

LAKE OKEECHOBEE WATERSHED

Protection Program

Historical Data Analyses

South Florida Water Management District

August 9, 2013

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SWET, Inc.

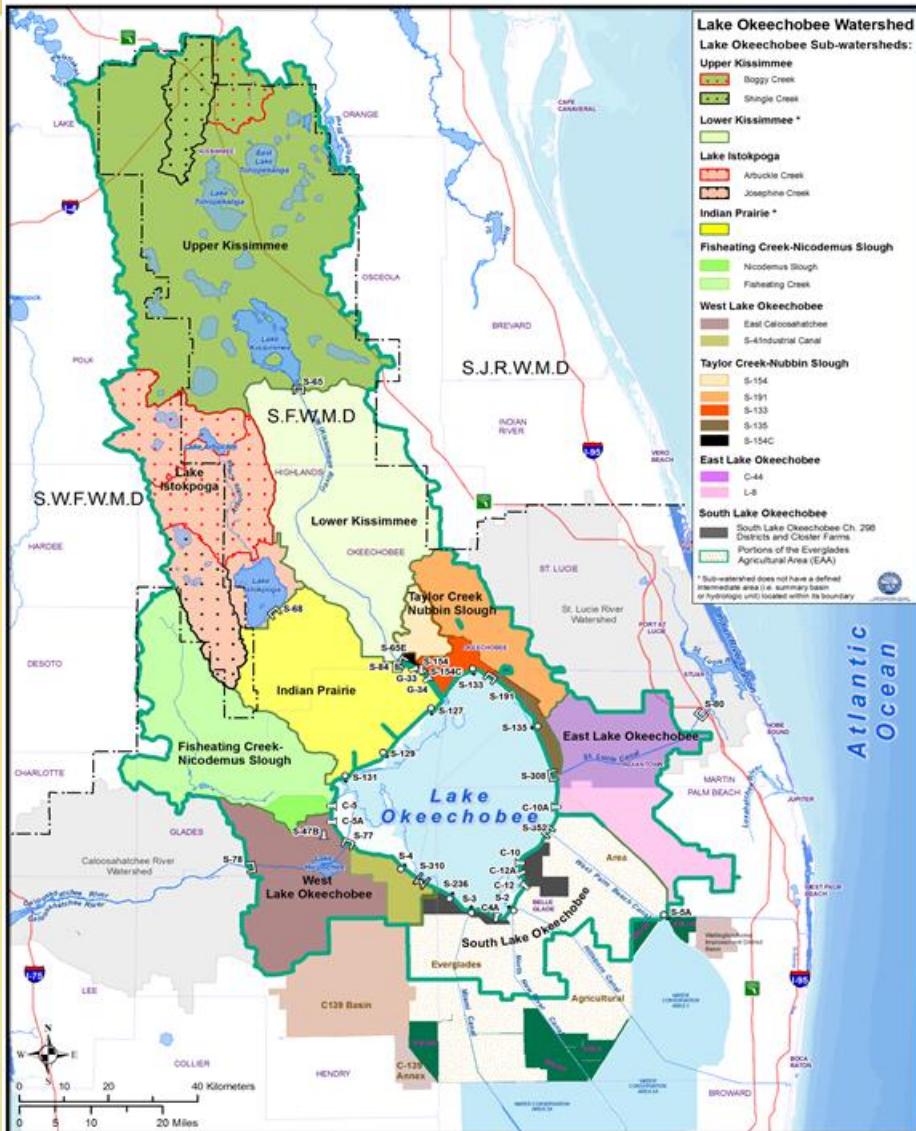
Lewis Hornung, Inc.

Overview

- The objectives of this presentation are
 - to describe the historical data analyses used for establishing performance measures for the SFWMD's collective source control program for the Lake Okeechobee Watershed (LOW).
 - to help identify ways the historical data can be used to support BMAP development and evaluations. For example:
 - Direct use of historical data - over 1.5 million station-days of data analyzed
 - Quantify TP load reductions achieved to date
 - Measure progress towards achieving water quality goals over time

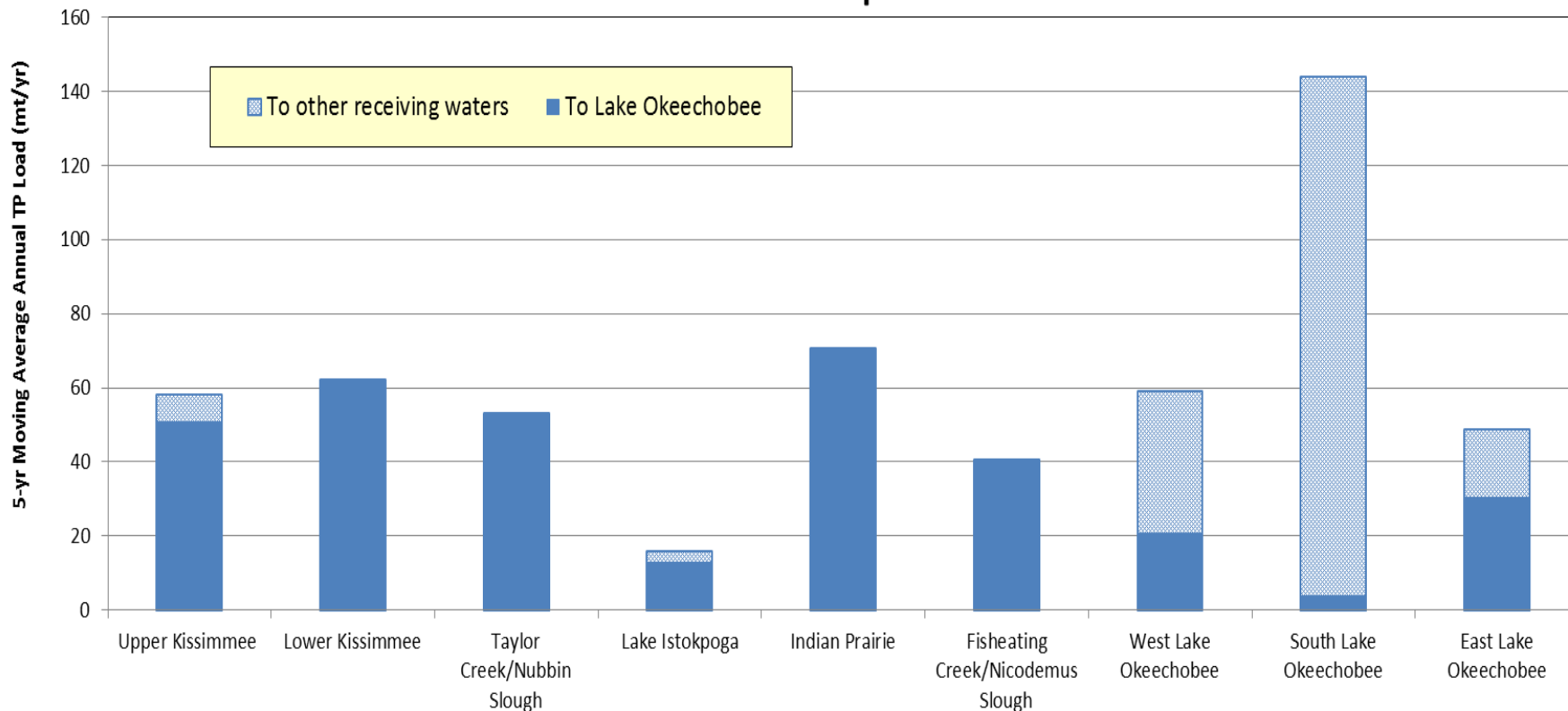
Lake Okeechobee Watershed

- Almost 3.5 million acres of diverse land use, including
 - Municipalities, agriculture, residential, natural lands and wetlands
 - Kissimmee River Restoration Project
 - Regional treatment projects
- Nine sub-watersheds
 - Numerous hydrologic units, including basins that discharge both to Lake and coastal estuaries, addition of Upper Kissimmee Sub-watershed, Ch. 298 districts, portions of the Everglades Agricultural Area (EAA)



TP Loads from Lake Okeechobee Sub-watershed

Average annual loads from Lake Okeechobee Sub-watersheds for the WY2008-2012 period

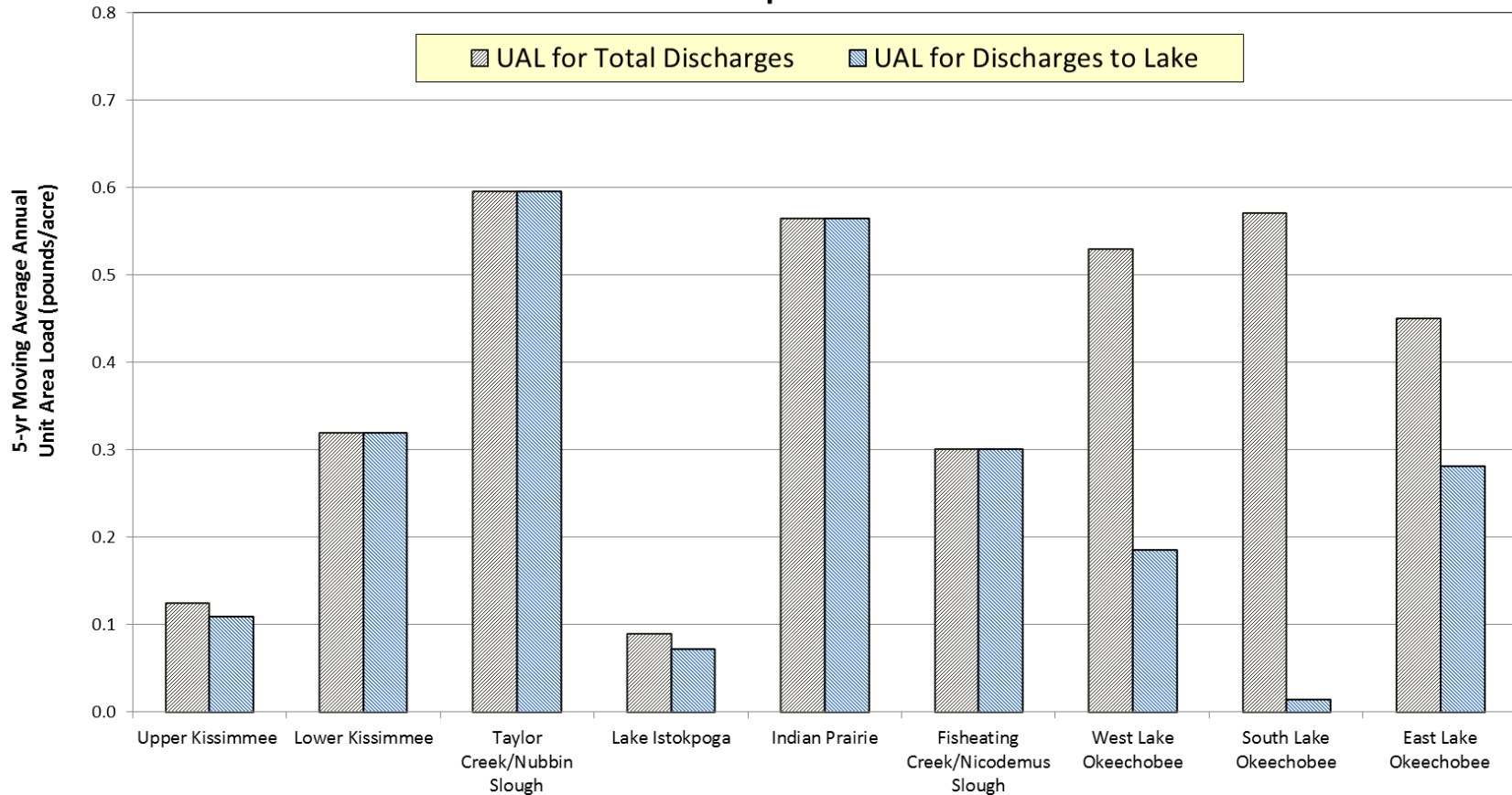


- Notes: 1. Upper Kissimmee Sub-watershed includes Shingle Creek (13.0 mt/yr) and Boggy Creek (3.1 mt/yr).
 2. Lake Istokpoga Sub-watershed includes Arbuttle Creek (24.1 mt/yr) and Josephine Creek (1.8 mt/yr).
 3. Loads for South Lake Okeechobee include discharges from areas outside the Sub-watershed boundary.

Unit Area TP Loads by Sub-watershed

5-yr Moving Average TP Unit Area Loads (UALs) from the Lake Okeechobee Sub-watersheds for the period WY2008-2012

REVISED
1/2014



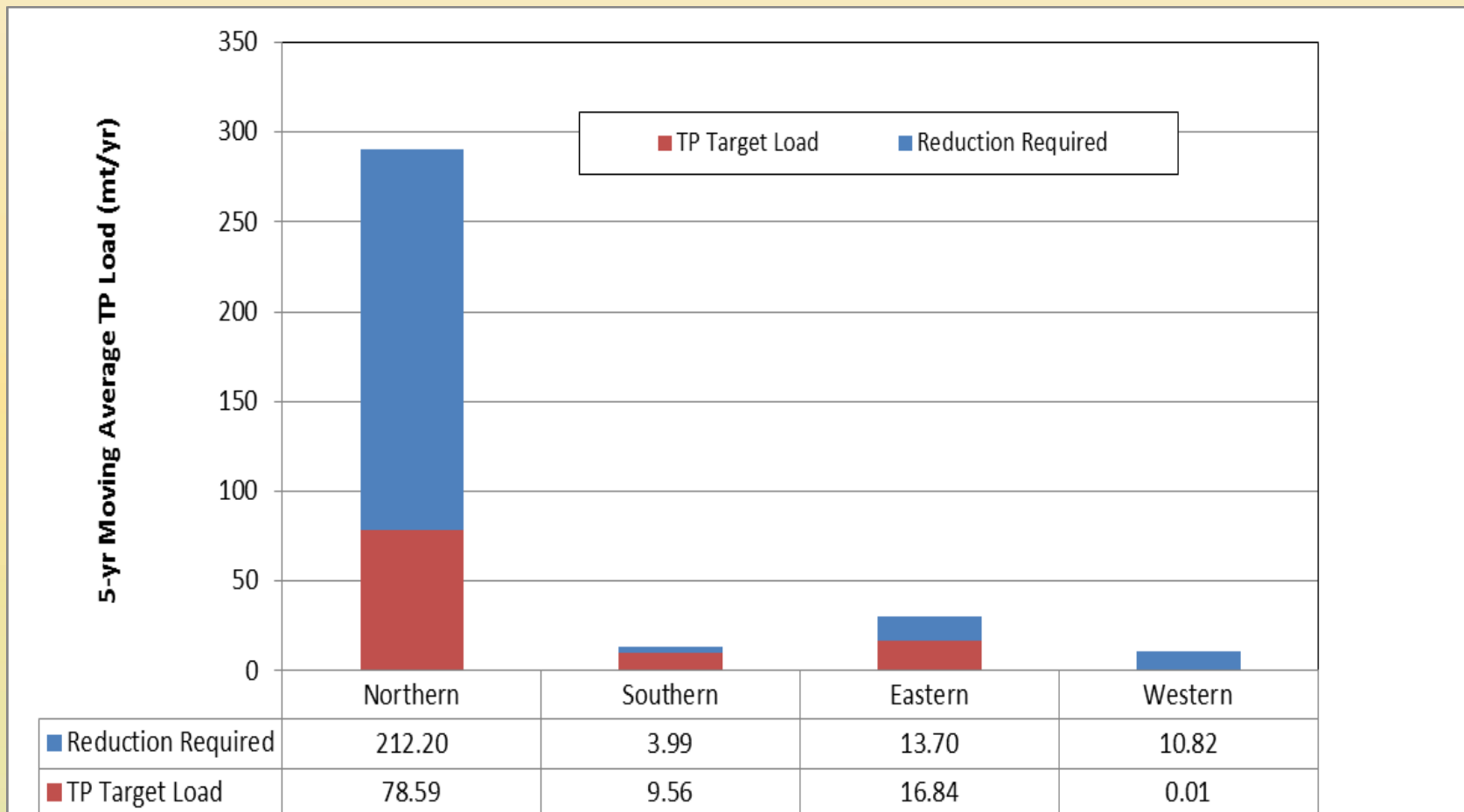
Note: Unit area loads for South Lake Okeechobee Sub-watershed include discharges from areas outside the Sub-watershed boundary.

Lake Okeechobee Operating Permit

- The Lake Okeechobee Operating Permit (LOOP) was issued by the Florida Department of Environmental Protection (FDEP) to the District
- The LOOP organizes discharges into Lake Okeechobee into four regions, each with a TP Load Target, measured as a 5-year moving average annual load:
 - Northern: 78.59 metric tons per year (mt/yr)
 - Southern: 9.56 mt/yr
 - Eastern: 16.84 mt/yr
 - Western: 0.01 mt/yr
- Slight variations between four regions and LOW boundaries due to different statutory mandates

Regional TP Load Reductions Required to Achieve Lake Okeechobee TP Target Loads:

WY2008-2012 TP Loads

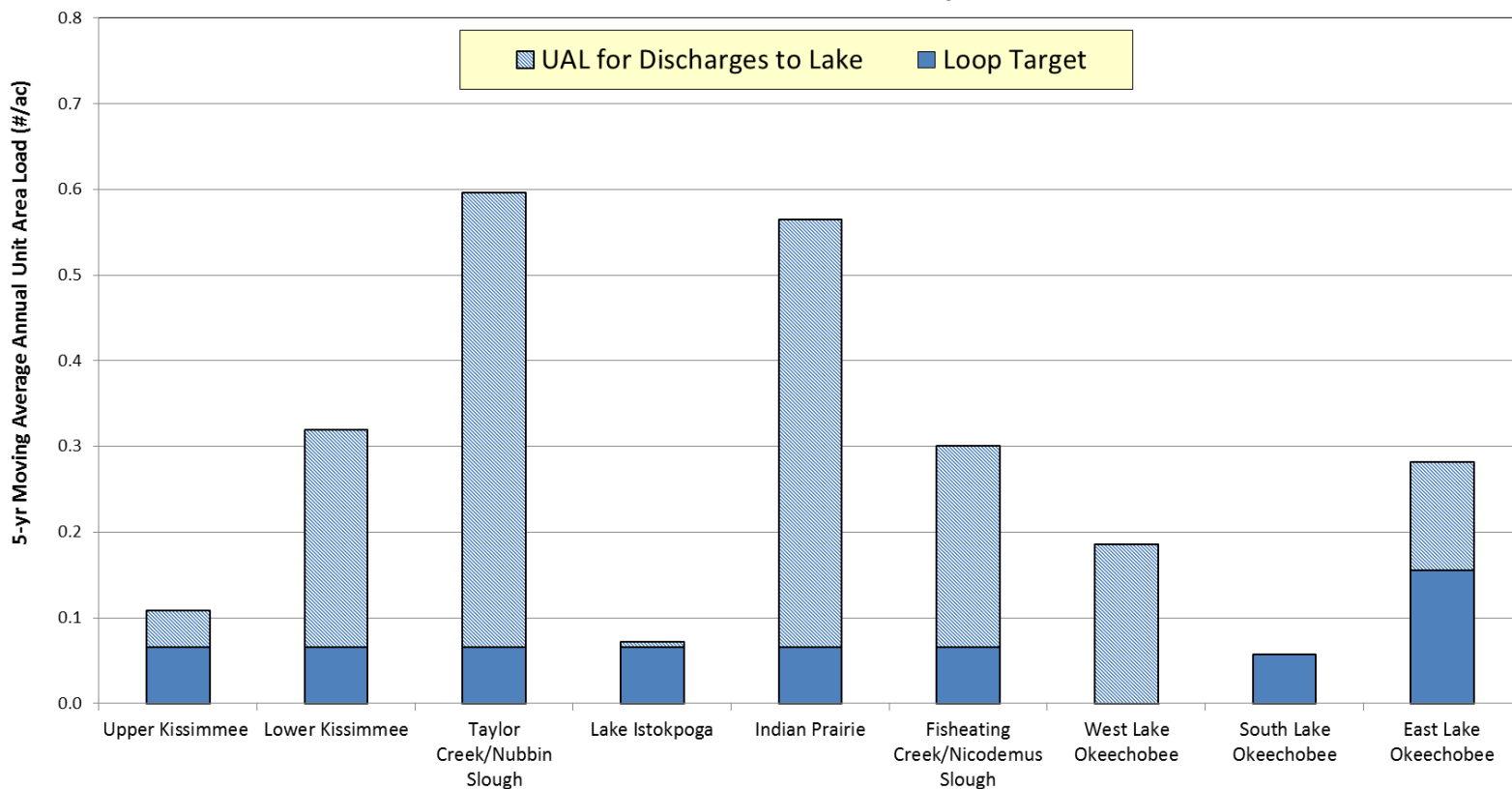


Regional TP Load Reductions Required to Achieve Lake Okeechobee TP Target Loads

The average LOOP Target UAL is 0.07 #/ac

5-yr Moving Average TP Unit Area Loads (UALs) from Lake Okeechobee Sub-watersheds to the Lake for the WY2008-2012 period

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Note: Unit area load for South Lake Okeechobee was 0.01 #/ac and includes discharges from areas outside the Sub-watershed boundary.

Cross Reference with LOOP Regions

LOOP Region and 5-yr Moving Average TP Load Target	Structures	Lake Okeechobee Watershed Sub-watershed	Basin	Area, acres	Area, % of Watershed	WY2008-2012 Percent of Load to Lake O
Northern Region Target = 78.59 mt/yr	S-65E	Lower Kissimmee Sub-watershed & Upper Kissimmee Sub-watershed, including Boggy Creek and Shingle Creek		1,457,609	42.2%	32.7%
	S-133	Taylor Creek/Nubbin Slough Sub-watershed	S-133 Summary Basin	25,626	0.7%	0.8%
	S-135		S-135 Summary Basin	17,756	0.5%	0.3%
	S-154		S-154 Summary Basin	31,815	0.9%	3.7%
	S-154C		S-154C Summary Basin	2,134	0.1%	0.6%
	S-191		S-191 Summary Basin	119,402	3.5%	10.1%
	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, including Arbuckle Creek and Josephine Creek		670,780	19.4%	24.2%
	Fisheating Creek/FECSR78	Fisheating Creek / Nicodemus Slough Sub-watershed	Fisheating Creek Summary Basin	298,713	8.7%	11.8%
	Culvert 5		Nicodemus Slough Summary Basin	19,329	0.6%	
	HP-7, Inflow 1, Inflow 2, Inflow 3	Not included (Note 1)				
G-207, G-208	Not included (Note 2)					N/A
Southern Region Target = 9.56 mt/yr	S-2, S-3, S-351, S-352, S-354	South Lake Okeechobee Sub-watershed	EAA Basin (40E-61)	288,760	8.4%	0.8%
	Culvert 4A, Culvert 10, Culvert 12, Culvert 12A, S-236		Ch. 298 Districts	33,502	1.0%	0.3%
	S-4, Industrial Canal (S-310)	West Lake Okeechobee Sub-watershed	S-4 / Industrial Canal	42,145	1.2%	2.9%
Western Region Target = 0.01 mt/yr	S-77		East Caloosahatchee	204,094	5.9%	3.1%
	Culvert 5A	0.0%			N/A	
Eastern Region Target = 16.84 mt/yr	S-308	East Lake Okeechobee Sub-watershed	C-44 Summary Basin	132,572	3.8%	6.3%
	Culvert 10A		L-8 Summary Basin	106,440	3.1%	2.5%

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.

Historical Data Analysis: Over 1.5 million station-days of data analyzed

Lake Okeechobee Watershed Sub-watershed	Basin	Period of Record	Years of Data Analyzed	Number of Flow Stations	Number of Water Quality Sites	Number of Rainfall Stations
Upper Kissimmee		WY1977-2012	36	1	1	11
	Boggy Creek	WY1992-2012	12	1	1	3
	Shingle Creek	WY1992-2012	30	1	1	3
Lower Kissimmee		WY1977-2012	36	1	1	8
Taylor Creek/Nubbin Slough Sub-watershed	S-133 Summary Basin	WY1977-2012	36	1	1	2
	S-135 Summary Basin	WY1977-2012	36	2	1	3
	S-154 Summary Basin	WY1977-2012	36	1	1	4
	S-154C Summary Basin	WY2009-2012	4	1	1	2
	S-191 Summary Basin	WY1977-2012	36	1	1	4
Lake Istokpoga		WY1989-2012	24	1	1	N/A
	Arbuckle Creek	WY1992-2012	21	1	1	4
	Josephine Creek	WY1997-2012	16	1	1	2
Indian Prairie		WY1989-2012	24	18	15	4
Fisheating Creek / Nicodemus Slough	Fisheating Creek	WY1998-2012	15	1	1	3
	Nicodemus Slough	WY2009-2012	4	2	1	N/A
East Lake Okeechobee	C-44	WY1982-2012	31	2	2	5
	L-8	WY1995-2012	18	5	5	4
West Lake Okeechobee	S-4 / Industrial Canal	WY1993-2012	20	5	5	1
	East Caloosahatchee	WY1982-2012	31	3	3	5
South Lake Okeechobee	Everglades Agricultural Area (Rule 40E-63)					
	Ch. 298 Districts	WY1991-2012	22	12	12	6
Total				>61	>56	>77

Historical Data Analysis

- Data from representative water quality and flow monitoring stations serving a hydrologic area (e.g., discharge structures serving a sub-watershed) were reviewed
- Rainfall data from representative stations were evaluated
- If an area discharged runoff to more than one watershed (Everglades, LOK, St. Lucie River, or Caloosahatchee River), **total** discharge was considered
- Only nutrient loads generated from the area (i.e., runoff) subject to the source controls were evaluated
 - Pass-through flow and load from external sources to the basin were calculated, and excluded from calculation of the basin's discharge

Historical Data Analysis

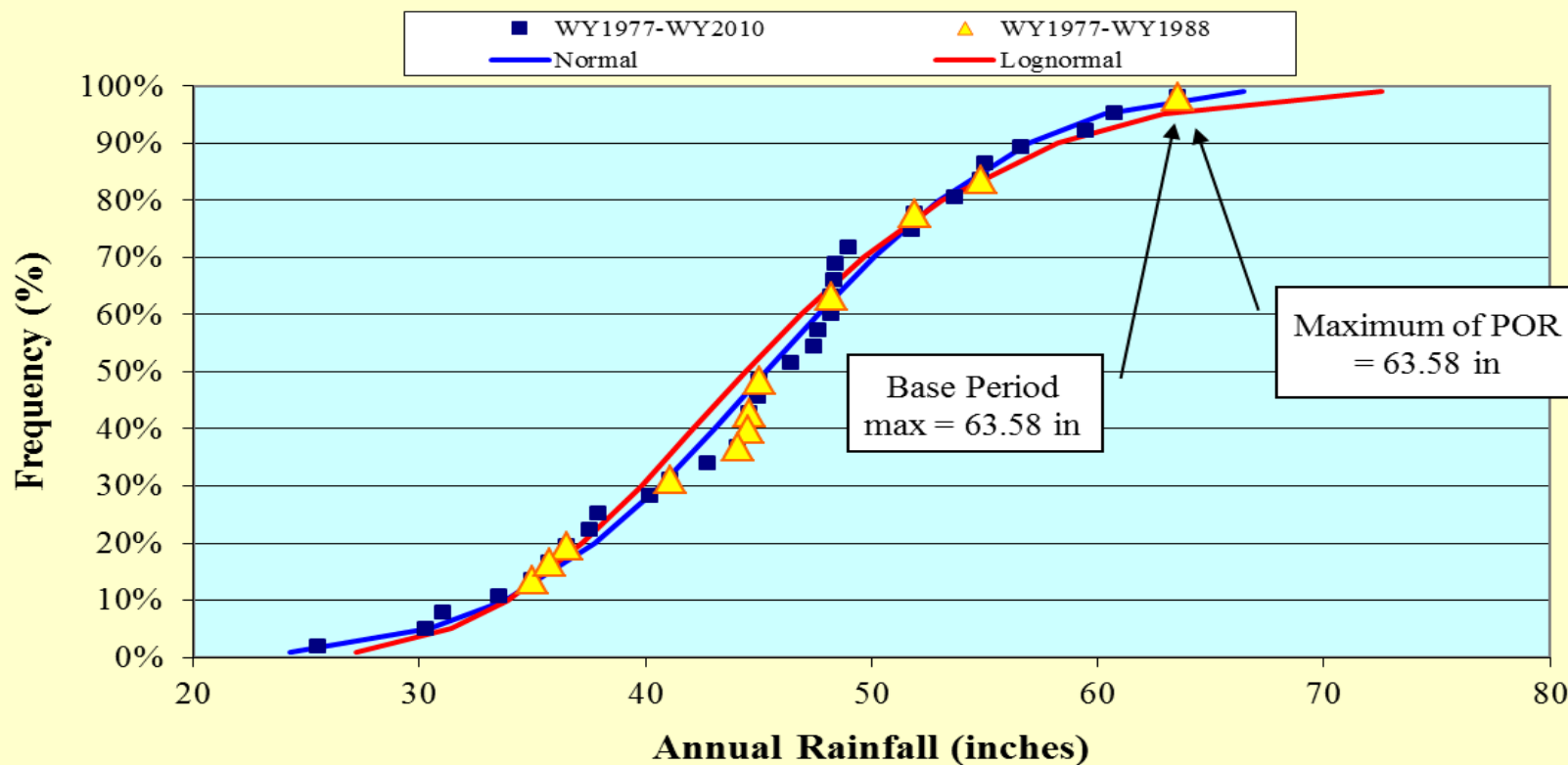
- Standard statistical analyses on monthly and annual values, for period of record and base period
 - Evaluated rainfall, flows, loads and concentrations
 - Unit area runoff, Unit area loads
 - Frequency histograms & cumulative frequency distributions
 - Tests for normal and log-normal distributions
 - Potential outliers
 - Test for temporal trends –
 - Annual – linear regression
 - Monthly - Seasonal Kendall Tau
 - Spatial variability within sub-watershed as applicable, e.g., Taylor Creek / Nubbin Slough
 - Rainfall:runoff relationships examined

Cumulative Frequency Distribution

S-191

Cumulative Frequency Distribution for Annual Rainfall

Maximum of POR = 63.58 inches; maximum of Base Period = 63.58 inches



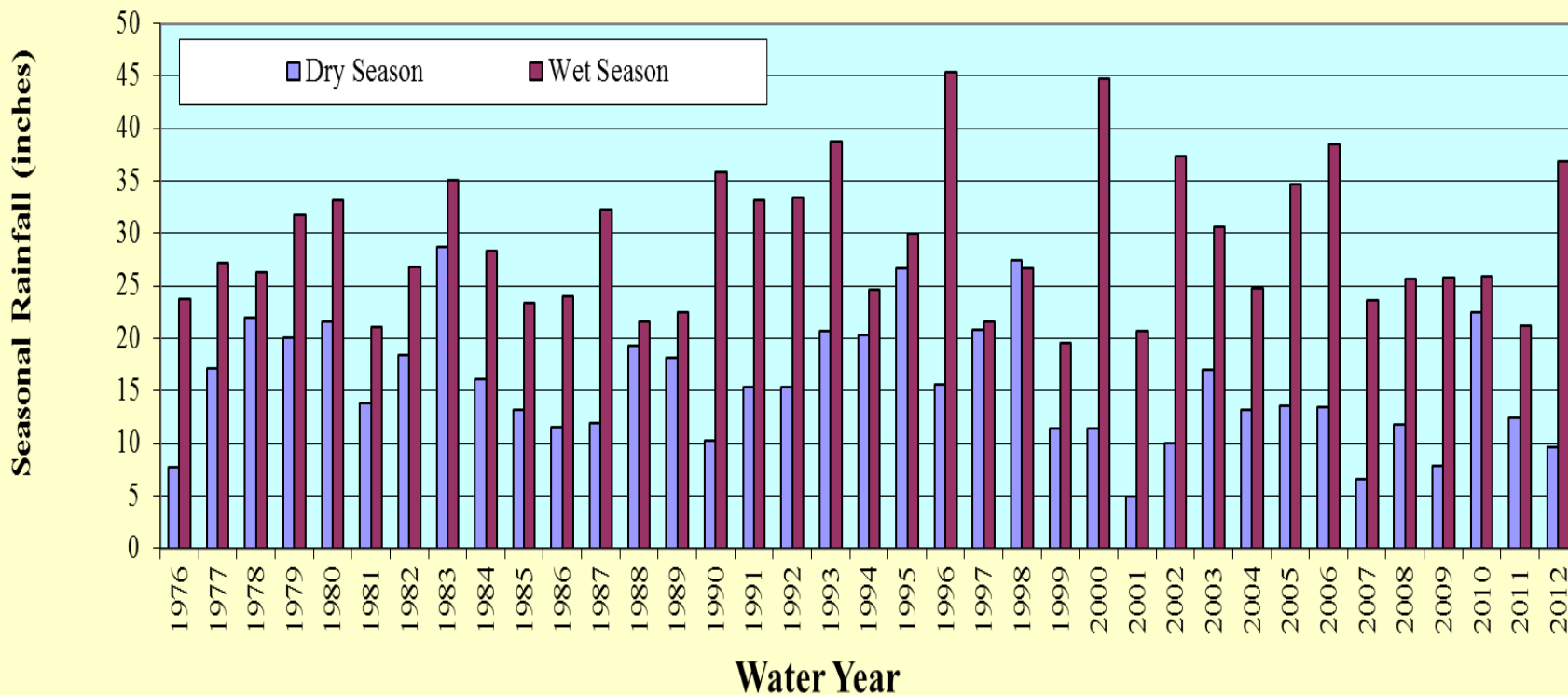
Evaluated temporal trend in seasonal rainfall

S-191 - TP

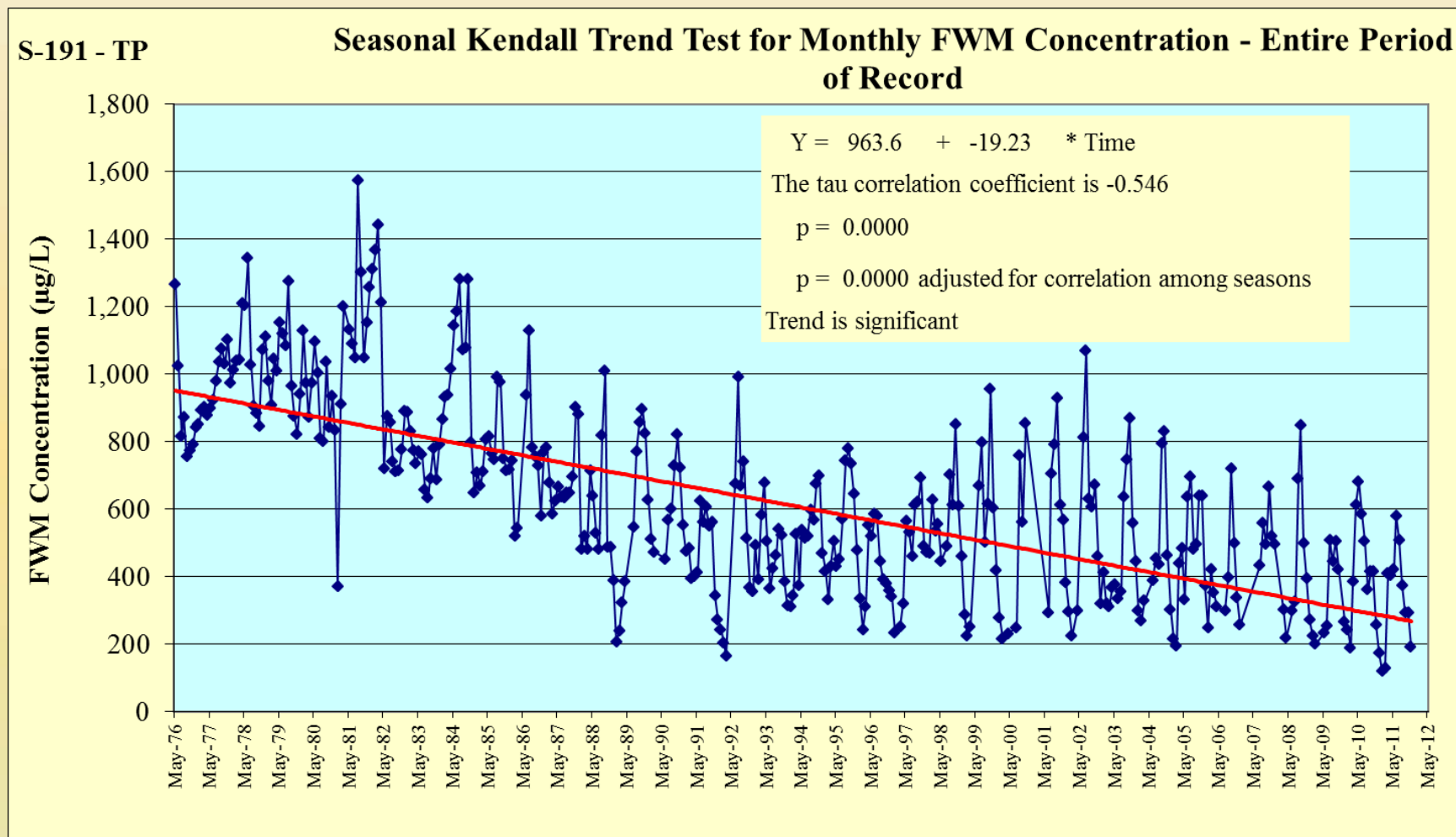
Period of Record Seasonal Rainfall

Dry Season slope is significant at the 95% confidence level

Wet season slope is not significant at the 95% confidence level



Temporal Trend Analysis – monthly data

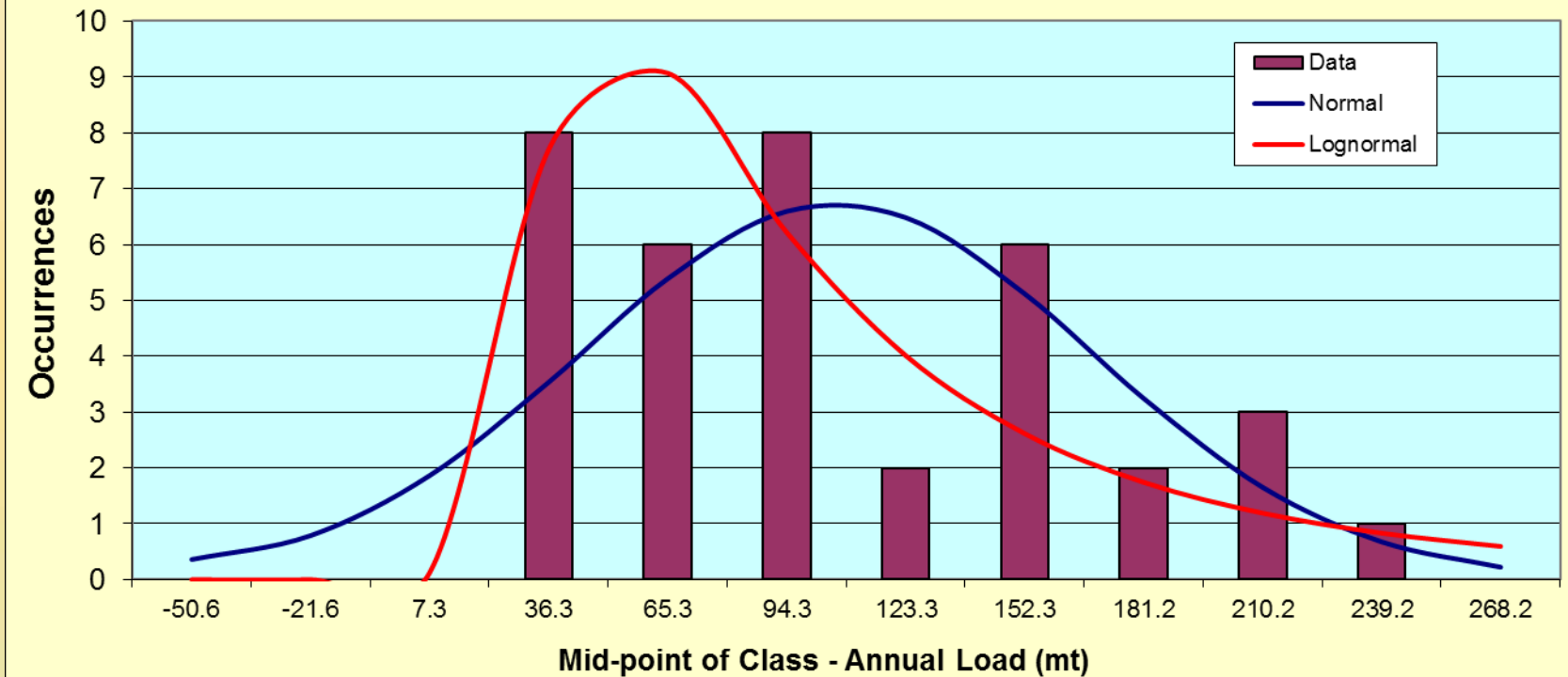


Tested for Normality of Annual Data

S-191 - TP

We cannot reject the hypothesis that the data came from a population with a normal distribution.

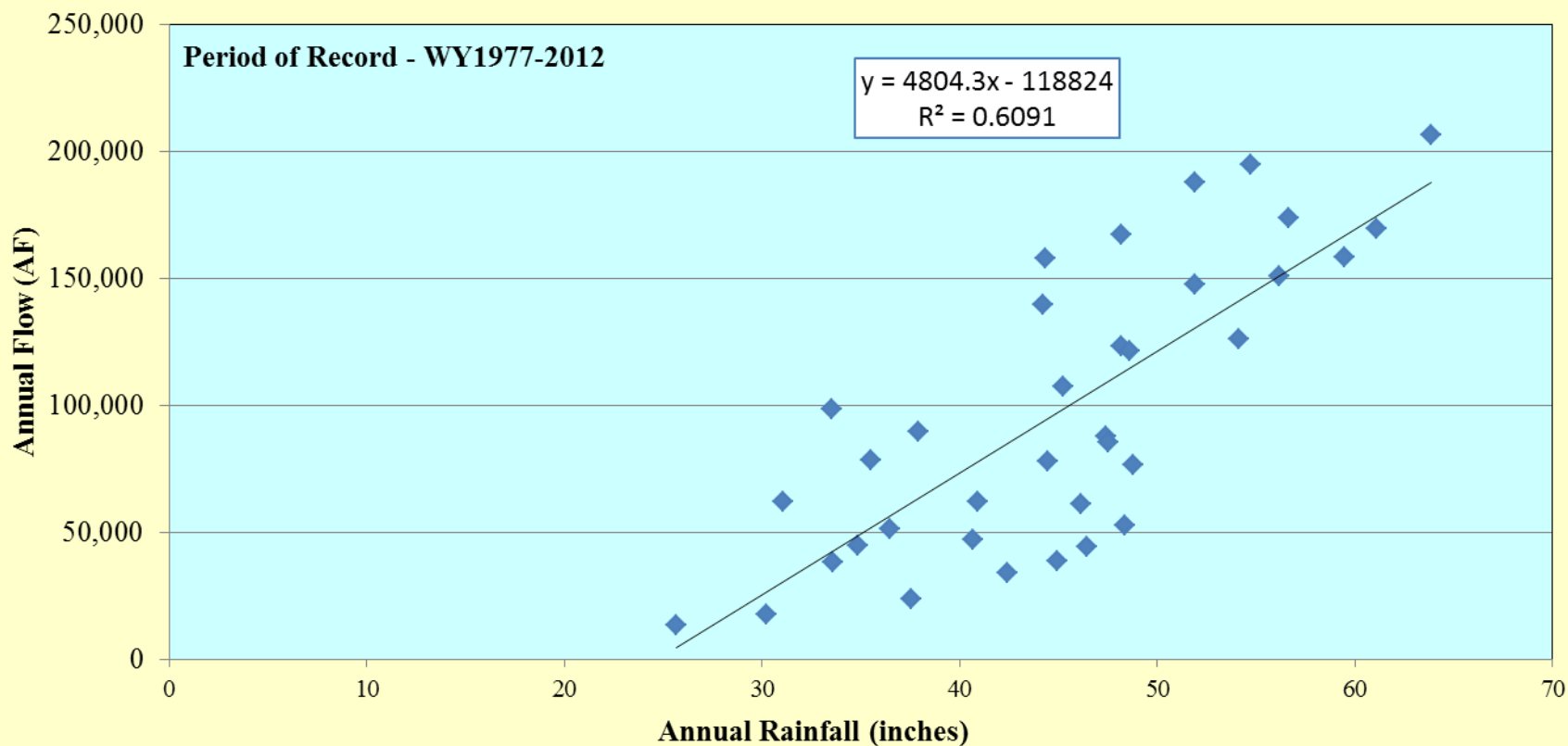
We cannot reject the hypothesis that the data came from a population with a lognormal distribution.



Evaluated rainfall:runoff relationships

S-191 - TP

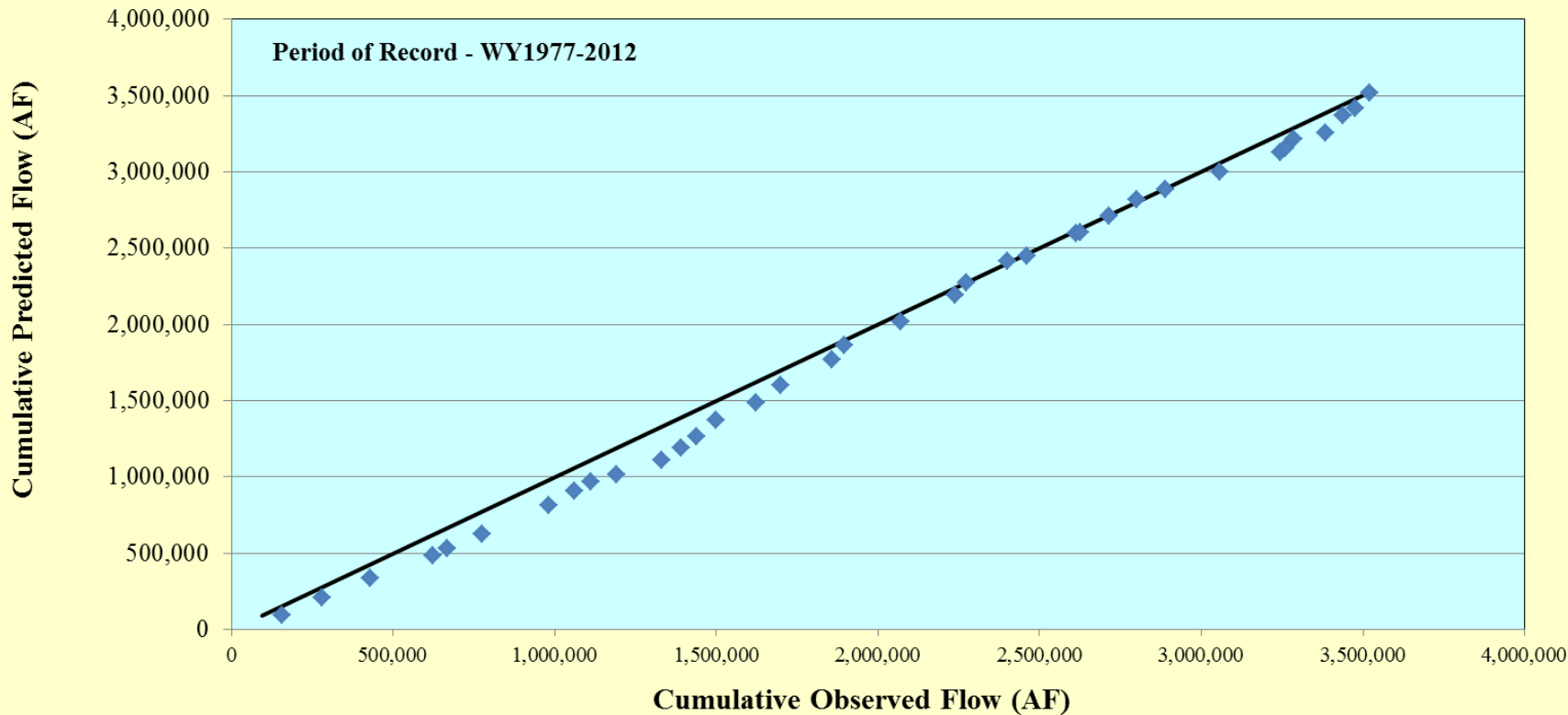
Flow as a function of Rainfall - POR



Evaluated stability of rainfall:runoff using double mass curve

S-191 - TP

**Relationship of Predicted Flow to Observed Flow - Using POR Regression;
Excluding years with negative flow or load**



Selection of Base Period

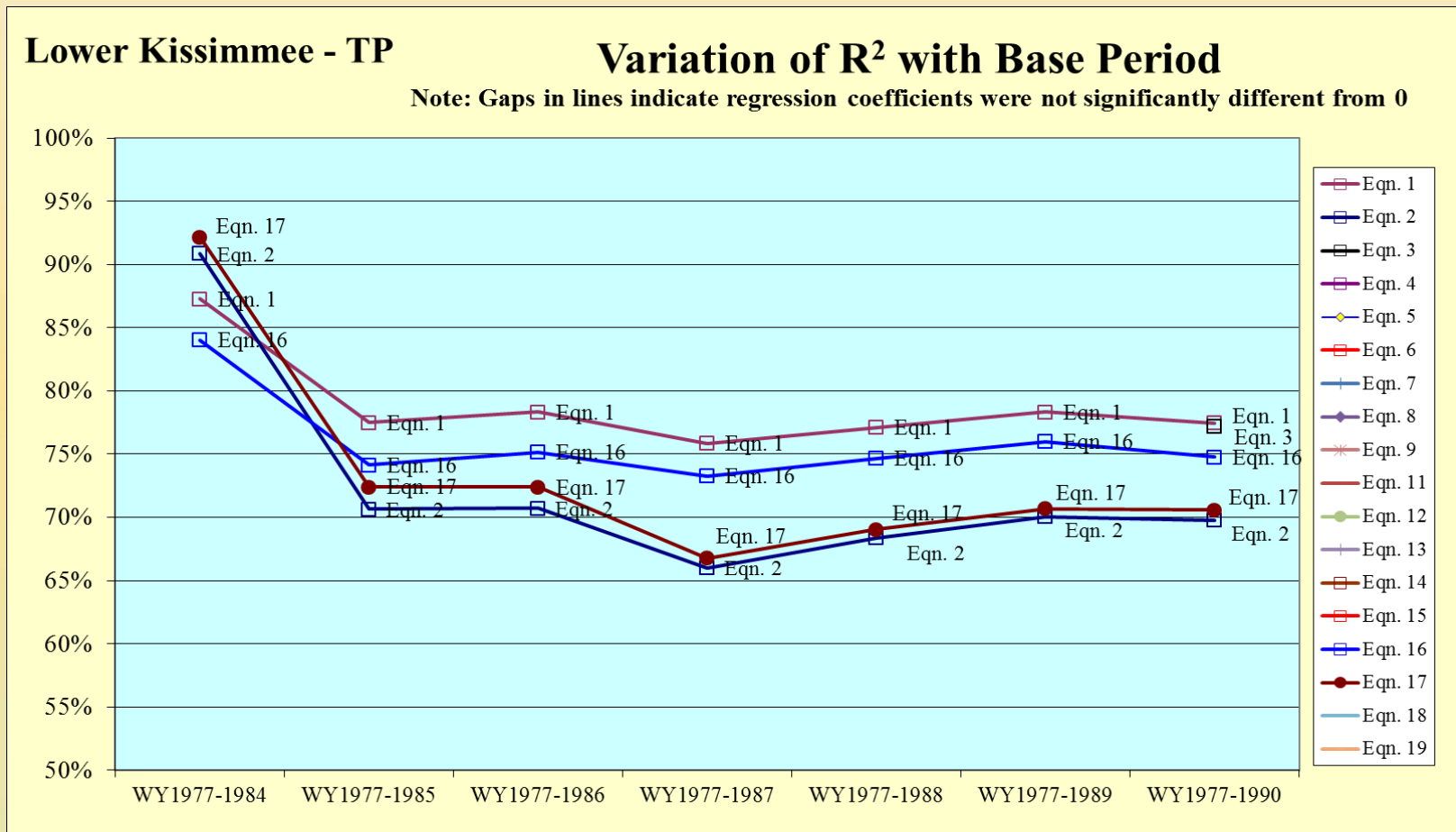
- Base Period: the benchmark period of historical data on which comparisons are based
- Precedes implementation of source control measures as much as possible
- At least 8 years of concentration and flow data
- Represents nutrient levels through a wide range of hydrologic conditions
- Representative of current operating conditions affecting nutrient loading, to the extent practical
- Has a reasonable correlation between annual nutrient loads and rainfall
- Free of trends in loads that cannot be explained by rainfall

Prediction Equations

- Prediction equations describe a basis for comparing future loads relative to a base period
- Hydrologic variability of annual TP loads expressed by regression equations
 - Annual Load, $\ln(\text{load})$ and $\sqrt{\text{load}}$ as dependent variables
 - Annual concentration also evaluated
 - Rainfall characteristics (annual, CV, S, K and previous year's rainfall)
 - Evaluated for multiple time periods, i.e., alternative base periods
- Examined over 50 combinations of rainfall characteristics

Example of Prediction Equation: Lower Kissimmee Sub-watershed

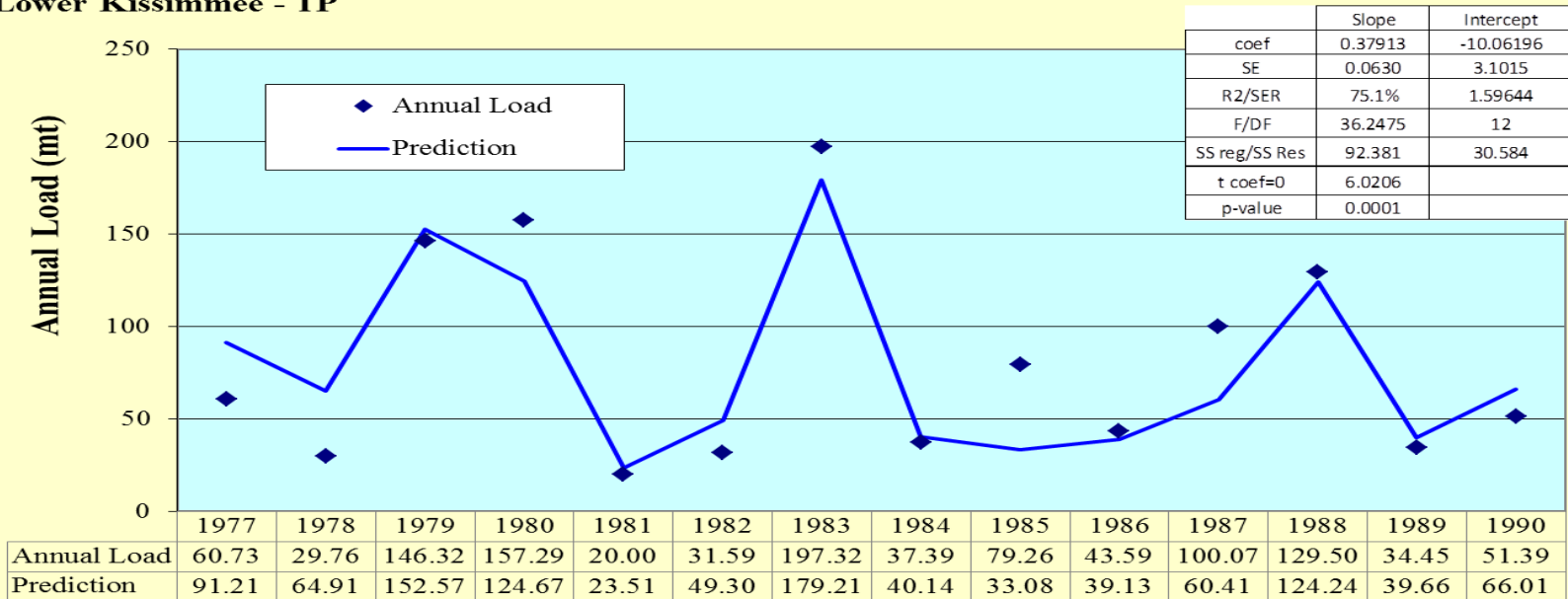
➤ A few of the equations evaluated:



Example of Prediction Equation: Lower Kissimmee Sub-watershed

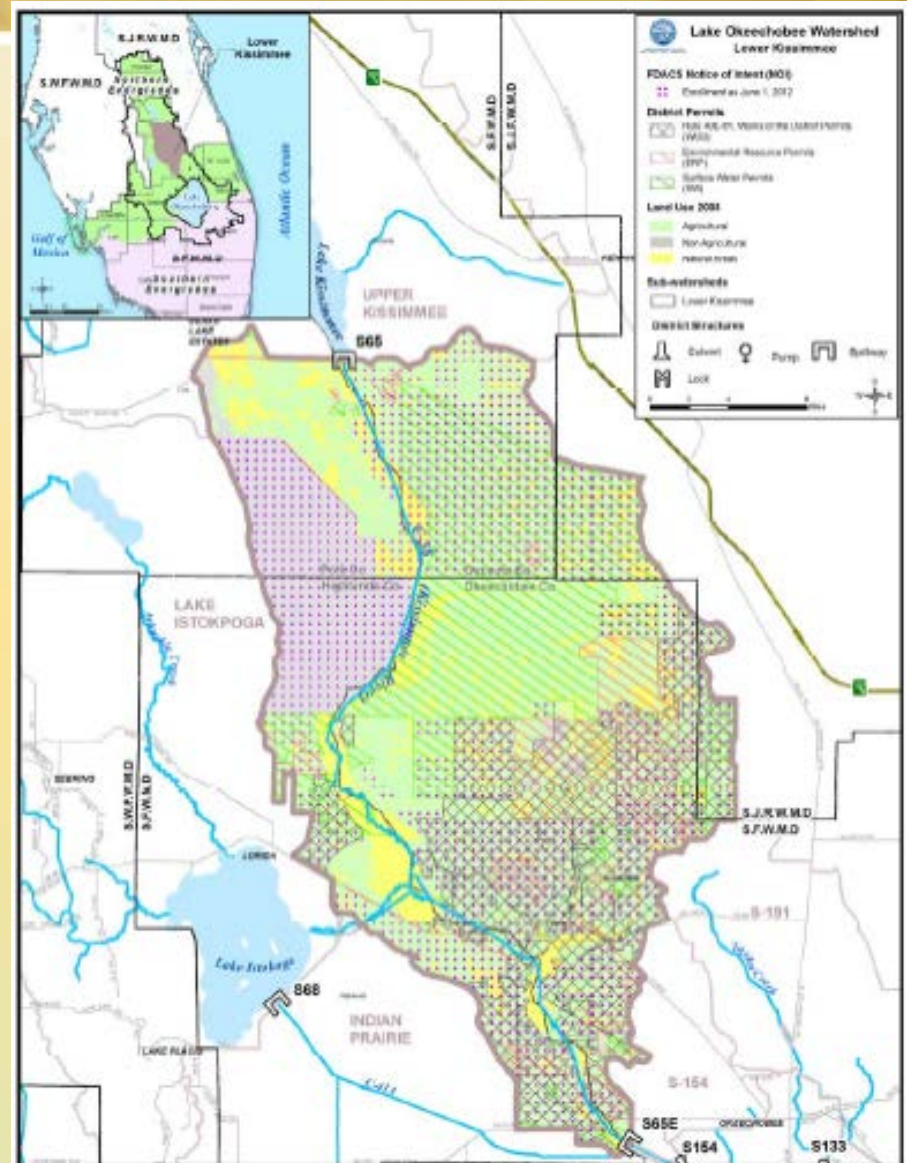
- Multiple selection factors were used to select the recommended equation
 - Strength of the correlation to rainfall (e.g., adjusted R² and standard error of the prediction), statistical significance of regression coefficients, residuals were normally distributed, lack of collinearity between predictor variables, absence of overparameterization
 - At least three times the number of years as variables

Lower Kissimmee - TP



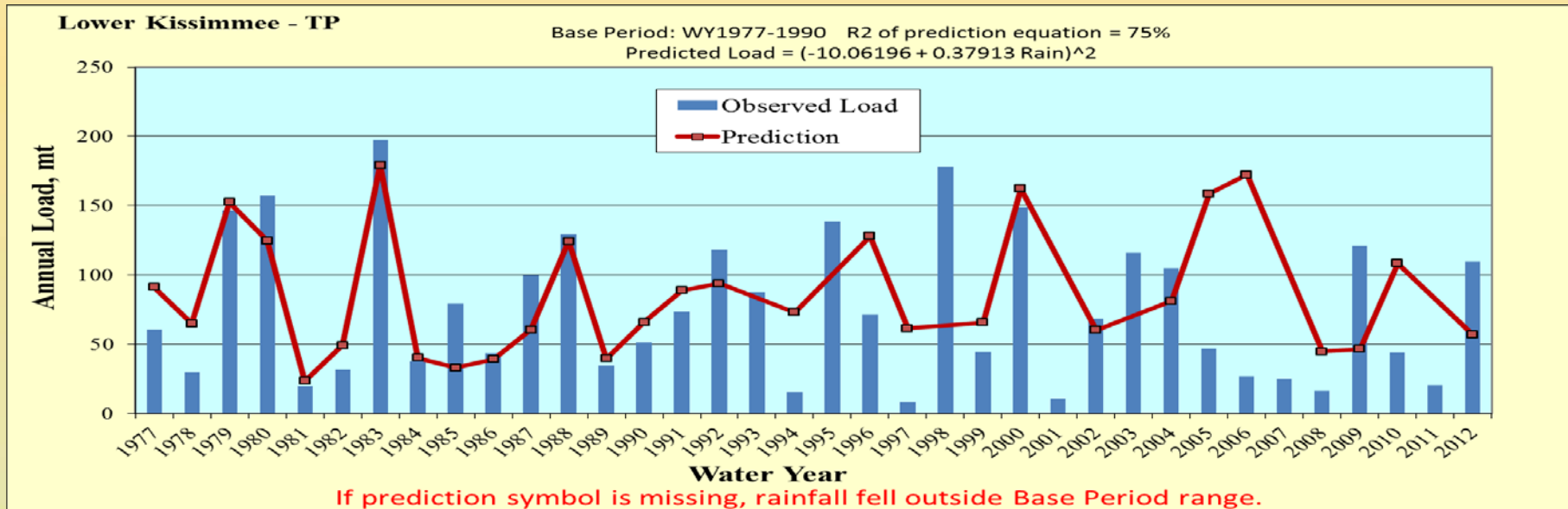
Lower Kissimmee Sub-watershed

- Basin area: 429,188 acres (12% of LOW area)
- Period of Record analyzed: 5/1/1976 – 4/30/2012
- Receiving waterbody: Lake Okeechobee



Lower Kissimmee Sub-watershed

- WY2001-2012 average annual TP load: 59.16 metric tons (13%)
- Percent of LOW TP Load (range for WY2001-2012): 3.5 – 34.5%
- Basin Load_{LowerKiss} = Outflow Load_{LowerKiss} - Pass Through Load_{LowerKiss}
- Outflow Load_{LowerKiss} = (Flow_{S-65E} * Conc_{S-65E})
- Pass Through Load_{LowerKiss} = Pass Through Flow_{LowerKiss} * Conc_{S-65}
- Pass Through Flow_{LowerKiss} = minimum(Flow_{S-65}, Flow_{S-65E})
- Prediction equation: Annual TP Load = (-10.06916 + 0.37913*Rain)²



Common technique applied to all basins

- Some basin-specific features:

Sub-watershed	Basin	Pass - Through Loads?	Prediction Equation R ²	Basin Receiving Waters
Taylor Creek/Nubbin Slough	S-133	No	79%	Lake Okeechobee
Taylor Creek/Nubbin Slough	S-135	No	N/A	Lake Okeechobee
Taylor Creek/Nubbin Slough	S-154	No	80%	Lake Okeechobee
Taylor Creek/Nubbin Slough	S-154C	No	N/A	Lake Okeechobee
Taylor Creek/Nubbin Slough	S-191	No	89%	Lake Okeechobee
Lower Kissimmee		Yes	75%	Lake Okeechobee
East Lake Okeechobee	C-44	Yes	84%	Lake Okeechobee, St Lucie River and Estuary
East Lake Okeechobee	L-8	Yes	84%	Lake Okeechobee, EAA, C-51W, STA-1 Inflow Works, WPB Catchment Area
Indian Prairie		Yes	91%	Lake Okeechobee
Fisheating Creek / Nicodemus Slough	Fisheating Creek	No	54%	Lake Okeechobee
Lake Istokpoga	Arbuckle Creek	No	68%	Lake Istokpoga
Lake Istokpoga	Josephine Creek	No	93%	Lake Istokpoga
Upper Kissimmee Sub-watershed		No	77%	Lower Kissimmee, Lake Okeechobee
Upper Kissimmee	Boggy Creek	No	98%	Lake Kissimmee
Upper Kissimmee	Shingle Creek	No	97%	Lake Kissimmee
West Lake Okeechobee	S-4 / Industrial Canal	Yes	76%	Lake Okeechobee, East Caloosahatchee
West Lake Okeechobee	East Caloosahatchee	Yes	73%	Lake Okeechobee, S-4/Industrial Canal, Caloosahatchee River

Some challenges to data analysis

- How to select an appropriate, representative, Base Period?
- How to fill in missing data?
- What to do for areas that don't have a sufficiently long period of record?
- How to account for the nutrient assimilation in lakes?
- What to do when regression equations don't explain a high amount of the variability in loads?

How can the historical data be used to support BMAP development and evaluations?

- Recent period TP load, concentration and flow from all sources have been established for basins through WY2012; currently compiling WY2013
- Basins can be aggregated to many levels (i.e. Sub-watershed, LOOP regions, Watershed) with established monitoring locations
- The data analysis methods and prediction equations provide tools to quantify TP load reductions achieved to date by all sources
 - can be expanded to a methodology to estimate the balance of load reductions required by projects to achieve the TMDL
 - Can be used to measure progress towards achieving water quality goals over time



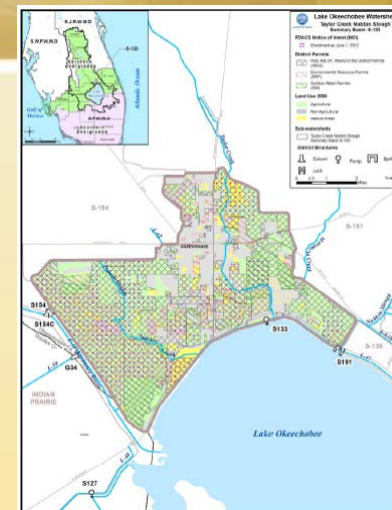
Comments and Questions?

Detailed “back-pocket” slides...

- Individual basins
- Flow/load calculation & Pass-through
- Accounting for future Regional Projects
- Adjusted Rainfall

TCNS Sub-watershed: S-133

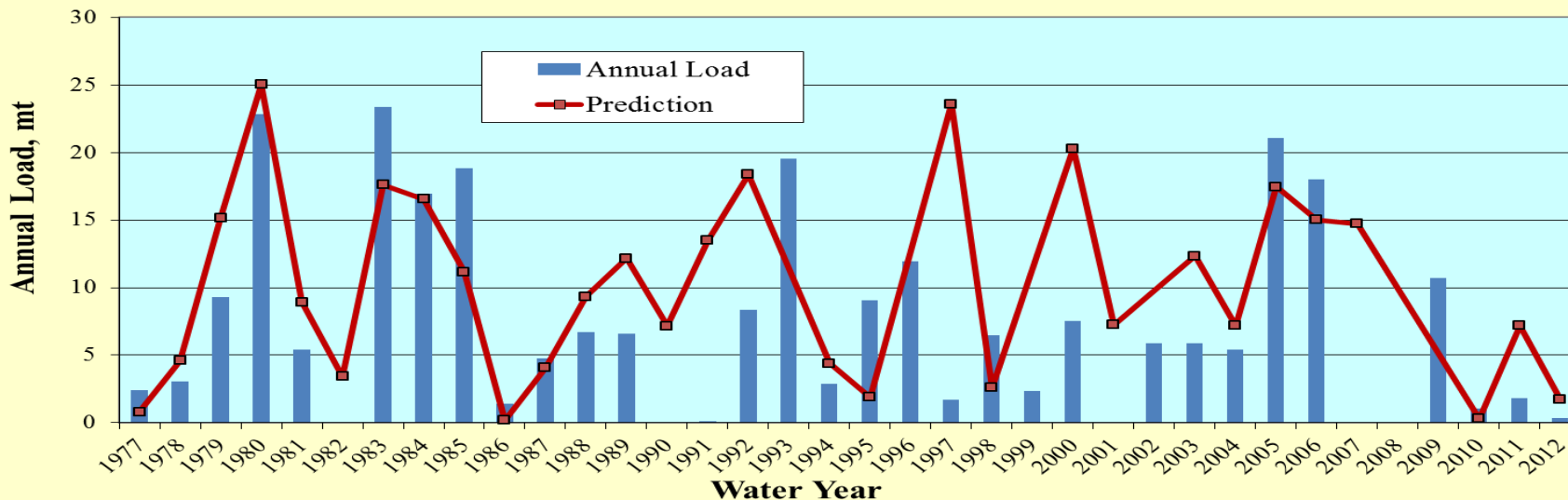
- Basin area: 25,626 acres (<1% of total LOW area)
- Pump station S-133 discharges directly to Lake Okeechobee
- WY2001-2012 average annual TP load: 5.85 metric tons (1.2% of total loads to Lake Okeechobee)
- Percent of LOW TP Load (range for WY2001-2012): 0 – 2.3%; average of 1.2%



S-133 - TP

Base Period: WY1977-1986 R2 of prediction equation = 79%

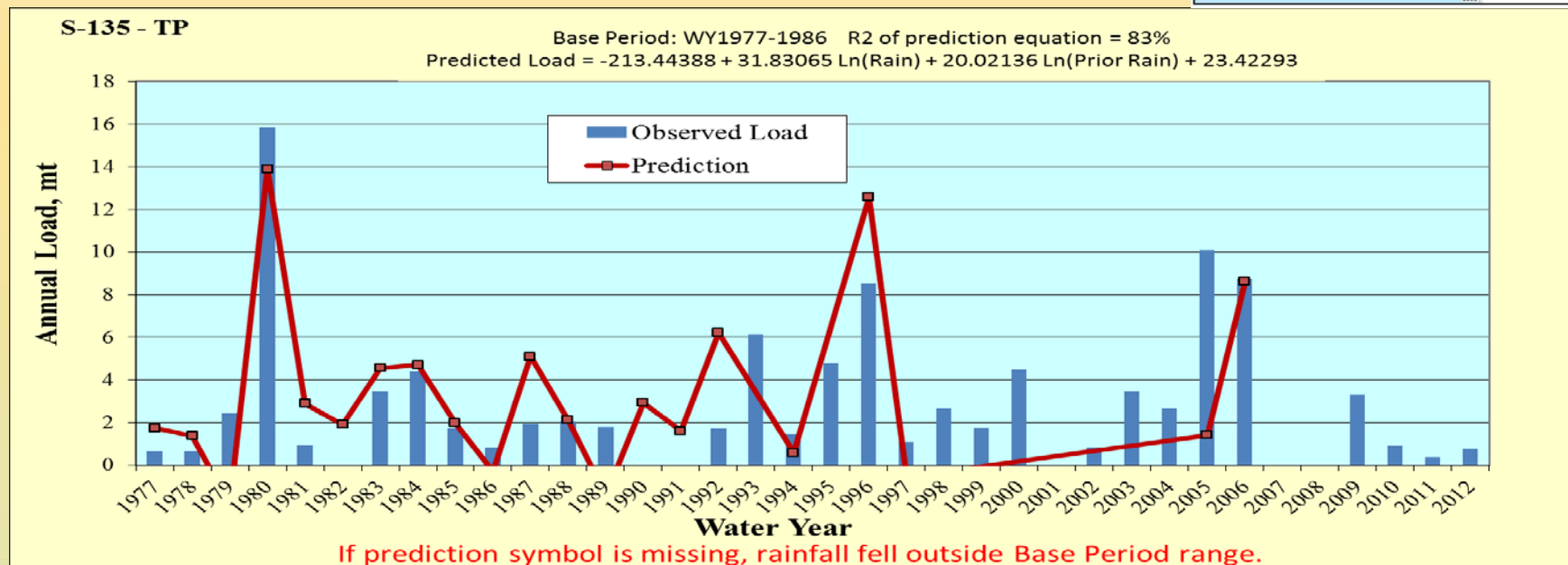
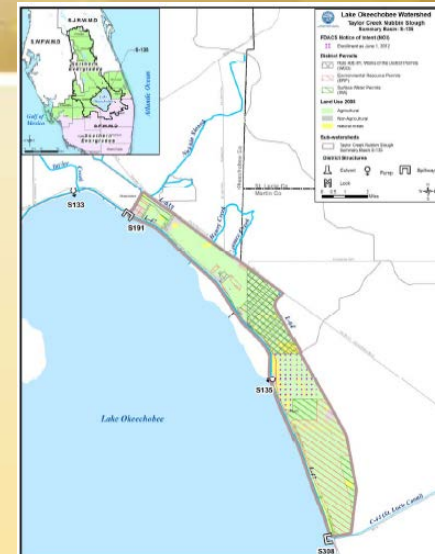
$$\text{Predicted Load} = -268.02789 + 26.15685 \ln(\text{Rain}) + 39.26711 \ln(\text{Prior Rain}) + 40.67692$$



If prediction symbol is missing, rainfall fell outside Base Period range.

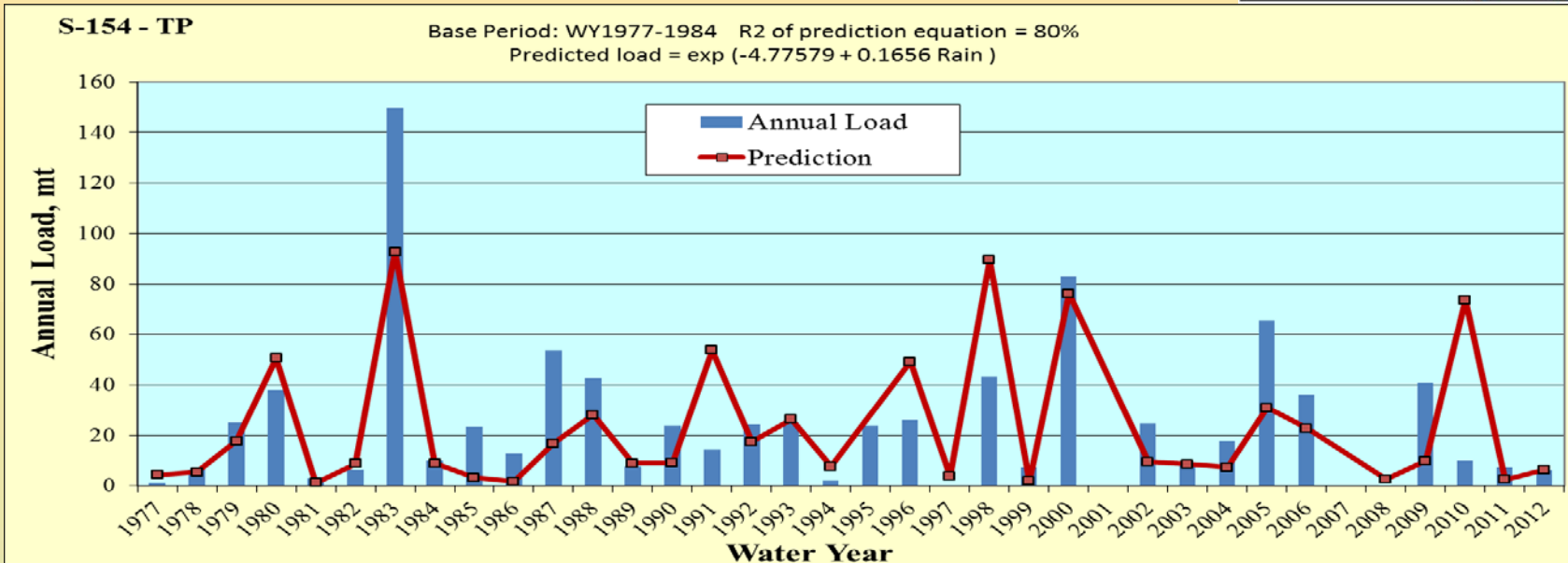
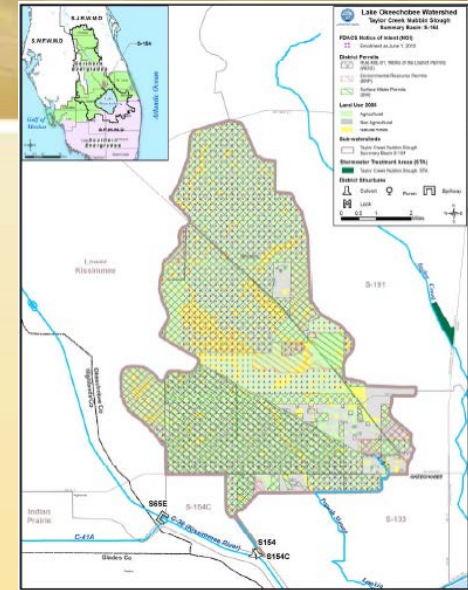
TCNS Sub-watershed: S-135

- Basin area: 17,756 acres (<1% of LOW area)
- Pump Station S-135 and associated culvert discharge directly into Lake Okeechobee
- WY2001-2012 average annual TP load: 2.60 metric tons (<1%)
- Percent of LOW TP Load (range for WY2001-2012): 0 - 1.1%



TCNS Sub-watershed: S-154

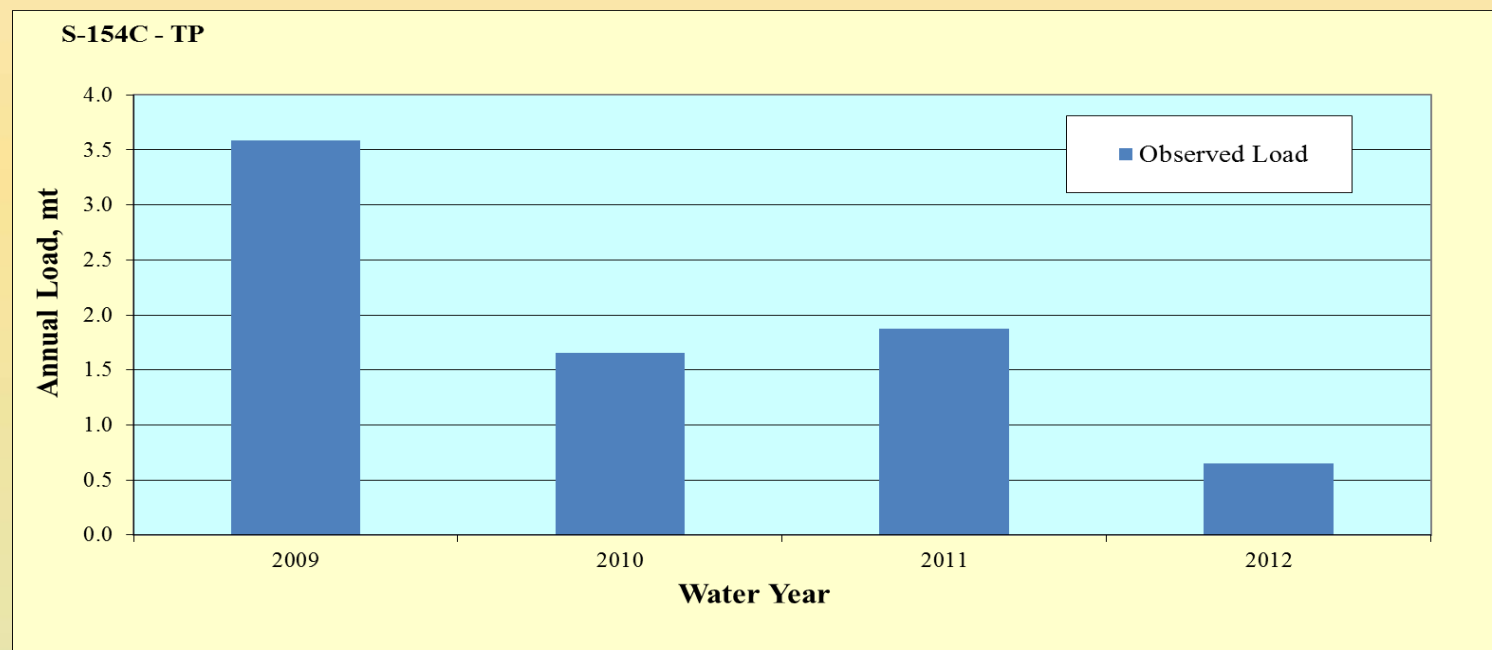
- Basin area: 31,815 acres (<1% of LOW area)
- Structure S-154 discharges into C-38 downstream of S-65E just upstream of Lake Okeechobee
- WY2001-2012 average annual TP load: 18.12 metric tons (4%)
- Percent of LOW TP Load (range for WY2001-2012): 0 – 7.0%



If prediction symbol is missing, rainfall fell outside Base Period range.

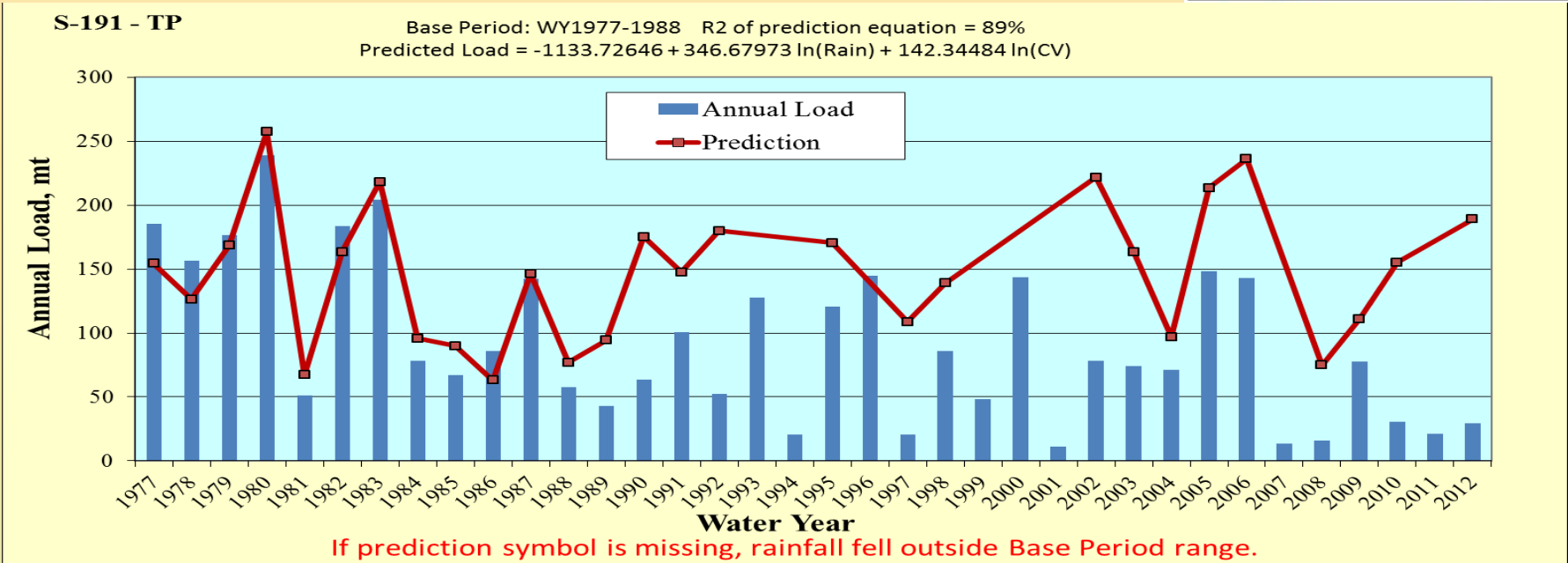
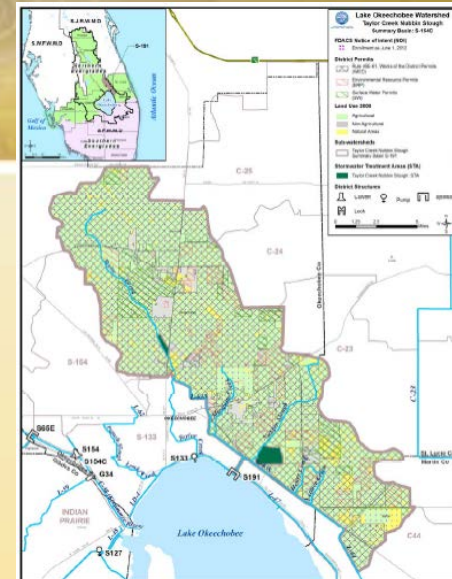
TCNS Sub-watershed: S-154C

- Basin area: 2,134 acres (<1% of LOW area)
- Structure S-154C discharges into C-38 downstream of S-65E just upstream of Lake Okeechobee
- WY2001-2012 average annual TP load: 1.94 metric tons (<1%)
- Percent of LOW TP Load (range for WY2001-2012): 0 – 1.4%



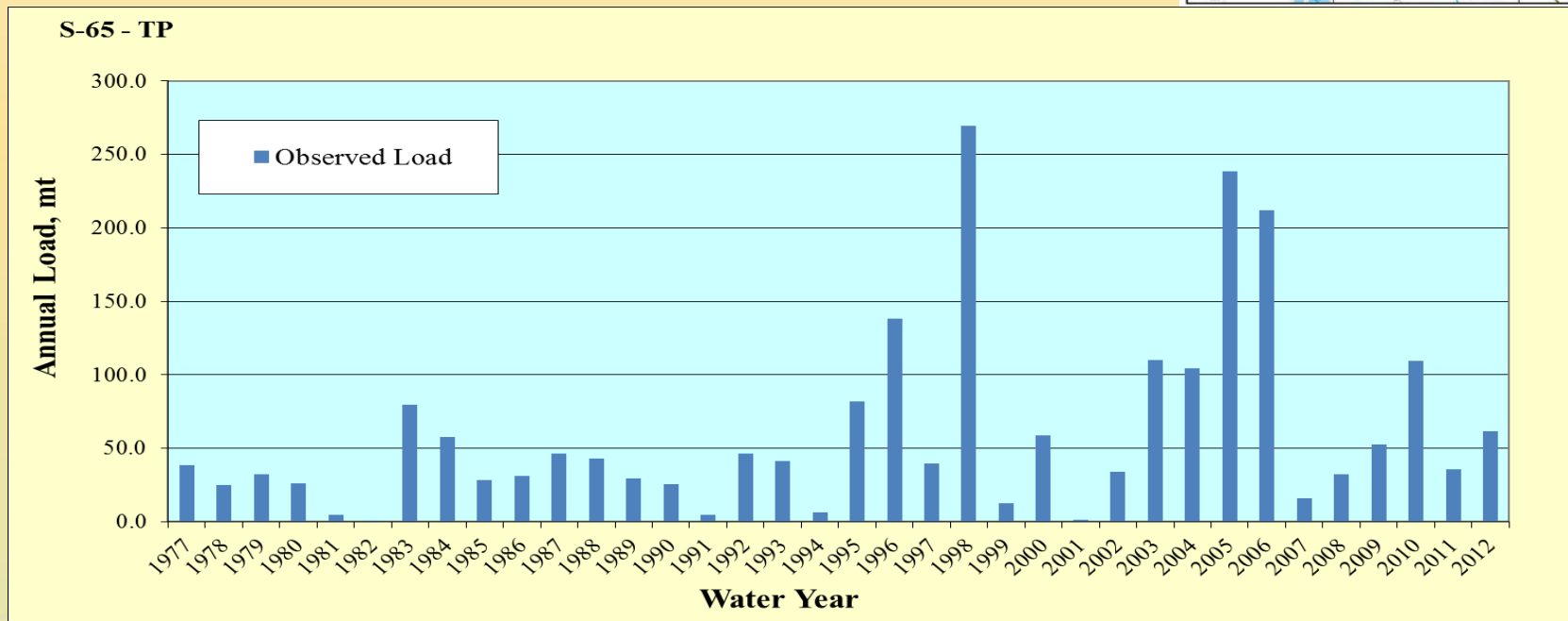
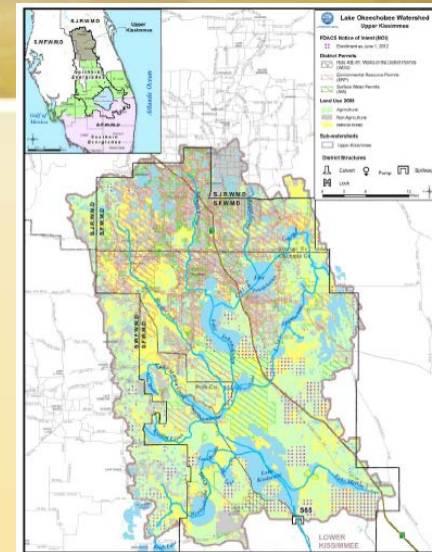
TCNS Sub-watershed: S-191

- Basin area: 119,402 acres (3.5% of total LOW area)
- Spillway S-191 discharges directly to Lake Okeechobee
- WY2001-2012 average annual TP load: 59.55 metric tons (13%)
- Percent of LOW TP Load (range for WY2001-2012): 6.9 - 18.5%



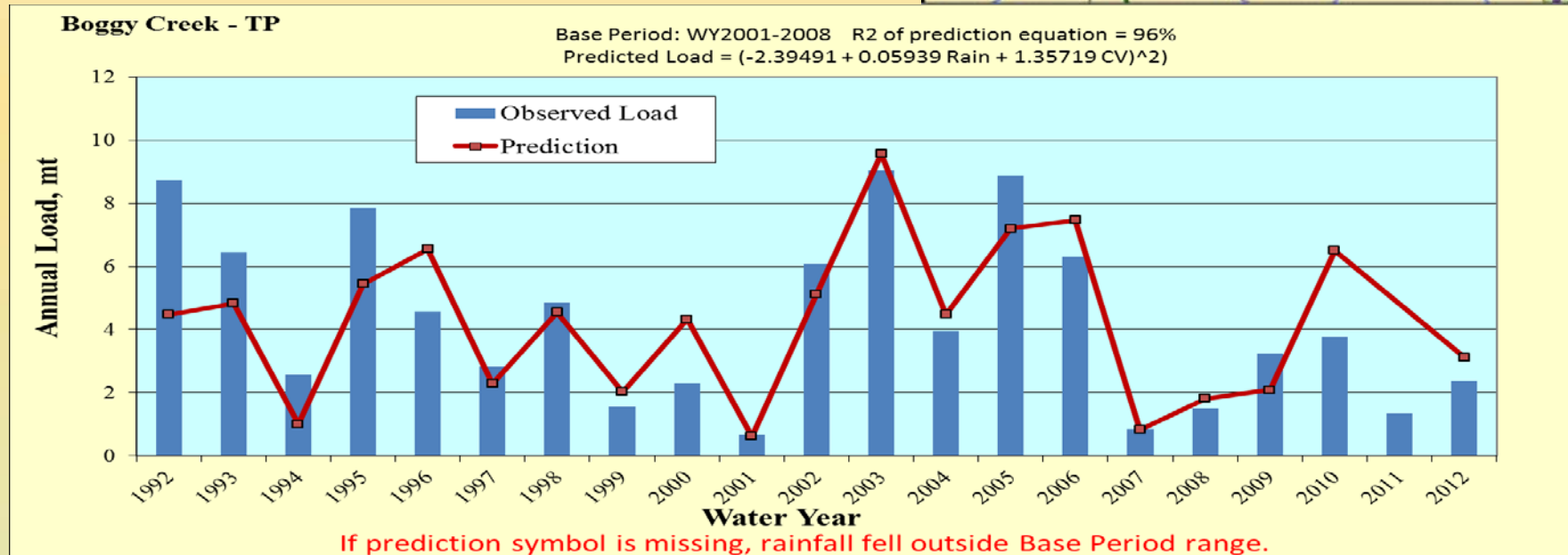
Upper Kissimmee Sub-watershed

- Sub-watershed area: 1,028,421 acres (30% of total LOW area)
- Sub-watershed water quality monitored at Lake Kissimmee outlet to Kissimmee River (S-65)
- WY2001-2012 average annual TP load: 84.0 metric tons (17%)
 - Approximately 4.5 metric tons/yr of Upper Kissimmee discharges (6%) remain in Lower Kissimmee Sub-watershed
- Percent of LOW TP Load (range for WY2001-2012): 0.8 - 27.1%



Upper Kissimmee Sub-watershed: Boggy Creek

- Basin area: 52,415 acres (1.5% of LOW area; 5% of sub-watershed)
- Boggy Creek discharges into East Lake Tohopekaliga
- WY2001-2012 average annual TP load: 4.0 metric tons



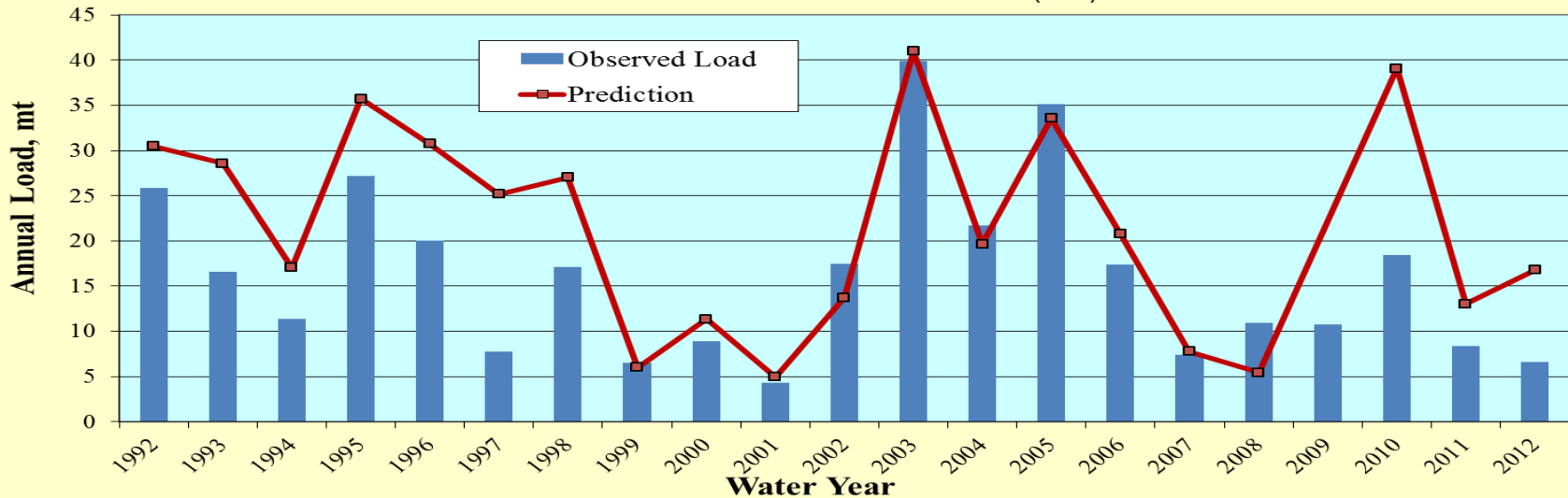
Upper Kissimmee Sub-watershed: Shingle Creek

- Basin area: 68,153 acres (2% of LOW area; 6.6% of sub-watershed)
- Shingle Creek discharges into Lake Tohopekaliga
- WY2001-2012 average annual TP load: 16.54 metric tons



Shingle Creek - TP

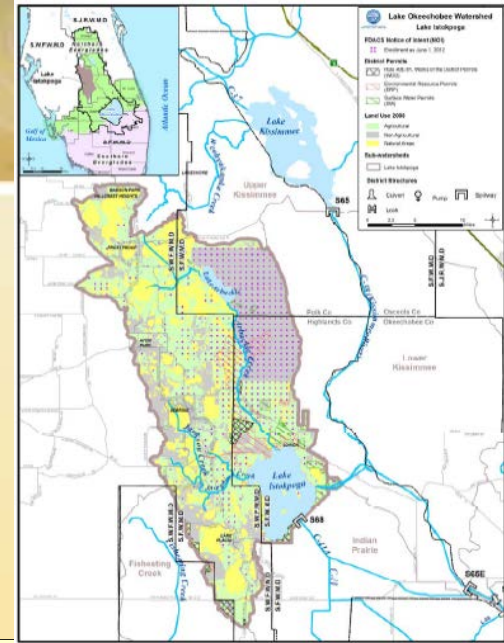
Base Period: WY1999-2007 R2 of prediction equation = 97%
 Predicted Load = $-140.82331 + 43.29617 \ln(\text{Rain}) + -9.1697 S$



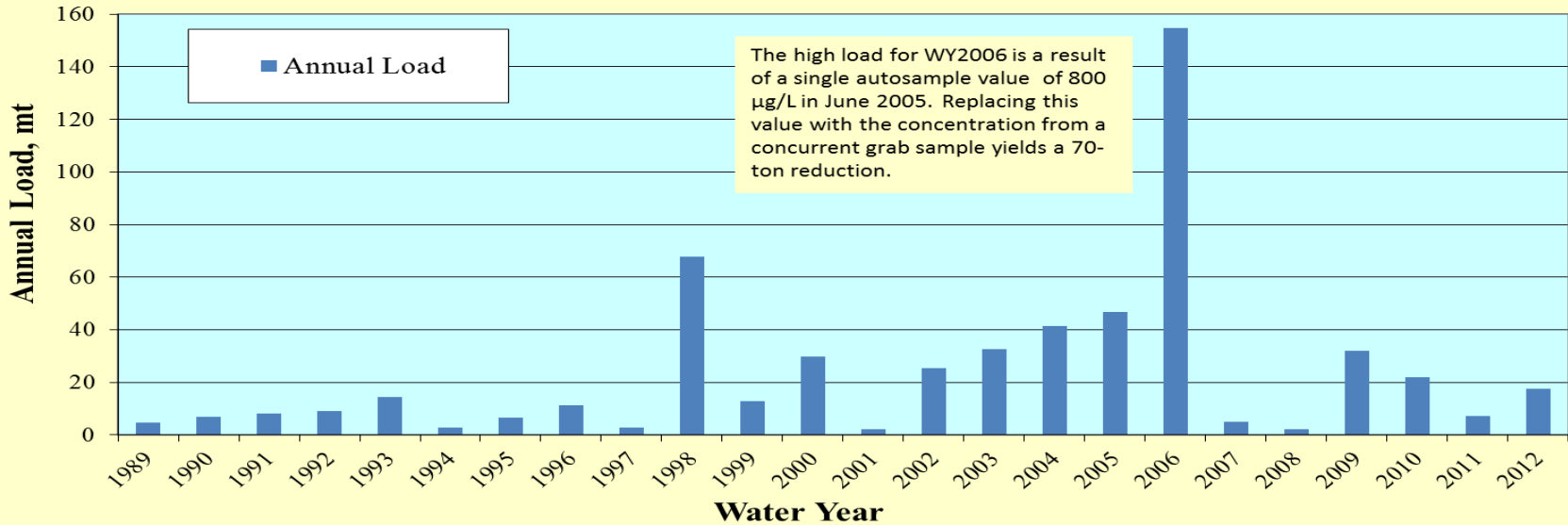
If prediction symbol is missing, rainfall fell outside Base Period range.

Lake Istokpoga Sub-watershed

- Basin area: 394,203 acres (11% of total LOW area)
- Spillway S-68 discharges to C-41A into Indian Prairie Sub-watershed
- WY2001-2012 average annual TP load: 32.34 metric tons (6.4%)
 - Approximately 3.1 metric tons/yr of Lake Istokpoga discharges (11%) remain in Indian Prairie Sub-watershed
- Percent of LOW TP Load (range for WY2001-2012): 0.1 – 19.5%

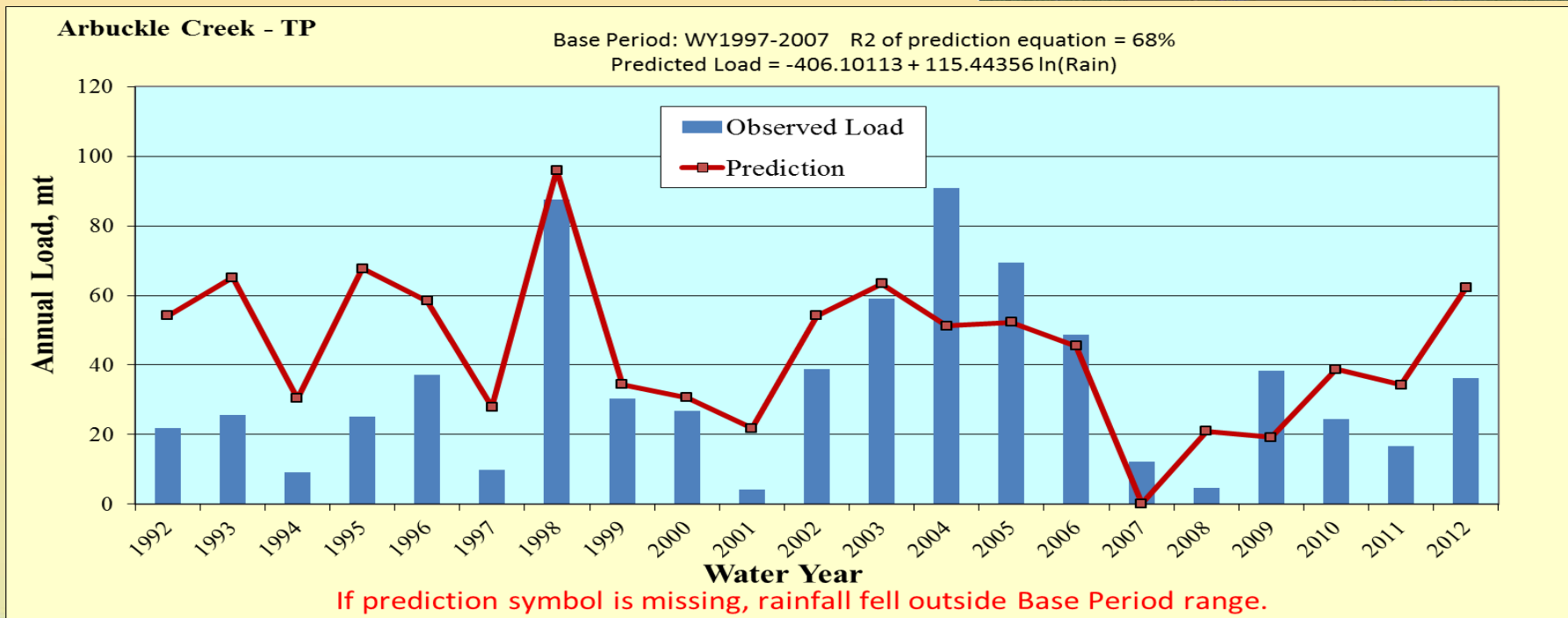


S-68 - TP



Lake Istokpoga Sub-watershed: Arbuckle Creek

- Basin area: 246,264 acres (7.1% of LOW area; 62.5% of sub-watershed)
- Arbuckle Creek discharges into Lake Istokpoga
- WY2001-2012 average annual TP load: 36.94 metric tons



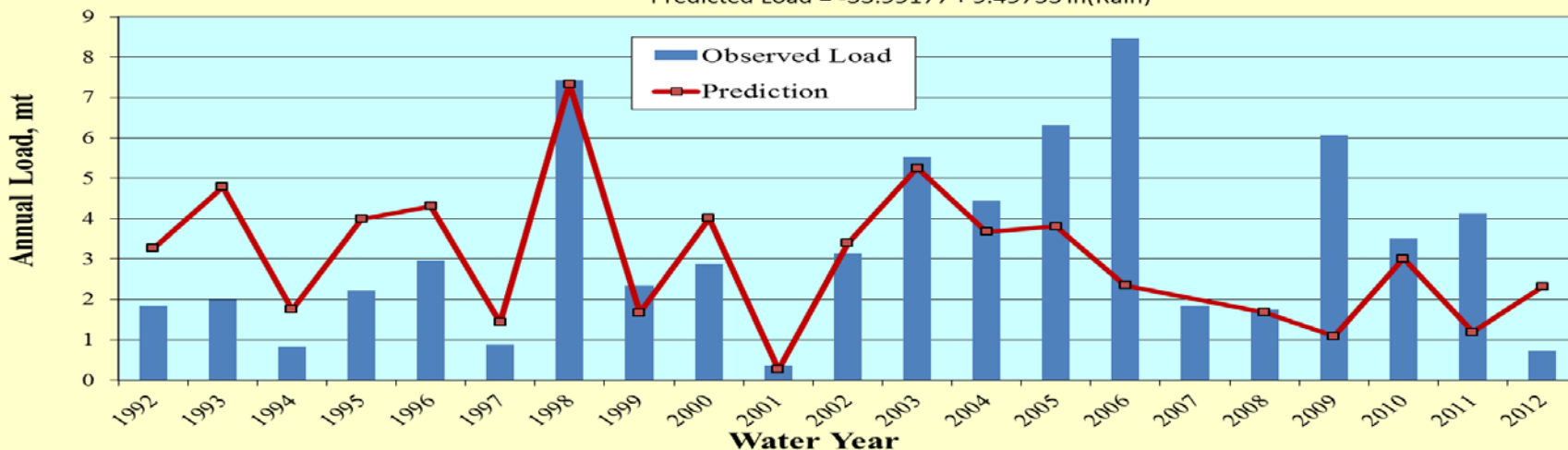
Lake Istokpoga Sub-watershed: Josephine Creek

- Basin area: 90,607 acres (2.6% of LOW area; 23% of sub-watershed)
- Josephine Creek discharges into Lake Istokpoga
- WY2001-2012 average annual TP load: 2.96 metric tons



Josephine Creek - TP

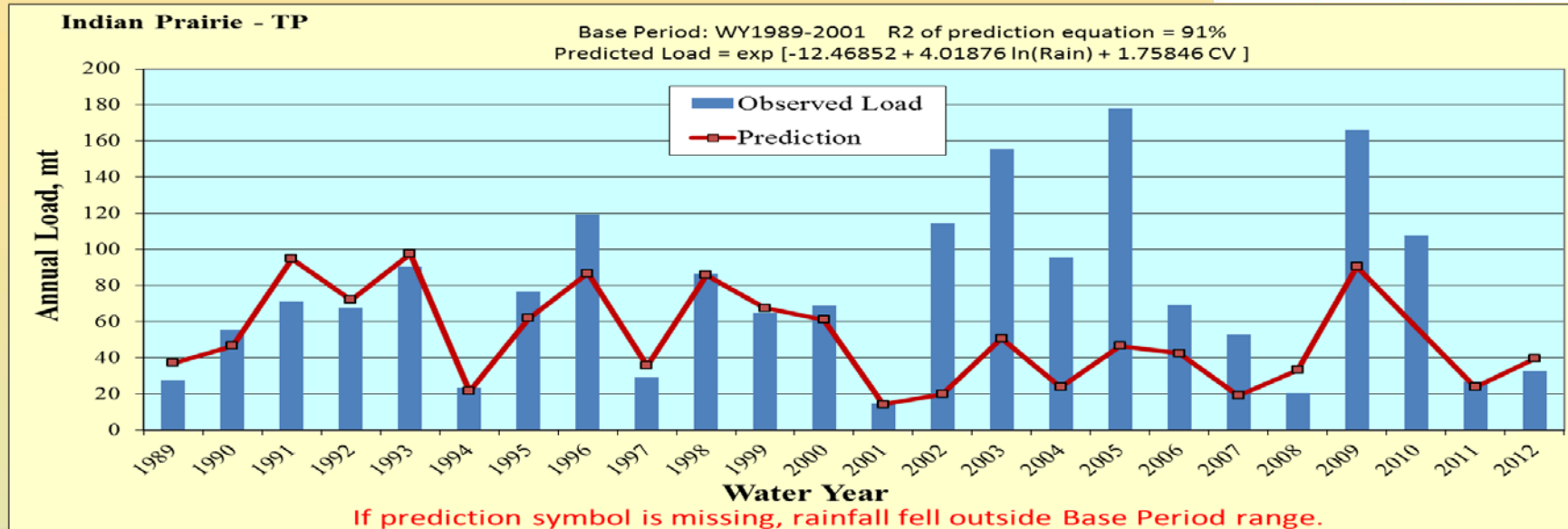
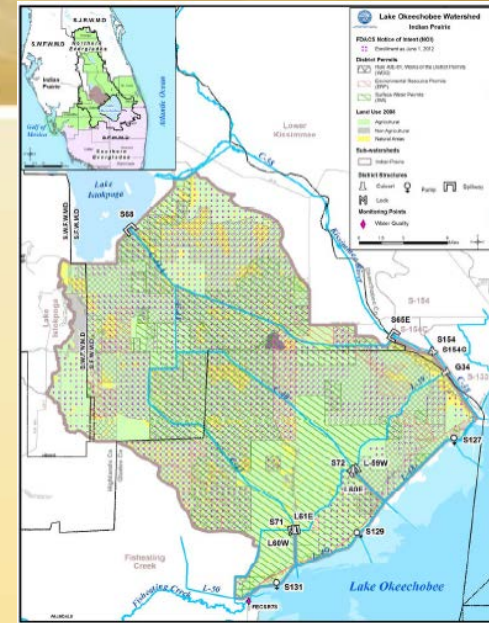
Base Period: WY1997-2004 R2 of prediction equation = 93%
 Predicted Load = $-33.99177 + 9.49753 \ln(\text{Rain})$



If prediction symbol is missing, rainfall fell outside Base Period range.

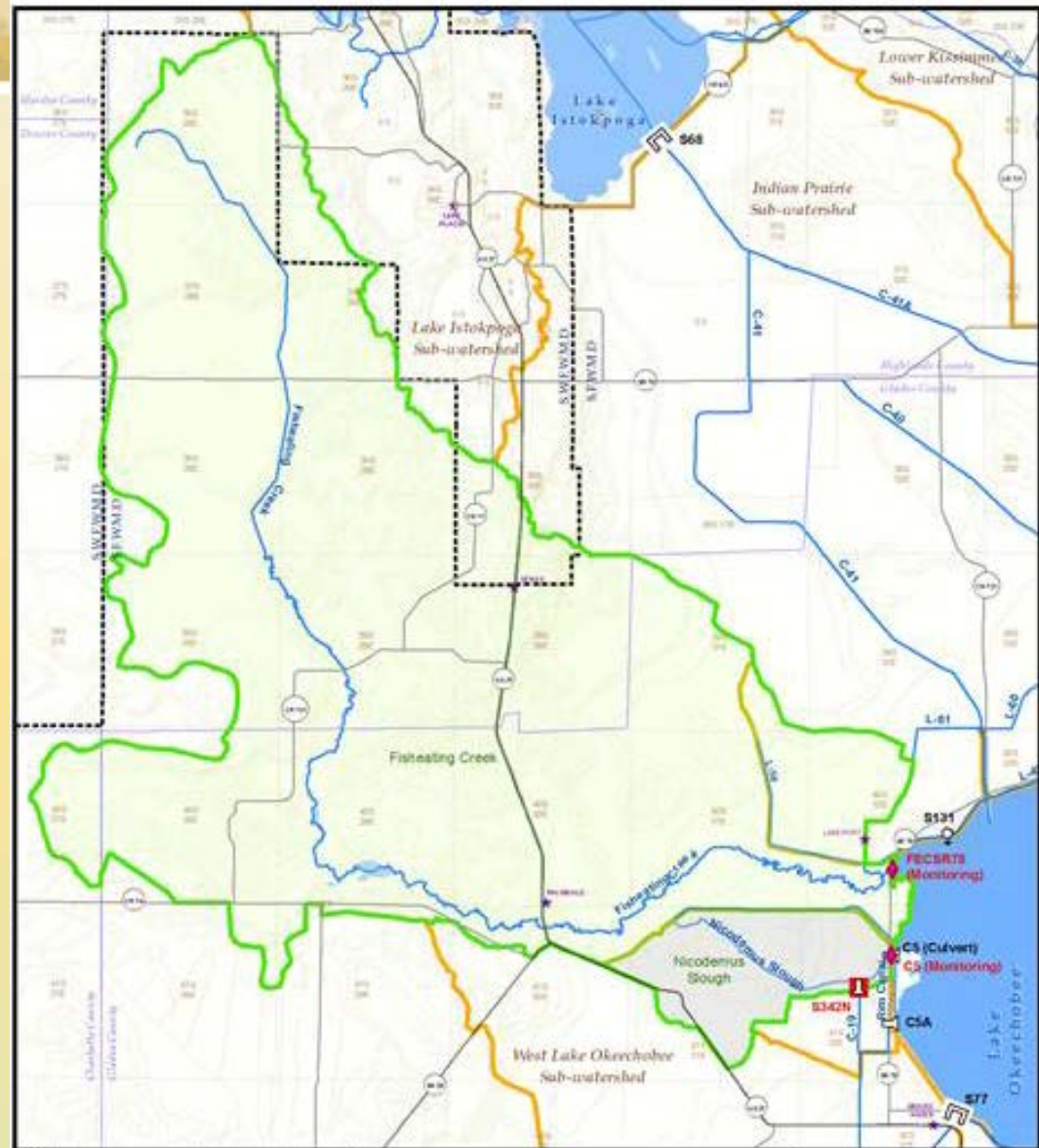
Indian Prairie Sub-watershed

- Sub-watershed area: 276,577 acres (8.0% of LOW area)
- WY2001-2012 average annual TP load: 86.23 metric tons (19%)
- Percent of LOW TP Load (range for WY2001-2012): 8.9 – 26.8%



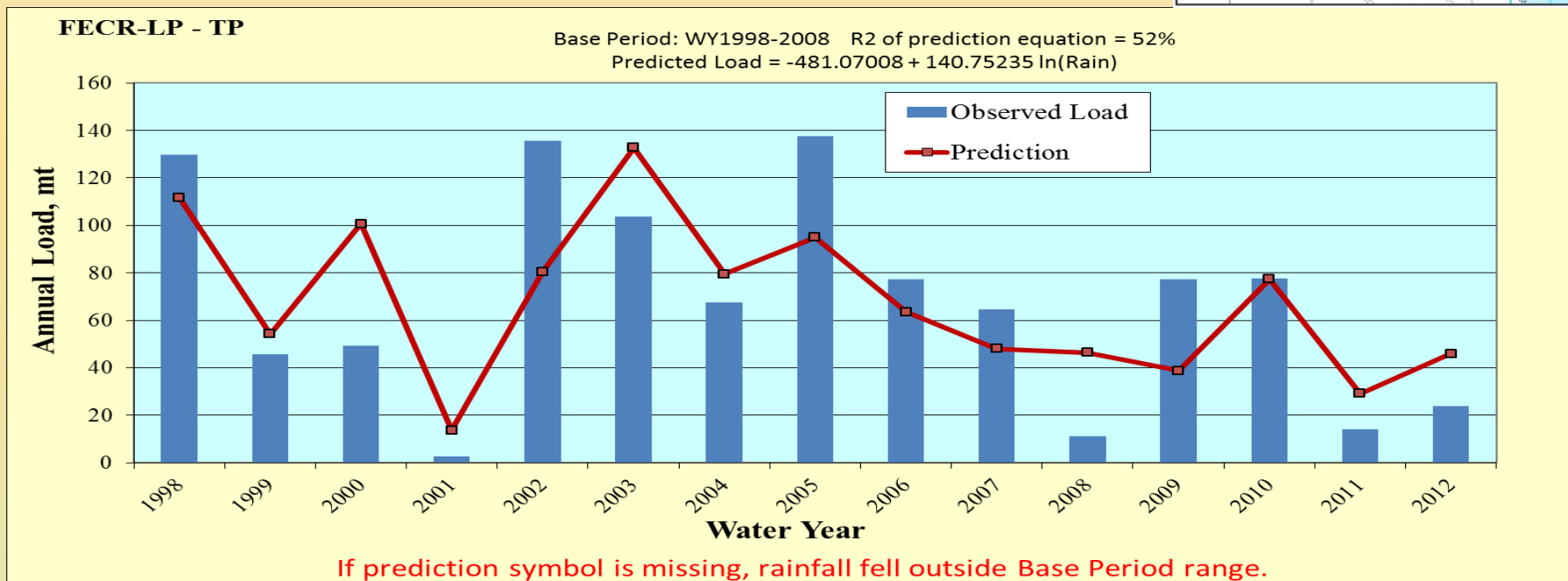
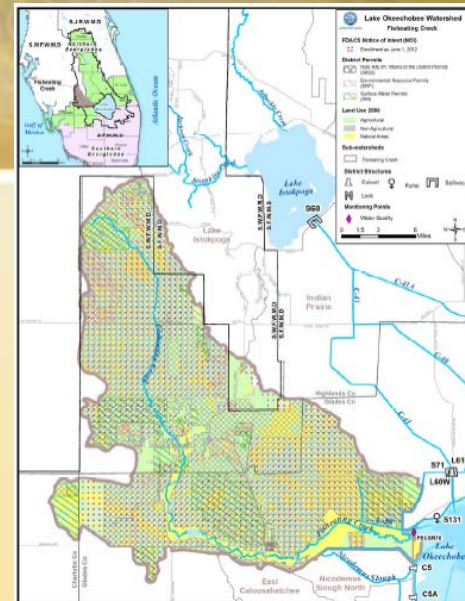
Fisheating Creek / Nicodemus Slough Sub-watershed

- Sub-watershed area: 318,042 acres (9.2% of LOW area)
- Fisheating Creek Basin – sufficient data to analyze
- Nicodemus Slough Basin – insufficient data to analyze; discharges to Lake Okeechobee and Caloosahatchee River Watershed



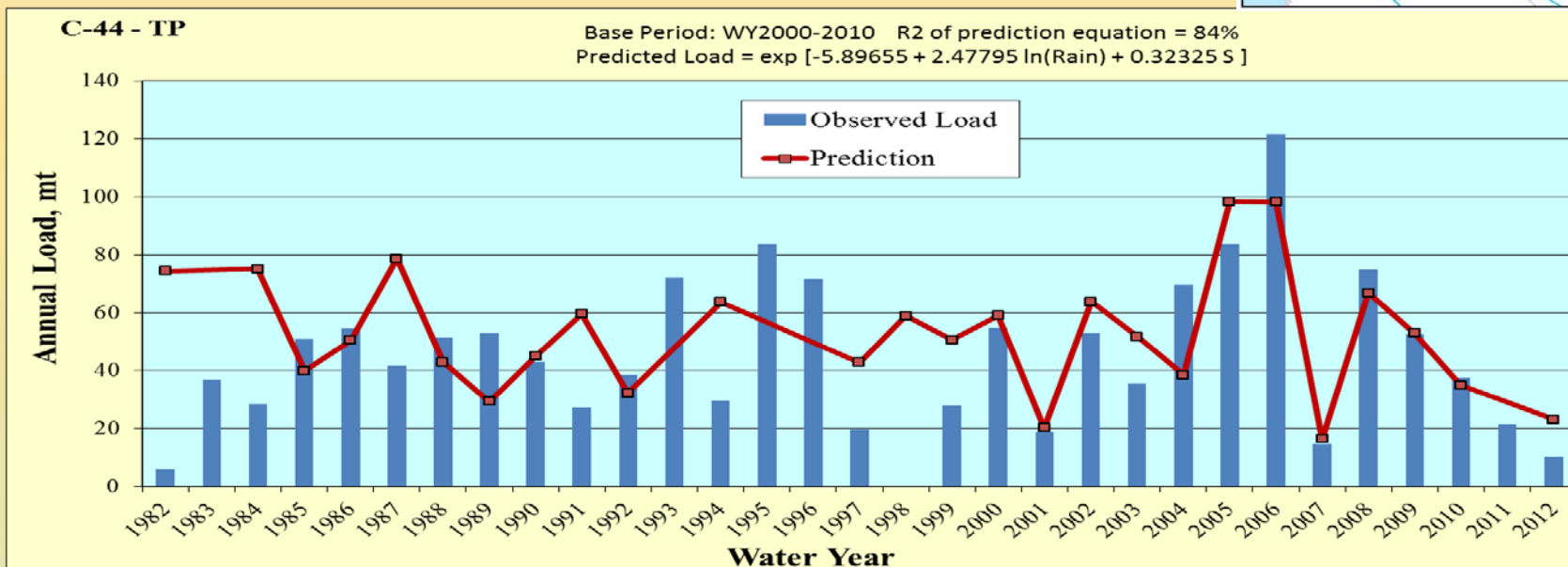
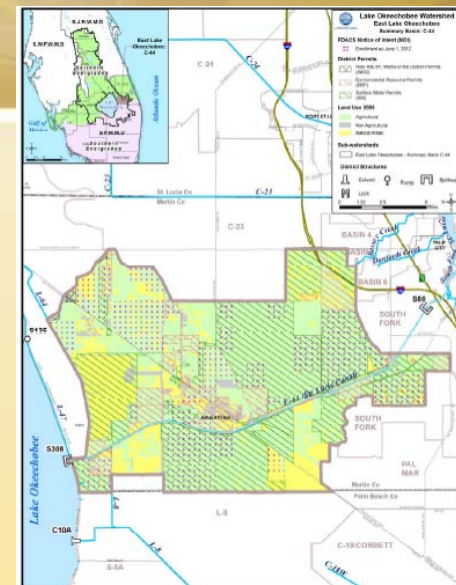
Fisheating Creek Basin

- Fisheating Creek Basin area: 298,713 acres (8.7% of LOW area; 94% of sub-watershed)
- Receiving waterbody: Lake Okeechobee
- WY2001-2012 average annual TP load: 66.1 metric tons (14% of total load to Lake Okeechobee)
- Percent of LOW TP Load (range for WY2001-2012): 3.0 – 32.7%



East Lake Okeechobee Sub-watershed: C-44 Basin

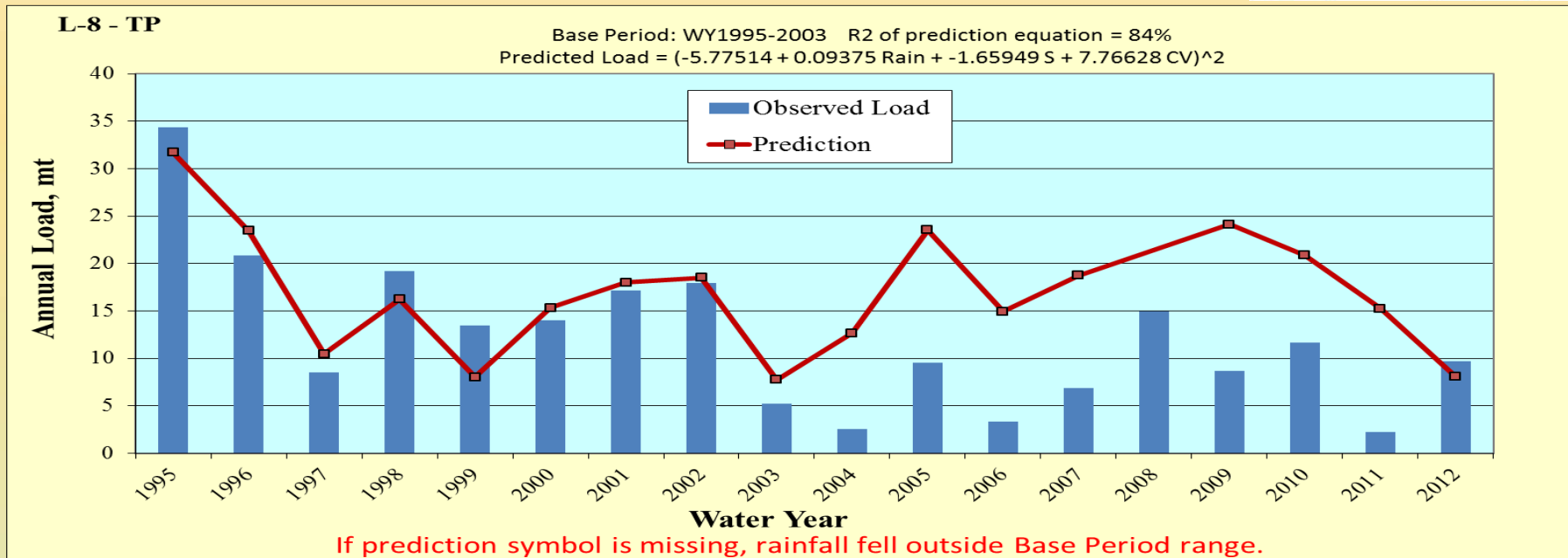
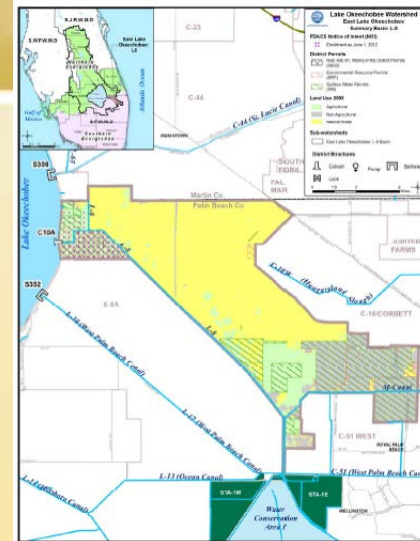
- Basin area: 132,572 acres (3.8% of LOW area; 55% of sub-watershed)
- Basin discharges to Lake Okeechobee (S-308) and St. Lucie River (S-80)
- WY2001-2012 average annual TP load: 49.5 metric tons
 - To Lake: 18.7 metric tons (4.1%)
- Percent of LOW TP Load (range for WY2001-2012): 0 – 35.2%



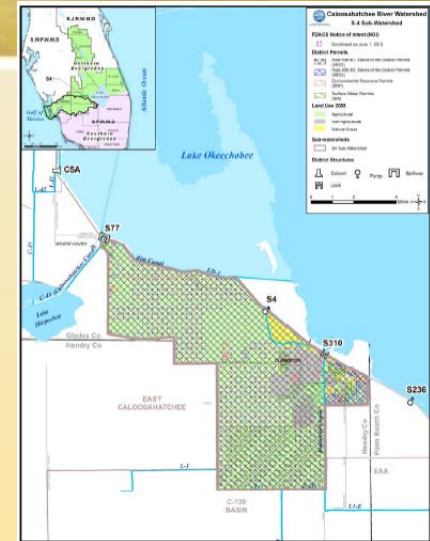
If prediction symbol is missing, rainfall fell outside Base Period range.

East Lake Okeechobee Sub-watershed: L-8 Basin

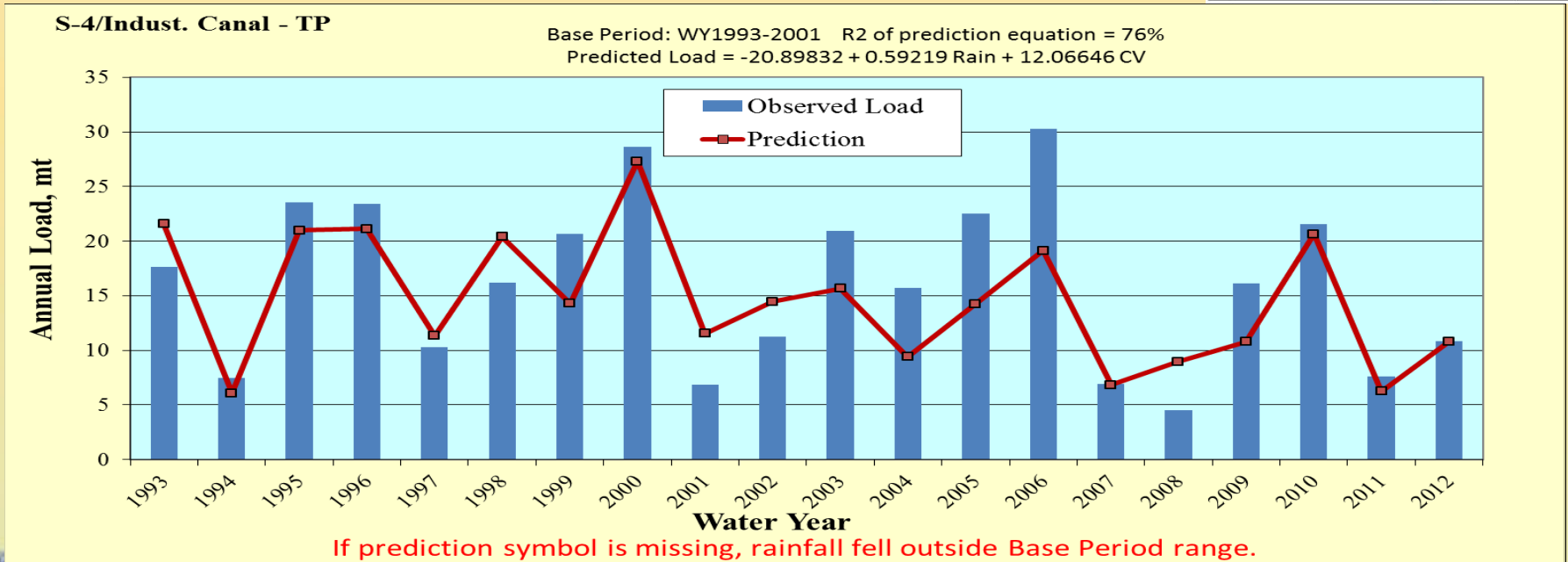
- Basin area: 106,440 acres (3.1% of LOW area ; 45% of sub-watershed)
- Basin discharges to Lake Okeechobee, EAA, City of West Palm Beach Water Catchment Area, STA-1E/1W and C-51
- WY2001-2012 average annual TP load: 9.16 metric tons/yr; to Lake: 8.14 metric tons/yr (1.8%)
- Percent of LOW TP Load (range for WY2001-2012): 0.3 – 14.0%



West Lake Okeechobee Sub-watershed: S-4 /Industrial Canal Basin

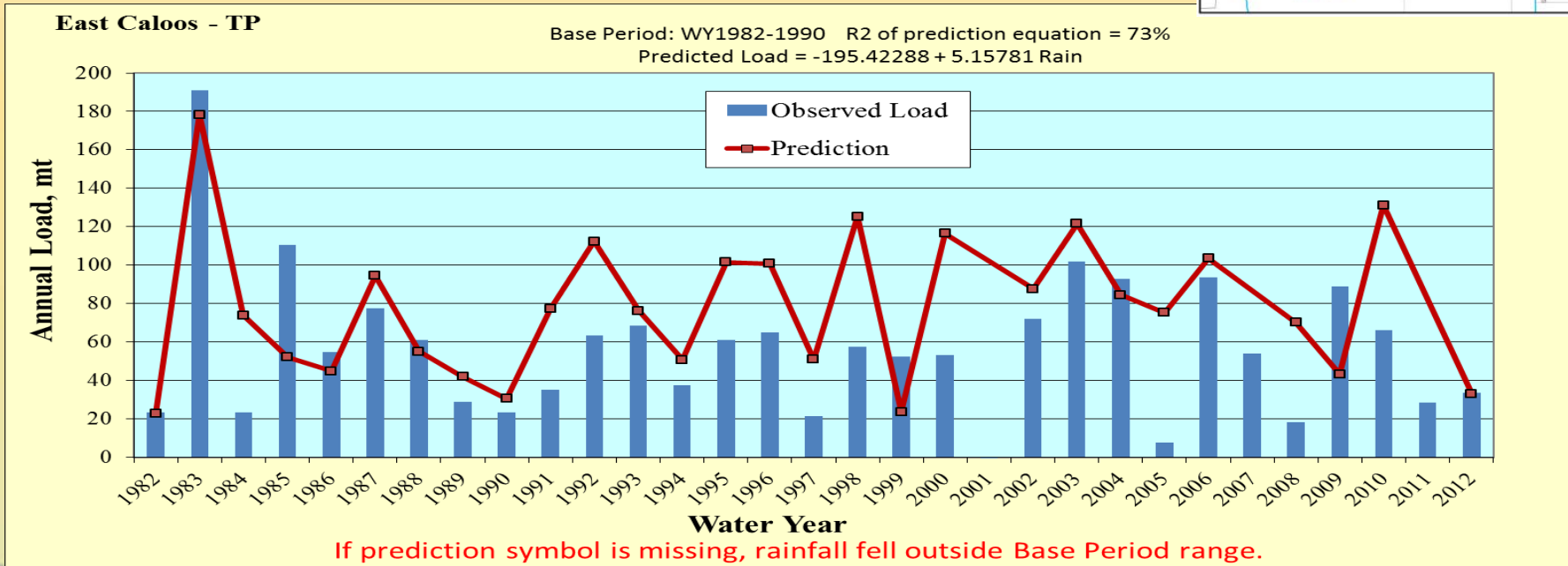
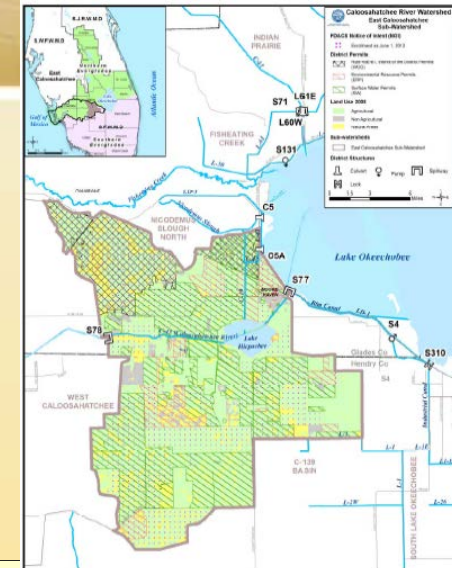


- Basin area: 42,145 acres (1.2% of LOW area; 17% of sub-watershed)
- Basin discharges to Lake Okeechobee and Caloosahatchee River Watershed
- Basin receives water from Lake Okeechobee, Caloosahatchee River Watershed and South Florida Conservancy District
- WY2001-2012 average annual TP load: 14.59 metric tons; to Lake: 9.31 MT/yr (2%)
- Percent of LOW TP Load (range for WY2001-2012): 0.8 – 3.6%



West Lake Okeechobee Sub-watershed: East Caloosahatchee Basin

- Basin area: 204,094 acres (5.9% of LOW area; 83% of sub-watershed)
- Basin discharges to Lake Okeechobee and Caloosahatchee River Watershed
- WY2001-2012 average annual TP load: 54.52 metric tons; to Lake: 5.97 MT/yr (1.3%)
- Percent of LOW TP Load (range for WY2001-2012): 0 – 8.2%



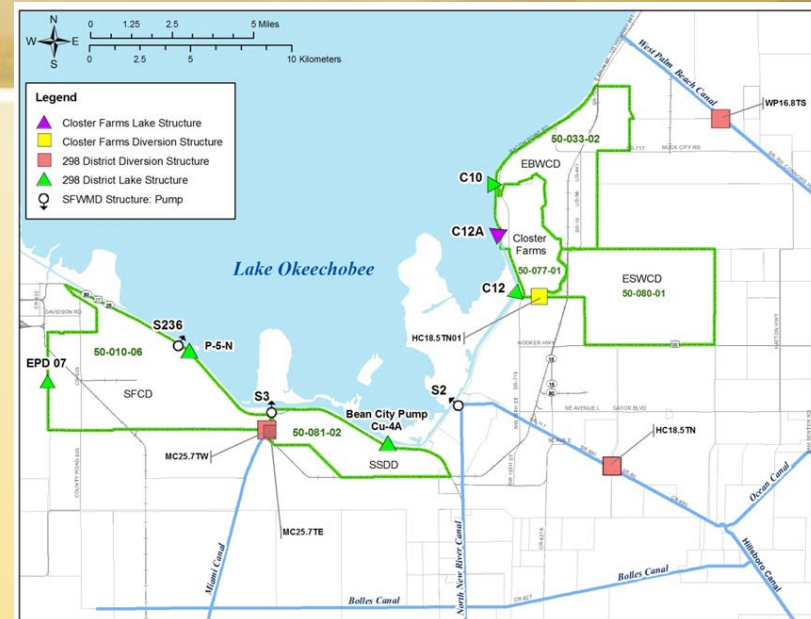
South Lake Okeechobee Sub-watershed

- Sub-watershed area: 322,262 acres (9.3% of LOW area)
- Discharges to Lake Okeechobee, STAs, L-8 Basin, Everglades Protection Area
- Everglades Agricultural Area
 - S-2, S-3, S-352
 - Regulatory Program described in Rule 40E-63
- Four Ch. 298 Districts and state-leased land
 - East Shore Water Control District
 - East Beach Water Control District
 - South Shore Drainage District
 - South Florida Conservancy District
 - 715 Farms (aka Closter Farms)
 - collectively referred to as “Ch. 298 Districts”



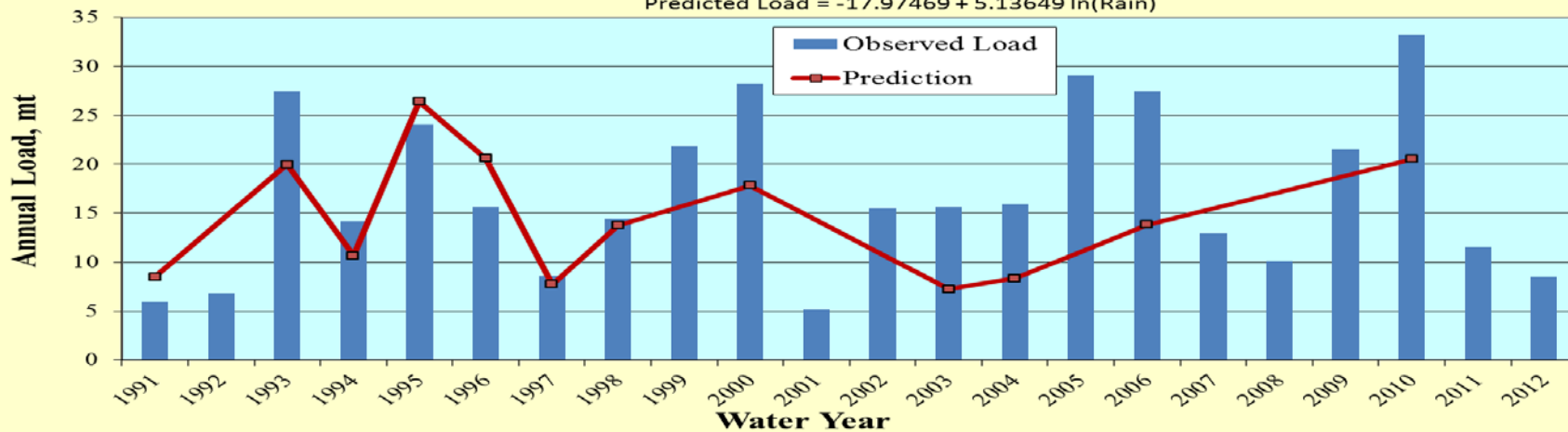
South Lake Okeechobee Sub-watershed: Ch. 298 Districts

- Basin area: 33,502 acres (1.0% of LOW area)
- Flow and TP measured at twelve structures
- WY2001-2012 average annual TP load: 17.2 MT/yr; to Lake: 3.44 MT/yr (<1%)
- Percent of LOW TP Load (range for WY2001-2012): 0 – 5.3%



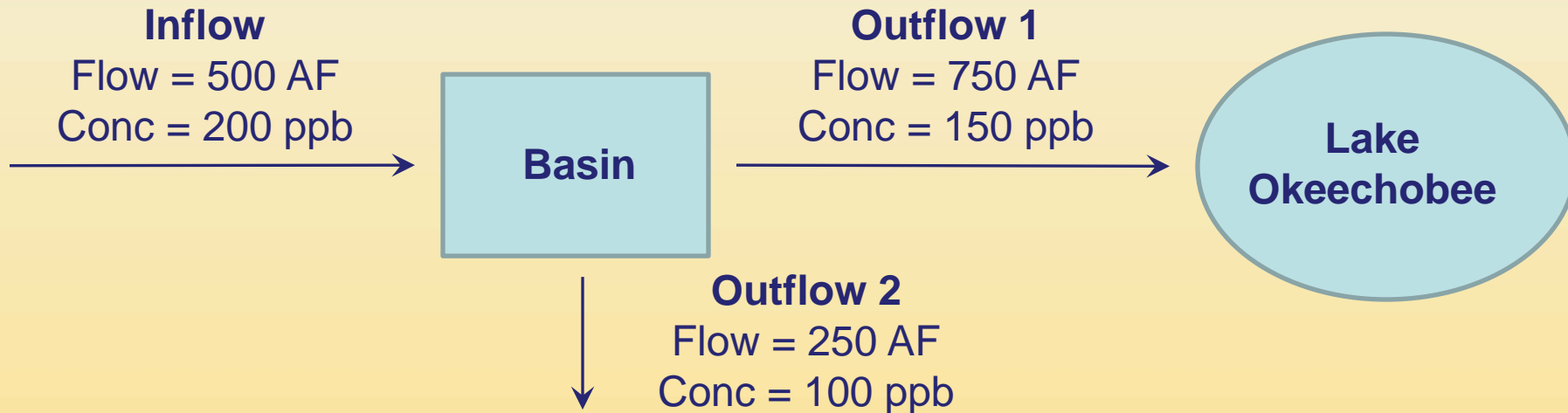
Ch. 298 Districts - TP

Base Period: WY1991-1998 R² of prediction equation = 81%
Predicted Load = -17.97469 + 5.13649 ln(Rain)



If prediction symbol is missing, rainfall fell outside Base Period range.

Daily Basin Flow/Load Calculations



Basin Flow Calculation – to Lake and other waterbodies

Pass Through Flow = $\text{Min}(\text{Inflow}, \text{Outflow}) = \text{min}(500, 1000) = 500 \text{ AF}$

Basin Flow = Outflow – Pass Through = $1000 - 500 \text{ AF} = 500 \text{ AF}$

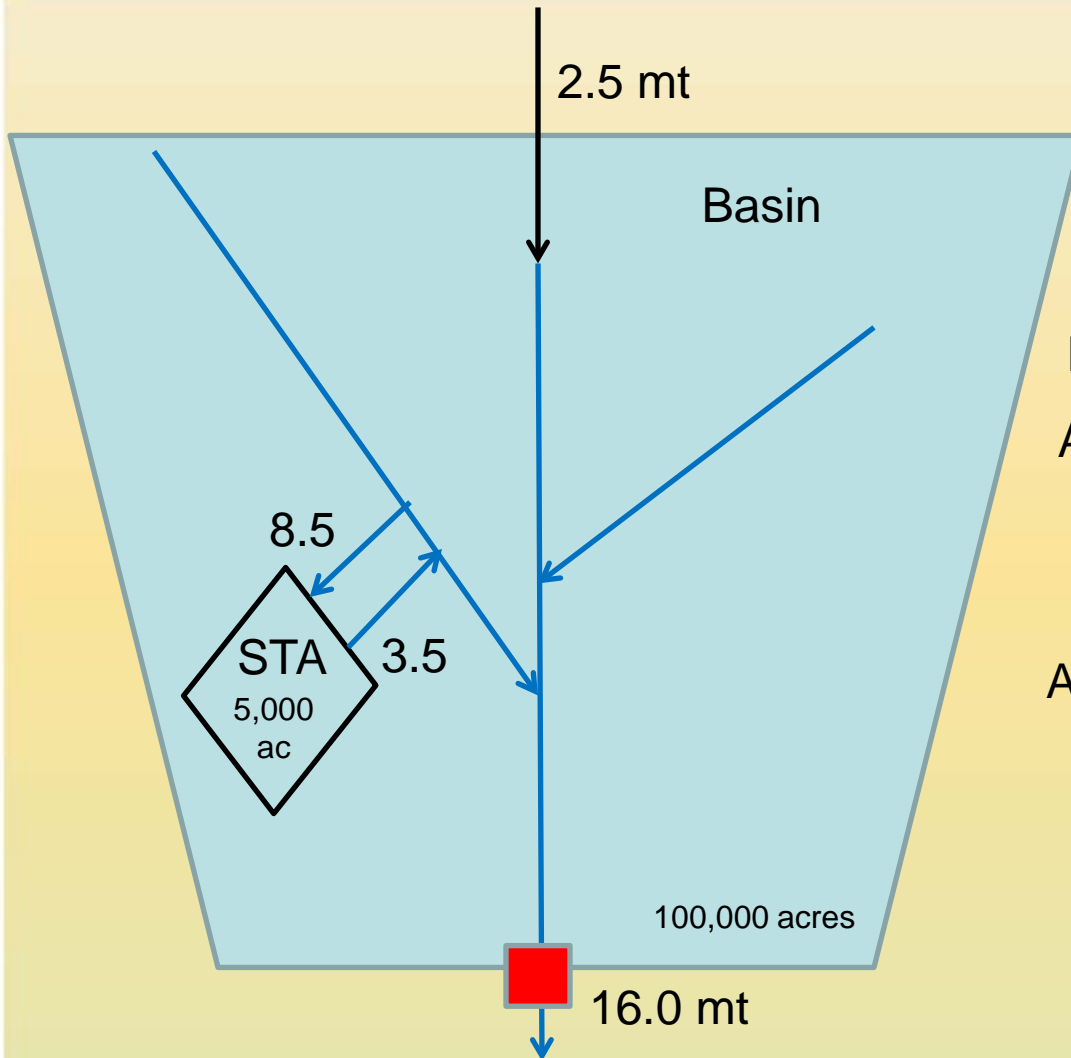
Basin Load Calculation - to Lake and other waterbodies

Outflow Load = $\sum(\text{Outflow} * \text{Conc}) = [(750*150) + (250*100)] * 0.0012335 = 169.6 \text{ kg}$

Pass Through Load = $\text{Pass Through Flow} * \text{Inflow Conc} = 500 * 200 * 0.0012335 = 123.4 \text{ kg}$

Basin Load = Outflow Load – Pass Through Load = $169.6 - 123.4 = 46.2 \text{ kg}$

Adjustment for Regional Project



Example calculations:

Measured load = 16.0 mt

Pass-through load = 2.5 mt

Regional project reduction = 8.5 – 3.5

Adj. basin load = 16 – 2.5 + (8.5 – 3.5)

Adj. basin load = 18.5 mt

Adj. Target = Target * $\frac{(100,000 - 5,000)}{100,000}$

Adj. Target = 20 * 0.95 = 19 mt

Adj. Limit based on Adj. Target

Adjusted Rainfall

- Used to determine when rainfall conditions were outside range of Base Period
- For basins with Targets/Limits derived from multiple predictor variables (e.g., annual rainfall and coefficient of variation, CV), an **adjusted rainfall** amount reflects the cumulative effect of the predictor variables.
- The adjusted rainfall is the rainfall that would produce the equivalent annual load using the prediction equation by setting the value of other predictor variables to their mean values for the Base Period.

Example: S-191

$$\text{Adj. Rainfall} = \exp [X + 0.41059 (CV + CV_m)]$$

CV_m is the mean value of CV during the Base Period

Identical to the process used to in Ch. 40E-63 (EAA & C-139 basins)