22,304	3.912	142	46.36	11,534	23.21	0.75
2010	36,945	7.015	154	63.97	11,534	38.44	1.34
2011	18,327	2.534	112	42.89	11,534	19.07	0.48
2012	14,609	2.012	112	37.31	11,534	15.20	0.38
<i>Minimum</i>	<i>11,337</i>	<i>2.012</i>	<i>81</i>	<i>37.31</i>	<i>11,534</i>	<i>11.80</i>	<i>0.38</i>
<i>Average</i>	<i>25,205</i>	<i>4.389</i>	<i>141</i>	<i>52.69</i>	<i>11,534</i>	<i>26.22</i>	<i>0.84</i>
<i>Maximum</i>	<i>45,171</i>	<i>7.752</i>	<i>199</i>	<i>67.62</i>	<i>11,534</i>	<i>47.00</i>	<i>1.48</i>
<i>Std. Dev.</i>	<i>9,634</i>	<i>2.038</i>	<i>33</i>	<i>9.65</i>	<i>0</i>	<i>10.02</i>	<i>0.39</i>
<i>Skewness</i>	<i>0.361</i>	<i>0.618</i>	<i>-0.330</i>	<i>0.135</i>		<i>0.361</i>	<i>0.62</i>
<i>Median</i>	<i>23,682</i>	<i>3.517</i>	<i>152</i>	<i>52.10</i>	<i>11,534</i>	<i>24.64</i>	<i>0.67</i>

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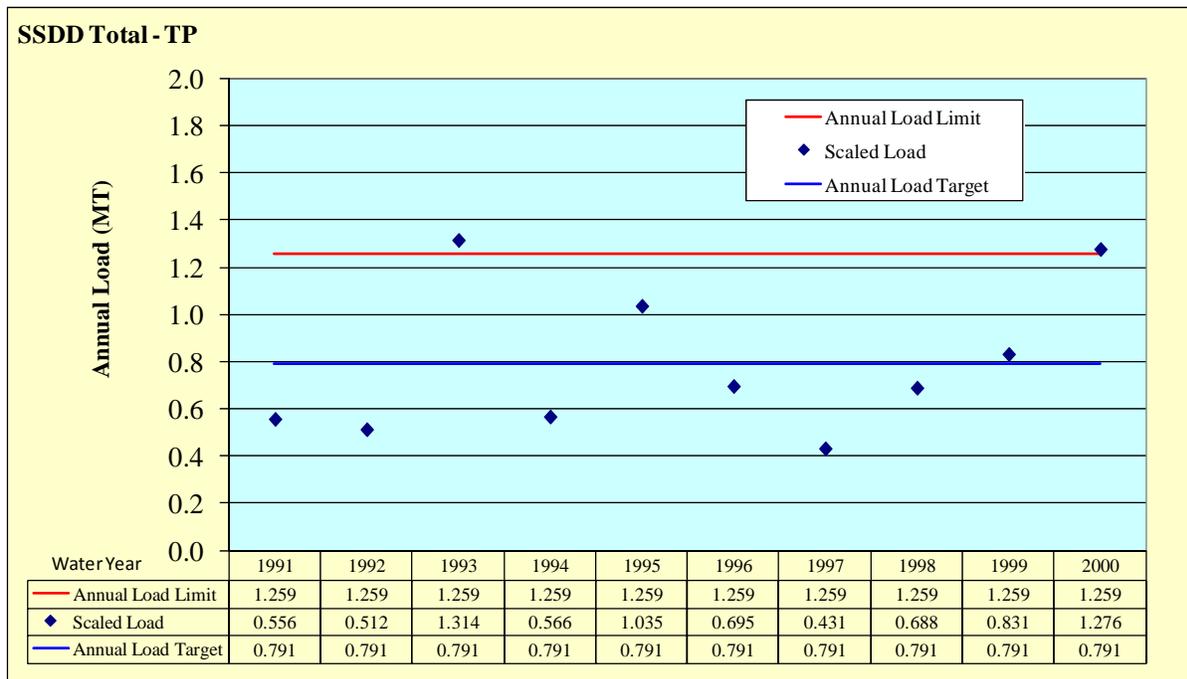
Table 3-69. SSDD TP Load Performance Measure.

Base Period Mean Annual Load mt	Explained Variance R ²	Recommended Source Control Reduction	Base Period Rainfall	
			Minimum inches	Maximum inches
1.054	NA*	25%	42.90	60.83
Target = 0.7905 mt				
Limit = 1.259 mt				

4726 * An alternative method of establishing annual target predictions and limit is recommended.
4727 The annual target value to be equal to the scaled base period average (arithmetic mean).

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Figure 3-56. Comparison of the scaled Base Period annual TP loads with the Annual Targets and Limits for the SSDD based on a 25% load reduction.



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Table 3-70. Summary of historical discharges from SSDD.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Area acres	Unit Area Runoff in/yr	Unit Area Load lbs/ac
1990				39.07			
1991	4,005	0.741	150	49.88	4,230	11.36	0.39
1992	6,041	0.683	92	48.81	4,230	17.14	0.36
1993	9,606	1.752	148	54.64	4,230	27.25	0.91
1994	7,307	0.755	84	48.28	4,230	20.73	0.39
1995	11,331	1.380	99	60.83	4,230	32.14	0.72
1996	8,882	0.927	85	56.77	4,230	25.20	0.48
1997	7,471	0.575	62	50.37	4,230	21.19	0.30
1998	7,522	0.917	99	53.83	4,230	21.34	0.48
1999	7,196	1.108	125	42.90	4,230	20.41	0.58
2000	11,413	1.701	121	51.32	4,230	32.38	0.89
2001	2,968	0.605	165	37.02	4,230	8.42	0.32
2002	3,156	0.518	133	43.65	4,230	8.95	0.27
2003	6,695	0.987	120	36.17	4,230	18.99	0.51
2004	5,534	0.581	85	43.36	4,230	15.70	0.30
2005	10,985	1.842	136	51.51	4,230	31.16	0.96
2006	15,122	2.521	135	58.39	4,230	42.90	1.31
2007	6,175	0.972	128	30.10	4,230	17.52	0.51
2008	2,763	0.568	167	36.77	4,230	7.84	0.30
2009	7,780	1.639	171	39.62	4,230	22.07	0.85
2010	12,286	2.227	147	55.47	4,230	34.85	1.16
2011	10,431	1.816	141	45.04	4,230	29.59	0.95
2012	8,128	1.173	117	43.47	4,230	23.06	0.61
Minimum	2,763	0.518	62	30.10	4,230	7.84	0.27
Average	7,854	1.181	122	47.19	4,230	22.28	0.62
Maximum	15,122	2.521	171	60.83	4,230	42.90	1.31
Std. Dev.	3,225	0.589	30	8.09	0	9.15	0.31
Skewness	0.277	0.776	-0.258	-0.285		0.277	0.78
Median	7,497	0.980	127	48.55	4,230	21.27	0.51

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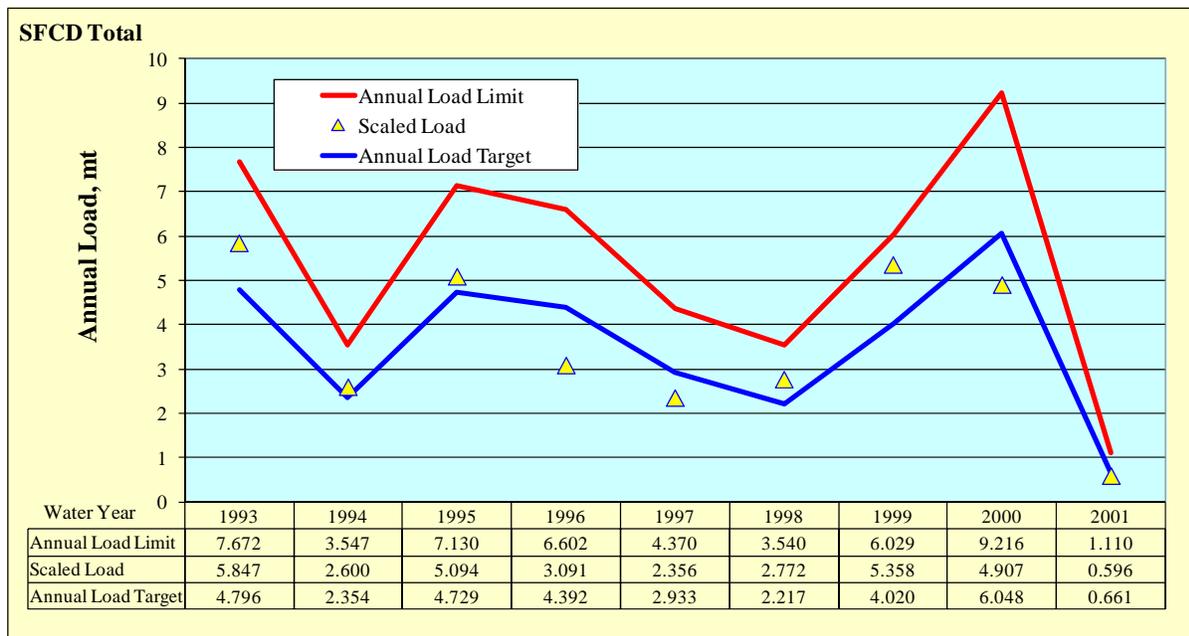
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Table 3-71. SFCD TP Load Performance Measure.

Base Period Median Annual Load mt	Explained Variance R ²	Recommended Source Control Reduction	Base Period Rainfall	
			Minimum inches	Maximum inches
4.121	90%	25%	28.30	56.17
Target = exp (-10.37045 + 2.87238 ln(Rain) + 0.68204 S)] S = the skewness calculated from 12 monthly rainfall totals				
Limit = Target + 1.43976 (0.26292 [1 + 1/9 + 3.0389 (ln(Rain) - 3.85125) ² + 0.92149 (S - 0.63211) ² - 0.4311 (ln(Rain) - 3.85125) (S-0.63211)] ^{0.5}				

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Figure 3-57. Comparison of the scaled Base Period annual TP loads with the Annual Targets and Limits for the SFCD based on a 25% load reduction.



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Lake Okeechobee Watershed Performance Measures

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Table 3-72. Summary of historical discharges from SFCD.

Water Year	Flow AF	TP Load mt	FWM TP Conc µg/L	Rainfall inches	Area acres	Unit Area Runoff in/yr	Unit Area Load lbs/ac
1990				39.36			
1991	6,991	1.528	177	49.96	9,775	8.58	0.34
1992	4,360	0.893	166	48.65	9,775	5.35	0.20
1993	24,809	7.796	255	46.67	9,775	30.46	1.76
1994	24,578	3.466	114	45.75	9,775	30.17	0.78
1995	36,654	6.792	150	54.74	9,775	45.00	1.53
1996	32,576	4.121	103	53.62	9,775	39.99	0.93
1997	20,416	3.141	125	46.90	9,775	25.06	0.71
1998	26,795	3.696	112	49.16	9,775	32.89	0.83
1999	39,814	7.144	145	49.21	9,775	48.88	1.61
2000	49,990	6.543	106	56.17	9,775	61.37	1.48
2001	5,952	0.795	108	28.30	9,775	7.31	0.18
2002	19,473	2.734	114	49.37	9,775	23.91	0.62
2003	27,283	2.977	88	44.02	9,775	33.49	0.67
2004	27,611	3.498	103	47.01	9,775	33.90	0.79
2005	35,241	4.456	103	65.42	9,775	43.26	1.00
2006	43,760	6.751	125	66.06	9,775	53.72	1.52
2007	15,385	2.177	115	37.08	9,775	18.89	0.49
2008	7,191	0.784	88	38.11	9,775	8.83	0.18
2009	21,358	3.140	119	43.63	9,775	26.22	0.71
2010	27,130	3.902	117	53.94	9,775	33.31	0.88
2011	14,710	1.475	81	39.53	9,775	18.06	0.33
2012	18,201	2.613	116	49.19	9,775	22.34	0.59
Minimum	4,360	0.784	81	28.30	9,775	5.35	0.18
Average	24,104	3.656	123	48.30	9,775	29.59	0.82
Maximum	49,990	7.796	255	66.06	9,775	61.37	1.76
Std. Dev.	12,414	2.144	38	8.56	0	15.24	0.48
Skewness	0.206	0.557	2.233	0.032		0.206	0.56
Median	24,694	3.304	115	48.91	9,775	30.31	0.75

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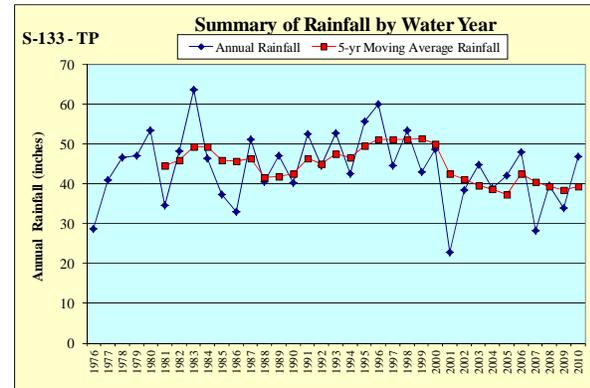
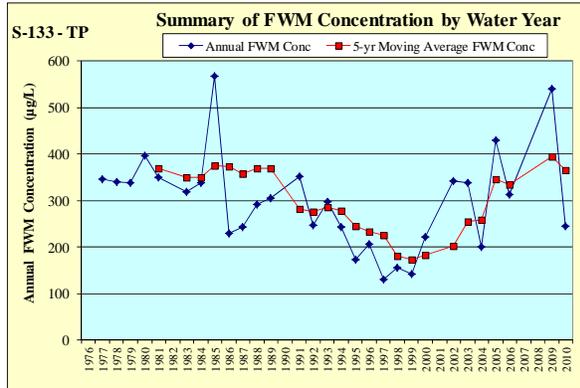
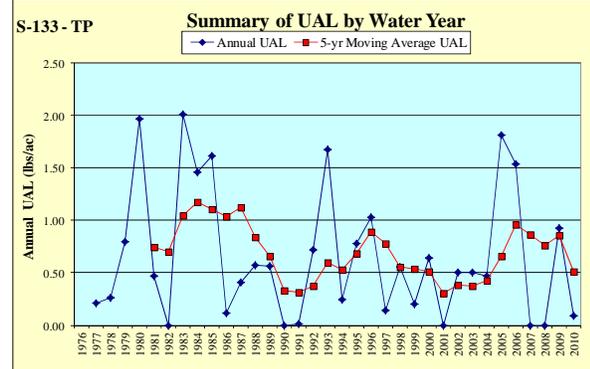
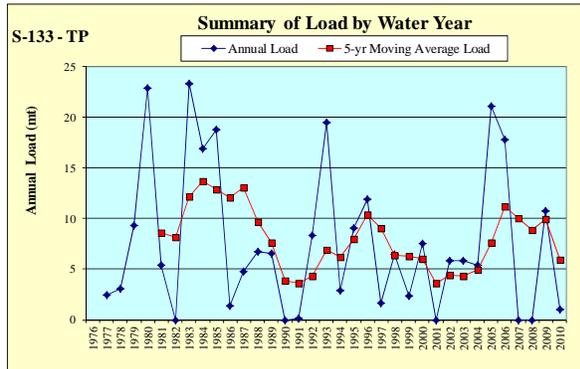
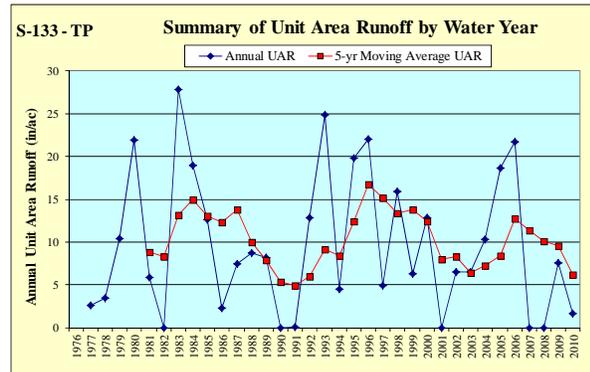
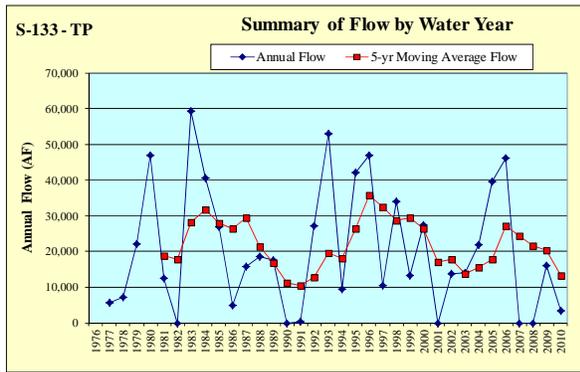


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APPENDIX A - SUPPLEMENTAL INFORMATION FOR THE DERIVATION OF
THE PERFORMANCE MEASURE METHODOLOGIES FOR THE LAKE
OKEECHOBEE WATERSHED

TAYLOR CREEK-NUBBIN SLOUGH SUB-WATERSHED

Summary of annual flow, TP and rainfall for S-133 Summary Basin



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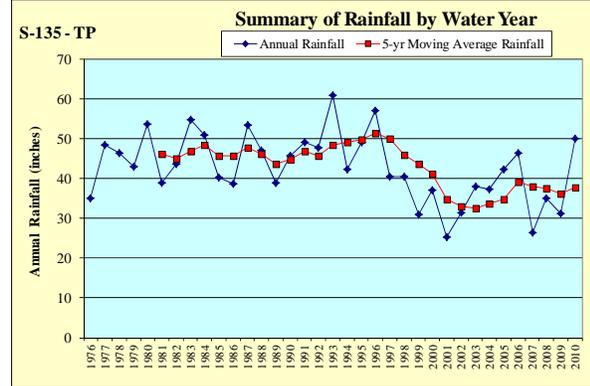
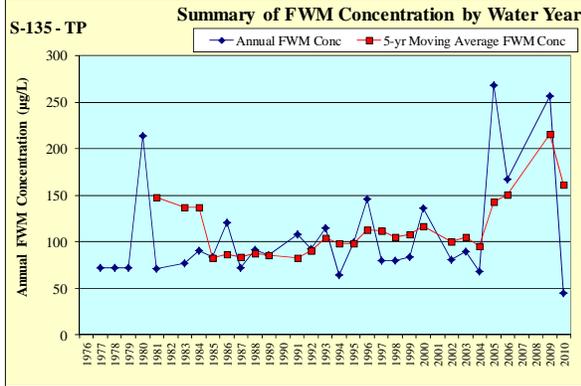
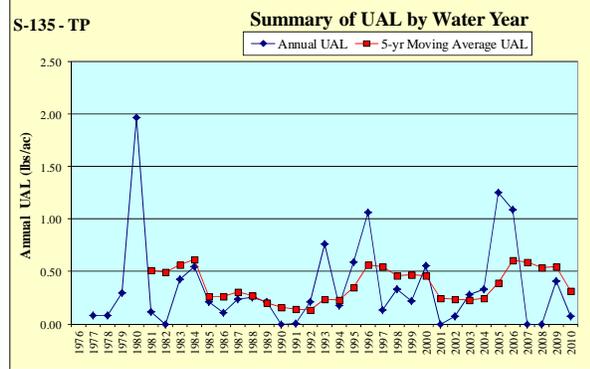
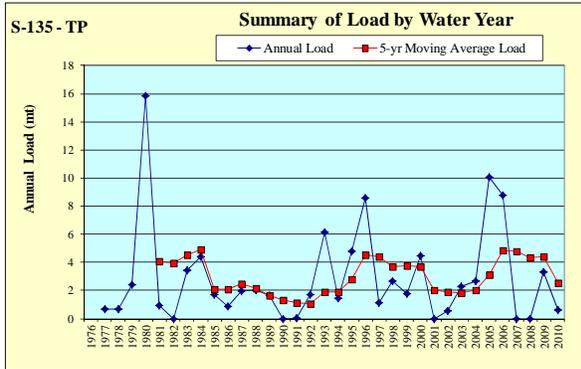
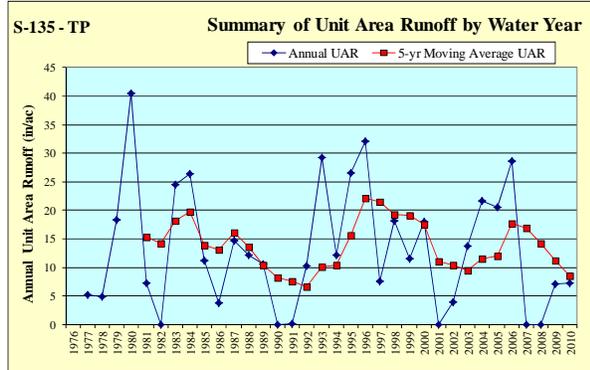
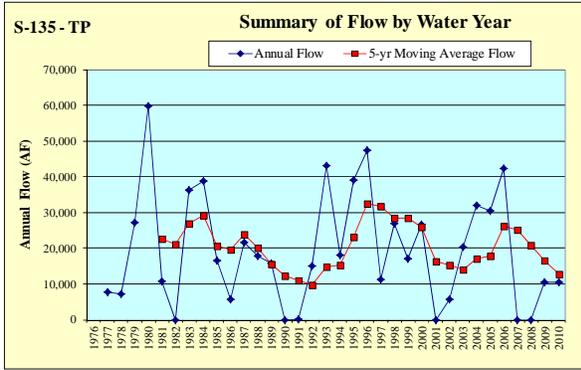


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Summary of annual flow, TP and rainfall for S-135 Summary Basin



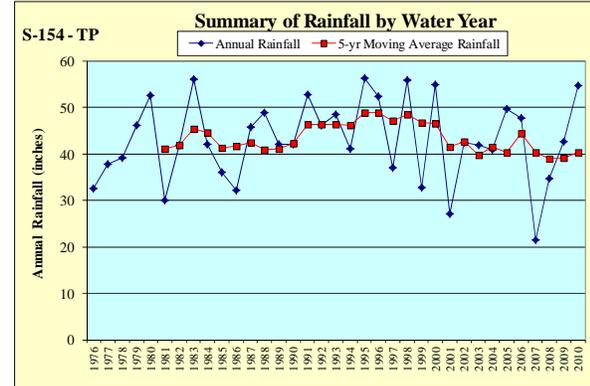
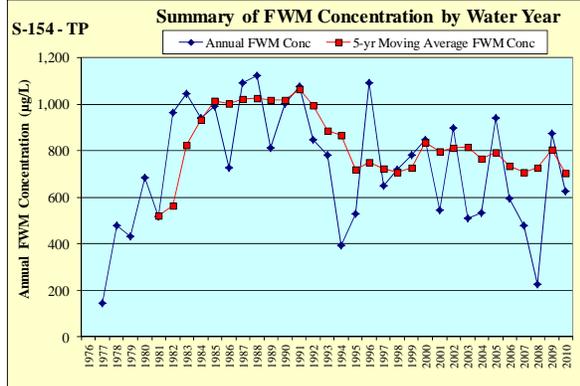
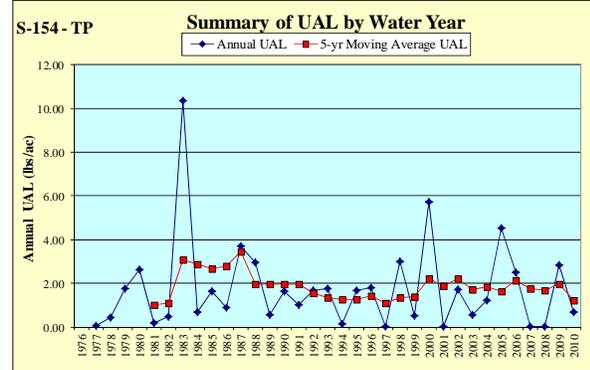
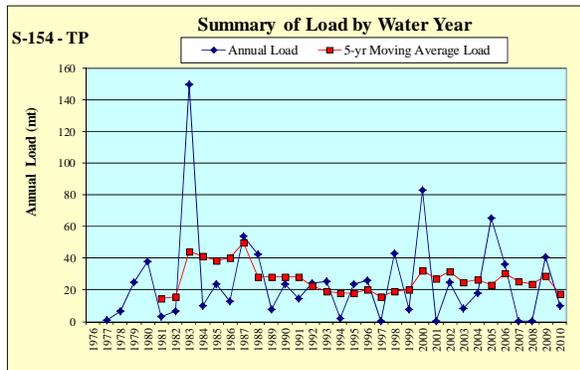
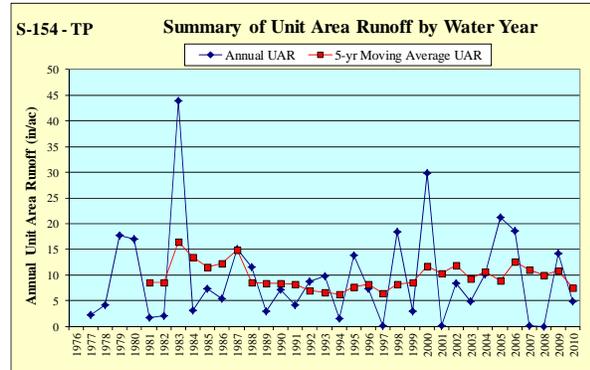
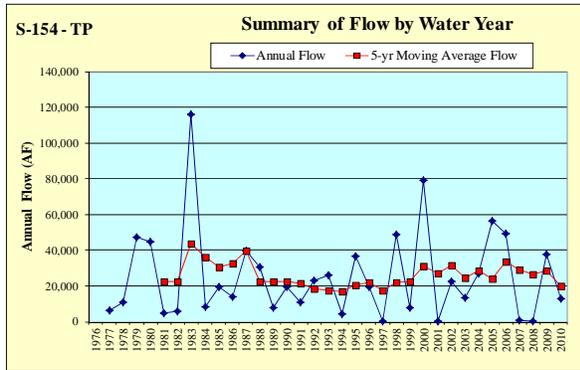
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Summary of annual flow, TP and rainfall for S-154 Summary Basin



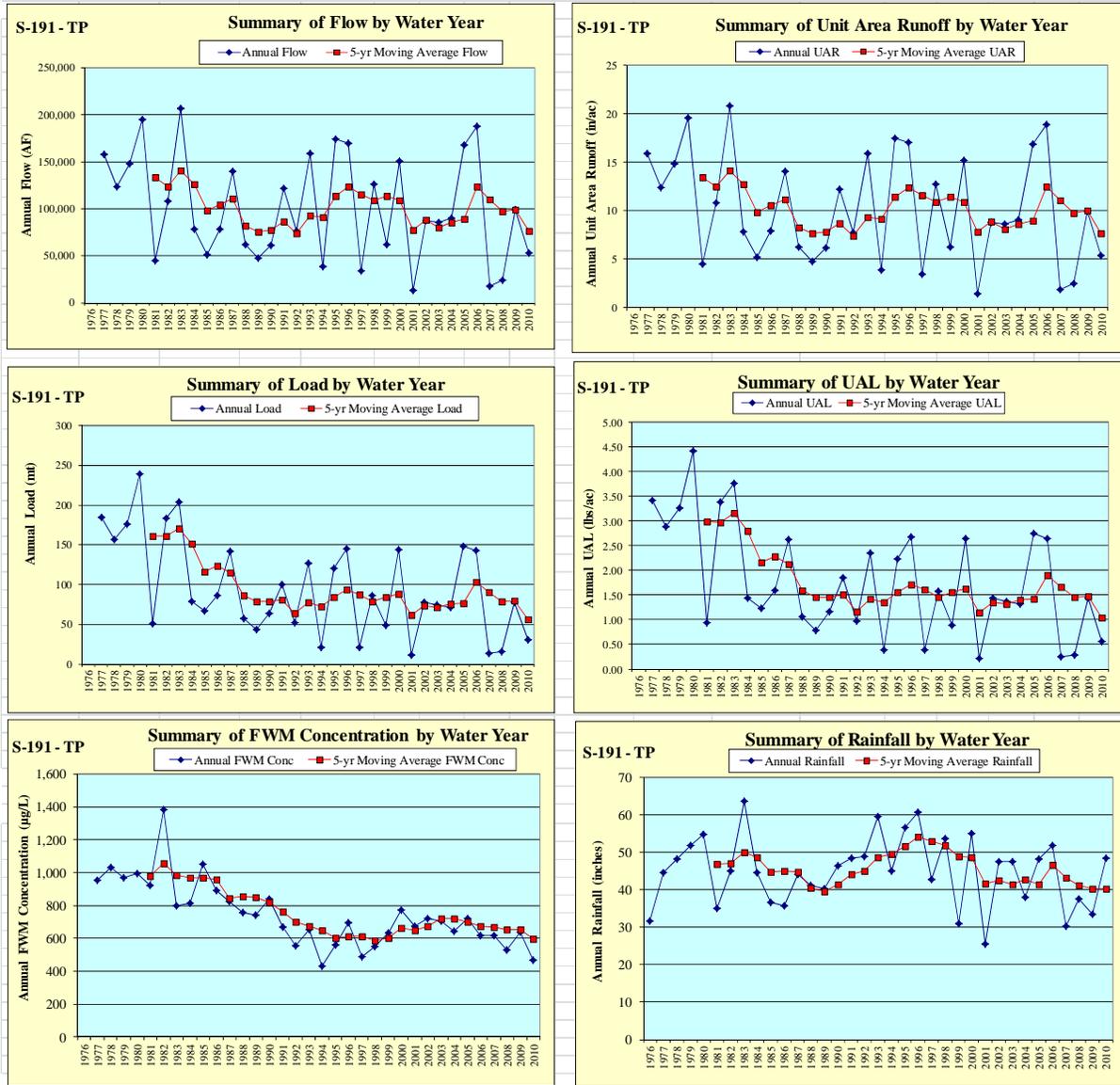
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Summary of annual flow, TP and rainfall for S-191 Summary Basin



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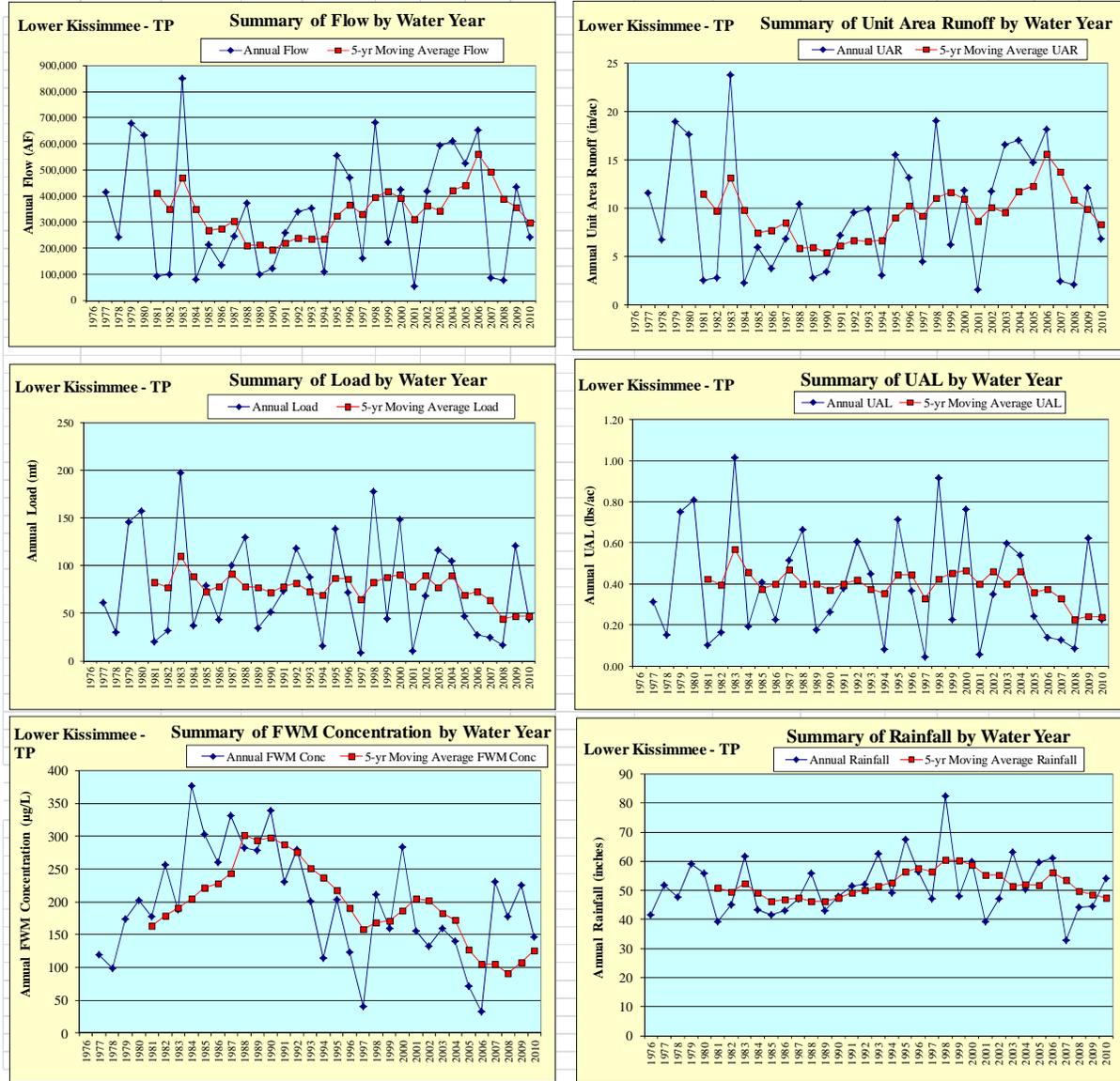


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Lake Okeechobee Watershed Performance Measures

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Summary of annual flow, TP and rainfall for the Lower Kissimmee Sub-watershed



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Calculation of Net Basin TP Loads for the Lower Kissimmee Sub-watershed

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The Lower Kissimmee Sub-watershed receives surface inflows from the Upper Kissimmee Sub-watershed at S-65 and discharges to Lake Okeechobee at S-65E. Some of the inflows from the Upper Kissimmee are retained in the Lower Kissimmee Sub-watershed as a result of evapotranspiration, water supply withdrawals, groundwater recharge, increased storage, etc. The portion of the total inflow from S-65 that is “passed through” the Lower Kissimmee and discharged to Lake Okeechobee is not considered in this evaluation. Only basin flows that are the result of local rainfall and runoff from the Lower Kissimmee Sub-watershed are evaluated in this analysis. (Note: Inflows from Lake Istokpoga via G-85 are limited to leakage through closed culvert stop logs and are considered insignificant.) Basin flows are calculated on a daily basis as follows:

- I_{LK} = Total Inflow to the Lower Kissimmee Sub-watershed
= Q_{S-65} = S-65 discharge
- O_{LK} = Total Outflow from the Lower Kissimmee Sub-watershed
= Q_{S-65E} = S-65E discharge
- PT_{LK} = Pass-through flow
= the portion of S-65 inflow that is passed through the Lower Kissimmee Sub-watershed
= minimum (I_{LK} , O_{LK})
- B_{LK} = net basin flow produced by local rainfall and runoff
= $O_{LK} - PT_{LK}$

TP loading from the Lower Kissimmee Sub-watershed is the result of direct rainfall and runoff from within the sub-watershed and does not include external TP loading from the Upper Kissimmee Sub-watershed. Lower Kissimmee Sub-watershed basin loading is calculated using the following equations.

- C_{S-65} = S-65 TP concentration
- PTL_{LK} = pass through TP load = the portion of S-65 TP load that is passed through the Lower Kissimmee Sub-watershed
= $PT_{LK} * C_{S-65}$
- C_{S-65E} = S-65E TP concentration
- BL_{LK} = net basin TP loads produced by local rainfall and runoff
= $(Q_{S-65E} * C_{S-65E}) - PTL_{LK}$

These calculations were performed on a daily time-step and the results were summed to monthly and annual totals.



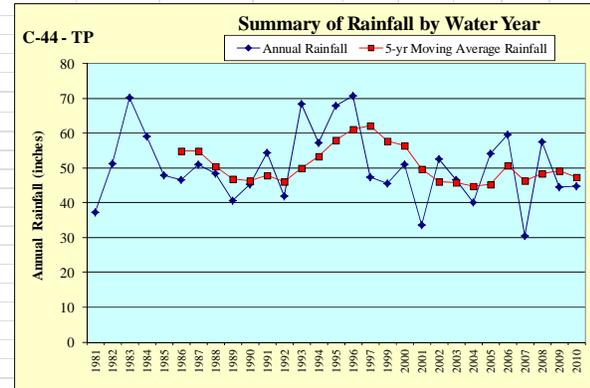
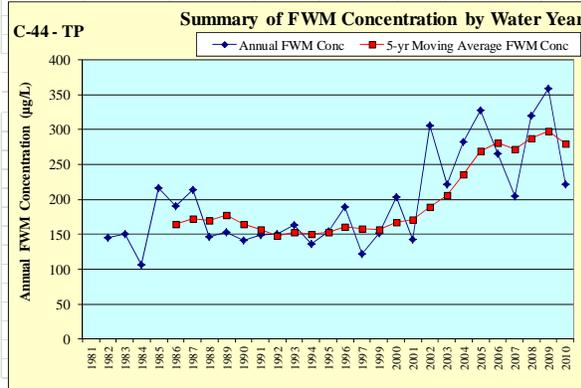
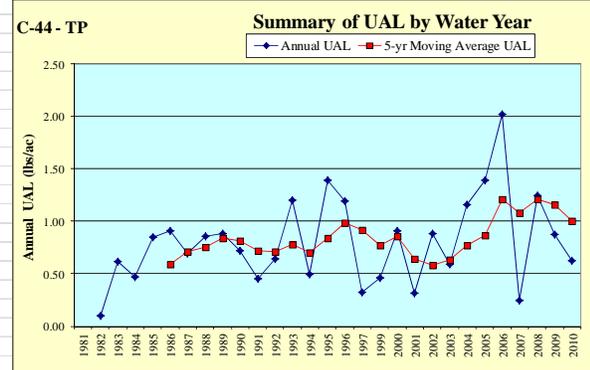
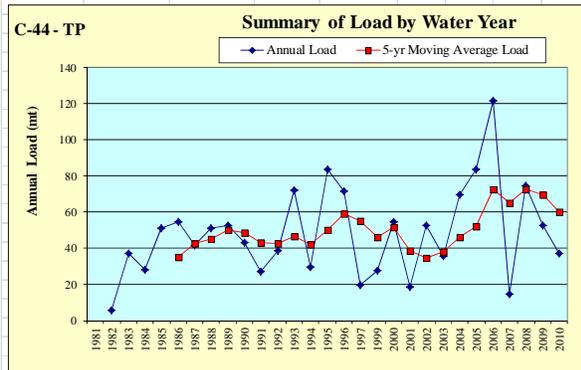
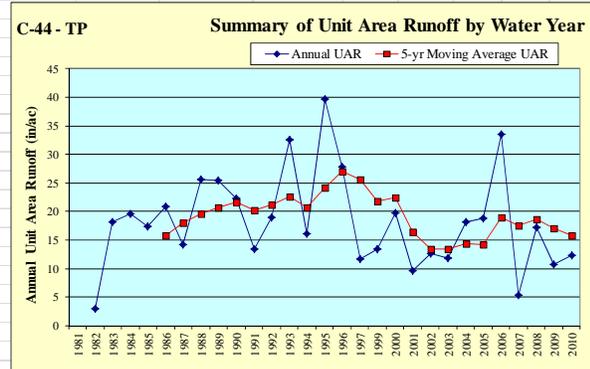
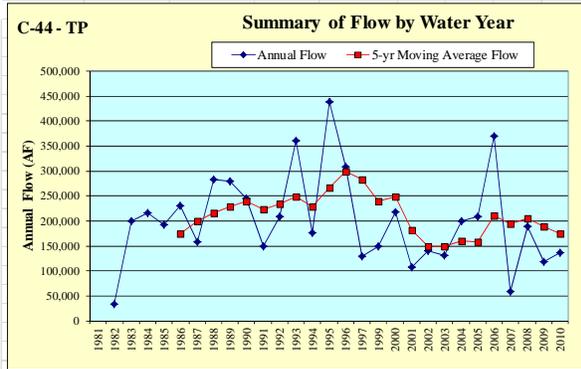


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Lake Okeechobee Watershed Performance Measures

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EAST LAKE OKEECHOBEE SUB-WATERSHED
C-44 Hydrologic Unit



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4922 **Calculation of Net Basin TP Loads for the C-44 Hydrologic Unit**

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4924 **C-44 Hydrologic Unit Flows**

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4926	$Q_{S-308In}$	= S-308 discharges from Lake Okeechobee to C-44
4927	$Q_{S-308Out}$	= S-308 discharges C-44 to Lake Okeechobee
4928	Q_{S-80}	= S-80 discharges from C-44 to St. Lucie Estuary
4929	I_{C-44}	= total inflow to C-44
4930		= $Q_{S-308In}$
4931	O_{C-44}	= total outflow from C-44
4932		= $Q_{S-308Out} + Q_{S-80}$
4933	PT_{C-44}	= pass-through flow for C-44
4934		= minimum (I_{C-44} , O_{C-44})
4935	B_{C-44}	= net basin flow produced by local rainfall and runoff
4936		= $O_{C-44} - PT_{C-44}$

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4939 **C-44 Hydrologic Unit Loads**

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4941	C_{In}	= total inflow concentration
4942		= total inflow load to C-44 / total inflow to C-44
4943		= $(Q_{S-308In} * C_{S-308In}) / I_{C-44}$
4944	PTL_{C-44}	= pass-through load for C-44
4945		= $PT_{C-44} * C_{In}$
4946	C_{S-80}	= S-80 concentration
4947	C_{S-308}	= S-308 concentration
4948	OL_{C-44}	= total outflow load from C-44
4949		= $(Q_{S-80} * C_{S-80}) + (Q_{S-308Out} * C_{S-308})$
4950	BL_{C-44}	= net basin load produced by local rainfall and runoff
4951		= $OL_{C-44} - PTL_{C-44}$

4952

4953 **Comments:**

4954

- The outflow concentration at S-308 to Lake Okeechobee (C_{S-308}) should be the grab concentrations at S-308C, as these reflect discharges from the C-44 into the lake.
- However, the inflow concentrations at S-308 from Lake Okeechobee into the C-44 are the autosampler concentrations at S308C based on meeting with Cheol Mo on August 27, 2010.

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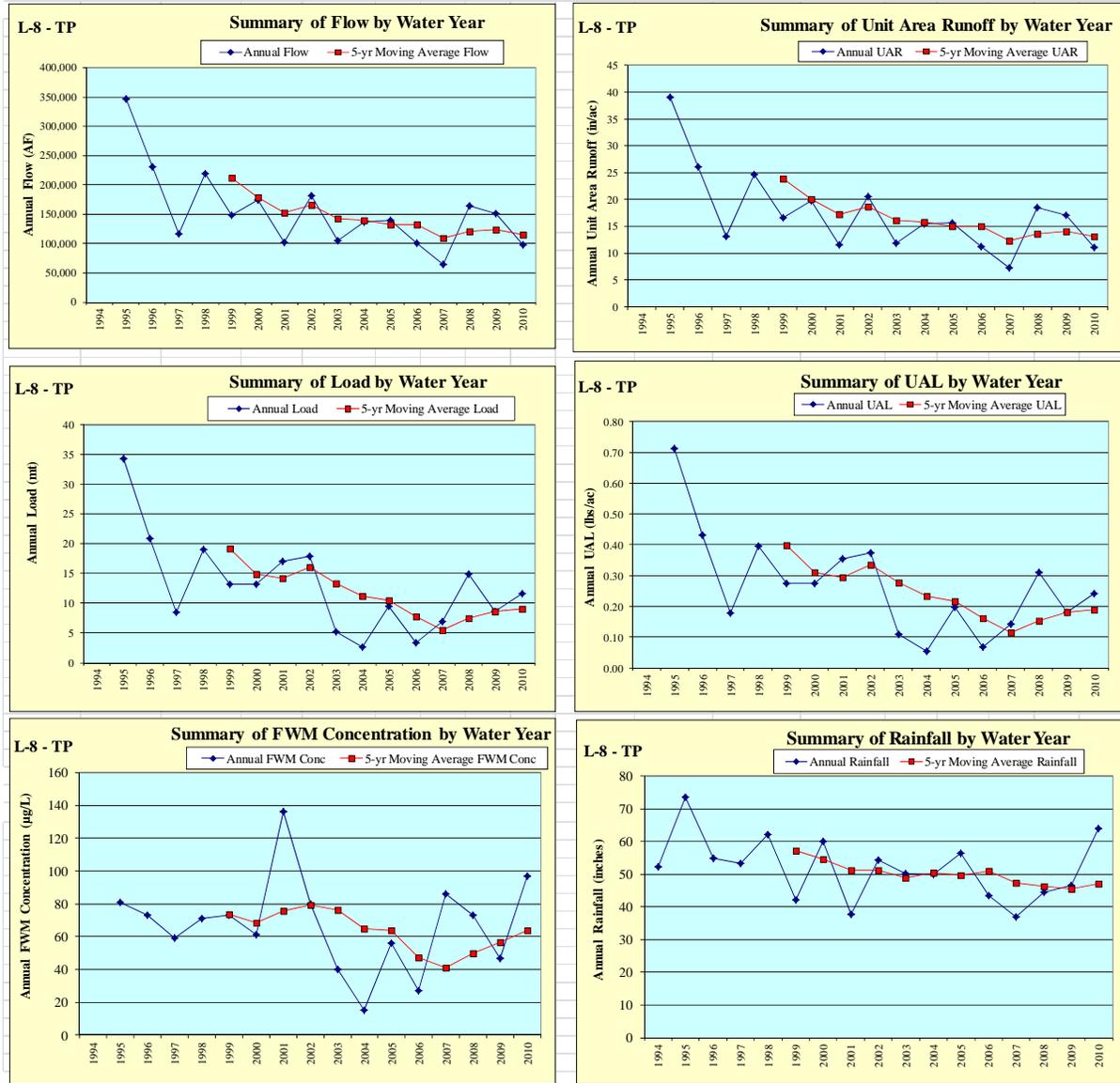


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Technical Support Document Lake Okeechobee Watershed Performance Measures

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L-8 Summary Basin



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4970 **Calculation of Net Basin TP Loads for the L-8 Summary Basin**

4971 A combination of stormwater runoff and water supply deliveries are discharged from the L-8
4972 Canal to multiple receiving waters: to Lake Okeechobee at C-10A, to the City of West Palm
4973 Beach’s water catchment system at Control No. 2, to the EAA at S-5AW, to the WCA-1 at S-
4974 5AS, and to the C-51W Canal at S-5AE. The L-8 Summary Basin receives inflows from
4975 Lake Okeechobee at C-10A, from WCA-1 at S-5AS, from the C-51W Canal at S-5AE, and
4976 from the West Palm Beach Canal in the EAA at S-5AW. Some of the inflows are retained in
4977 the basin as a result of evapotranspiration, water supply withdrawals, groundwater recharge,
4978 increased storage, etc. The portion of the total inflow that is “passed through” the L-8
4979 Summary Basin and discharged to adjacent waters is not considered basin flow in the
4980 evaluation of historical data analyses for the purpose of developing performance measures.
4981 Only basin flows that are the result of local rainfall and runoff from the L-8 Summary Basin
4982 are considered basin flow in the evaluation of historical data analyses. Following the
4983 standard District algorithm, L-8 Summary Basin flows were calculated on a daily basis by
4984 initially estimating the pass through volumes as follows:
4985

- 4986 I_{L-8} = total inflow to the L-8 Summary Basin
- 4987 = sum [$Q_{S-5AEIn} + Q_{S-5AWIn} + Q_{S-5ASIn} + Q_{C-10AIn}$]
- 4988 $Q_{S-5AEIn}$ = flow at structure S-5AE into the L-8 Summary Basin
- 4989 $Q_{S-5AWIn}$ = flow at structure S-5AW into the L-8 Summary Basin
- 4990 $Q_{S-5ASIn}$ = flow at structure S-5AS into the L-8 Summary Basin
- 4991 $Q_{C-10AIn}$ = flow at structure C-10A into the L-8 Summary Basin
- 4992
- 4993 O_{L-8} = total outflow from the L-8 Summary Basin
- 4994 = sum [$Q_{S-5AEOut} + Q_{S-5AWOut} + Q_{S-5ASOut} + Q_{C-10AOut} + Q_{WPB2}$]
- 4995 $Q_{S-5AEOut}$ = flow at structure S-5AE out of the L-8 Summary Basin
- 4996 $Q_{S-5AWOut}$ = flow at structure S-5AW out of the L-8 Summary Basin
- 4997 $Q_{S-5ASOut}$ = flow at structure S-5AS out of the L-8 Summary Basin
- 4998 $Q_{C-10AOut}$ = flow at structure C-10A out of the L-8 Summary Basin
- 4999 Q_{WPB2} = flow at City of West Palm Beach pump No. 2
- 5000
- 5001 PT_{L-8} = pass-through flow
- 5002 = minimum [I_{L-8}, O_{L-8}]
- 5003 B_{L-8} = net basin flow produced by local rainfall and runoff
- 5004 = $O_{L-8} - PT_{L-8}$
- 5005

5006 These calculations were performed on a daily basis and the results were summed to monthly
5007 and annual totals. Daily flow and TP data were provided by the District. Flow data for the
5008 City of West Palm Beach’s Control No. 2 was only available beginning May 1994, hence the
5009 historical data analysis for the L-8 Summary Basin began at this point in time.





5010 Net Basin TP loading from the L-8 Summary Basin is the result of direct rainfall and runoff
5011 from within the summary basin and does not include external TP loading from surrounding
5012 basins. Following the standard District algorithm for calculating pass-through loads, the L-8
5013 Summary Basin loading was calculated on a daily basis for each boundary structure using the
5014 following algorithms.

- 5015
- 5016 PTL_{L-8} = PT_{L-8} * cumulative flow-weighted mean inflow concentration
- 5017 measured at S-5AE, S-5AW, S-5AS and C-10A
- 5018 C_{L-8In} = [($Q_{S5ASIn} * C_{S5ASIn} + Q_{S5AEIn} * C_{S5AEIn} + Q_{S5AWIn} * C_{S5AWIn} +$
- 5019 $Q_{C10AIn} * C_{C10AIn}$) / I_{L-8}]
- 5020 PTL_{L-8} = $PT_{L-8} * C_{L-8In}$
- 5021
- 5022 C_{S5ASIn} = S-5AS TP inflow concentration
- 5023 C_{S5AEIn} = S-5AE TP inflow concentration
- 5024 C_{S5AWIn} = S-5AW TP inflow concentration
- 5025 C_{C10AIn} = C-10A TP inflow concentration
- 5026
- 5027 O_{L-8} = total outflow load from the L-8 Summary Basin
- 5028 = $Q_{S5ASOut} * C_{S5ASOut} + Q_{S5AEOut} * C_{S5AEOut} + Q_{S5AWOut} * C_{S5AWOut} +$
- 5029 $Q_{C10AOut} * C_{C10AOut} + Q_{WPB2} * C_{WPB2}$
- 5030 $C_{S5ASOut}$ = S-5AS TP outflow concentration
- 5031 $C_{S5AEOut}$ = S-5AE TP outflow concentration
- 5032 $C_{S5AWOut}$ = S-5AW TP outflow concentration
- 5033 $C_{C10AOut}$ = C-10A TP outflow concentration
- 5034 C_{WPB2} = estimated concentration at City of West Palm Beach pump No. 2
- 5035 = estimated as the cumulative flow-weighted mean inflow
- 5036 concentration measured at S-5AE, S-5AW, S-5AS and C-10A
- 5037 = C_{L-8In}
- 5038 BL_{L-8} = net basin TP loads produced by local rainfall and runoff
- 5039 = $OL_{L-8} - PTL_{L-8}$
- 5040

5041 These calculations were performed on a daily time-step and the results were summed to
5042 monthly and annual total loads.

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Algorithm for Estimating TP Loads Discharged from the Southern L-8 Canal Structures (S-5AW, S-5AS, S-5AE): Deriving a Common Daily Time Series of TP Concentrations

1. Using the District’s LOAD Program for the period WY1995-2011, daily, monthly and annual flow weighted mean (FWM) TP concentrations for discharges through the S-5AW, S-5AS and S-5AE²³ exhibited considerable heterogeneity, with annual coefficients of variation (standard deviation / mean) ranging up to 1.02 (see **Table A-1** and **Figure A-1**).
2. For structures located as close together as these three, it was expected that there would be a closer range of FWM concentrations²⁴. However, the LOAD Program looks only at the specific station in question in establishing an appropriate concentration to apply to the flow, and does not look at adjacent stations. As a result, TP concentrations from grab samples were applied to flow values up to 2,229 days (i.e., more than six years) distant from the date of flow in estimating load (see **Table A-2**).
3. An alternative algorithm was investigated to reduce the heterogeneity between the concentrations at these structures, utilizing a common concentration time series for the southern terminus of the L-8 Canal. The time series was derived according to the following procedure.
 - a. TP concentrations collected on days when flow occurred at each structure, with the following criteria
 - i. S-5AW:
 1. Priority was given to grab samples collected at S-5AW on days with flow.
 2. If a grab sample was not collected at S-5AW on the day with flow, a concurrent grab sample at S-5A was used if the flow at S-5A was less than or equal to the flow from S-5AW, in order to minimize the influence of EAA water quality on the S-5A sample.

²³ Discharge through S-5AW from east to west (to the S-5A Basin); discharge through S-5AS from north to south (to the STA 1 Inflow and Distribution Works); discharge through S-5AE from west to east (to the C-51 West Basin).

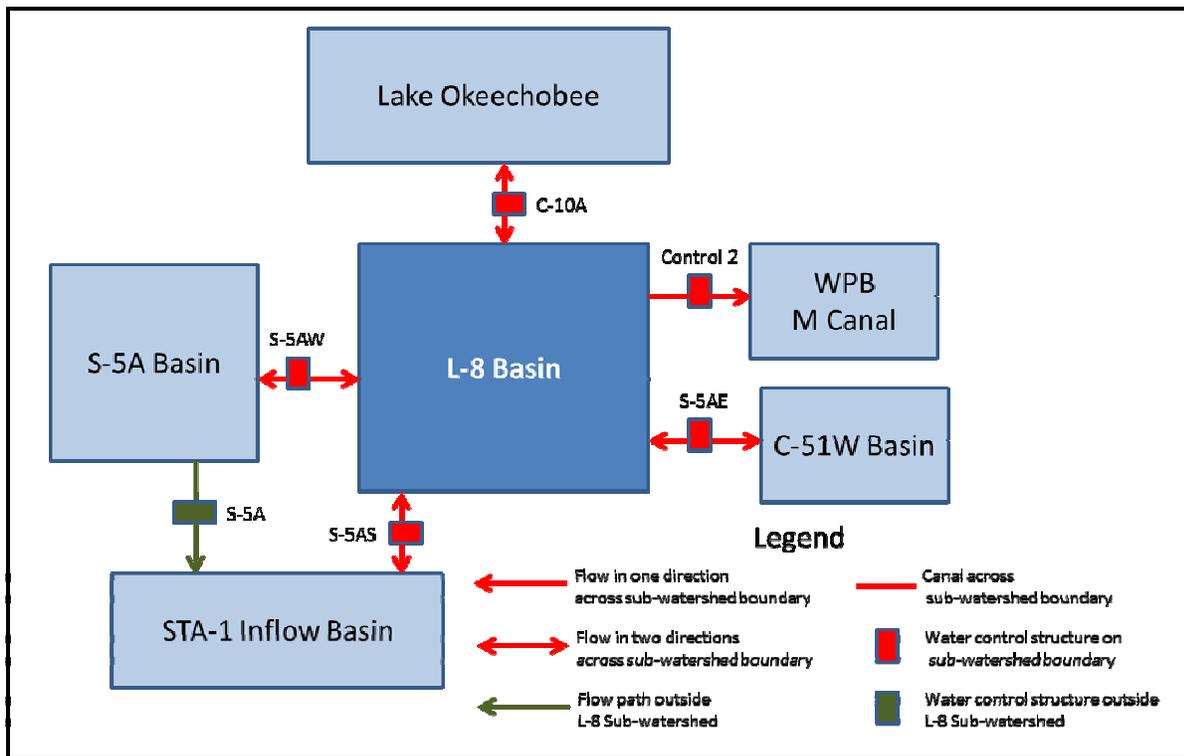
²⁴ A recent decision by the District to eliminate sampling at S-5AS and S-5AW and use samples taken at S-5AE was based on analyses that bear out this expectation.





- 5077 ii. S-5AE:
- 5078 1. Within a 14-day window, priority was given to autosampler
- 5079 composite concentrations over grab sample concentration,
- 5080 consistent with the LOAD Program algorithm using the 14-day
- 5081 window option.

5082 **Figure A-1. Flow diagram for the L-8 Summary Basin**



- 5083
- 5084 b. A single daily time series was compiled from the concentrations at the three
- 5085 structures.
- 5086 i. If values were available at all three stations, an arithmetic average was
- 5087 calculated for that day (note: this concurrent sample collection never
- 5088 occurred).
- 5089 ii. If values were available for only two structures, an arithmetic average
- 5090 was calculated for that day (note: this occurred 16 days during of the
- 5091 period of record)
- 5092 iii. If only one value was available, that value was used for that day (note:
- 5093 this occurred 758 days during the period of record).





- 5094 iv. Concentrations on days prior to the first value were set to the first
- 5095 value.
- 5096 v. Concentrations on days after the last value were set to the last value.
- 5097 vi. Concentrations for days with no value were estimated from linear
- 5098 interpolation.
- 5099 c. The resulting time series was then applied to the daily flow for each structure
- 5100 to calculate a daily TP load.
- 5101 d. The heterogeneity of daily, monthly and annual FWM TP concentrations was
- 5102 reduced in 13 of the 17 years of record (**Table A-3** and **Figure A-2**).
- 5103 e. The net effect was to decrease the estimated total TP loads discharged out of
- 5104 the L-8 Canal (see **Table A-4**). Ninety-six (96) percent of the net change in
- 5105 TP loads occurred in WY1995, with most of that (97%) attributed to a
- 5106 revision in the TP loads estimated leaving through S-5AW.
 - 5107 i. S-5AW: a net reduction of 28.848 mt (1.697 mt/yr)
 - 5108 ii. S-5AS: a net reduction of 4.594 mt (0.270 mt/yr)
 - 5109 iii. S-5AE: a net increase of 3.593 mt (0.211 mt/yr)
- 5110
- 5111 4. The updated data sets for the L-8 Basin utilized this alternative algorithm for
- 5112 estimating TP loads from these three structures.

5113 Calculations are contained in the spreadsheet:
 5114 "L-8 Southern Concentrations – 1 5 2012.xlsx" and
 5115 "L-8 Basin Flows and Loads – 1 5 2012.xlsx"

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Table A-1. Annual FWM TP Concentrations at the Southern L-8 Canal Structures.

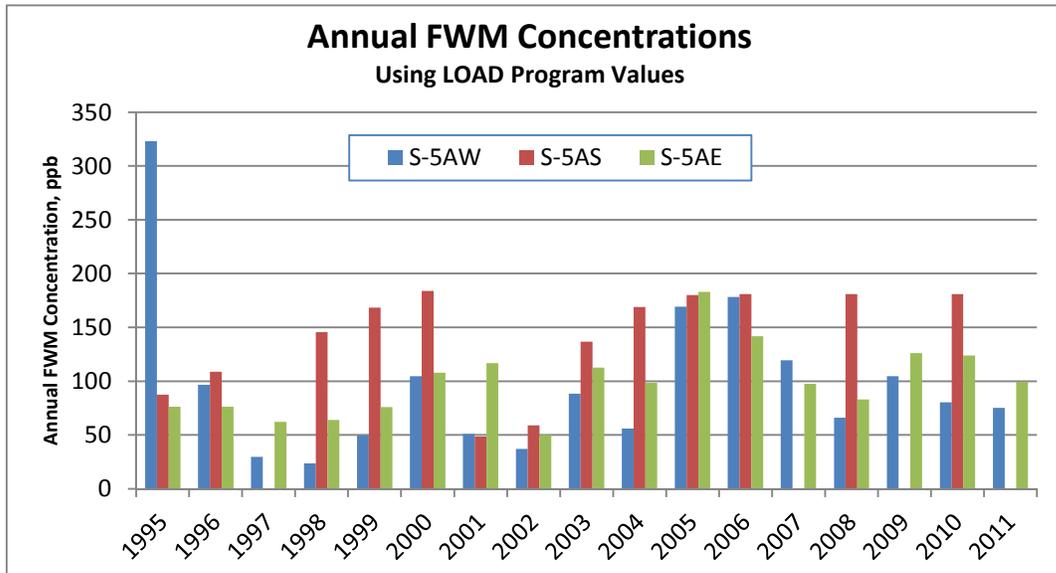
Water Year	S-5AW Conc, ppb	S-5AS Conc, ppb	S-5AE Conc, ppb	Total Conc, ppb	Coef. Of Variation
1995	323	84	76	132	0.87
1996	97	109	76	84	0.18
1997	30	0	62	56	1.02
1998	24	145	64	62	0.80
1999	49	171	76	82	0.65
2000	105	184	108	119	0.34
2001	51	49	117	73	0.54
2002	37	59	50	50	0.23
2003	88	137	113	112	0.21
2004	56	169	98	99	0.53
2005	169	180	183	181	0.04
2006	178	181	142	143	0.13
2007	119	0	97	102	0.88
2008	66	181	83	69	0.56
2009	105	0	126	125	0.88
2010	80	181	124	122	0.39
2011	75	0	99	99	0.89
Total	133	127	103	109	

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5152 Figure A-1. Annual FWM Concentrations Using Standard LOAD Program Algorithm.
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5154 Table A-2. Summary Statistics for Southern L-8 Canal Structures During WY1995-
5155 2011.
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Station	Days with Flow days	Days with Flow % of POR	Number of grab samples	# of grab samples on days with flow	% of days with flow that have grab samples	% of grab samples on days with flow	Maximum # of days between grab samples on days with flow
S-5AW	729	12%	93	29	4%	31%	602
S-5AS	309	5%	166	6	2%	4%	2294
S-5AE	3669	59%	425	293	8%	69%	532

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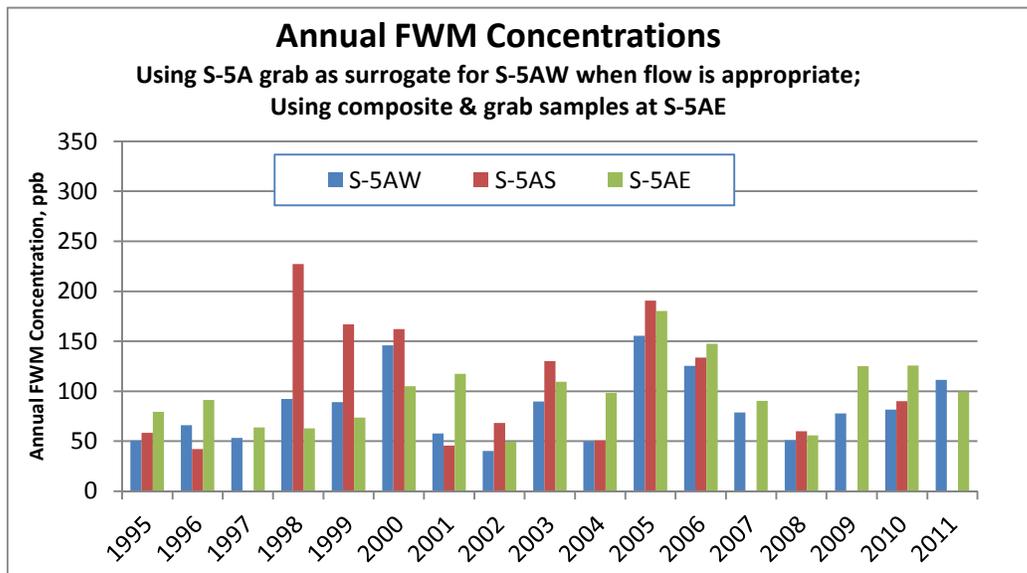
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Table A-3. Annual FWM TP Concentrations at the Southern L-8 Canal Structures, Using Common Time Series of Concentrations.

Water Year	S-5AW Conc, ppb	S-5AS Conc, ppb	S-5AE Conc, ppb	Total Conc, ppb	Coef. Of Variation
1995	51	59	79	70	0.24
1996	66	42	91	81	0.37
1997	53	0	64	62	0.88
1998	92	227	63	66	0.69
1999	89	167	74	84	0.46
2000	146	162	105	121	0.21
2001	58	46	117	76	0.52
2002	40	68	50	51	0.27
2003	90	130	109	109	0.18
2004	50	51	98	97	0.42
2005	155	191	180	177	0.10
2006	125	134	148	147	0.08
2007	79	0	90	88	0.87
2008	51	60	56	52	0.08
2009	78	0	125	122	0.93
2010	82	90	126	124	0.24
2011	111	0	99	100	0.87
Total	78	107	104	101	

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Figure A-2. Annual FWM Concentrations Using Alternative Algorithm.



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Table A-4. Comparison of Annual TP Loads.

Water Year	Original				Using a Composite Daily Time Series			
	S-5AW Load, kg	S-5AS Load, kg	S-5AE Load, kg	Total Load, kg	S-5AW Load, kg	S-5AS Load, kg	S-5AE Load, kg	Total Load, kg
1995	32,759	5,926	21,703	60,388	5,141	4,121	22,526	31,789
1996	12,489	1,402	19,142	33,033	8,520	541	22,858	31,919
1997	721	0	5,879	6,600	1,293	0	6,037	7,330
1998	403	308	14,676	15,386	1,566	481	14,383	16,429
1999	858	2,709	10,586	14,153	1,546	2,645	10,249	14,441
2000	5,120	7,889	20,906	33,915	7,145	6,955	20,364	34,464
2001	1,354	585	2,340	4,280	1,533	549	2,353	4,434
2002	475	888	3,487	4,850	517	1,027	3,451	4,996
2003	1,777	1,529	27,187	30,493	1,803	1,451	26,399	29,653
2004	371	1,096	31,242	32,709	331	329	31,237	31,897
2005	6,748	4,301	35,118	46,167	6,190	4,557	34,574	45,321
2006	256	1,344	40,925	42,525	180	993	42,579	43,751
2007	992	0	3,113	4,105	652	0	2,889	3,541
2008	3,250	197	256	3,703	2,518	65	172	2,755
2009	1,116	0	18,901	20,018	832	0	18,694	19,525
2010	533	0	21,714	22,247	541	0	21,993	22,534
2011	137	0	14,491	14,628	204	0	14,501	14,705
Total	69,359	28,174	291,666	389,199	40,511	23,714	295,259	359,484
Average	4,080	1,657	17,157	22,894	2,383	1,395	17,368	21,146
Change from Original				Total	-28,848	-4,460	3,593	-29,715
				Average	-1,697	-262	211	-1,748
Percent Change from Original				Total	-42%	-16%	1%	-8%
				Average	-42%	-16%	1%	-8%

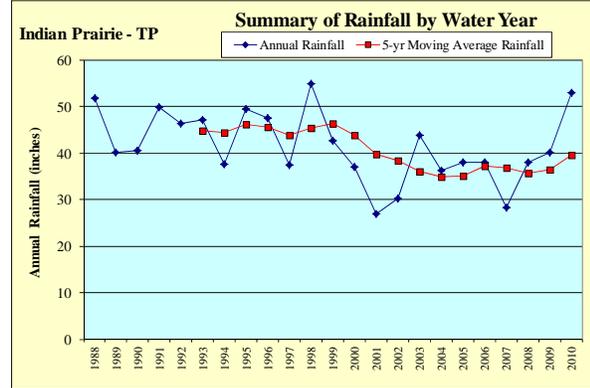
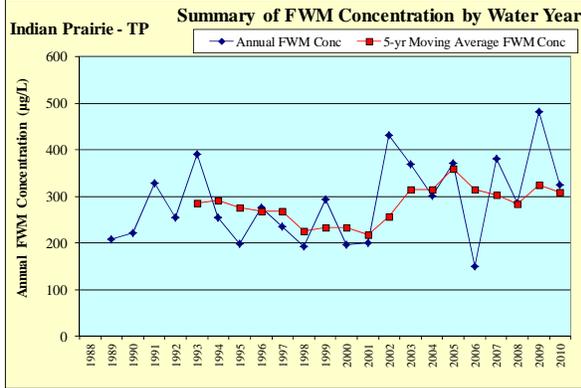
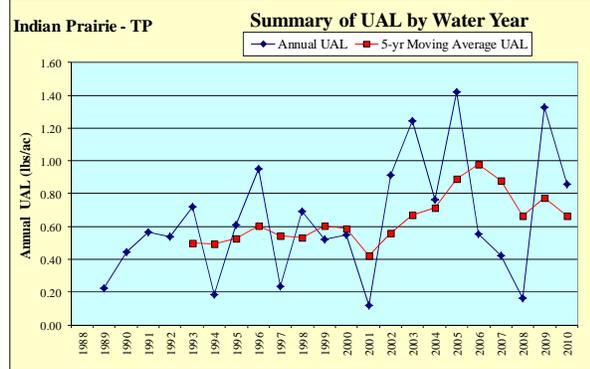
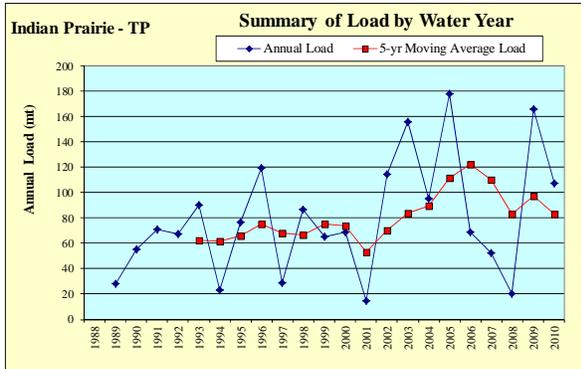
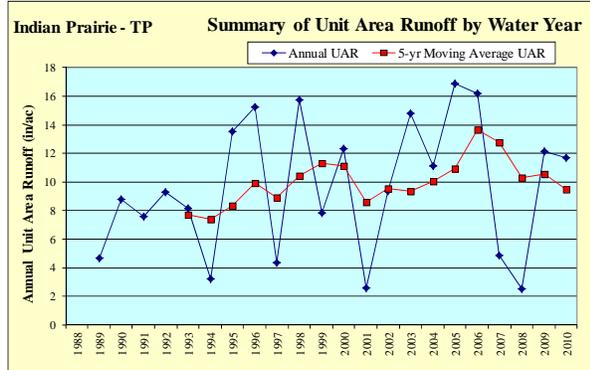
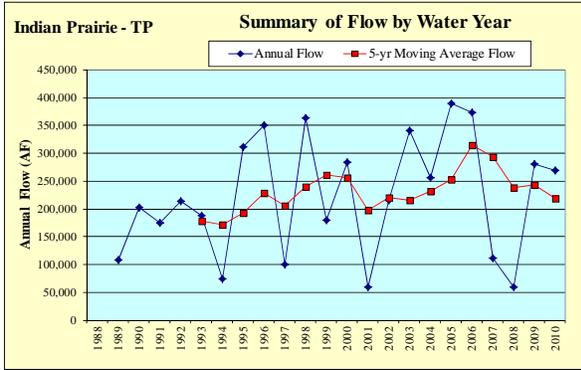
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INDIAN PRAIRIE SUB-WATERSHED



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Calculation of Net Basin TP Loads for the Indian Prairie Sub-watershed

- 5191
- 5192
- 5193 I_{IP} = total inflow to the Indian Prairie Sub-watershed
- 5194 = Q_{S-68}
- 5195 Q_{S68} = flow at S-68
- 5196
- 5197 O_{IP} = total outflow from the Indian Prairie Sub-watershed
- 5198 = $Q_{S131} + Q_{S71} + Q_{S72} + Q_{S129} + Q_{S127} + Q_{S84} + Q_{LCanal}$
- 5199 Q_{S131} = flow at S-131
- 5200 Q_{S71} = flow at S-71
- 5201 Q_{S72} = flow at S-72
- 5202 Q_{S129} = flow at S-129²⁵
- 5203 Q_{S127} = flow at S-127
- 5204 Q_{S84} = flow at S-84
- 5205 Q_{LCanal} = total flow at L-59E, L-59W, L-60E, L-60W, L-61E, and L-61W
- 5206
- 5207 PT_{IP} = pass-through flow
- 5208 = minimum (I_{IP} , O_{IP})
- 5209 B_{IP} = net basin flow produced by local rainfall and runoff
- 5210 = $O_{IP} - PT_{IP}$
- 5211
- 5212 OL_{IP} = total outflow TP load from the Indian Prairie Sub-watershed
- 5213 = $Q_{S131} * C_{S131} + Q_{S71} * C_{S71} + Q_{S72} * C_{S72} + Q_{S129} * C_{S129} +$
- 5214 $Q_{S127} * C_{S127} + Q_{S84} * C_{S84} + Q_{LCanal} * C_{LCanal}$
- 5215 C_{S131} = TP concentration at S-131
- 5216 C_{S71} = TP concentration at S-71
- 5217 C_{S72} = TP concentration at S-72
- 5218 C_{S129} = TP concentration at S-129
- 5219 C_{S127} = TP concentration at S-127
- 5220 C_{S84} = TP concentration at S-84
- 5221
- 5222 PTL_{IP} = pass through TP load
- 5223 = $PT_{IP} * C_{S68}$
- 5224 C_{S68} = TP concentration at S-68
- 5225
- 5226 BL_{IP} = net basin load produced by local rainfall and runoff
- 5227 = $OL_{IP} - PTL_{IP}$
- 5228

²⁵ After a review of the S-129 spillway data, it was determined that the negative flows were not reliable, and therefore, they were omitted from the analyses.



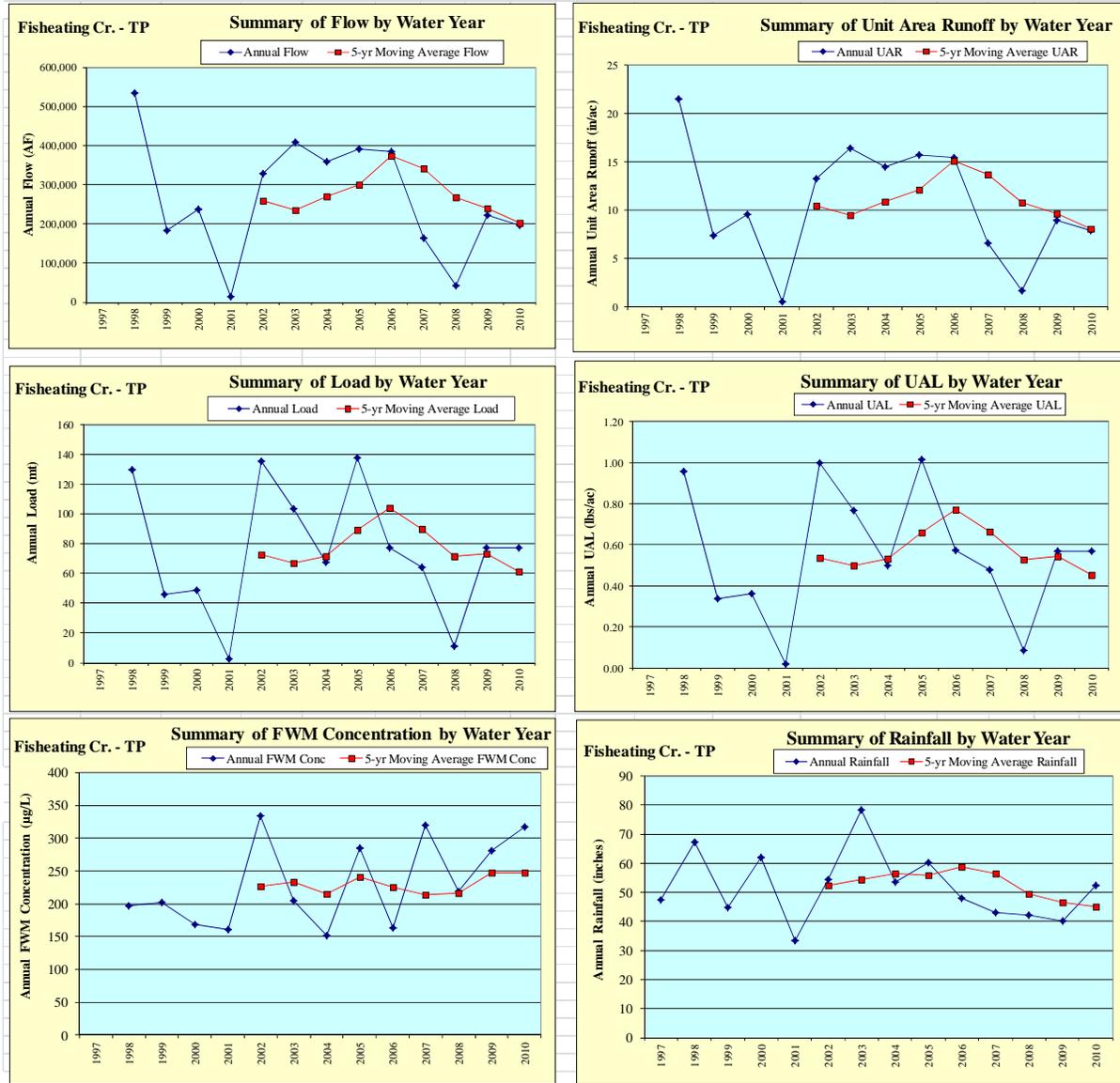


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Fisheating Creek Summary Basin



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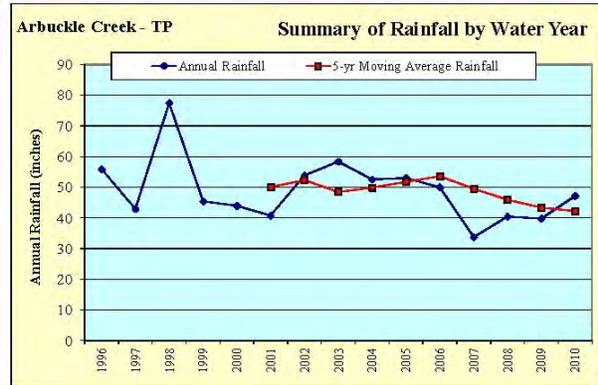
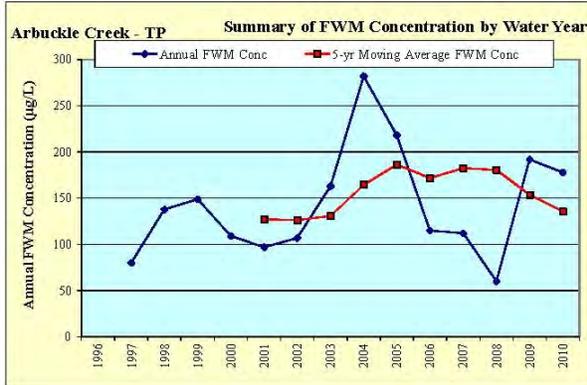
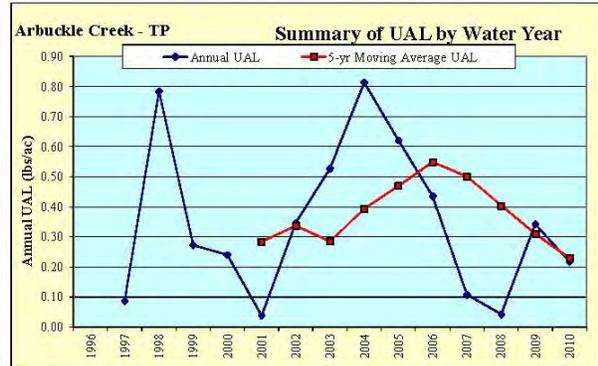
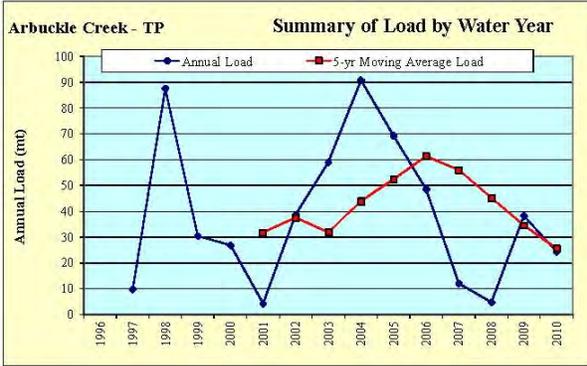
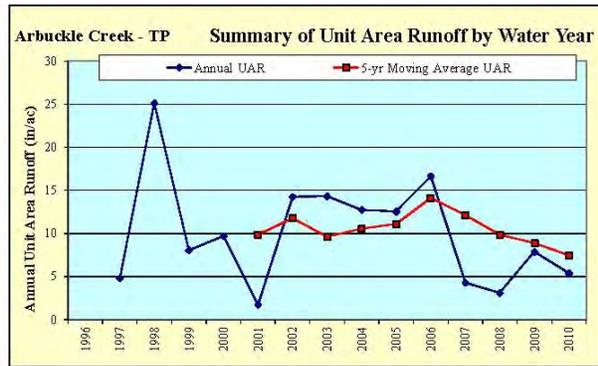
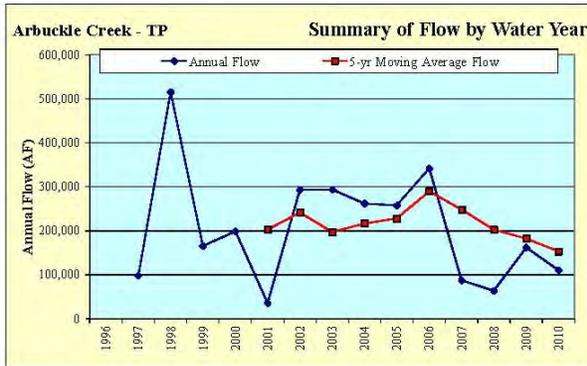




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LAKE ISTOKPOGA SUB-WATERSHED

Summary of annual flow, TP and rainfall for Arbuckle Creek



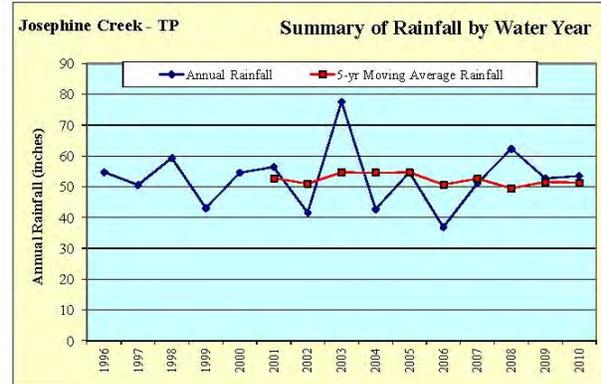
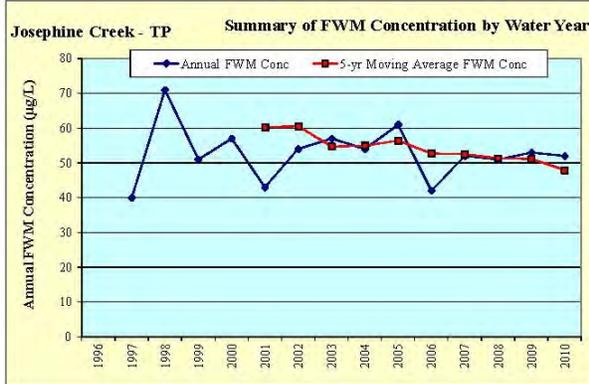
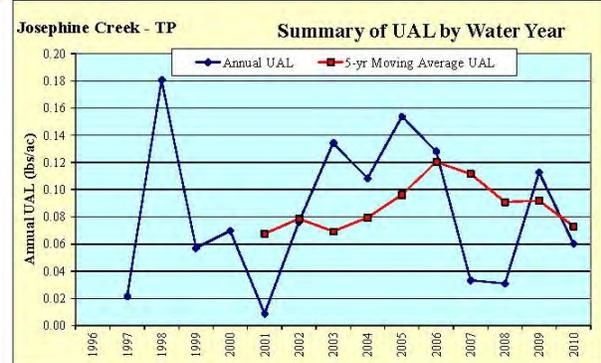
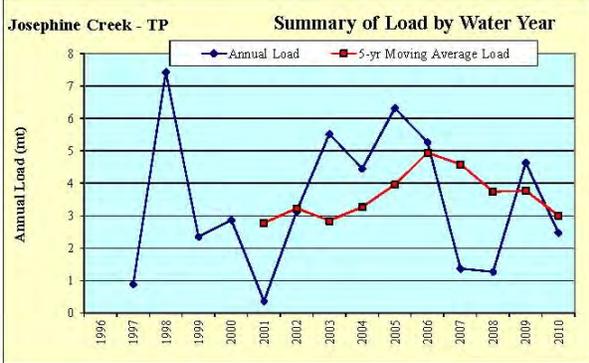
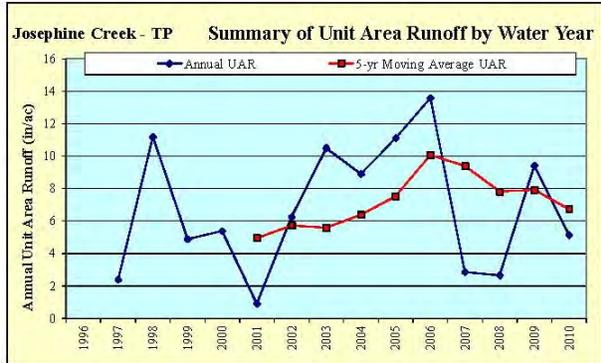
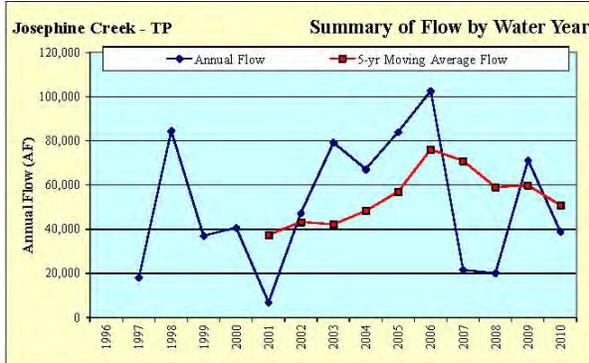
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Summary of annual flow, TP and rainfall for Josephine Creek



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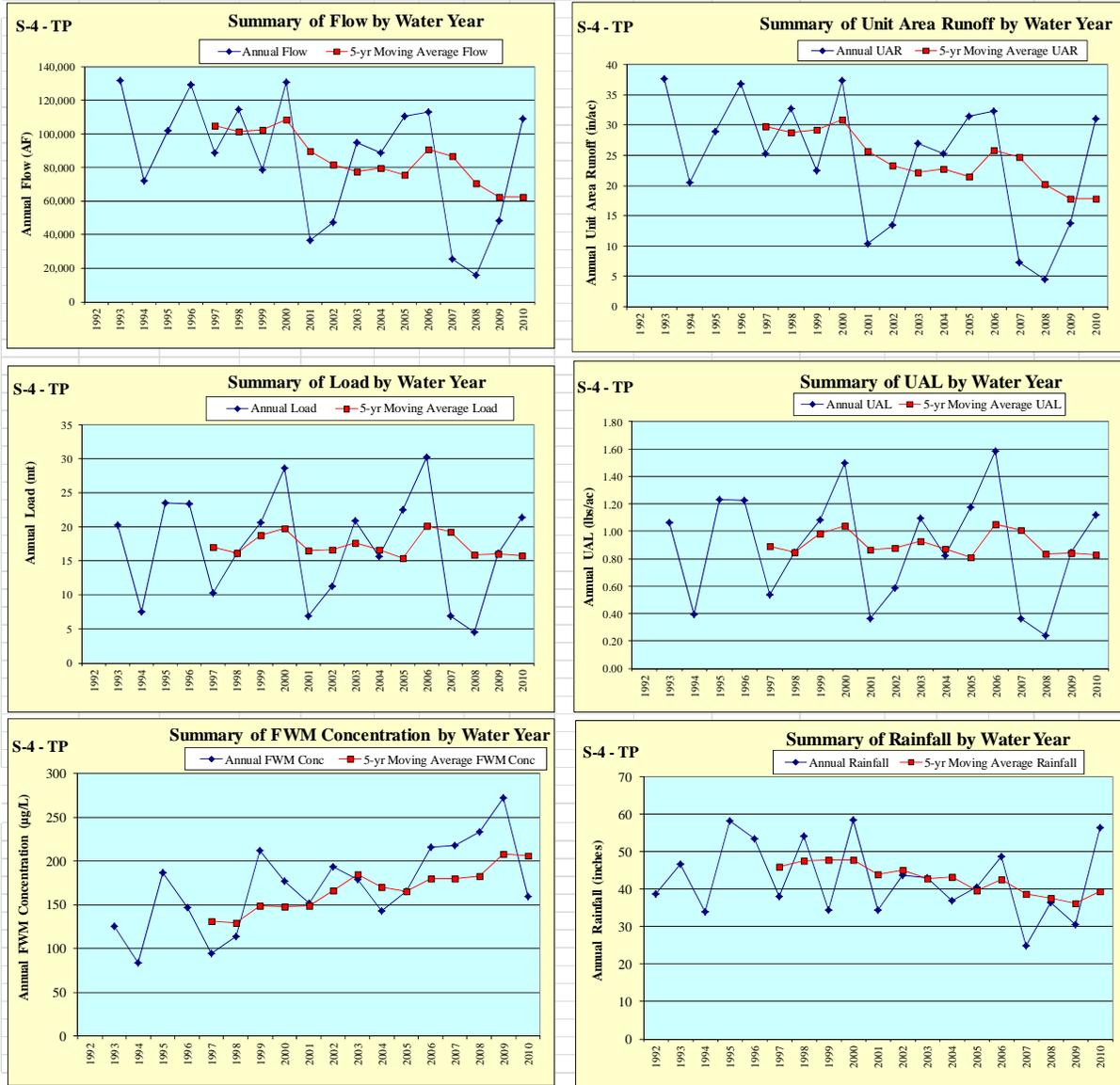


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Lake Okeechobee Watershed Performance Measures

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WEST CALOOSA HATCHEE SUB-WATERSHED
S-4/Industrial Canal Hydrologic Unit



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Calculation of Net Basin TP Loads for the S-4/Industrial Canal Hydrologic Unit

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The S-4/Industrial Canal Hydrologic Unit receives inflows from Lake Okeechobee, the East Caloosahatchee Hydrologic Unit, and from Unit 5 of the South Florida Conservancy District (EPD-07 of the SFCD). The S-4/Industrial Canal Hydrologic Unit discharges to Lake Okeechobee and the East Caloosahatchee Hydrologic Unit. Some or all of the total inflows to the S-4/Industrial Canal Hydrologic Unit may be retained in the basin as a result of meeting agricultural and urban water supply demands, evapotranspiration, groundwater infiltration, or increasing internal storage. Pass-through flows and loads are the portion of the total inflows that are discharged from the hydrologic unit. Because S-169 controls flow between the S-4 Sub-basin and the Industrial Canal Sub-basin, flow through S-169 must be considered in the calculation of the hydrologic unit’s pass-through flows and loads. Failure to do so will result in overestimates of pass through, e.g., on days when S-169 is closed, inflows to the hydrologic unit through S-310 cannot physically reach S-235 and therefore, cannot contribute to pass through at that structure. Basin flows and loads result from rainfall and runoff from the hydrologic unit and do not include pass-through flows and loads.

In order to properly account for the S-169 operations, it’s necessary to make a minor modification to the standard algorithm for calculating pass-through flows and loads. Pass-through flows are calculated using applicable algorithms for four operational conditions:

1. On days when the total inflows or total outflows are zero;
2. On days when the total inflows and total outflows are nonzero and S-169 is closed;
3. On days when the total inflows and total outflows are nonzero and S-169 is discharging from the Industrial Canal Sub-basin to the S-4 Sub-basin (positive flow values in DBHYDRO);
4. On days when the total inflows and total outflows are nonzero and S-169 is discharging from the S-4 Sub-basin to the Industrial Canal Sub-basin (negative flow values in DBHYDRO);

The following equations describe how pass-through flows are calculated for each of these conditions.

1. If

$$\text{Total Inflow} = Q_{S310In} + Q_{EPD07} + Q_{S235In} = 0$$

or

$$\text{Total Outflow} = Q_{S310Out} + Q_{S4} + Q_{S235Out} = 0$$

then

$$PT_{S4IC} = \text{pass-through flow} = 0$$

where Q_{S310In} = Discharges at S-310 from Lake Okeechobee to the Industrial Canal

$Q_{S310Out}$ = Discharges at S-310 from the Industrial Canal to Lake Okeechobee

Q_{S235In} = Discharges at S-235 from the East Caloosahatchee Hydrologic Unit to the S-4 Sub-basin





5291 $Q_{S235Out}$ = Discharges at S-235 from the S-4 Sub-basin to the East Caloosahatchee
5292 Hydrologic Unit
5293 Q_{EPD07} = Discharges at pump station EPD-07 from SFCD to the Industrial Canal
5294 Q_{S4} = Discharges at S-4 from the S-4 Sub-basin to Lake Okeechobee
5295 PT_{S4IC} = Portion of the total inflow to the S-4/Industrial Canal Hydrologic Unit that is
5296 discharged from the hydrologic unit
5297 Notes: Q_{S4} is unidirectional out of the hydrologic unit
5298 Q_{EPD07} is unidirectional into the hydrologic unit
5299 2. If
5300 Total Inflow > 0
5301 and
5302 Total Outflow > 0
5303 and
5304 $Q_{S169West} = 0$
5305 and
5306 $Q_{S169East} = 0$
5307 then
5308 $PT_{S4} = \text{minimum}(Q_{S235In}, Q_{S4})$
5309 $PT_{IC} = \text{minimum}(Q_{EPD07}, Q_{S310Out})$
5310 $PT_{S4IC} = PT_{S4} + PT_{IC}$
5311 where $Q_{S169West}$ = Discharges at S-169 from the Industrial Canal to the S-4 Sub-basin
5312 $Q_{S169East}$ = Discharges at S-169 from the S-4 Sub-basin to the Industrial Canal
5313 Sub-basin
5314 PT_{S4} = Portion of the total inflow to the S-4 Sub-basin that is discharged from the
5315 Sub-basin
5316 PT_{IC} = Portion of the total inflow to the Industrial Canal Sub-basin that is discharged
5317 from the Sub-basin
5318 3. If
5319 Total Inflow > 0
5320 and
5321 Total Outflow > 0
5322 and
5323 $Q_{S169West} > 0$
5324 then
5325 $PT_{IC} = \text{minimum}(Q_{S310In} + Q_{EPD07}, Q_{S310Out})$
5326 $PT_{S4} = \text{minimum}(Q_{S235In} + \text{minimum}(Q_{S169West}, (Q_{S310In} + Q_{EPD07} - PT_{IC})), (Q_{S4} +$
5327 $Q_{S235Out}))$
5328 $PT_{S4IC} = PT_{S4} + PT_{IC}$
5329 4. If
5330 Total Inflow > 0
5331 and





5332 Total Outflow > 0

5333 and

5334 $Q_{S169East} > 0$

5335 then

5336 $PT_{S4} = \text{minimum} (Q_{S235In}, Q_{S4} + Q_{S235Out})$

5337 $PT_{IC} = \text{minimum} (Q_{S310In} + Q_{EPD07} + \text{minimum} (Q_{S169East}, (Q_{S235In} - PT_{S4}), Q_{S310Out}))$

5338 $PT_{S4IC} = PT_{S4} + PT_{IC}$

5339
5340 For all conditions,

5341 $B_{S4IC} = \text{net basin flow produced by local rainfall and runoff}$

5342 $= O_{S4IC} - PT_{S4IC}$

5343
5344 All calculations were performed on a daily time step and then summed to monthly and
5345 annual totals.

5346
5347 Pass through TP loads are calculated using the appropriate hydrologic unit flow weighted
5348 inflow concentrations, based on the applicable algorithms for the following three S-169 flow
5349 conditions:

- 5350 1. On days when S-169 is closed;
- 5351 2. On days when S-169 discharges to the west, from the Industrial Canal to the S-4
5352 Sub-basin; and
- 5353 3. On days when S-169 discharges to the east, from the S-4 Sub-basin to the
5354 Industrial Canal.

5355
5356 The following algorithms are used for the three conditions described above:

5357 1. If $Q_{S169West} = Q_{S169East} = 0$

5358
5359 Then

5360 $PTL_{IC} = PT_{IC} * C_{EPD07}$

5361 $PTL_{S4} = PT_{S4} * C_{S235In}$

5362 $PTL_{S4IC} = PTL_{IC} + PTL_{S4}$

5363 where PTL_{IC} = Portion of the total inflow load to the Industrial Canal Sub-basin that
5364 is discharged from the Sub-basin

5365 C_{EPD07} = Concentration of discharges at pump station EPD-07

5366 PTL_{S4} = Portion of the total inflow load to the S-4 Sub-basin that is discharged from
5367 the Sub-basin

5368 C_{S235In} = Concentration of S-235 discharges from the East Caloosahatchee Hydrologic
5369 Unit to the S-4 Sub-basin

5370 PTL_{S4IC} = Portion of the total inflow load to the S-4/Industrial Canal Hydrologic Unit
5371 that is discharged from the Hydrologic Unit

5372 2. If





5373 $Q_{S169West} > 0$

5374 Then

5375 $PTL_{IC} = PT_{IC} * C_{EPD07}$

5376 $PTC_{S4} = (Q_{S235In} * C_{S235In} + Q_{EPD07} * C_{EPD07} + Q_{S310In} * C_{S310In}) / (Q_{S235In} + Q_{EPD07} + Q_{S310In})$

5377 $PTL_{S4} = PT_{S4} * PTC_{S4}$

5378 $PTL_{S4IC} = PTL_{IC} + PTL_{S4}$

5379 where PTC_{S4} = Flow weighted inflow concentration of S-4 Sub-basin

5380 C_{S235In} = Concentration of flows at S-235 from East Caloosahatchee Hydrologic Unit
5381 to the S-4 Sub-basin

5382 C_{EPD07} = Concentration discharged at pump station EPD-07 into the Industrial Canal
5383 Sub-basin

5384 C_{S310In} = Concentration discharged at S-310 from Lake Okeechobee into the
5385 Industrial Canal Sub-basin

5386 3. If

5387 $Q_{S169East} > 0$

5388 Then

5389 $PTL_{IC} = PT_{IC} * (Q_{S235In} * C_{S235In} + Q_{EPD07} * C_{EPD07}) / (Q_{S235In} + Q_{EPD07})$

5390 $PTL_{S4} = PT_{S4} * C_{S235In}$

5391 $PTL_{S4IC} = PTL_{IC} + PTL_{S4}$

5392
5393 Once the pass-through loads are calculated, the hydrologic unit's net basin loads are
5394 calculated by subtracting pass-through loads from the total outflow loads as follows:
5395

5396 BL_{S4IC} = net basin load produced by local rainfall and runoff
5397 = $OL_{S4IC} - PTL_{S4IC}$

5398 OL_{S4IC} = $OL_{S235} + OL_{S4} + OL_{S310Out}$

5399 OL_{S235} = load discharged at S-235 to the East Caloosahatchee Hydrologic
5400 Unit

5401 OL_{S4} = load discharged at S-4 to Lake Okeechobee

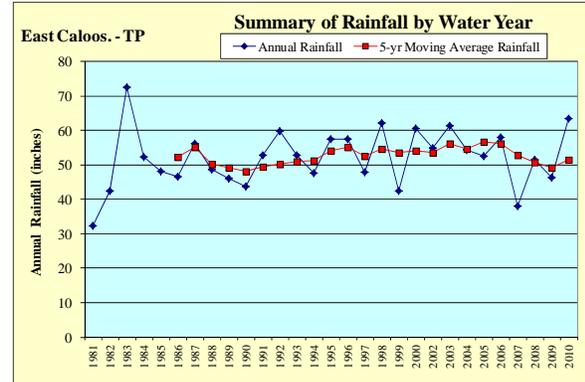
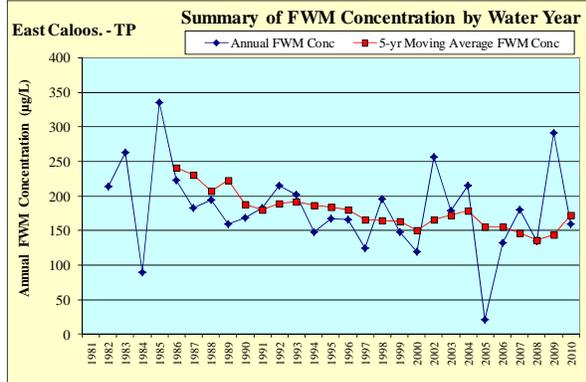
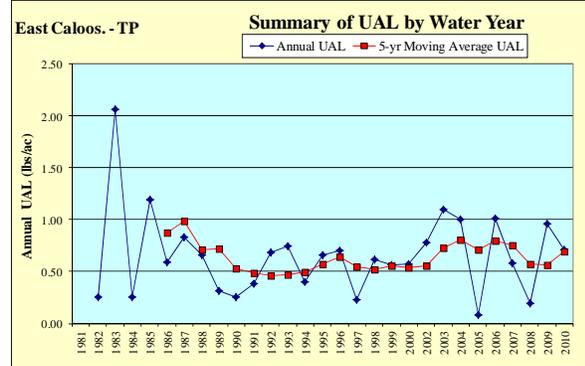
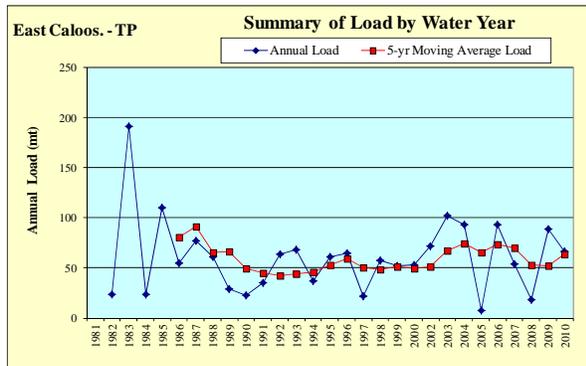
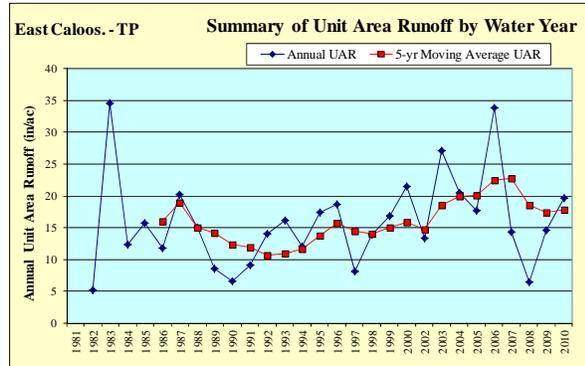
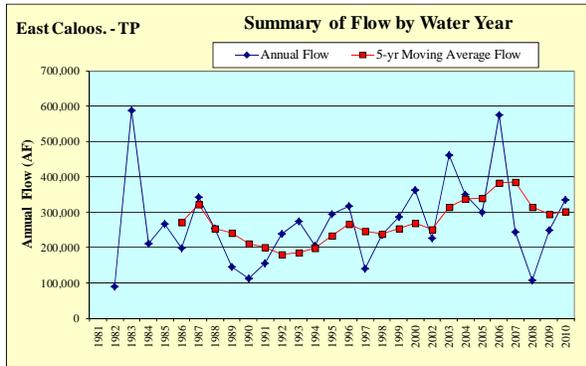
5402 $OL_{S310Out}$ = load discharged at S-310 to Lake Okeechobee





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East Caloosahatchee Hydrologic Unit



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Calculation of Net Basin TP Loads for the East Caloosahatchee Hydrologic Unit

East Caloosahatchee Hydrologic Unit Flows

- 5414
- 5415
- 5416
- 5417
- 5418 I_{EC} = total inflow to the East Caloosahatchee Hydrologic Unit
- 5419 = $Q_{S77In} + Q_{S235In}$
- 5420 Q_{S77In} = S-77 discharges from Lake Okeechobee into C-43
- 5421 Q_{S235In} = S-235 discharges from the L-D3 Canal into C-43
- 5422
- 5423 O_{EC} = total outflow from the East Caloosahatchee Hydrologic Unit
- 5424 = $Q_{S77Out} + Q_{S235Out} + Q_{S78}$
- 5425 Q_{S77Out} = S-77 discharges from C-43 into Lake Okeechobee
- 5426 $Q_{S235Out}$ = S-235 discharges from C-43 into the L-D3 Canal
- 5427 Q_{S78} = S-78 discharges
- 5428
- 5429 PT_{EC} = pass through flow
- 5430 = minimum (I_{EC} , O_{EC})
- 5431
- 5432 B_{EC} = net basin flow produced by local rainfall and runoff
- 5433 = $O_{EC} - PT_{EC}$
- 5434

East Caloosahatchee Hydrologic Unit Loads

- 5435
- 5436
- 5437 OL_{EC} = total outflow TP load
- 5438 = $Q_{S77Out} * C_{S77Out} + Q_{S235Out} * C_{S235Out} + Q_{S78} * C_{S78}$
- 5439 C_{S77Out} = S-77 TP outflow concentration
- 5440 $C_{S235Out}$ = S-235 TP outflow concentration
- 5441 C_{S78} = S-78 TP concentration
- 5442
- 5443 PTL_{EC} = pass through TP load
- 5444 = $PT_{EC} * C_{In}$
- 5445 C_{In} = cumulative flow weighted mean inflow concentration
- 5446 = $(Q_{S77In} * C_{S77In} + Q_{S235In} * C_{S235In}) / I_{EC}$
- 5447
- 5448 BL_{EC} = net basin load produced by local rainfall and runoff
- 5449 = $OL_{EC} - PTL_{EC}$
- 5450 C_{S77In} = S-77 TP inflow concentration
- 5451 C_{S235In} = S-235 TP inflow concentration
- 5452
- 5453

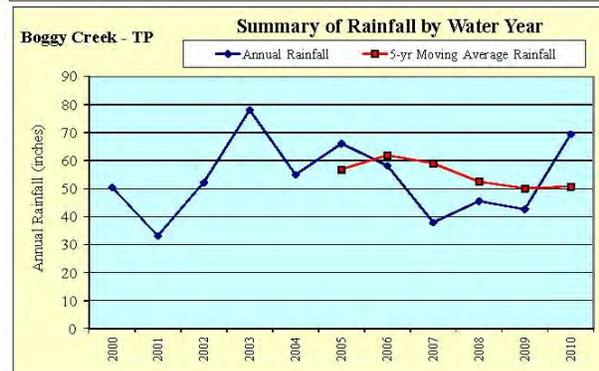
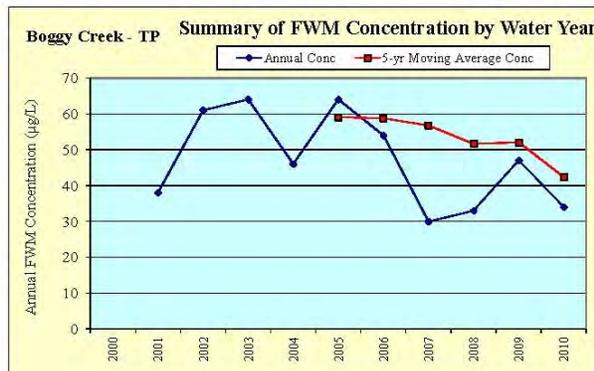
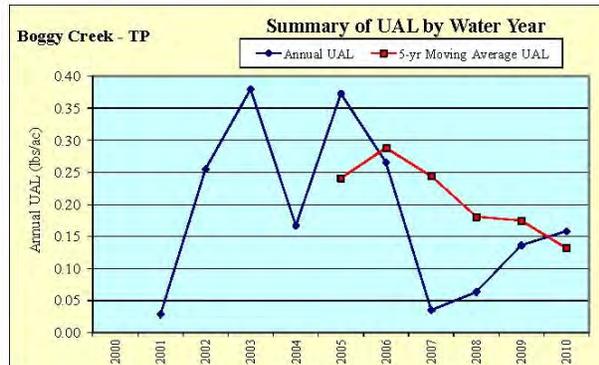
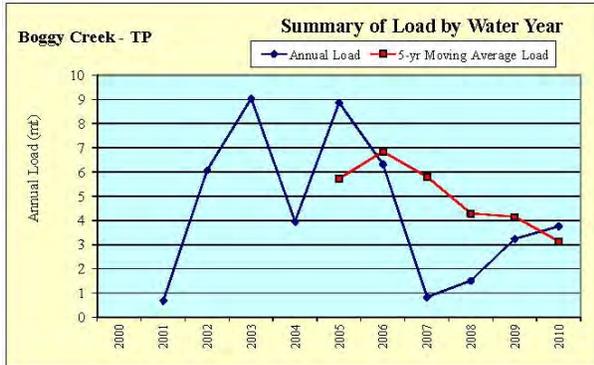
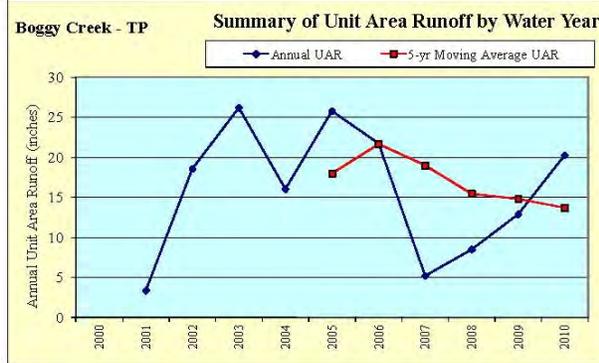
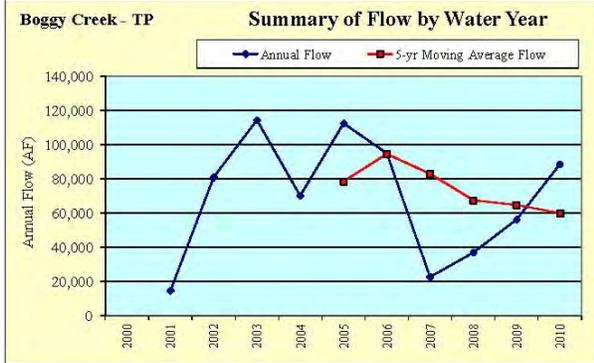




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UPPER KISSIMMEE SUB-WATERSHED

Summary of annual flow, TP and rainfall for Boggy Creek



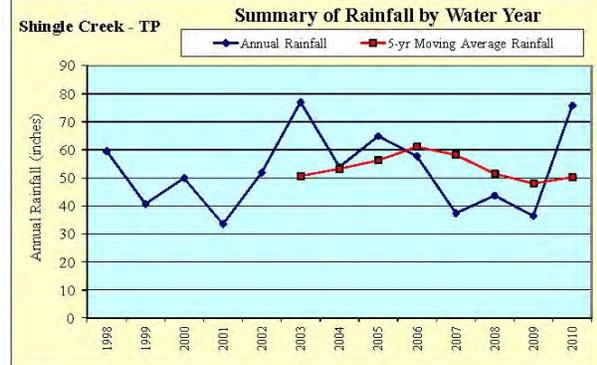
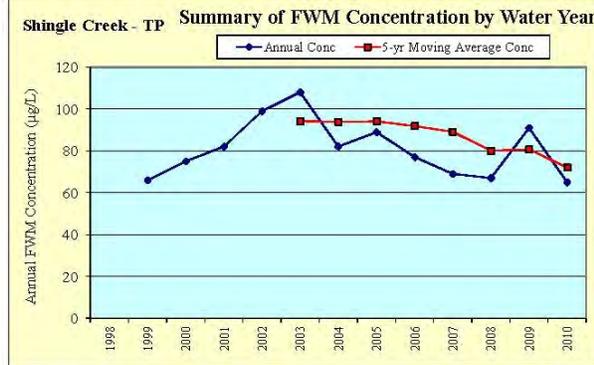
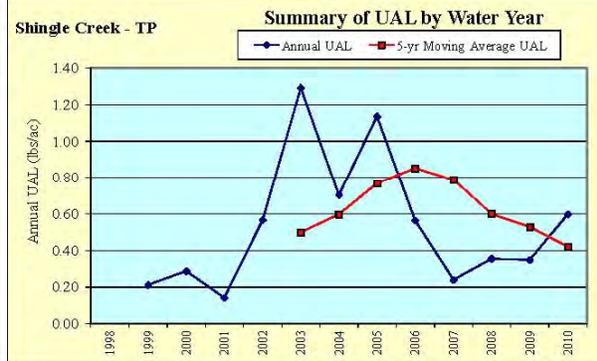
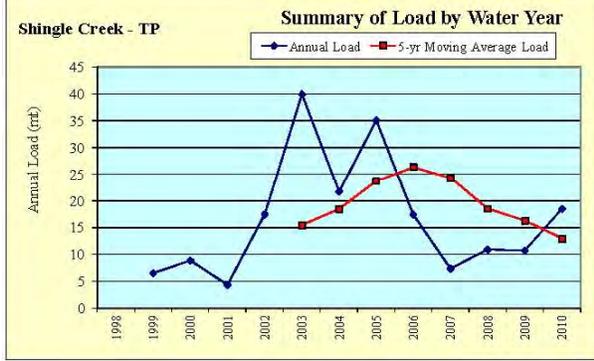
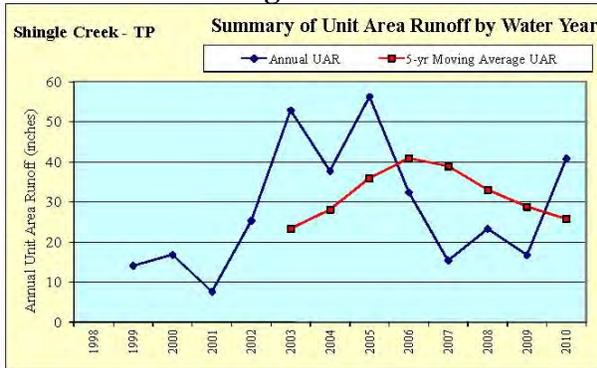
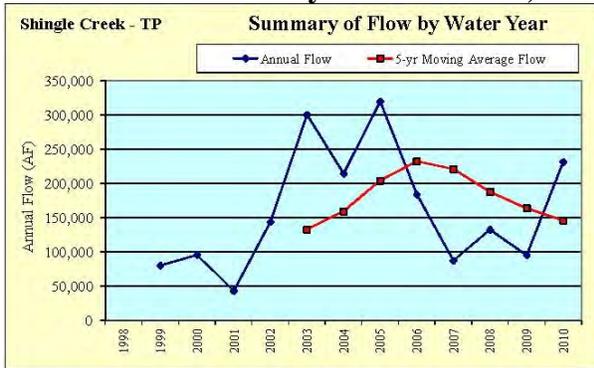
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Summary of annual flow, TP and rainfall for Shingle Creek



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**APPENDIX B – DERIVATION OF EQUATIONS FOR THE
PERFORMANCE MEASURE METHODOLOGIES OF THE
LAKE OKEECHOBEE WATERSHED**

TAYLOR CREEK-NUBBIN SLOUGH SUB-WATERSHED

S-133 Summary Basin

Following the procedures described in Section 2.6, the annual load discharged from S-133 was expressed as a function of the variability of the annual rainfall. Using a zero percent load reduction, prediction equations for the annual TP load and annual upper confidence limit above the prediction were derived using this regression equation. The resulting prediction equation for the annual load was

$$\text{annual load prediction (mt)} = L = a + b_1X + b_2P + b_3C$$

Where L = 12-month load (mt),

a = the intercept of the regression line

b₁ = the regression coefficient for X

b₂ = the regression coefficient for P

b₃ = the regression coefficient for C

X = the natural logarithm of the 12-month total rainfall (inches)

P = natural logarithm of the previous year's rainfall, i.e., previous year's X

C = the coefficient of variation calculated from 12 monthly rainfall totals

The predictors X, P and C are calculated from the first two moments (m₁ and m₂) of the 12 monthly rainfall totals for the Water Year:

r_i = monthly rainfall, for i=1 to 12 months of the Evaluation Year

$$m_1 = \text{Sum} [r_i] / 12$$

$$m_2 = \text{Sum} [r_i - m_1]^2 / 12$$

$$X = \ln(12 m_1)$$

$$C = [(12/11) m_2]^{0.5} / m_1$$

Applying the coefficients derived using the ordinary least squares method yields the following prediction for the annual load

$$\text{annual load prediction} = -267.97167 + 26.1842 \text{ Ln(Rain)} + 39.22017 \text{ Ln(Prior Rain)} + 40.70221 \text{ CV}$$





5506 The coefficient of determination (R^2) for the resulting equation was 0.791, with a standard
5507 error of regression of 5.181 mt. The standard error of regression was approximately 50
5508 percent of the Base Period mean annual load. The coefficients of the regression line were
5509 significantly different from zero at the 90 percent confidence level, with p-values less than 10
5510 percent for the coefficients b_1 , b_2 and b_3 .

5511
5512 Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual
5513 load was derived as the upper 90 percent confidence limit above the prediction, with an
5514 associated theoretical Type I error (i.e., false positive) rate of 10 percent²⁶. In deriving the
5515 upper 90 percent upper confidence limit on the predicted annual load, the product of the
5516 appropriate t-statistic and an expression of the prediction's standard error (SE_p) is added to
5517 the predicted annual load, as expressed below:

5518
5519
$$\text{annual load UCL} = TP_{90\% \text{ CL}} = \text{predicted Annual Load} + [(t_{\alpha, n-4}) SE_p]$$

5520
5521 where $TP_{90\% \text{ CL}}$ is the upper 90 percent confidence limit on the predicted annual load,
5522 $t_{\alpha, n-4}$ is the value of the one-tailed t statistic at significance level α , with $n-4$ degrees
5523 of freedom (for 90 percent confidence level, $\alpha = 0.10$), and
5524 n is the number of annual TP loads in the Base Period (= 10)

5525
5526 The standard error of the prediction (SE_p) is comprised of the standard error of the regression
5527 equation and the standard error of the predicted mean value, expressed in the equation below
5528 (Haan 1977)

5529
5530
$$SE_p = s \left[1 + \frac{1}{n} + \text{var}(b_1) \frac{(X - X_m)^2}{s^2} + \text{var}(b_2) \frac{(P - P_m)^2}{s^2} + \text{var}(b_3) \frac{(C - C_m)^2}{s^2} + \right.$$

5531
5532
$$\left. 2 \text{cov}(b_1, b_2) \frac{(X - X_m)(P - P_m)}{s^2} + 2 \text{cov}(b_1, b_3) \frac{(X - X_m)(C - C_m)}{s^2} + 2 \text{cov}(b_2, b_3) \frac{(P - P_m)(C - C_m)}{s^2} \right]^{0.5}$$

5533
5534 where s is the standard error of the regression equation = 5.18054 mt
5535 X_m = average value of the predictor in the Base Period = 3.79116
5536 P_m = average value of the predictor in the Base Period = 3.77727
5537 C_m = average value of the predictor in the Base Period = 0.75970
5538 $n = 10$
5539 $t_{\alpha, n-4} = 1.43976$

²⁶ The Type I error rate is the probability that the performance measure methodology will reject the null hypothesis (i.e., a determination that the TP load does not meet the performance measure) when in reality the null hypothesis is true – the annual load meets the performance measure, and is therefore also known as the false positive rate.





- 5540 var(b₁) = 80.95311
- 5541 var(b₂) = 107.40530
- 5542 var(b₃) = 282.32889
- 5543 cov(b₁,b₂) = 5.10816
- 5544 cov(b₁,b₃) = 39.16755
- 5545 cov(b₂,b₃) = 116.41471

5546
5547 Collecting terms yields

5548
5549 $SE = 5.18054 [1 + 1/10 + 3.01636 (X-X_m)^2 + 4.00199 (P-P_m)^2 + 10.51975 (C-C_m)^2 +$
5550
5551 $0.38068 (X-X_m) (P-P_m) + 2.91882 (X-X_m) (C-C_m) + 8.67536 (P-P_m) (C-C_m)]^{0.5}$
5552

5553 The above equations can be converted to a performance measure by means of the following
5554 conversions to incorporate the load reduction for the collective source controls²⁷.

5555
5556 For an Annual Load Target with Y percent load reduction, e.g., using a 25 percent reduction
5557 (Y = 0.25), based on untransformed annual loads,

5558
5559 Target equation intercept = intercept at 0% reduction * (1 - Y)

5560
5561 Target equation coefficients (b_i) = b_i at 0% reduction * (1 - Y)

5562
5563 For an Annual Load Limit with Y percent load reduction based on untransformed annual
5564 loads,

5565
5566 s and SE_p = value at 0% reduction * (1 - Y)

5567
5568 var(b_i) & cov(b_i,b_j) = value at 0% reduction * (1 - Y)²

- 5569
- 5570
- 5571
- 5572
- 5573
- 5574
- 5575
- 5576
- 5577

²⁷ Because of the potential for round-off errors in the calculations, it is recommended to use the accompanying spreadsheets rather than a calculator and the above values.





5578 **S-154 Summary Basin**

5579

5580 Following the procedures described in Section 2.6, the annual load discharged from S-154
5581 was expressed as a function of the variability of the annual rainfall. Using a zero percent
5582 load reduction, prediction equations for the annual TP load and annual upper confidence limit
5583 above the prediction were derived using this regression equation. The resulting prediction
5584 equation for the annual load was

5585

$$\text{annual load prediction (mt)} = L = \exp(a + b_1X)$$

5587

5588 Where L = 12-month load (mt)

5589 a = the intercept of the regression line

5590 b₁ = the regression coefficient for X

5591 X = the 12-month total rainfall (inches)

5592

5593 The predictor X is calculated from the first moment (m₁) of the 12 monthly rainfall totals for
5594 the Water Year:

5595 r_i = monthly rainfall, for i=1 to 12 months of the Evaluation Year

$$m_1 = \text{Sum} [r_i] / 12$$

$$X = 12 m_1$$

5598

5599 Applying the coefficients derived using the ordinary least squares method yields the
5600 following prediction for the annual load

5601

$$\text{annual load prediction} = \exp(-4.77448 + 0.16555 \text{ Rain})$$

5603

5604 The coefficient of determination (R²) for the resulting equation was 0.802, with a standard
5605 error of regression of 0.74115. Since a transformation of load was required in deriving the
5606 prediction equation, a “back-transformed” standard error of the regression equation was
5607 calculated after the predictions were transformed back to the original units (mt): 24.108 mt.
5608 The back-transformed standard error of regression was approximately 80 percent of the Base
5609 Period mean annual load. The coefficient of the regression line was significantly different
5610 from zero at the 90 percent confidence level, with a p-value less than 10 percent for the
5611 coefficient b₁.

5612

5613 Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual
5614 load was derived as the upper 90 percent confidence limit above the prediction, with an
5615 associated theoretical Type I error (i.e., false positive) rate of 10 percent. In deriving the
5616 upper 90 percent upper confidence limit on the predicted annual load, the product of the
5617 appropriate t-statistic and an expression of the prediction’s standard error (SE_p) is added to
5618 the predicted annual load:





5619
5620 annual load UCL = $TP_{90\% CL} = \text{predicted Annual Load} * \exp[(t_{\alpha, n-2}) SE_p]$

5621
5622 where $TP_{90\% CL}$ is the upper 90 percent confidence limit on the predicted annual load,
5623 $t_{\alpha, n-2}$ is the value of the one-tailed t statistic at significance level α , with n-2 degrees
5624 of freedom (for 90 percent confidence level, $\alpha = 0.10$), and
5625 n is the number of annual TP loads in the Base Period (= 8)
5626

5627 The standard error of the prediction (SE_p) is comprised of the standard error of the regression
5628 equation and the standard error of the predicted mean value, expressed in the equation below
5629 (Haan 1977)
5630

5631
$$SE_p = s \left[1 + \frac{1}{n} + \frac{(X - X_m)^2}{\sum (X_i - X_m)^2} \right]^{0.5}$$

5632 where s is the standard error of the regression equation = 0.74115
5633 X_m = average value of the predictor in the Base Period = 43.2588
5634 n = 8
5635 $t_{\alpha, n-2} = 1.43976$
5636 $1 / \sum (X_i - X_m)^2 = 1 / 485.64409$

5637
5638
5639 Collecting terms yields

5640
5641 $SE_p = 0.74036 [1 + 1/8 + (X-X_m)^2 / 485.64409]^{0.5}$

5642
5643 The above equations can be converted to a performance measure by means of the following
5644 conversions after a load reduction for the collective source controls has been determined.

5645
5646 For an Annual Load Target with Y percent load reduction based on log transformed annual
5647 loads,

5648
5649 Target equation intercept (a) = intercept at 0% reduction - $\ln [1/(1 - Y)]$

5650 Target equation coefficient (b_i) = b_i at 0% reduction

5651
5652 For an Annual Load Limit with Y percent load reduction based on log transformed annual
5653 loads,

5654
5655 SE_p = value at 0% reduction
5656
5657





5658 **S-191 Summary Basin**

5659
5660 Following the procedures described in Section 2.6, the annual load discharged from S-191
5661 was expressed as a function of the variability of the annual rainfall. Using a zero percent
5662 load reduction, prediction equations for the annual TP load and annual upper confidence limit
5663 above the prediction were derived using this regression equation. The resulting prediction
5664 equation for the annual load was

5665
5666
$$\text{annual load prediction (mt)} = L = a + b_1X + b_2C$$

5667
5668 Where L = 12-month load (mt)

- 5669
5670 a = the intercept of the regression line
5671 b₁ = the regression coefficient for X
5672 b₂ = the regression coefficient for C
5673 X = the natural logarithm of the 12-month total rainfall (inches)
5674 C = the natural logarithm of the coefficient of variation calculated from 12 monthly
5675 rainfall totals

5676
5677 The predictors X and C are calculated from the first two moments (m₁ and m₂) of the 12
5678 monthly rainfall totals for the Water Year:

5679 $r_i = \text{monthly rainfall, for } i=1 \text{ to } 12 \text{ months of the Evaluation Year}$
5680 $m_1 = \text{Sum} [r_i] / 12$
5681 $m_2 = \text{Sum} [r_i - m_1]^2 / 12$
5682 $X = \ln(12 m_1)$
5683 $C = \ln\{ [(12/11) m_2]^{0.5} / m_1 \}$

5684
5685 Applying the coefficients derived using the ordinary least squares method yields the
5686 following prediction for the annual load

5687
5688
$$\text{annual load prediction} = -1153.92264 + 351.50517 X + 141.49588 C$$

5689
5690 The coefficient of determination (R²) for the resulting equation was 0.894, with a standard
5691 error of regression of 23.325 mt. The standard error of regression was approximately 17
5692 percent of the Base Period mean annual load. The coefficients of the regression line were
5693 significantly different from zero at the 90 percent confidence level, with p-values less than 10
5694 percent for the coefficients b₁, and b₂.

5695
5696 Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual
5697 load was derived as the upper 90 percent confidence limit above the prediction, with an
5698 associated theoretical Type I error (i.e., false positive) rate of 10 percent. In deriving the





5699 upper 90 percent upper confidence limit on the predicted annual load, the product of the
5700 appropriate t-statistic and an expression of the prediction's standard error (SE_p) is added to
5701 the predicted Annual Load, as expressed below:

5702
5703
$$\text{annual load UCL} = TP_{90\% \text{ CL}} = \text{predicted Annual Load} + [(t_{\alpha, n-3}) SE_p]$$

5704
5705 where TP_{90%CL} is the upper 90 percent confidence limit on the predicted annual load,
5706 $t_{\alpha, n-3}$ is the value of the one-tailed t statistic at significance level α , with n-3 degrees
5707 of freedom (for 90 percent confidence level, $\alpha = 0.10$), and
5708 n is the number of annual TP loads in the Base Period (= 12)

5709
5710 The standard error of the prediction (SE_p) is comprised of the standard error of the regression
5711 equation and the standard error of the predicted mean value, expressed in the equation below
5712 (Haan 1977)

5713
5714
$$SE_p = s \left[1 + \frac{1}{n} + \text{var}(b_1) \frac{(X - X_m)^2}{s^2} + \text{var}(b_2) \frac{(C - C_m)^2}{s^2} + 2 \text{cov}(b_1, b_2) \frac{(X - X_m)(C - C_m)}{s^2} \right]^{0.5}$$

5715
5716 where s is the standard error of the regression equation = 23.32480 mt
5717 X_m = average value of the predictor in the Base Period = 3.80143
5718 C_m = average value of the predictor in the Base Period = -0.33003
5719 n = 12
5720 $t_{\alpha, n-3} = 1.38303$
5721 $\text{var}(b_1) = 1699.21897$
5722 $\text{var}(b_2) = 1152.79755$
5723 $\text{cov}(b_1, b_2) = 419.10211$

5724
5725 Collecting terms yields

5726
5727
$$SE_p = 23.3248 [1.08333 + 3.12333 (X - X_m)^2 + 2.11893 (C - C_m)^2 + 1.54068 (X - X_m)(C - C_m)]^{0.5}$$

5728
5729 The above equations can be converted to a performance measure by means of the following
5730 conversions to incorporate the load reduction for the collective source controls.

5731
5732 For an Annual Load Target with Y percent load reduction based on untransformed annual
5733 loads,

5734 Target equation intercept = intercept at 0% reduction * (1 - Y)

5735
5736 Target equation coefficients (b_i) = b_i at 0% reduction * (1 - Y)





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5737 For an Annual Load Limit with Y percent load reduction based on untransformed annual
5738 loads,

5739
5740 s and $SE_p = \text{value at 0\% reduction} * (1 - Y)$

5741
5742 $\text{var}(b_i) \ \& \ \text{cov}(b_i, b_j) = \text{value at 0\% reduction} * (1 - Y)^2$

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5745





LOWER KISSIMMEE SUB-WATERSHED

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Following the procedures described in Section 2.6, the annual load discharged from the Lower Kissimmee Sub-watershed was expressed as a function of the variability of the annual rainfall. Using a zero percent load reduction, prediction equations for the annual TP load and annual upper confidence limit above the prediction were derived using this regression equation. The resulting prediction equation for the annual load was

$$\text{annual load prediction (mt)} = L = (a + b_1X)^2$$

- Where L = 12-month load (mt)
- a = the intercept of the regression line
- b₁ = the regression coefficient for X
- X = the 12-month total rainfall (inches)

The predictor X is calculated from the first moment (m₁) of the 12 monthly rainfall totals for the Water Year:

- r_i = monthly rainfall, for i=1 to 12 months of the Evaluation Year
- m₁ = Sum [r_i] / 12
- X = (12 m₁)

Applying the coefficients derived using the ordinary least squares method yields the following prediction for the annual load

$$\text{annual load prediction} = [-10.07535 + 0.37945 \text{ Rain}]^2$$

The coefficient of determination (R²) for the resulting equation was 0.751, with a standard error of the regression equation of 1.59630. Since a transformation of load was required in deriving the prediction equation, a “back-transformed” standard error of the regression equation was calculated after the predictions were transformed back to the original units (mt): 25.697 mt. The back-transformed standard error of regression was approximately 32 percent of the Base Period mean annual load. The coefficient of the regression line was significantly different from zero at the 90 percent confidence level, with a p-value less than 10 percent for the coefficient b₁.

Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual load was derived as the upper 90 percent confidence limit above the prediction, with an associated theoretical Type I error (i.e., false positive) rate of 10 percent. In deriving the upper 90 percent upper confidence limit on the predicted annual load, the product of the appropriate t-statistic and an expression of the prediction’s standard error (SE_p) is added to the predicted annual load, as expressed below:





5787
5788 annual load UCL = $TP_{90\%CL} = [\text{sqrt}(\text{predicted annual load}) + (t_{\alpha,n-2} SE_p)]^2$

5789
5790 where $TP_{90\%CL}$ is the upper 90 percent confidence limit on the predicted annual load,
5791 $t_{\alpha,n-2}$ is the value of the one-tailed t statistic at significance level α , with n-2 degrees
5792 of freedom (for 90 percent confidence level, $\alpha = 0.10$), and
5793 n is the number of annual TP loads in the Base Period (= 14)

5794
5795 The standard error of the prediction (SE_p) is comprised of the standard error of the regression
5796 equation and the standard error of the predicted mean value, expressed in the equation below
5797 (Haan 1977)

5798
5799
$$SE_p = s \left[1 + \frac{1}{n} + \frac{(X - X_m)^2}{\sum (X_i - X_m)^2} \right]^{0.5}$$

5800
5801 where s is the standard error of the regression equation = 1.59630
5802 X_m = average value of the predictor in the Base Period = 48.77 inches
5803 n = 14
5804 $t_{\alpha,n-2} = 1.35622$
5805 $1 / \sum (X_i - X_m)^2 = 1 / 641.63129$

5806
5807 Collecting terms yields
5808
5809 $SE_p = 1.59630 [1 + 1/14 + (X-X_m)^2 / 641.63129]^{0.5}$

5810
5811 The above equations can be converted to a performance measure by means of the following
5812 conversions to incorporate the load reduction for the collective source controls.

5813
5814 For an Annual Load Target with Y percent reduction and sqrt-transformed annual load,
5815 Target equation intercept = value at 0% reduction * sqrt(1 - Y)
5816 Target equation coefficient (b_i) = value at 0% reduction * sqrt(1 - Y)

5817
5818 For an Annual Load Limit with Y percent load reduction and sqrt-transformed annual load,
5819 s = value at 0% reduction * sqrt(1 - Y)





5822 **EAST LAKE OKEECHOBEE SUB-WATERSHED**

5823

5824 **C-44 Hydrologic Unit**

5825

5826 Following the procedures described in Section 2.6, the annual load discharged from S-191
5827 was expressed as a function of the variability of the annual rainfall. Using a zero percent
5828 load reduction, prediction equations for the annual TP load and annual upper confidence limit
5829 above the prediction were derived using this regression equation. The resulting prediction
5830 equation for the annual load was

5831

5832 annual load prediction (mt) = L = exp [a + b₁ X + b₂ S]

5833

5834 Where a = the intercept of the regression line

5835 b₁ = the regression coefficient for X

5836 X = the natural logarithm of the 12-month total rainfall (inches)

5837 b₂ = the regression coefficient for S

5838 S = skewness of annual rainfall

5839

5840 The predictors X and S are calculated from the first three moments (m₁, m₂ and m₃) of the 12
5841 monthly rainfall totals for the Water Year:

5842 r_i = monthly rainfall, for i=1 to 12 months of the Evaluation Year

5843 m₁ = Sum [r_i] / 12

5844 m₂ = Sum [r_i - m₁]² / 12

5845 m₃ = Sum [r_i - m₁]³ / 12

5846 X = ln(12 m₁)

5847 S = (12/11) m₃ / m₂^{1.5}

5848

5849 Applying the coefficients derived using the ordinary least squares method yields the
5850 following prediction for the annual load

5851

5852 annual load prediction = exp [-5.90005 + 2.47871 X + 0.32418 S]

5853

5854 The coefficient of determination (R²) for the resulting equation was 83.9 percent, with a
5855 standard error of regression of 0.28226. Since a transformation of load was required in
5856 deriving the prediction equation, a “back-transformed” standard error of the regression
5857 equation was calculated after the predictions were transformed back to the original units
5858 (mt): 16.588 mt. The back-transformed standard error of regression was approximately 30
5859 percent of the Base Period mean annual load. The coefficients of the regression line were
5860 significantly different from zero at the 90 percent confidence level, with p-values less than 10
5861 percent for the coefficients b₁, b₂ and b₃.





5862
 5863 Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual
 5864 load was derived as the upper 90 percent confidence limit above the prediction, with an
 5865 associated theoretical Type I error (i.e., false positive) rate of 10 percent²⁸. In deriving the
 5866 upper 90 percent upper confidence limit on the predicted Annual Load, the product of the
 5867 appropriate t-statistic and an expression of the prediction's standard error (SE_p) is added to
 5868 the predicted annual load, as expressed below:

5869
 5870 Upper Conf. Limit on prediction = exp [ln(annual load) + (t-value * SE_p)]
 5871 = predicted annual load * exp (1.39682 * SE_p)
 5872

5873 $SE_p = 0.28226 [1 + 1/11 + 2.17746 (X-X_m)^2 + 0.37718 (S-S_m)^2 + -0.19128 (X-X_m) (S-S_m)]^{0.5}$
 5874

5875 Where X_m = mean of the log-transformed annual total rainfall for the Base Period = 3.82565
 5876 S_m = mean of the skewness of the annual total rainfall for the Base Period = 0.880
 5877 t = 1.39682
 5878

5879 The above equations can be converted to a performance measure by means of the following
 5880 conversions after a load reduction for the collective source controls has been determined.

5881 For an Annual Load Target with Y percent load reduction based on log transformed annual
 5882 loads,

5883
 5884 Target equation intercept (a) = intercept at 0% reduction - ln [1/(1 - Y)]
 5885 Target equation coefficient (b_i) = b_i at 0% reduction
 5886
 5887

5888 For an Annual Load Limit with Y percent load reduction based on log transformed annual
 5889 loads,

5890
 5891 SE_p = value at 0% reduction
 5892
 5893
 5894

²⁸ The Type I error rate is the probability that the performance measure methodology will reject the null hypothesis (i.e., a determination that the TP load does not meet the performance measure) when in reality the null hypothesis is true – the annual load meets the performance measure, and is therefore also known as the false positive rate.





5895 **L-8 Summary Basin**

5896

5897 Following the procedures described in Section 2.6, the annual load discharged from the L-8
5898 Summary Basin was expressed as a function of the variability of the annual rainfall. Using a
5899 zero percent load reduction, prediction equations for the annual TP load and annual upper
5900 confidence limit above the prediction were derived using this regression equation. The
5901 resulting prediction equation for the annual load was

5902

5903 annual load prediction (mt) = $L = (a + b_1X + b_2S + b_3C)^2$

5904

5905 Where L = 12-month load (mt)

5906 a = the intercept of the regression line

5907 b₁ = the regression coefficient for X

5908 X = the 12-month total rainfall (inches)

5909 b₂ = the regression coefficient for S

5910 S = the 12-month total rainfall skewness

5911 b₃ = the regression coefficient for C

5912 C = the 12-month total rainfall coefficient of variation

5913

5914 The predictors X, S and C are calculated from the first moment (m₁) of the 12 monthly
5915 rainfall totals for the Water Year:

5916 r_i = monthly rainfall, for i=1 to 12 months of the Evaluation Year

5917 $m_1 = \text{Sum} [r_i] / 12$

5918 $m_2 = \text{Sum} [r_i - m_1]^2 / 12$

5919 $m_3 = \text{Sum} [r_i - m_1]^3 / 12$

5920 $X = (12 m_1)$

5921 $C = [(12/11) m_2]^{0.5} / m_1$

5922 $S = (12/11) m_3 / m_2^{1.5}$

5923

5924 Applying the coefficients derived using the ordinary least squares method yields the
5925 following prediction equation for the annual load

5926

5927 annual load Prediction = $(-5.6662 + 0.09213 X - 1.72191 S + 7.75787 C)^2$

5928

5929 The coefficient of determination (R²) for the resulting equation was 0.841, with a standard
5930 error of regression of 0.51599. Since a transformation of load was required in deriving the
5931 prediction equation, a “back-transformed” standard error of the regression equation was
5932 calculated after the predictions were transformed back to the original units (mt): 3.560 mt.
5933 The back-transformed standard error of regression was approximately 21 percent of the Base





5934 Period mean annual load. The coefficients of the regression line were significantly different
5935 from zero at the 90 percent confidence level, with p-values less than 10 percent for the
5936 coefficients b₁, b₂ and b₃.
5937

5938 Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual
5939 load was derived as the upper 90 percent confidence limit above the prediction, with an
5940 associated theoretical Type I error (i.e., false positive) rate of 10 percent²⁹. In deriving the
5941 upper 90 percent upper confidence limit on the predicted annual load, the product of the
5942 appropriate t-statistic and an expression of the prediction’s standard error (SE_p) is added to
5943 the predicted Annual Load, as expressed below:

5944
5945 annual load UCL = TP_{90%CL} = [sqrt(predicted annual load) + (t_{α,n-4}) SE_p]²
5946

5947 where TP_{90%CL} is the upper 90 percent confidence limit on the predicted annual load,
5948 t_{α,n-4} is the value of the one-tailed t statistic at significance level α, with n-4 degrees
5949 of freedom (for 90 percent confidence level, α = 0.10), and
5950 n is the number of annual TP loads in the Base Period (= 9)
5951

5952 The standard error of the prediction (SE_p) is comprised of the standard error of the regression
5953 equation and the standard error of the predicted mean value, expressed in the equation below
5954 (Haan 1977)
5955

5956
$$SE_p = s \left[1 + \frac{1}{n} + \text{var}(b_1) \frac{(X - X_m)^2}{s^2} + \text{var}(b_2) \frac{(S - S_m)^2}{s^2} + \text{var}(b_3) \frac{(C - C_m)^2}{s^2} + \right.$$

5957
5958
$$\left. 2 \text{cov}(b_1, b_2) \frac{(X - X_m)(S - S_m)}{s^2} + 2 \text{cov}(b_1, b_3) \frac{(X - X_m)(C - C_m)}{s^2} + 2 \text{cov}(b_2, b_3) \frac{(S - S_m)(C - C_m)}{s^2} \right]^{0.5}$$

5959 where s is the standard error of the regression equation = 0.51601
5960 Where X_m = mean rainfall during Base Period (54.299 inches)
5961 S_m = mean rainfall skewness during Base Period (0.557)
5962 C_m = mean rainfall coefficient of variation during Base Period (0.720)
5963 t-value = 1.47588
5964 n = 9
5965 var(b₁) = 0.00056
5966 var(b₂) = 0.26130
5967 var(b₃) = 3.89591
5968

²⁹ The Type I error rate is the probability that the performance measure methodology will reject the null hypothesis (i.e., a determination that the TP load does not meet the performance measure) when in reality the null hypothesis is true – the annual load meets the performance measure, and is therefore also known as the false positive rate.





5969 cov(b₁,b₂) = -0.00007
 5970 cov(b₁,b₃) = 0.02660
 5971 cov(b₂,b₃) = -0.58242

5972
 5973 Collecting terms yields

5974
 5975 $SE = 0.516 [1 + 1/9 + 0.0021 (X-X_m)^2 + 0.9814 (S-S_m)^2 + 14.6322 (C-C_m)^2 + 0.0006 (X-$
 5976 $X_m) (S-S_m) + 0.1998 (X-X_m) (C-C_m) + -4.375 (S-S_m) (C-C_m)]^{0.5}$

5977
 5978 The above equations can be converted to a performance measure by means of the following
 5979 conversions to incorporate the load reduction for the collective source controls.

5980
 5981 For an Annual Load Target with Y percent reduction and sqrt-transformed annual load,
 5982 Target equation intercept = value at 0% reduction * sqrt(1 - Y)
 5983 Target equation coefficient (b_i) = value at 0% reduction * sqrt(1 - Y)

5984
 5985 For an Annual Load Limit with Y percent load reduction and sqrt-transformed annual load,
 5986 s = value at 0% reduction * sqrt(1 - Y)

5987
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 6000





6001 **Indian Prairie Sub-watershed**

6002

6003 Following the procedures described in Section 2.6, the annual load discharged from the
6004 Indian Prairie Sub-watershed was expressed as a function of the variability of the annual
6005 rainfall. Using a zero percent load reduction, prediction equations for the annual TP load and
6006 annual upper confidence limit above the prediction were derived using this regression
6007 equation. The resulting prediction equation for the annual load was

6008

6009
$$\text{annual load prediction (mt)} = \ln(L) = \exp(a + b_1X + b_2C)$$

6010

6011 Where L = 12-month load (mt),

6012 a = the intercept of the regression line

6013 b₁ = the regression coefficient for X

6014 b₂ = the regression coefficient for C

6015 X = the natural logarithm of the 12-month total rainfall [ln(inches)]

6016 C = the 12-month total rainfall coefficient of variation

6017

6018 The predictors X and C are calculated from the first two moments (m₁ and m₂) of the 12
6019 monthly rainfall totals for the Water Year:

6020 r_i = monthly rainfall, for i=1 to 12 months of the Evaluation Year

6021
$$m_1 = \text{Sum} [r_i] / 12$$

6022
$$m_2 = \text{Sum} [r_i - m_1]^2 / 12$$

6023

6024
$$X = \ln(12 m_1)$$

6025
$$C = [(12/11) m_2]^{0.5} / m_1$$

6026

6027 Applying the coefficients derived using the ordinary least squares method yields the
6028 following prediction for the annual load

6029

6030
$$\text{annual load prediction} = \exp[-12.48183 + 4.02125 \ln(\text{Rain}) + 1.7627 \text{ CV}]$$

6031

6032 The coefficient of determination (R²) for the resulting equation was 0.911, with a standard
6033 error of regression of 0.20346. Since a transformation of load was required in deriving the
6034 prediction equation, a “back-transformed” standard error of the regression equation was
6035 calculated after the predictions were transformed back to the original units (mt): 14.794 mt.
6036 The back-transformed standard error of regression was approximately 24 percent of the Base
6037 Period mean annual load. The coefficients of the regression line were significantly different
6038 from zero at the 90 percent confidence level, with p-values less than 10 percent for the
6039 coefficients b₁ and b₂.





6040 Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual
 6041 load was derived as the upper 90 percent confidence limit above the prediction from
 6042 Equation (1), with an associated theoretical Type I error (i.e., false positive) rate of 10%³⁰.
 6043 In deriving the upper 90 percent upper confidence limit on the predicted annual load, the
 6044 product of the appropriate t-statistic and an expression of the prediction's standard error
 6045 (SE_p) is added to the predicted annual load, as expressed below:

6046
 6047 annual load UCL = TP_{90%CL} = exp [ln(predicted annual load) + [(t_{α,n-3}) SE_p]

6048
 6049 where TP_{90%CL} is the upper 90 percent confidence limit on the predicted annual load,
 6050 t_{α,n-3} is the value of the one-tailed t statistic at significance level α, with n-3 degrees of
 6051 freedom (for 90 percent confidence level, α = 0.10), and
 6052 n is the number of annual TP loads in the Base Period (= 13)

6053
 6054 The standard error of the prediction (SE_p) is comprised of the standard error of the regression
 6055 equation and the standard error of the predicted mean value, expressed in the equation below
 6056 (Haan 1977)
 6057

6058
$$SE_p = s \left[1 + \frac{1}{n} + \text{var}(b_1) \frac{(X - X_m)^2}{s^2} + \text{var}(b_2) \frac{(C - C_m)^2}{s^2} + 2 \text{cov}(b_1, b_2) \frac{(X - X_m)(C - C_m)}{s^2} \right]^{0.5}$$

6059
 6060 where s is the standard error of the regression equation = 0.20346
 6061 X_m = average value of the predictor in the Base Period = 3.74445
 6062 C_m = average value of the predictor in the Base Period = 0.788
 6063 t_{α,n-3} = 1.37218
 6064 var(b₁) = 0.16228
 6065 var(b₂) = 0.13236
 6066 cov(b₁,b₂) = 0.08990

6067
 6068 Collecting terms yields
 6069
 6070 SE = 0.20346 [1 + 1/13 + 3.92019 (X-X_m)² + 3.19741 (C-C_m)² + 4.34342 (X-X_m) (C-C_m)]^{0.5}

6071
 6072 The above equations can be converted to a performance measure by means of the following
 6073 conversions after a load reduction for the collective source controls has been determined.

6074
 6075 For an Annual Load Target with Y% load reduction and log-transformed annual load,

³⁰ The Type I error rate is the probability that the performance measure methodology will reject the null hypothesis (i.e., a determination that the TP load does not meet the performance measure) when in reality the null hypothesis is true – the annual load meets the performance measure, and is therefore also known as the false positive rate.





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6076 Target Equation intercept = value at 0% reduction – $\ln[1/(1-Y)]$

6077

6078 Target Equation coefficients (b_i) = value at 0% reduction

6079

6080 For example, if the load reduction = 30 percent, the Annual Load Target becomes

6081

6082 Annual Load Target = $\exp [-12.48183 - \ln[1/(1-0.3)] + 4.02125 \ln(\text{Rain}) + 1.7627 \text{ CV}]$

6083

6084 Annual Load Target = $\exp (-12.83843 + 4.02125 X + 1.7627 C)$

6085

6086 For an Annual Load Limit with Y percent load reduction based on log transformed annual
6087 loads,

6088

6089 SE_p = value at 0% reduction

6090

6091

6092

6093





6094 **Fisheating Creek Summary Basin**

6095

6096 Following the procedures described in Section 2.6, the annual load discharged from the
6097 Fisheating Creek Summary Basin was expressed as a function of the variability of the annual
6098 rainfall. Using a zero percent load reduction, prediction equations for the annual TP load and
6099 annual upper confidence limit above the prediction were derived using this regression
6100 equation. The resulting prediction equation for the annual load was

6101

$$\text{annual load prediction (mt)} = L = a + b_1X$$

6102

6103 Where L = 12-month load (mt),

6104

a = the intercept of the regression line,

6105

b₁ = the regression coefficient for X,

6106

X = the natural logarithm of the 12-month total rainfall (inches)

6107

6108 The predictor X is calculated from the first moment (m₁) of the 12 monthly rainfall totals for
6109 the Water Year:

6110

r_i = monthly rainfall, for i=1 to 12 months of the Evaluation Year

6111

m₁ = Sum [r_i] / 12

6112

X = ln(12 m₁)

6113

6114 Applying the coefficients derived using the ordinary least squares method yields the
6115 following prediction for the annual load

6116

$$\text{annual load prediction} = -486.14648 + 142.06268 \ln(\text{Rain})$$

6117

6118
6119 The coefficient of determination (R²) for the resulting equation was 0.535, with a standard
6120 error of regression of 34.040 mt. The standard error of regression was approximately 45
6121 percent of the Base Period mean annual load. The coefficient of the regression line was
6122 significantly different from zero at the 90 percent confidence level, with a p-value less than
6123 10 percent for the coefficient b₁.

6124

6125 Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual
6126 load was derived as the upper 90 percent confidence limit above the prediction from
6127 Equation (1), with an associated theoretical Type I error (i.e., false positive) rate of 10%³¹.
6128 In deriving the upper 90 percent upper confidence limit on the predicted annual load, the

³¹ The Type I error rate is the probability that the performance measure methodology will reject the null hypothesis (i.e., a determination that the TP load does not meet the performance measure) when in reality the null hypothesis is true – the annual load meets the performance measure, and is therefore also known as the false positive rate.





6129 product of the appropriate t-statistic and an expression of the prediction's standard error
6130 (SE_p) is added to the predicted annual load, as expressed below:

6131 annual load UCL = TP_{90% CL} = predicted Annual Load + [(t_{α,n-2}) SE_p]

6132
6133 where TP_{90%CL} is the upper 90 percent confidence limit on the predicted annual load,
6134 t_{α,n-2} is the value of the one-tailed t statistic at significance level α, with n-2 degrees
6135 of freedom (for 90 percent confidence level, α = 0.10), and
6136 n is the number of annual TP loads in the Base Period (= 11)

6137
6138 The standard error of the prediction (SE_p) is comprised of the standard error of the regression
6139 equation and the standard error of the predicted mean value, expressed in the equation below
6140 (Haan 1977)

6141
6142
$$SE_p = s \left[1 + \frac{1}{n} + \frac{(X - X_m)^2}{\sum (X_i - X_m)^2} \right]^{0.5}$$

6143 where s is the standard error of the regression equation = 34.04011
6144 X_m = average value of the predictor in the Base Period = 3.9502
6145 n = 11
6146 t_{α,n-2} = 1.38303
6147 1 / Σ(X_i-X_m)² = 1 / 0.59477

6148
6149
6150 Collecting terms, Eqn (4) becomes

6151
6152 SE_p = SE = 34.04011 [1 + 1/11 + (X-X_m)² / 0.59477]^{0.5}

6153
6154 The above equations can be converted to a performance measure by means of the following
6155 conversions after a load reduction for the collective source controls has been determined.

6156
6157 For an Annual Load Target with Y percent reduction based on untransformed annual loads,

6158
6159 Target Eqn. Intercept = intercept at 0% reduction * (1 - Y)

6160
6161 Target Equation coefficients (b_i) = b_i at 0% reduction * (1 - Y)

6162
6163 For an Annual Load Limit with Y percent reduction based on untransformed annual loads,

6164
6165 s and SE_p = value at 0% reduction * (1 - Y)

6166
6167 var(b_i) & cov(b_i,b_j) = value at 0% reduction * (1 - Y)²

6168





6169 **WEST LAKE OKEECHOBEE SUB-WATERSHED**

6170

6171 **S-4/Industrial Canal Hydrologic Unit**

6172 Following the procedures described in Section 2.6, the annual load discharged from the S-4
6173 Hydrologic Unit was expressed as a function of the variability of the annual rainfall. Using a
6174 zero percent load reduction, prediction equations for the annual TP load was derived using
6175 this regression equation. The resulting prediction equation for the annual load was

6176

6177
$$\text{annual load prediction (mt)} = L = a + b_1X + b_2C$$

6178

6179 Where: L = 12-month load (mt)

6180 a = the intercept of the regression line

6181 b₁ = the regression coefficient for X

6182 b₂ = the regression coefficient for C

6183 X = the 12-month total rainfall (inches)

6184 C = the coefficient of variation calculated from 12 monthly rainfall totals

6185

6186 The predictors X and C are calculated from the first two moments (m₁ and m₂) of the 12
6187 monthly rainfall totals for the Water Year:

6188 r_i = monthly rainfall, for i=1 to 12 months of the Evaluation Year

6189
$$m_1 = \text{Sum} [r_i] / 12$$

6190
$$m_2 = \text{Sum} [r_i - m_1]^2 / 12$$

6191
$$X = 12 m_1$$

6192
$$C = [(12/11) m_2]^{0.5} / m_1$$

6193

6194 The coefficient of determination (R²) for the resulting equation was 0.762, with a standard
6195 error of regression of 4.323 mt. The standard error of regression was approximately 25
6196 percent of the Base Period mean annual load. The slope coefficients of the regression
6197 equation were significantly different from zero at the 90 percent confidence level, with p-
6198 values less than ten percent for the coefficients b₁ and b₂.

6199

6200 Consistent with Chapter 40E-63 F.A.C., the upper confidence limit was derived as the upper
6201 90 percent confidence limit above the annual load prediction described above, with an
6202 associated theoretical Type I error (i.e., false positive) rate of 10%. In deriving the upper 90
6203 percent upper confidence limit (UCL), the product of the appropriate t-statistic and an
6204 expression of the prediction's standard error (SE_p) is added to the predicted annual load:

6205

6206
$$\text{UCL on the annual load Limit} = TP_{90\% \text{ CL}} = \text{Target} + [(t_{\alpha, n-3}) TP_{90\% \text{ CL}} = \text{Target} + [(t_{\alpha, n-3}) SE_p]$$

6207





6208 where: $TP_{90\%CL}$ is the UCL corresponding to the upper 90 percent confidence limit,
 6209 $t_{\alpha,n-3}$ is the value of the one-tailed t statistic at significance level α , with n-3 degrees
 6210 of freedom (for 90 percent confidence level, $\alpha = 0.10$), and
 6211 n is the number of annual TP loads in the Base Period (= 9)

6212
 6213 The standard error of the prediction (SE_p) is comprised of the standard error of the regression
 6214 equation and the standard error of the predicted mean value, expressed in the equation below
 6215 (Haan 1977)

6216
 6217
$$SE_p = s \left[1 + \frac{1}{n} + \text{var}(b_1) \frac{(X - X_m)^2}{s^2} + \text{var}(b_2) \frac{(C - C_m)^2}{s^2} + 2 \text{cov}(b_1, b_2) \frac{(X - X_m)(C - C_m)}{s^2} \right]^{0.5}$$

6218
 6219 where: s is the standard error of the regression equation = 4.323 mt
 6220 X_m = average value of the predictor in the Base Period = 45.7044 inches
 6221 C_m = average value of the predictor in the Base Period = 0.9137
 6222 n = 9
 6223 $t_{\alpha,n-3} = 1.43976$
 6224 $\text{var}(b_1) = 0.02094$
 6225 $\text{var}(b_2) = 38.08623$
 6226 $\text{cov}(b_1, b_2) = 0.08270$

6227
 6228 Collecting terms yields
 6229 $SE_p = 4.32303 \left[1 + 1/9 + 0.00112 (X-X_m)^2 + 2.03794 (C-C_m)^2 + 0.00886 (X-X_m) (C-C_m) \right]^{0.5}$

6230
 6231 The above equations can be converted to a performance measure by means of the following
 6232 conversions after a load reduction for the collective source controls has been determined.

6233
 6234 For an Annual Load Target with Y percent reduction based on untransformed annual loads,
 6235 Target Eqn. Intercept = intercept at 0% reduction * (1 - Y)
 6236 Target Equation coefficients (b_i) = b_i at 0% reduction * (1 - Y)
 6237 For an Annual Load Limit with Y percent reduction based on untransformed annual loads,
 6238 s and SE_p = value at 0% reduction * (1 - Y)
 6239 $\text{var}(b_i)$ & $\text{cov}(b_i, b_j)$ = value at 0% reduction * (1 - Y)²

6240
 6241
 6242
 6243 **East Caloosahatchee Hydrologic Unit**

6244





6245 Following the procedures described in Section 2.6, the annual load discharged from the East
6246 Caloosahatchee Hydrologic Unit was expressed as a function of the variability of the annual
6247 rainfall. Using a zero percent load reduction, prediction equations for the annual TP load and
6248 annual upper confidence limit above the prediction were derived using this regression
6249 equation. The resulting prediction equation for the annual load was

6250
6251
$$\text{annual load prediction (mt)} = L = a + b_1X$$

6252
6253 Where L = 12-month load (mt),
6254 a = the intercept of the regression line,
6255 b₁ = the regression coefficient for X,
6256 X = the 12-month total rainfall (inches)

6257
6258 The predictor X is calculated from the first moment (m₁) of the 12 monthly rainfall totals for
6259 the Water Year:

6260
$$r_i = \text{monthly rainfall, for } i=1 \text{ to } 12 \text{ months of the Evaluation Year}$$

6261
$$m_1 = \text{Sum } [r_i] / 12$$

6262
$$X = (12 m_1)$$

6263
6264 Applying the coefficients derived using the ordinary least squares method yields the
6265 following prediction for the annual load

6266
6267
$$\text{annual load prediction} = -195.41118 + 5.12752 (\text{Rain})$$

6268
6269 The coefficient of determination (R²) for the resulting equation was 0.726, with a standard
6270 error of regression of 31.138 mt. The standard error of regression was approximately 47
6271 percent of the Base Period mean annual load. The coefficient of the regression line was
6272 significantly different from zero at the 90 percent confidence level, with a p-value less than
6273 10 percent for the coefficient b₁.

6274
6275 Consistent with Chapter 40E-63 F.A.C., the upper confidence limit for the predicted annual
6276 load was derived as the upper 90 percent confidence limit above the prediction from
6277 Equation (1), with an associated theoretical Type I error (i.e., false positive) rate of 10%³².
6278 In deriving the upper 90 percent upper confidence limit on the predicted annual load, the
6279 product of the appropriate t-statistic and an expression of the prediction's standard error
6280 (SE_p) is added to the predicted annual load, as expressed below:

6281

³² The Type I error rate is the probability that the performance measure methodology will reject the null hypothesis (i.e., a determination that the TP load does not meet the performance measure) when in reality the null hypothesis is true – the annual load meets the performance measure, and is therefore also known as the false positive rate.





6282 annual load UCL = $TP_{90\% CL} = \text{predicted Annual Load} + [(t_{\alpha, n-2}) SE_p]$

6283
6284 where $TP_{90\% CL}$ is the upper 90 percent confidence limit on the predicted annual load,
6285 $t_{\alpha, n-2}$ is the value of the one-tailed t statistic at significance level α , with n-2 degrees
6286 of freedom (for 90 percent confidence level, $\alpha = 0.10$), and
6287 n is the number of annual TP loads in the Base Period (= 9)
6288

6289 The standard error of the prediction (SE_p) is comprised of the standard error of the regression
6290 equation and the standard error of the predicted mean value, expressed in the equation below
6291 (Haan 1977)
6292

6293 $SE_p = s \left[1 + \frac{1}{n} + \frac{(X - X_m)^2}{\sum (X_i - X_m)^2} \right]^{0.5}$

6294 where s is the standard error of the regression equation = 31.13751
6295 X_m = average value of the predictor in the Base Period = 3.9502
6296 n = 9
6297 $t_{\alpha, n-2} = 1.41492$
6298 $1 / \sum (X_i - X_m)^2 = 1 / 675.50602$
6299

6300
6301 Collecting terms yields

6302
6303 $SE_p = SE = 31.13751 [1 + 1/9 + (X-X_m)^2 / 675.50602]^{0.5}$
6304

6305 The above equations can be converted to a performance measure by means of the following
6306 conversions after a load reduction for the collective source controls has been determined.

6307
6308 For an Annual Load Target with Y percent reduction based on untransformed annual loads,

6309
6310 Target Eqn. Intercept = intercept at 0% reduction * (1 - Y)

6311
6312 Target Equation coefficients (b_i) = b_i at 0% reduction * (1 - Y)

6313
6314 For an Annual Load Limit with Y percent reduction based on untransformed annual loads,

6315
6316 s and SE_p = value at 0% reduction * (1 - Y)
6317 $\text{var}(b_i)$ & $\text{cov}(b_i, b_j)$ = value at 0% reduction * (1 - Y)²





**APPENDIX C – SUMMARY OF DATA SOURCES USED FOR
THE DEVELOPMENT OF THE PERFORMANCE MEASURE
METHODOLOGIES**

Data Collection Sources and Methods: Water Quantity – Flows

The District computes flow at all of the primary water control structures serving the basins within the Lake Okeechobee Watershed. Water control structures include pumps, gated spillways, and gated culverts.

The District’s hydrologic database (DBHYDRO) stores one or more flow data sets at each structure. Each flow data set is created using a unique combination of sources of stage and control operations data. The District uses its data to perform water budget analyses and flow estimation techniques to obtain a "preferred" flow data set at each structure. **Table C-1** shows the basin discharge flow data sets used in the annual phosphorus load calculation for those basins with a load-based performance measure³³; these are available in the District’s hydrologic database. The list of outfall structures used in the annual phosphorus load calculation will be adjusted by the District to account for any changes in outflow structures from the individual basins, including those changes caused by construction of regional projects.

Water Quality

Raw water samples for the Lake Okeechobee Watershed phosphorus load calculations are collected by automatic samplers or grab samples. Current raw water sample collecting methods at structures utilized in the Lake Okeechobee Watershed basins phosphorus load calculation are listed in **Table C-2**.

³³ A similar table will be prepared at a later date for those basins where a performance indicator is recommended.





DRAFT

Technical Support Document
Lake Okeechobee Watershed Performance Measures

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Table C-1. Database keys for structure flow data.

Sub-watershed	Summary Basin or Hydrologic Unit	Structure	DBKEY	Type*
Taylor Creek/Nubbin Slough	S-133 Summary Basin	S-133	15637	PREF
Taylor Creek/Nubbin Slough	S-154 Summary Basin	S-154	15629	PREF
Taylor Creek/Nubbin Slough	S-191 Summary Basin	S-191	15639	PREF
Lower Kissimmee		S-65E	15631	PREF
East Lake Okeechobee	C-44	S-308	15626	PREF
East Lake Okeechobee	C-44	S-80	JW224	PREF
East Lake Okeechobee	L-8	Culv 10A	15640	PREF
East Lake Okeechobee	L-8	S-5AW	MG614	N/A
East Lake Okeechobee	L-8	S-5AS	TA410	PREF
East Lake Okeechobee	L-8	S-5AE	L7443	TELE
East Lake Okeechobee	L-8	City of WPB #2	TW079	TELE
Indian Prairie Sub-watershed		G-33	US349	TELE
Indian Prairie Sub-watershed		G-34	W3841	TELE
Indian Prairie Sub-watershed		G-74	88187	TELE
Indian Prairie Sub-watershed		G-75	87646	TELE
Indian Prairie Sub-watershed		G-76	87645	TELE
Indian Prairie Sub-watershed		L-61 E	15654	N/A
Indian Prairie Sub-watershed		S-68	15632	PREF
Indian Prairie Sub-watershed		S-71	15633	PREF
Indian Prairie Sub-watershed		S-72	15634	PREF
Indian Prairie Sub-watershed		S-84	15636	PREF
Indian Prairie Sub-watershed		S-127 (Pump)	15641	PREF
Indian Prairie Sub-watershed		S-127 (Spillway)	15819	TELE
Indian Prairie Sub-watershed		S-129 (Pump)	15642	PREF
Indian Prairie Sub-watershed		S-129 (Spillway)	15823	TELE
Indian Prairie Sub-watershed		S-131 (Pump)	15643	PREF
Indian Prairie Sub-watershed		S-131 (Spillway)	M2931	TELE
Fisheating Creek/Nicodemus Slough	Fisheating Creek	FISHCR	WH036	USGS
West Lake Okeechobee		S-4 / Industrial Canal	EPD-07	EAA EPD
West Lake Okeechobee	S-4 / Industrial Canal	S-310	15628	PREF
West Lake Okeechobee	S-4 / Industrial Canal	S-169	15590	NA
West Lake Okeechobee	S-4 / Industrial Canal	S-4	15630	PREF
West Lake Okeechobee	S-4 / Industrial Canal	S-235	15564	SP01
West Lake Okeechobee	East Caloosahatchee	S-77	DJ235	COE
West Lake Okeechobee	East Caloosahatchee	S-78	DJ236	COE
West Lake Okeechobee	East Caloosahatchee	CULV5A	TA604	CR10
South Lake Okeechobee		EAA	See 40E-61, F.A.C.	
South Lake Okeechobee	Ch 298 Districts	C-10	15645	PREF
South Lake Okeechobee	Ch 298 Districts	C-12	15646	PREF
South Lake Okeechobee	Ch 298 Districts	C-12A	15647	PREF
South Lake Okeechobee	Ch 298 Districts	C-4A	15648	PREF
South Lake Okeechobee	Ch 298 Districts	S-236	15644	PREF

* Flow data type:

- | | |
|------|---|
| PREF | PREFERRED VALUE |
| CR10 | CAMPBELL SCIENTIFIC INC. MEASUREMENT AND CONTROL MODULE |
| TELE | TELEMETRY (RADIO NETWORK) |
| 102 | UNKNOWN CHART-TYPE RECORDER |
| NA | NOT APPLICABLE |
| SP01 | SOLID STATE LOGGER |
| COE | U.S. ARMY CORPS OF ENGINEERS |
| USGS | U.S. GEOLOGICAL SERVICE |

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Table C-2. Sampling methods for structure water quality data.

Sub-watershed	Summary Basin or Hydrologic Unit	Structure or Station	TP Collection Site ID	TP Collection Site	Instrument
Taylor Creek/Nubbin Slough	S-133 Summary Basin	S-133	S133	Pump	Grab
Taylor Creek/Nubbin Slough	S-154 Summary Basin	S-154	S154	Gravity	A*
Taylor Creek/Nubbin Slough	S-191 Summary Basin	S-191	S191	Pump	A*
Lower Kissimmee		S-65E	S65E	Gravity	A*
East Lake Okeechobee	C-44	S-308	S308C	Gravity	Grab
East Lake Okeechobee	C-44	S-80	S80	Gravity	Grab
East Lake Okeechobee	L-8	Culv 10A	CLV10A	Gravity	Grab
East Lake Okeechobee	L-8	S-5AW	S5AW	Gravity	Grab (Note 1)
East Lake Okeechobee	L-8	S-5AS	S5AS	Gravity	Grab (Note 1)
East Lake Okeechobee	L-8	S-5AE	S5AE	Gravity	Grab (Note 1)
East Lake Okeechobee	L-8	City of WPB #2	None	Pump	None (Note 2)
Indian Prairie Sub-watershed		G-33	C38W	Gravity	Grab
Indian Prairie Sub-watershed		G-34	L59E	Gravity	Grab
Indian Prairie Sub-watershed		G-74	L59W	Gravity	Grab
Indian Prairie Sub-watershed		G-75	L60E	Gravity	Grab
Indian Prairie Sub-watershed		G-76	L60W	Gravity	Grab
Indian Prairie Sub-watershed		L-61 E	L61E	Gravity	Grab
Indian Prairie Sub-watershed		S-68	S68	Gravity	Grab
Indian Prairie Sub-watershed		S-71	S71	Gravity	A*
Indian Prairie Sub-watershed		S-72	S72	Gravity	A*
Indian Prairie Sub-watershed		S-84	S84	Gravity	Grab
Indian Prairie Sub-watershed		S-127 (Pump)	S127	Pump	Grab
Indian Prairie Sub-watershed		S-127 (Spillway)	S127	Gravity	Grab
Indian Prairie Sub-watershed		S-129 (Pump)	S129	Pump	Grab
Indian Prairie Sub-watershed		S-129 (Spillway)	S129	Gravity	Grab
Indian Prairie Sub-watershed		S-131 (Pump)	S131	Pump	Grab
Indian Prairie Sub-watershed		S-131 (Spillway)	S131	Gravity	Grab
Fisheating Creek/Nicodemus Slough	Fisheating Creek	FISHCR	FECSR78	Gravity	Grab
West Lake Okeechobee	S-4 / Industrial Canal	EPD-07	EPD-07	Pump	Grab
West Lake Okeechobee	S-4 / Industrial Canal	S-310	S310	Gravity	Grab
West Lake Okeechobee	S-4 / Industrial Canal	S-169	S169	Gravity	Grab
West Lake Okeechobee	S-4 / Industrial Canal	S-4	S4	Pump	Grab
West Lake Okeechobee	S-4 / Industrial Canal	S-235	S235	Gravity	Grab
West Lake Okeechobee	East Caloosahatchee	S-77	S77	Gravity	Grab
West Lake Okeechobee	East Caloosahatchee	S-78	S78	Gravity	Grab
West Lake Okeechobee	East Caloosahatchee	CULV5A	CULV5A	Gravity	Grab
South Lake Okeechobee	EAA	See 40E-61, F.A.C.			
South Lake Okeechobee	Ch 298 Districts	C-10	C-10	Pump	Grab (Note 3)
South Lake Okeechobee	Ch 298 Districts	C-12	C-12	Pump	Grab (Note 3)
South Lake Okeechobee	Ch 298 Districts	C-12A	C-12A	Pump	Grab (Note 3)
South Lake Okeechobee	Ch 298 Districts	C-4A	C-4A	Pump	Grab (Note 3)
South Lake Okeechobee	Ch 298 Districts	S-236	S-236	Pump	Grab (Note 3)

Notes:

* A = autosampler primary method, grab sample back-up

- (1) TP concentrations for S-5AW, S-5AS and S-5AE were calculated based on the algorithm described in Appendix A.
- (2) TP concentrations for City of WPB No. 2 are set to the cumulative basin flow-weighted mean inflow TP concentration.
- (3) The EPD data is collected by daily grabs on flow composited for the sampling period. (J Madden e-mail 9/16/2011)

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**APPENDIX D – ESTIMATION OF NUTRIENT LOAD
REDUCTIONS RESULTING FROM IMPLEMENTATION OF
COLLECTIVE SOURCE CONTROL PROGRAMS IN BASINS
WITH LOAD BASED PERFORMANCE MEASURES IN THE
LAKE OKEECHOBEE WATERSHED**

This appendix provides additional clarification on the technical sources, methods and assumptions for estimating source control effectiveness for the S-133, S-154, S-191, Lower Kissimmee, L-8, Indian Prairie, Fisheating Creek, S-4/Industrial Canal, and East Caloosahatchee basins. Details on the methods to estimate the nutrient reductions for the C-44 Hydrologic Unit are described in Appendix A of Deliverable 6.1 “Data Analysis and Performance Measure Development for the St. Lucie River Watershed Source Control Program.” (HDR, Inc. 2011).

In order to estimate nutrient load reductions resulting from the implementation of the collective source control programs, reductions were developed for each land use based on technical documentation and expert best professional judgment. Reductions were estimated for BMPs and source control programs that were not implemented during the base period. To estimate the collective reduction, the reduction for each land use was weighted based on the land use acreage and land use unit load.

For validation, land uses between the base period and the most current period for which land use breakdown is available were compared to determine if there were substantial differences affecting the weighted effectiveness. Loads between the base period and current conditions were also compared to determine if statistical differences existed that warranted adjustment, e.g., if land uses conversions did not appear substantial based on acreage but could have affected loading contributions.

Finally, the nutrient load reduction percentage was rounded to the closest 5 percent increment recognizing the inherent uncertainty of the data. The nutrient loads after the reductions were applied were reviewed to determine whether these levels appeared reasonable based on reductions from other source control programs.

The following information is presented in this report:

1. Land use data for the historical and current conditions.
2. Unit area load coefficients that were used for this analysis and how they were developed through an iterative process beginning with their initial development in 2003 in support of the Lake Okeechobee Protection Plan through 2008 when they





- 6389 were modified for use in the St. Lucie River and Caloosahatchee Watershed River
- 6390 Protection Plans.
- 6391 3. Descriptions of the estimates of source control reductions utilized for each land use
- 6392 category and how they were developed in support of the watershed protection plans.
- 6393 4. Descriptions of how the appropriate land use data, unit area loads, and source control
- 6394 reductions for each land use category were used in spreadsheet models that calculated
- 6395 the total nutrient load reductions for each basin.

Land Uses

6396

6397 The initial step in this procedure was to determine the land use distribution for each basin for

6398 its base period, so that estimated land use specific unit total phosphorus (TP) loads could be

6400 applied. First, the availability and quality of the land use data had to be evaluated. A series

6401 of land use/ land cover (LCLU) maps have been produced by the South Florida Water

6402 Management District (SFWMD) since the early 1970s representing the following points in

6403 time:

6404

- 6405
- 6406 • 1972
- 6407 • 1988
- 6408 • 1995
- 6409 • 1999
- 6410 • 2004
- 6411 • 2008

6412

6413 After reviewing these land use datasets, the 1995 dataset was selected for the reduction

6414 calculations. The 1995 land use coverage was nearest to the time range of the base periods

6415 (**Table D-1**). This dataset was complemented with data from the St. Johns River Water

6416 Management District and Southwest Florida Water Management District, for the Upper

6417 Kissimmee and Lake Istokpoga Sub-watershed areas outside the SFWMD boundaries.

6418

6419 Once the 1995 land use coverage for the entire Lake Okeechobee Watershed was completed,

6420 it was overlaid with the GIS coverages of the Okeechobee Sub-watersheds and summary

6421 basins in order to generate a detailed land use distribution table for each basin (see Excel

6422 spreadsheets LU_SummaryBasins.xlsx and LU_Watersheds.1995.xlsx in **Attachment 1**).

6423 Standard ArcMap tools were used to complete this task.

6424

6425

6426

6427

6428

6429





6430 **Table D-1. Sub-watersheds and Basins Performance Measure Base Periods**

Sub-watershed	Basin	Base Period
Taylor Creek – Nubbin Slough	S-133	WY1977 – 1986
	S-154	WY1977 – 1984
	S-191	WY1977 – 1988
Lower Kissimmee	N/A	WY1977 – 1990
East Lake Okeechobee	C-44	WY2000 – 2010
	L-8 (C-10A)	WY1995 – 2003
Indian Prairie	N/A	WY1989 – 2001
Fisheating Creek-Nicodemus Slough	Fisheating Creek	WY1998 – 2008
West Lake Okeechobee	S-4/Industrial Canal	WY1993 – 2001
	East Caloosahatchee	WY1982 - 1990

6431
6432 **Table D-2** provides the land use areas in each of the basins for 1995 and 2008. In general,
6433 the land use that experienced the greatest decline in acreage was natural areas. The land use
6434 with the greatest gain was urban. However, there were not substantial differences affecting
6435 the weighted effectiveness between 1995 and the 2008 land use acreages, nor statistical
6436 significant differences in the loads observed during the baseline periods, including those
6437 dating back to 1977.

6438
6439 **Unit Area Loads and BMP Effectiveness – Current Project**

6440 The major parameters that this analysis depends on are TP unit area loads (UALs) for the
6441 various land uses. Percent reductions expected to result from source control measures on a
6442 particular land use are applied to the UALs for that land use. UALs represent the annual
6443 average nutrient loads per unit area discharged in runoff. The UALs are typically presented
6444 in lbs/ac/yr and are calculated by multiplying daily concentration by daily flow, summing
6445 over the water year, and dividing by the land area of the respective land use. It is recognized
6446 that UALs will be different for each time period and for different areas with similar land uses
6447 due to many factors including variability in rainfall, runoff, nutrient soil concentrations, and
6448 management practices. However, the weighting effect of the UALs provides for a ratio of
6449 contribution among the land uses, which can proportionally change from year to year. The
6450 combined effect of these variables is reflected in the observed UALs, Unit Area Flows
6451 (UAFs), and concentrations recorded at the monitoring locations for each basin.

6452
6453 The UALs and source control reductions used in this analysis are based on those that were
6454 initially developed in 2003 (Bottcher and Harper, 2003) and then incrementally refined in
6455 subsequent reports (Bottcher, 2006 and SWET, 2008). The UALs have been based on the
6456 results of prior studies to the extent possible, but it was also necessary to apply expert best
6457 professional judgment. The iterative process of developing the UALs used for this analysis is
6458 described below.





Table D-2¹. 1995 and 2008 land use acreages by basin.

Land use	S-133		S-154		S-191		Lower Kissimmee		L-8		Indian Prairie		Fisheating Creek		S-4/Industrial Canal	
	1995	2008	1995	2008	1995	2008	1995	2008	1995	2008	1995	2008	1995	2008	1995	2008
Abandoned Tree Crops	0	0	0	18	0	250	0	12	0	2,179	0	73	0	5	0	0
Aquaculture	11	5	0	0	35	90	0	24	0	0	205	306	60	62	0	0
Cattle Feeding Operations	0	0	0	0	0	628	0	498	0	0	0	0	0	0	0	0
Citrus	159	123	0	0	2,782	2,768	12,123	10,064	8,003	113	30,756	30,167	11,029	7,554	151	39
Communications and Utilities	0	43	0	0	73	76	0	37	2,248 ²	1,443	0	19	91	14	170	107
Dairies	20	0	1,728	767	6,848	3,494	4,347	1,795	0	0	393	0	0	18	34	0
Fallow-Crop Land	0	0	158	0	589	86	1,370	429	345	2,441	1,182	1,170	725	741	42	0
Field Crops	0	355	420	817	1,418	3,397	2,674	15,540	0	93	2,143	393	1,817	732	72	0
Field Crops - Sugar cane	0	0	0	0	0	0	0	0	6,094	9,751	0	19,207	0	1	31,929	32,371
Horse Farms	0	143	109	38	54	240	609	265	285	360	53	25	20	0	0	0
Improved Pasture	10,864	8,524	17,020	17,921	60,013	67,590	138,849	128,001	0	489	120,064	121,134	81,983	95,152	1,859	883
Natural Areas ²	4,615	3,371	5,942	5,234	27,592	15,230	149,724	95,431	65,818	62,929	64,512	44,547	119,120	96,655	2,285	2,011
Ornamentals	0	16	0	0	68	51	12	17	7	158	9	55	164	391	35	19
Other Groves	0	33	0	0	0	60	0	9	0	0	15	53	6	41	20	0
Poultry Feeding Operations	0	0	0	0	0	72	0	0	0	0	0	40	0	5	0	0
Residential High Density	624	60	136	0	0	0	33	25	0	0	96	0	0	0	0	75
Residential Low Density	1,729	1,666	2,054	1,374	4,597	4,786	1,883	4,152	18,998	20,049	2,279	1,874	2,280	2,275	345	574
Residential Medium Density	2,511	2,796	164	781	680	242	130	35	171	167	308	394	7	130	1,724	1,537
Row Crops	0	0	378	9	1,897	262	5,033	5,165	23	21	1,694	1,168	995	19	156	0
Sod Farms	0	1,521	0	0	0	0	267	0	0	0	2,086	0	555	737	179	0
Transportation	653	222	305	156	52	314	2,834	239	0	9	446	127	775	610	350	330
Tree Plantations	0	0	0	0	0	55	11,031	58	0	0	59	404	24,471	19,718	0	0
Unimproved Pastures	862	1,078	323	2,091	6,658	6,603	21,889	43,295	2,337	33	30,285	24,212	21,053	35,908	0	0
Urban ³	1,741	2,751	287	354	291	899	1,128	50,816	147	364	976	970	100	293	1,240	2,563
Water	981	762	195	133	1,675	654	4,297	3,283	1,074	2,862	4,360	2,887	965	808	1,428	739
Woodland Pastures/Rangeland	397	2,147	2,297	1,881	2,957	11,331	76,837	69,986	98	1,723	14,660	27,081	32,395	36,186	51	445

¹The landuse acreages for the C-44 basin are reported in Appendix A of Deliverable 6.1 "Data Analysis and Performance Measure Development for the St. Lucie River Watershed Source Control Program" (HDR Inc. 2011).

²Includes all categories that comprise Natural Areas except Water (FLUCCS Code 5000).

³Includes all categories that comprise Urban except the Residential landuses (FLUCCS Code 1100, 1200, and 1300).

⁴The L-8 basin acreage was calculated by taking the original acreage for each landuse and subtracting Basin 8's acreages from L-8. In the original landuse acreages for L-8 only transportation had an acreage greater than zero, so the acreages listed in this table reflect the original L-8 transportation acreage minus the acreage that Basin 8's transportation landuse consisted of.





6460 Letter Report Entitled: Estimation of Best Management Practices and Technologies
6461 Phosphorus Reduction Performance and Implementation Costs in the Northern Lake
6462 Okeechobee Watershed, October 2003 (Bottcher and Harper, 2003)
6463

6464 This letter report contained estimates of UALs for agricultural and urban land uses and
6465 estimates of TP load reductions that could be expected to result from implementation of best
6466 management practices (a.k.a. source control programs). The information presented in the
6467 report was based on prior studies to the extent possible. However, due the limitations of
6468 available documentation, it was also necessary to apply the expert best professional judgment
6469 of the authors, Dr. Del Bottcher and Dr. Harvey Harper. The UALs and TP load reductions
6470 were developed based on conditions that existed for the 2003 timeframe and are presented in
6471 Table D-3 (see the column labeled, "Existing Unit Load (lbs-P/ac/yr)").
6472

6473 Table D-3. Table 1 From Bottcher and Harper, 2003: Estimates of TP UAL and load
6474 reductions expected from implementation of source control programs in the Lake
6475 Okeechobee Watershed.
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FLUCCS Description	Acres	% of Total Landuse Area	Existing Unit Load (lbs-P/ac/yr)	Total P Load (tons)	Estimated % Reduction	Total P after Reduction (tons)
Primary Agricultural Land Use						
Improved Pastures	431,391	36.24%	0.72	155	30	109
Unimproved Pastures	70,927	5.96%	0.27	10	20	8
Woodland Pastures	8,652	0.73%	0.27	1	20	1
Rangeland	110,579	9.29%	0.23	13	20	10
Urban	27,280	2.29%	0.66	9	30	6
Dairies	29,084	2.44%	3.38	49	32	33
Citrus	54,763	4.60%	1.62	44	40	27
Field Crops - Sugarcane	16,586	1.39%	0.63	5	25	4
Sod Farms	10,652	0.89%	2.52	13	40	8
Row Crops	7,024	0.59%	6.30	22	60	9
SUM OF "Primary Ag Land Uses"	766,938	64.43%	Subtotal	322	33	215
Other Land Uses						
Field Crops	3,000	0.25%	0.50	1	10	1
Fruit Orchards	6,665	0.56%	0.50	2	10	1
Other Groves	16	0.00%	0.50	0	10	0
Poultry Feeding Operations	49	0.00%	0.50	0	10	0
Tree Nurseries	411	0.03%	0.50	0	10	0
Ornamentals	7,320	0.61%	0.50	2	10	2
Floriculture	21	0.00%	0.50	0	10	0
Horse Farms	310	0.03%	0.50	0	10	0
Aquaculture	833	0.07%	0.50	0	10	0
Fallow Crop Land	2,477	0.21%	0.50	1	10	1
Upland Forests	115,989	9.74%	0.50	29	0	29
Pine Plantation	32,600	2.74%	0.18	3	11	3
Water	12,966	1.09%	0.50	3	0	3
Wetlands	224,117	18.83%	0.50	56	0	56
Barren Land	10,646	0.89%	0.50	3	0	3
Transportation, Communication, and Utilities	5,907	0.50%	0.50	1	0	1
Special Classifications	0	0.00%	0.50	0	0	0
SUM OF "Other Land Use"	423,326	35.57%	Subtotal	101	1	100
Grand Total	1190264	100.00%		423	25	314

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6482 **Letter Report Entitled: Phosphorus Reduction Performance and Implementation Costs**
6483 **under BMPs and Technologies in the Lake Okeechobee Protection Plan Area, August**
6484 **2006 (Bottcher, 2006)**
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6486 In 2006, the work performed in the 2003 Letter Report (Bottcher and Harper) was re-
6487 evaluated and refined. A workshop was held with experts having specific knowledge of
6488 agricultural practices and water quality in the Lake Okeechobee Watershed. The following
6489 individuals participated:

- 6490 • Dr. Joyce Zhang, SFWMD
- 6491 • Drs. Don Graetz and Tom Obreza (Soil Science, University of Florida (UF))
- 6492 • Drs. Roger Nordstedt, Ken Campbell, and Sanjay Shukla (ABE, UF)
- 6493 • Dr. Ed Hanlon (Director, SWFREC, UC)
- 6494 • Dr. Patrick Bohlen, Director of Research, MacArthur Agro-ecology Research Center
- 6495 • Dr. Ike Ezenwa (Agronomy, UF) was not present at the workshop but provided input
6496 afterwards on sand-land sugarcane production practices.

6497
6498 The workshop participants agreed upon the following refinements to UALs and estimates of
6499 source control TP load reductions.

- 6500
- 6501 1. Table 1 from the 2003 letter report was reorganized to eliminate confusion for the
6502 listed primary land uses. Also, one of the land uses “ornamentals”, which was
6503 previously under “other land uses”, was considered significant enough to be analyzed
6504 separately during this assessment.
- 6505 2. The stormwater retention and wetland restoration BMPs were separated with
6506 significantly less emphasis being placed on wetland restoration P reductions due to
6507 recent field data that showed these restoration projects are less effective than
6508 originally thought. Two important assumptions were: 1) stormwater retention
6509 systems will not impact in-field water tables, and 2) retention ponds are not
6510 constructed on fields with historical high P levels or if they are, the land is treated
6511 with alum prior to flooding.
- 6512 3. New UALs and BMP reductions were developed for “unimproved pastures” to
6513 differentiate them from “range/woodland pastures”. The workshop group agreed that
6514 the typical definition of unimproved pasture has animal densities and grass and
6515 fertility practices somewhere in between the improved and range/woodland pastures
6516 categories. Table values were adjusted accordingly.
- 6517 4. The land use category of “ornamentals” was added and assumed to be an intensive
6518 ornamental nursery operation, but it is recognized that ornamental field crops, such as
6519 caladiums, may also be mapped under this category. It was suggested that the “row
6520 crops” land use category include ornamental field crops.





- 6521 5. An assessment table for the land use category of field crops was added and assumed
6522 to be a hay field that is fertilized with P. The workshop group helped develop
6523 estimates for existing and BMP P reduction and cost estimates.
6524 6. The workshop group found the previous P fertilizer rates for “citrus” to be high
6525 because P fertilization on citrus typically only occurs over the first few years after
6526 planting. This change significantly reduced the potential P reductions for the fertility
6527 BMP.
6528 7. A “natural areas” category was broken out from “other land uses” and included,
6529 “upland forests”, “water”, “wetlands”, “barren land”, “open land”, “transportation,
6530 communication, and utilities”, and “special classifications” land use categories.
6531 8. There were a few other minor changes made to TP reduction ranges and typical
6532 values and the estimated costs of implementation suggested by the workshop group.
6533 Most of these changes were associated with stormwater retention and the fertility
6534 BMP.
6535 9. An assessment table was also developed for the urban land use category because of
6536 this land use’s importance in any watershed BMP implementation programs.
6537

6538 **Table D-4** presents the UALs and TP load reductions expected to result from implementation
6539 of source control programs developed in the 2006 report. It addresses the northern Lake
6540 Okeechobee Watershed, except for the Upper Kissimmee Sub-watershed.
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Table D-4. Table 1 From Bottcher, 2006, UALs and TP reductions.

Landuse Category	FLUCCS	FLUCCS Description	Unit Load (lbs/acre/ yr)	Owner Implemented BMPs (1)	Typical Cost Share BMPs	Alternative Practices
Urban	1009	Mobile Home Units	0.66	3%	0%	0%
	1100	Residential Low Density				
	1200	Residential Medium Density				
	1300	Residential High Density				
	1400	Commercial and Services				
	1500	Industrial				
	1600	Extractive				
	1700	Institutional				
	1800	Recreational				
Improved Pastures	2110	Improved Pastures	0.72	11%	19%	49%
Unimproved Pastures	2120	Unimproved Pastures	0.49	7%	13%	44%
Woodland Pastures/Rangeland	2130/3000	Woodland Pastures/Rangeland	0.27	4%	6%	35%
Row Crops	2140	Row Crops	6.30	30%	30%	50%
Sugarcane	2156	Field Crops - Sugarcane	0.83	10%	23%	52%
Citrus	2210	Citrus	1.62	12%	20%	42%
Sod / Turf	2420	Sod Farms	2.52	20%	27%	50%
Ornamentals	2430	Ornamentals	4.10	32%	35%	50%
Dairies	2520	Dairies	3.38	9%	28%	48%
Pine Plantations	4400	Tree Plantations/Pine	0.18	1%	10%	50%
Dairies in non-priority basins		Dairies in Istokpoga and Caloosahatchee	0.17	2%	30%	48%
Natural Areas	4000	Upland Forests (not including 4400's)	0.20	0%	0%	0%
	5000	Water				
	6000	Wetlands				
	7000	Barren Land				
	1900	Open Land				
	8000	Transportation, Communication, and Utilities				
	9000	Special Classifications				
Other Areas	2150	Field Crops	0.70	10%	0%	0%
	2230	Other Groves				
	2220	Fruit Orchards				
	2320	Poultry Feeding Operations				
	2410	Tree Nurseries				
	2450	Floriculture				
	2510	Horse Farms				
	2540	Aquaculture				
2610	Fallow Crop Land					

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Nutrient Loading Rates, Reduction Factors and Implementation Costs Associated with BMPs and Technologies, July 2008

This report was prepared in support of the St. Lucie River and Caloosahatchee River Watershed Protection Plans. Its purpose was to estimate TP and total nitrogen (TN) load reductions in both watersheds that could be expected to result from implementation of source control programs. Seven additional land use categories were added to replace the “urban” category; “low density residential”, “medium density residential”, “high density residential”, “horse farms”, “transportation”, “utilities”, and “other urban”. This created a total of 20 land use categories. Land uses were further broken down within the 20 primary categories for refinement of UALs. However, the final results were reported by aggregating the results of the individual land uses into the 20 primary categories.





6559 Initial UALs were based on those developed by Bottcher (2006) as described above, general
6560 Florida estimates by Harper and Baker (2003 and 2007), and data collected within the St
6561 Lucie River Watershed by Graves, et al (2004). Since UALs are a function of both
6562 concentration and flow, it was first necessary to establish reasonable unit area runoff (UAR)
6563 coefficients in inches/acre/year for each land use category (Harper and Baker, 2007). The
6564 resulting calculated average annual runoff for the period 1995 – 2005 was within 1% of the
6565 measured flow volume from the watershed to the St Lucie Estuary.
6566

6567 The final TP UALs were developed by iteratively adjusting the initial UALs using a
6568 spreadsheet to calculate the total loads from the watershed based on the UALs, and land use
6569 acreages. The UALs were iteratively adjusted until the calculated and measured values for
6570 flow, load, and concentration were reasonably close. Adjustments to the TP UALs were
6571 made for individual land uses, and then a global adjustment factor was used to obtain a
6572 reasonable agreement between the calculated and measured values. **Tables D-5 and D-6**
6573 present TP UALs used in the development of the St. Lucie River and Caloosahatchee River
6574 Watershed Protection Plans, respectively.
6575

6576 The primary sources of agricultural BMP information were research and extension reports
6577 completed by Institute of Food and Agriculture Sciences, University of Florida (IFAS, UF) in
6578 association with various state agencies and grower groups, while urban BMP information
6579 was primarily from summary reports by Environmental Research and Design, Inc. and
6580 University of Central Florida. For citrus, the studies by Brian Bowman and David Calvert at
6581 the Indian River Research and Education Center and Ashok Alva and S. Paramasivam at the
6582 Citrus Research and Education Center were primarily used. For cow-calf production, studies
6583 by Paul Mislevy and F.G. Martin at the Cattle Research Station in Ona and by Joyce Zhang,
6584 Jeff Hiscock, Del Bottcher, B.M. Jacobson, and Patrick Bohlen at Buck Island Ranch were
6585 primarily used. Vegetable production BMPs were reviewed from research studies across the
6586 state, but focused mostly on work out of IFAS' Gulf Coast (Immokalee) and the old
6587 Bradenton Research and Education Centers.
6588

6589 Though many of the research studies focused more on crop production responses to
6590 management practices as opposed to water quality responses, their results were very useful in
6591 bracketing the economical feasibility limits for BMPs. To further access the actual water
6592 quality responses, both field studies and hydrologic transport modeling were evaluated. The
6593 Watershed Assessment Model (WAM) model has been used extensively in the Okeechobee
6594 and Caloosahatchee basins to estimate water quality responses to BMPs which may not have
6595 been specifically addressed in the field studies.
6596

6597 A report developed by Dr. Harvey Harper (2003) for the northern Lake Okeechobee
6598 watershed was primarily used for the urban BMPs responses for TP. Load reductions were
6599 estimated on the assumption that specific source controls were being implemented, as





6600 described below for the land use categories with the largest acreage in the watershed (Table
6601 D-7). SWET (2008) indicates that these source control measures (BMPs) represent what
6602 would be expected to be implemented through a reasonably funded cost share program or a
6603 modest regulatory approach. The expected reductions from the ten most common land uses
6604 in the Lake Okeechobee Watershed and the expected nutrient reductions from those land use
6605 types are listed in Table D-8.

6606 **Table D-5. Table 3 from SWET, 2008, Unit Area Loads.**
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Table 3. Estimated Runoff, Unit N and P Loads and Concentration for 2004 Land Uses in the St. Lucie Watershed

Land Use Category	Land Use Description	FLUCCS	Runoff (in/yr)	Unit N Load	N Conc. (mg/l)	Unit P Load (lbs/acre/yr)	P Conc. (mg/l)
Residential Low Density	Residential Low Density ¹	1100	17.57	4.95	1.25	0.49	0.12
Residential Medium Density	Residential Medium Density ²	1200	20.76	7.20	1.53	1.40	0.30
Residential High Density	Residential High Density ²	1300	23.96	10.80	1.99	3.00	0.55
Other Urban	Commercial and Services ²	1400	25.55	9.90	1.71	1.40	0.24
	Industrial ²	1500	27.15	9.00	1.47	2.40	0.39
	Extractive ²	1600	23.96	6.30	1.16	0.66	0.12
	Institutional ²	1700	23.96	6.30	1.16	2.40	0.44
	Recreational ²	1800	17.57	6.30	1.59	0.96	0.24
Improved Pastures	Improved Pastures	2110	19.16	9.99	2.30	1.90	0.44
Unimproved Pastures	Unimproved Pastures	2120	15.97	4.95	1.37	0.92	0.25
Woodland Pastures/Rangeland	Woodland Pastures	2130	15.97	3.69	1.02	0.88	0.24
	Rangeland	3000	15.97	3.69	1.02	0.28	0.08
Row Crops	Row Crops	2140	22.36	13.50	2.67	4.50	0.89
Sugar Cane	Sugar Cane	2156	19.16	7.20	1.66	0.63	0.15
Citrus	Citrus	2210	19.16	7.65	1.76	1.80	0.42
Sod Farms	Sod Farms	2420	19.16	8.10	1.87	2.52	0.58
Ornamentals	Ornamentals	2430	19.16	10.80	2.49	2.90	0.67
Horse Farms	Horse Farms	2510	15.97	14.40	3.99	1.82	0.50
Dairies	Dairies	2520	15.97	18.00	4.98	9.38	2.60
Other Areas	Field Crops	2150	15.97	5.96	1.65	2.96	0.82
	Mixed Crops	2160	19.16	9.90	2.28	3.50	0.81
	Fruit Orchards	2220	19.16	8.10	1.87	2.30	0.53
	Other Groves	2230	19.16	8.10	1.87	2.30	0.53
	Cattle Feeding Operations	2310	19.16	48.65	11.22	8.96	2.07
	Poultry Feeding Operations	2320	19.16	9.00	2.08	1.50	0.35
	Tree Nurseries	2410	15.97	10.80	2.99	2.90	0.80
	Specialty Farms	2500	15.97	7.20	1.99	1.82	0.50
	Aquaculture	2540	7.99	9.00	4.98	0.70	0.39
	Fallow Crop Land	2610	19.16	6.30	1.45	0.70	0.16
Tree Plantations	Tree Plantations	4400	15.97	2.79	0.77	0.18	0.05
Water	Water	5000	3.19	0.81	1.12	0.05	0.07
Natural Areas	Upland Forests (not including 4400's)	4000	14.37	2.25	0.69	0.28	0.09
	Wetlands	6000	1.60	1.35	3.74	0.01	0.03
	Barren Land	7000	23.96	6.30	1.16	0.75	0.14
	Open Land	1900	15.97	3.60	1.00	0.28	0.08
Transportation	Transportation	8100	27.15	8.28	1.35	1.65	0.27
Communication/Utilities	Communications	8200	15.97	5.40	1.49	0.48	0.13
	Utilities	8300	15.97	5.40	1.49	0.48	0.13

1 Assumed on Septic

2 Assumed Discharge from WWT outside basin

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Table D-6. Table 12 from SWET, 2008, Unit Area Loads.

Table 12. Estimated Runoff, Unit N and P Loads and Concentration for 2004 Land Uses in the Caloosahatchee Watershed

Land Use Category	Land Use Description	FLUCCS	Runoff (in/yr)	Unit N Load (lbs/acre/yr)	N Conc. (mg/l)	Unit P Load (lbs/acre/yr)	P Conc. (mg/l)
Residential Low Density	Residential Low Density ¹	1100	27.43	7.26	1.17	0.68	0.11
Residential Medium Density	Residential Medium Density ²	1200	32.42	10.56	1.44	1.93	0.26
Residential High Density	Residential High Density ²	1300	39.90	15.84	1.75	4.14	0.46
Other Urban	Commercial and Services ²	1400	39.90	14.52	1.61	1.93	0.21
	Industrial ²	1500	42.39	13.20	1.38	3.31	0.35
	Extractive ²	1600	37.41	9.24	1.09	0.91	0.11
	Institutional ²	1700	37.41	9.24	1.09	3.31	0.39
	Recreational ²	1800	27.43	9.24	1.49	1.32	0.21
Improved Pastures	Improved Pastures	2110	29.93	14.65	2.16	1.93	0.29
Unimproved Pastures	Unimproved Pastures	2120	24.94	7.26	1.29	0.99	0.18
Woodland Pastures/Rangeland	Woodland Pastures	2130	24.94	5.41	0.96	0.83	0.15
	Rangeland	3000	19.95	5.41	1.20	0.25	0.06
Row Crops	Row Crops	2140	34.91	19.80	2.51	3.45	0.44
Sugar Cane	Sugar Cane	2156	29.93	10.56	1.56	0.55	0.08
Citrus	Citrus	2210	29.93	11.22	1.66	0.90	0.13
Sod Farms	Sod Farms	2420	29.93	11.88	1.75	2.79	0.41
Ornamentals	Ornamentals	2430	29.93	15.84	2.34	4.00	0.59
Horse Farms	Horse Farms	2510	24.94	21.12	3.74	2.51	0.45
Dairies	Dairies	2520	24.94	26.40	4.68	12.94	2.29
Other Areas	Field Crops	2150	24.94	8.74	1.55	4.09	0.73
	Mixed Crops	2160	29.93	14.52	2.14	4.83	0.71
	Fruit Orchards	2220	29.93	11.88	1.75	3.17	0.47
	Other Groves	2230	29.93	11.88	1.75	3.17	0.47
	Cattle Feeding Operations	2310	29.93	71.35	10.54	12.37	1.83
	Poultry Feeding Operations	2320	29.93	13.20	1.95	2.07	0.31
	Tree Nurseries	2410	24.94	15.84	2.81	4.00	0.71
	Specialty Farms	2500	24.94	10.56	1.87	2.51	0.45
	Aquaculture	2540	12.47	13.20	4.68	0.97	0.34
	Fallow Crop Land	2610	29.93	9.24	1.36	0.97	0.14
Tree Plantations	Tree Plantations	4400	14.96	4.09	1.21	0.21	0.06
Water	Water	5000	4.99	1.19	1.05	0.07	0.06
Natural Areas	Upland Forests (not including 4400's)	4000	14.96	3.30	0.97	0.10	0.03
	Wetlands	6000	7.48	1.98	1.17	0.01	0.01
	Barren Land	7000	37.41	9.24	1.09	1.04	0.12
	Open Land	1900	24.94	5.28	0.94	0.39	0.07
Transportation	Transportation	8100	49.88	12.14	1.08	2.28	0.20
Communication/Utilities	Communications	8200	27.43	7.92	1.28	0.66	0.11
	Utilities	8300	24.94	7.92	1.40	0.66	0.12

1 Assumed on Septic

2 Assumed about 70% of Discharge from WWT outside basin

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Table D-7. BMPs assumed to be implemented for estimates of nutrient load reductions (based on Botticher 2008)¹.

Land Use	Citrus		Improved Pastures	Residential and Urban	Dairies	Other agriculture
	1995	2008	22.4 %	6.9 %	0.5 %	18.3 %
Watershed acreage Percentage	7.0 %	4.6 %	21.4 %	13.0 %	0.2 %	23.3 %
Nutrient Mgt	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • P: Soil testing • Includes implementation of biosolids rule, the animal manure implementation rule, and the septage application rule • Includes implementation of biosolids rule (timing & placement, fertigation) • Spill prevention <p><i>High End:</i></p> <ul style="list-style-type: none"> • Slow release fertilizer 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • P: Soil testing • Includes implementation of biosolids rule, the animal manure implementation rule, and the septage application rule • Spill prevention • Grass management² and rotational grazing • Reduced cattle density • Alternate water sources, shade, restricted placement of feeders, supplements, and water, fencing <p><i>High End:</i></p> <ul style="list-style-type: none"> • Slow release fertilizer 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Reduced fertilization in accordance with the Urban Turf Fertilizer Rule • Controlled application (timing & placement) • Spill prevention <p><i>High End:</i></p> <ul style="list-style-type: none"> • Florida Friendly Landscape 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • P: Soil testing • CAFO rule, • Feed management • Grass management² and rotational grazing • Improved forage/sprayfield management - P balanced with high P uptake crop rotations <p><i>High End:</i></p> <ul style="list-style-type: none"> • Solids separation for offsite disposal • Add housing to move animals off field³ 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Storm water detention/retention because of improved irrigation and drainage, flooded fields, and riser board control or ERP permitted systems <p><i>High End:</i></p> <ul style="list-style-type: none"> • Wetland restoration 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Storm water detention/retention because of improved irrigation and drainage, flooded fields, and riser board control or ERP permitted systems <p><i>High End:</i></p> <ul style="list-style-type: none"> • Wetland restoration
Water Mgt	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Storm water detention/retention because of improved irrigation and drainage or ERP permitted systems <p><i>High End:</i></p> <ul style="list-style-type: none"> • Water reuse from existing retention/detention ponds • Wetland restoration 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Wetland restoration • Retention basin by working pens <p><i>High End:</i></p> <ul style="list-style-type: none"> • Stormwater detention/retention 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Dry detention swales (0.25 inch) and wet detention (0.25 inch) <p><i>High End:</i></p> <ul style="list-style-type: none"> • ERP permitted systems, when required • Regional projects for dry detention and wet detention 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Improved Irrigation and Drainage Management • Wetland restoration <p><i>High End:</i></p> <ul style="list-style-type: none"> • Expanded waste storage ponds • Expanded sprayfields • Storm water detention/retention 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Storm water detention/retention because of improved irrigation and drainage, flooded fields, and riser board control or ERP permitted systems <p><i>High End:</i></p> <ul style="list-style-type: none"> • Wetland restoration 	
Particulate Matter and Sediment Controls	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Grass management between trees • Sediment traps³ <p><i>High End:</i></p> <ul style="list-style-type: none"> • Grassed swales 	<p>Note: Grass management will also apply to particulate matter and sediment controls</p>	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Street sweeping • Sediment/baffle boxes 	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Buffer strips <p>Note: Grass management and improved forage/sprayfield management will also apply to particulate matter and sediment controls</p>	<p><i>Typical:</i></p> <ul style="list-style-type: none"> • Cover crops • Sediment traps 	

¹Based on telephone conversation with Dr. Botticher on 08/30/12.

²Includes selecting the appropriate grass variety and mowing to ensure healthy and uniform grass coverage.

³Includes associated waste pond and sprayfield expansions (this BMP would also be considered a Water Management BMP)





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Table D-8. Reduction values from the top 10 land uses based on Bottcher 2006 and SWET 2008 reports

Land Use	Expected Typical TP Reduction
Natural Areas	0
Improved Pasture	30
Urban ¹	10
Citrus	32
Rangeland	20
Unimproved Pasture	10
Sugarcane	33
Tree Plantations	11
Dairies	37
Row Crops	60

¹SWET 2008.

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Lake Okeechobee Watershed TP UALs and BMP Effectiveness

A spreadsheet model, consistent with the models developed for the Lake Okeechobee, Caloosahatchee River, and St. Lucie River Watershed Protection Plans, was used to calculate nutrient loads and reductions that could be reasonably expected from implementation of collective source control programs. The spreadsheet applies the unit area flow and unit area load for each land use to respective land use areas and sums them to calculate basin flows and loads, as indicated below:

- The unit area flow coefficients (expressed in inches/year) developed for each land use in the SWET 2008 report were used as a starting point for this analysis. The unit area flow coefficients were adjusted based on expert best professional judgment for Lake Okeechobee. The unit area flow coefficients were developed to represent the relative differences in flows that would be discharged from each land use. The unit area flow coefficient was multiplied times the number of acres of the corresponding land use to calculate the total flow from each land use. The computed flows from all land uses were then added to calculate the flows from the sub-watershed. A global adjustment factor was applied to each land use coefficient so that the calculated flows matched the measured flows for the sub-watershed.
- The UALs developed for each land use in the SLRWPP from Bottcher 2008 report were used as a starting point for this analysis. The unit area load coefficients were adjusted based on expert best professional judgment. The UAL coefficients used in this analysis were developed to represent the relative differences in nutrient loads that would be discharged from each land use. For example, a land use with a unit area





6644 load of 1 lb/acre/year would discharge half the nutrient load compared to a land use
6645 with a UAL of 2 lb/acre/year.

6646
6647 Since load is a function of flow and concentration, the unit area loads for a given land use
6648 will vary temporally due to variations in rainfall and flow. The average annual flow and
6649 nutrient load measured during the base period were used to adjust the simulated loadings for
6650 each basin.

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6652 **Adjustment Factors to Account for Differences in Source Control Implementation for**
6653 **Current and Base Period Conditions**

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6655 The estimates of source control nutrient load reductions developed in Bottcher 2006 and
6656 SWET 2008 were based on reductions that could be achieved relative to current conditions,
6657 i.e., 1990s forward. For a number of basins, the base periods selected were for a time period
6658 prior to BMP implementation which was prior to 1990. Therefore, Dr. Bottcher provided a
6659 range of reductions that also considered the historical base periods. The consulting team and
6660 the District reviewed reduction ranges for the historical periods and the Bottcher 2006 and
6661 SWET 2008 assumptions and reduction estimates. The reductions were adjusted as
6662 appropriate to account for differences in source control implementation to determine the
6663 recommended value to be used.

- 6664
- 6665 • The S-133, S-154, and S-191 required adjustments due to the extent of source
6666 controls that have been in place since the respective base periods. For example in the
6667 S-191 Basin, source controls on dairies began in the 1970s. In 1987, the FDEP Dairy
6668 Rule required additional source controls on dairies and in 1989, the Lake Okeechobee
6669 Works of the District program began requiring phosphorus control on other land use
6670 types. The adjustments accounted for the reductions from these programs.
 - 6671 • The base period for C-44, L-8, Indian Prairie, Fisheating Creek, S-4/Industrial Canal,
6672 and East Caloosahatchee were all more recent periods and/or areas with more limited
6673 BMP implementation. Therefore, the source control reductions for typical BMPs
6674 developed in the Bottcher 2006 and SWET 2008 reports were used without
6675 adjustment for these basins.
 - 6676 • The Lower Kissimmee had a mix of BMP implementation with earlier
6677 implementation in the southern portion but very limited implementation in the
6678 northern portion so no adjustment was applied.
- 6679

6680 The range of recommended reductions and the recommended reductions for each basin
6681 agreed upon by the consulting team and the District is shown in **Table D-9**; the spreadsheets
6682 associated with the recommended reductions are included in Attachment 1.

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6684 **Table D-9. Range of phosphorus load percent reductions relative to the base period**
6685 **anticipated for each basin.**

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6687

Basin	Low Reduction, %	High Reduction, %	Typical Reduction, %	Recommended Reduction, %
S-133	8	54	38	25
S-154	41	81	68	35 ⁽¹⁾
S-191	42	82	69	40 ⁽¹⁾
Lower Kissimmee	22	72	55	30
C-44	9	51	33	35
L-8	19	51	32	20
Indian Prairie	16	62	41	30
Fisheating Creek	12	51	28	30
S-4/Industrial Canal	16	54	32	30
East Caloosahatchee	33	70	50	30

6688 ⁽¹⁾These two basins are heavily influenced by dairy land use. The team decided to recommend a reduction
6689 below the low end of the range because BMPs such as chemical treatment for dairies were considered when the
6690 range was developed and these are not be considered to be a requirement for a regulatory program.
6691

6692

6693 **Validation of Measured and Simulated Flows and Loads**

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6695 The nutrient load discharged from an acre of any land use will not necessarily equal the load
6696 that reaches the receiving water. There are many potential reasons for this difference. For
6697 example, in-stream assimilation can significantly reduce the nutrient load after it flows from
6698 the source and before it reaches the receiving water, particularly if the flow distance is long
6699 and the stream is shallow with overbank wetlands. Another example is that surface water
6700 may be used for irrigation as it travels downstream from its source to the monitoring location
6701 at the sub-watershed outlet. The parcel to catchment adjustment factor may also account for
6702 variations in soil types and nutrient soil concentrations associated with the sub-watershed.
6703 The Unit flows and UALs are at the parcel level. To account for these differences, a parcel to
6704 basin adjustment factor was estimated for to determine the difference between basin
6705 measured and the parcel simulated flows and loads. While some attenuation is expected
6706 between the parcel and basin discharge levels (parcel loading based on unit flow and UAL
6707 and observed acreage, and basin loading based on measured data), the greater the difference,
6708 would suggest the higher uncertainty in the calculations.





6709 **References**

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- 6711 Bottcher and Harper. 2003. Estimation of Best Management Practices and Technologies
6712 Phosphorus Reduction Performance and Implementation Costs in the Northern
6713 Watershed of Lake Okeechobee. Letter report to South Florida Water Management
6714 District, West Palm Beach, FL.
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- 6719
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6722 *American Water Resources Association*. Paper No. 03194. 1405:1419.
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- 6724 Harper, H. H. 2003. Evaluation of Runoff Load Reductions from Urban Land Uses.
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- 6728 Harper, H. H. and D.M. Baker. 2007. Evaluation of Current Stormwater Design Criteria
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6743 Management District, West Palm Beach, FL.





**APPENDIX E – ADJUSTMENTS TO ACCOUNT FOR
REGIONAL PROJECTS**

1. The Annual Load Target and Annual Load Limit will be adjusted for regional projects according to the following equations.

b. Calculate the area adjustment factor (AAF)

$$AAF = (\text{total basin area minus area of regional project}) / (\text{average area in Base Period})$$

c. Adjust the Annual Load Target for the regional projects

$$\text{adjusted Annual Load Target} = AAF * \text{Annual Load Target}$$

c. Calculate the adjusted Annual Load Limit using basin-specific equations in Section 3 using the adjusted Annual Load Target calculated above.

2. The annual Runoff Load will be adjusted for regional projects according to the following equations.

a. Calculate the regional project load reduction as the annual load entering the regional project from the watershed less the annual load leaving the regional project and returning to the watershed

$$\text{regional project load reduction} = \text{regional project inflow load} - \text{regional project outflow load}$$

a. Calculate the basin's Runoff Load as the load observed at the basin discharge monitoring location(s) minus the pass-through loads

$$\text{Runoff Load} = \text{observed outflow load} - \text{pass-through load}$$

b. Adjust the basin's Runoff Load by the regional project load reduction

$$\text{adjusted Runoff Load} = \text{Runoff Load} + \text{regional projects load reduction}$$

Example

total basin area = 100,000 acres





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6781 area of regional project = 5,000 acres
6782 average area in Base Period = 100,000 acres
6783
6784 $AAF = (\text{total basin area minus area of regional project}) / (\text{average area in Base Period})$
6785
6786 $AAF = (100,000 - 5,000) / (100,000) = 0.95$
6787 Annual Load Target = 20 mt (from prediction equation)
6788 adjusted Annual Load Target = $0.95 * 20.0 \text{ mt} = 19.0 \text{ mt}$
6789 Annual Load Limit = adjusted Annual Load Target + 1.43976 SE (from prediction equation)
6790 Annual Load Limit = $19.0 \text{ mt} + 1.43976 (3.5) = 24.0 \text{ mt}$
6791
6792 regional project inflow load = 8.5 mt
6793 regional project outflow load = 3.5 mt
6794 regional project load reduction = regional project inflow load – regional project outflow load
6795 regional project load reduction = $8.5 \text{ mt} - 3.5 \text{ mt} = 5 \text{ mt}$
6796
6797 adjusted Runoff Load = Runoff Load + regional projects load reduction
6798 Runoff Load = observed outflow load – pass-through load
6799 observed load at basin outlet structures = 16.0 mt
6800 pass-through load = 2.5 mt
6801
6802 Therefore,
6803 adjusted Runoff Load = $16.0 \text{ mt} - 2.5 \text{ mt} + 5 \text{ mt} = 18.5 \text{ mt}$
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ATTACHMENT 1 – Associated Excel Spreadsheets

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The following Excel spreadsheets containing the relevant data analyses are attached by reference to this Draft *Technical Support Document*.

Taylor Creek-Nubbin Slough Sub-watershed spreadsheets:

DRAFT PM1 Stats S-133 - 9 15 2012
DRAFT PM2 Stats S-133 - 9 15 2012
MC 26 S-133 - 8 28 2012
SB-S133_LU_95_UnitLoads_BMPs alt method 3a
DRAFT PM1 Stats S-154 - 9 15 2012
DRAFT PM2 Stats S-154 - 9 15 2012
MC 17 S-154 - 8 28 2012
SB-S154_LU_95_UnitLoads_BMPs alt method 3a

Lower Kissimmee Sub-watershed spreadsheets:

DRAFT PM1 Stats LK - 8 25 2012
DRAFT PM2 Stats LK - 8 25 2012
MC 1 sqrt(L) LK - 8 28 2012
SW-LowerKissimmee_LU_95_UnitLoads_BMPs alt method 4





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6834 East Lake Okeechobee Sub-watershed spreadsheets:

- 6835 DRAFT PM1 Stats C-44 - 9 3 2012
- 6836 DRAFT PM2 Stats C-44 - 8 27 2012
- 6837 MC 3 C-44 - 8 28 2012

6838

- 6839 DRAFT PM1 Stats L8 - 8 25 2012
- 6840 DRAFT PM2 Stats L8 - 8 25 2012
- 6841 MC 8 sqrt(L) L-8 - 8 28 2012

6842 SB-L-8_LU_95_UnitLoads_BMPs - WY95-03 alt method 4

6843

6844 Indian Prairie Sub-watershed spreadsheets:

- 6845 DRAFT PM1 Stats IP - 8 27 2012
- 6846 DRAFT PM2 Stats IP - 9 7 2012
- 6847 MC 6 IP - 9 3 2012

6848 SW-IndianPrairie_LU_95_UnitLoads_BMPs rev1 alt method 4

6849

6850 Fisheating Creek-Nicodemus Slough Sub-watershed spreadsheets:

- 6851 DRAFT PM1 Stats FECR-LP - 8 25 2012
- 6852 DRAFT PM2 Stats FECR-LP - 8 25 2012
- 6853 MC 16 FECRLP - 8 28 2012

6854 SB-FisheatingCreek_LU_95_UnitLoads_BMPs alt method 3a

6855

6856 Lake Istokpoga Sub-watershed spreadsheets:

- 6857 DRAFT PM1 Stats Josephine Cr TP – 12 13 2012
- 6858 DRAFT PM2 Stats Josephine Cr TP – 12 13 2012
- 6859 MC 16 Josephine Cr TP – 1 25 2013

6860 DRAFT PM1 Stats Arbuckle Cr TP – 12 13 2012

6861 DRAFT PM2 Stats Arbuckle Cr TP – 12 13 2012

6862 MC 16 Arbuckle Cr TP – 1 25 2013





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6863 West Lake Okeechobee Sub-watershed spreadsheets:

- 6864 DRAFT PM1 Stats S4IC TP – 9 20 2012
- 6865 DRAFT PM2 Stats S4IC TP - 10 25 2012
- 6866 MC 14 S4IC – 10 30 2012
- 6867 (07-12-12) Revised SB-S-4_LU_95_UnitLoads XP

6868

- 6869 DRAFT PM1 Stats EC TP – 9 20 2012
- 6870 DRAFT PM2 Stats EC TP - 10 25 2012
- 6871 MC 14 EC - 8 28 2012
- 6872 (07-12-12) Revised SB-S-4_LU_95_UnitLoads XP

6873

6874 Upper Kissimmee Sub-watershed spreadsheets:

- 6875 DRAFT PM1 Stats Boggy Cr TP – 11 29 2012
- 6876 DRAFT PM2 Stats Boggy Cr TP – 12 13 2012
- 6877 MC sqrt14 Boggy Cr TP – 1 25 2013
- 6878 DRAFT PM1 Stats Shingle Cr TP – 11 26 2012
- 6879 DRAFT PM2 Stats Shingle Cr TP – 12 13 2012
- 6880 MC 19 Shingle Cr TP – 1 25 2013

6881

