TECHNICAL PUBLICATION
WMD 08-1001

CREAMS-WT Calibration for the Upper Kissimmee Region

By: Hongying Zhao, Joyce Zhang, R. Thomas James

Lake Okeechobee Division
Watershed Management Department
South Florida Water Management District
3301 Gun Club Road
West Palm Beach, FL 33406

October 01, 2008

Abstract

The **C**hemicals, **R**unoff, and **E**rosion from **A**gricultural **S**ystems – **W**ater **T**able (CREAMS-WT) model is designed to simulate the hydrologic, nutrient, and management characteristics under the typical flat, sandy, and high-water table conditions in South Florida flatwoods watersheds. This model has been applied to Lake Okeechobee Watershed and utilized as a modeling tool for land use change permit applications. This study intended to expand the model application domain to the Upper Kissimmee Region. To accomplish this task, we first researched the soil database, identified a new soil association, Candler-Astatula, and developed the representative soil parameter file required as input for the CREAMS-WT model. Then, we calibrated the model for the Upper Reedy Creek and Shingle Creek basins based on the 20-year period of observed data from 1986 to 2005 and developed unit flow and load datasets for different combinations of soil, weather, and land use practices. Finally, the model was verified by applying the model to another basin: Boggy Creek. The simulated long term annual flow and load series compare satisfactorily with observed datasets. The unit flow and load datasets were verified by satisfactorily predicting the basin's long term annual average flow and load. Based on the validation results, the calibrated CREAMS-WT model should be applicable to simulate the long term annual flow and load series for other basins in the Upper Kissimmee Region. The developed unit flow and load datasets also can be used to predict the long term annual average flow and load for a land parcel in this region.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. Introduction

The **C**hemicals, **Flow**, and **E**rosion from **A**gricultural **S**ystems – **W**ater **T**able (CREAMS-WT) model is designed to simulate the hydrologic, nutrient, and management characteristics in the South Florida Flatwoods watersheds (Knisel, 1980; Heatwole, 1986). The CREAMS-WT model has been used to simulate flow and phosphorus transport in the Lake Okeechobee Watershed (Kiker et al., 1992) for the Lake Okeechobee Agricultural Decision Support System (LOADSS, Negahban et al., 1995). The study simulated flow and phosphorus loading under a variety of weather, soil, and land use conditions. Specifically, the study grouped soils into 13 associations and developed 50 phosphorus control practices (PCPs). Results of this study were integrated into LOADSS to estimate the long term average annual flow and loads from each parcel. In 1999, the LOADSS was updated to account for substantial changes in dairy land uses, a new period of record (1976 to 1995), and additional land use change scenarios and associated costs of converting one land use to another (Zhang et al., 1999).

The CREAMS-WT model also is a component of the subbasin-scale phosphorous transport model for the Lake Okeechobee watershed (Wagner et al., 1996). This model predicted subbasin phosphorus loads and was applied to the Taylor Creek Subbasin (Zhang et al., 1996).). The CREAMS-WT model was also used by Zhang et al. (2002) to examine potential phosphorus load reductions from the Lake Okeechobee Works of the District (LOK WOD) out-of-compliance sites. The study estimated off-site phosphorus discharge loads using monitored phosphorus concentrations and CREAMS-WT model predicted runoff values.

For the LOK WOD, the staff from the Environment Resource Permit (ERP) Division at the South Florida Water Management District (the District) has used the CREAMS-WT to conduct phosphorus pre-post analysis. The Upper Kissimmee Region which is a part of Lake Okeechobee Protection Plan area, was not included in the previous model domain. Recently, the staff from the ERP Division requested the model be used to simulate the Upper Kissimmee Region, especially the Orlando area, where the land use changes are occurring rapidly. This area contains a large portion of industrial/commercial area.

Under the Lake Okeechobee Protection Program, the LOK WOD permit applicants may use the CREAMS-WT model to predict long term average annual phosphorus loads for current and proposed land uses (SFWMD, 2003). However, observed flow and phosphorus load values generally are not available for a given land parcel, meaning model calibration for that land parcel is not possible.

The first objective of this study was to calibrate the CREAMS-WT input parameter files and further verify the model with observed data to justify the model's applicability for the entire Upper Kissimmee Region. These files were initially based on those developed for the Lake Okeechobee Watershed CREAMS-WT application (Kiker et al., 1992). The calibrated input parameter files can be applied to simulate the long term annual flow and load series for basins within the region when combining with local rainfall data. The second objective was to develop unit flow and unit load datasets that can be applied to predict the long term annual average flow and load for basins or a land parcel within the Upper Kissimmee Region that have no long term daily rainfall data. To accomplish both objectives, the following analyses were conducted.

- Examined land use types, soil types, and the existing land use and soil parameters of the Upper Kissimmee Region developed under the Lake Okeechobee Watershed study for applicability and sufficiency.
- Selected three basins with available monitoring data for model calibration and validation.
- Analyzed land use and soil datasets; Developed a soil parameter file for the new soil association discovered in this region. Calculated the acreages of different parcels corresponding to different combination of land use and soil types.
- Setup the CREAMS-WT model for the Upper Kissimmee Region, which include generating the rainfall files and temperature and radiation files and revising the management file.
- Calibrated the model with data collected from two of the selected basins.
- Used calibration results to develop unit flow and unit load datasets for different combinations of soil associations and land use activities.
- Validated the model with data collected from the third basin.
- Updated the unit flow and unit load datasets for different combinations of soil associations and land use activities based on the validation results. The updated datasets are recommended values for predicting the long term annual average flow and load for unmonitored land parcels within the Upper Kissimmee Region.

II. Basin Descriptions

The Upper Kissimmee Region contributes a substantial amount of flow and nutrient loads to Lake Okeechobee through Kissimmee River. The total drainage area is 1,600 square miles. This region is further delineated into 18 basins Guardo (1992). The dominant land use types in the Upper Kissimmee Region are natural and urban areas. A detailed basin description can be found from Guardo (1992). The two basins selected for model calibration are the Upper Reedy Creek and Shingle Creek basins (Figure 2-1). The Boggy Creek basin was chosen for model validation. These basins were selected because of available long term flow and water quality data.

1. Upper Reedy Creek Basin

The Upper Reedy Creek basin has a drainage area of 178 square miles (Figure 2-1). This basin occupies the northwest corner of the Upper Kissimmee River basin. Walt Disney World is located in the Upper Reedy Creek Basin. Reedy Creek runs southeast for about 29 miles before splitting into two branches near Cypress Lake. Several rainfall gages are available with various data collection periods. Flow data have been collected since 1939 by the United State Geology Survey (USGS) at station REEDYLOU. No water quality data are available at this location. However, a water quality station, CREEDYBR, is located about 10 miles downstream of the flow monitoring site. This water quality station is maintained by the District and the record is available since 1985. This station provides the best available water quality data for this basin. This conclusion is made based on the landuse information. There are no significant landuse type changes between the drainage area upstream of the station REEDYLOU and the drainage area between the station REEDYLOU and station CREEDYBR.

2. Shingle Creek Basin

The area of Shingle Creek upstream of flow monitoring station SHING.AP is 89 square miles. The USGS has been collecting flow data at this station since 1950. Water quality data has been collected at station BWSHNGLE by the District since 1985. This basin occupies the north central part of Upper Kissimmee River region and is bounded by the Upper Reedy Creek basin to the west and the Boggy Creek basin to the east (Figure 2-1). The headwaters of this creek include a populated area west of Orlando, which has been subjected to major residential development. The part of Shingle Creek that is within this area has been channelized. Shingle Creek flow proceeds from the headwaters southward for 24 miles to its outlet into Lake Tohopekaliga. This is a major inflow source to the lake.

3. Boggy Creek Basin

The Boggy Creek basin has a drainage area of 87 square miles and is located in central western Orange County, east of Florida's Turnpike (Figure 2-1). Its drainage area extends southward from the center of Orlando to East Lake Tohopekaliga, where it is the major inflow. The main water-course of Boggy Creek is channelized, moving water southward passing under the Beeline Expressway, flowing through the Orlando International Airport property, and passing under Boggy Creek Road. Downstream of this point the creek is no longer channelized. This lower portion of the basin has a number of depressions and swamps, many of which are connected to the main stream by natural sloughs or small drainage ditches. The largest of these is known as the Boggy Creek Swamp, which covers nearly two square miles and functions as a natural retention area for basin flow. Upon leaving the swamp, flow from the creek passes through a well-defined outlet, located on the northwestern shore of East Lake Tohopekaliga. Landuse in the Boggy Creek basin includes agricultural, urban, and the Orlando International Airport. Boggy Creek swamp, together with other wetlands, lakes, and ponds, accounts for approximately 22% of the basin area. The remainder of the basin, which has no control structures, consists of forest upland and recreational lands. Flow has been observed at station BOGGY.TA by the USGS since 1959. Water quality has been monitored at station ABOGG by the District since 1981.

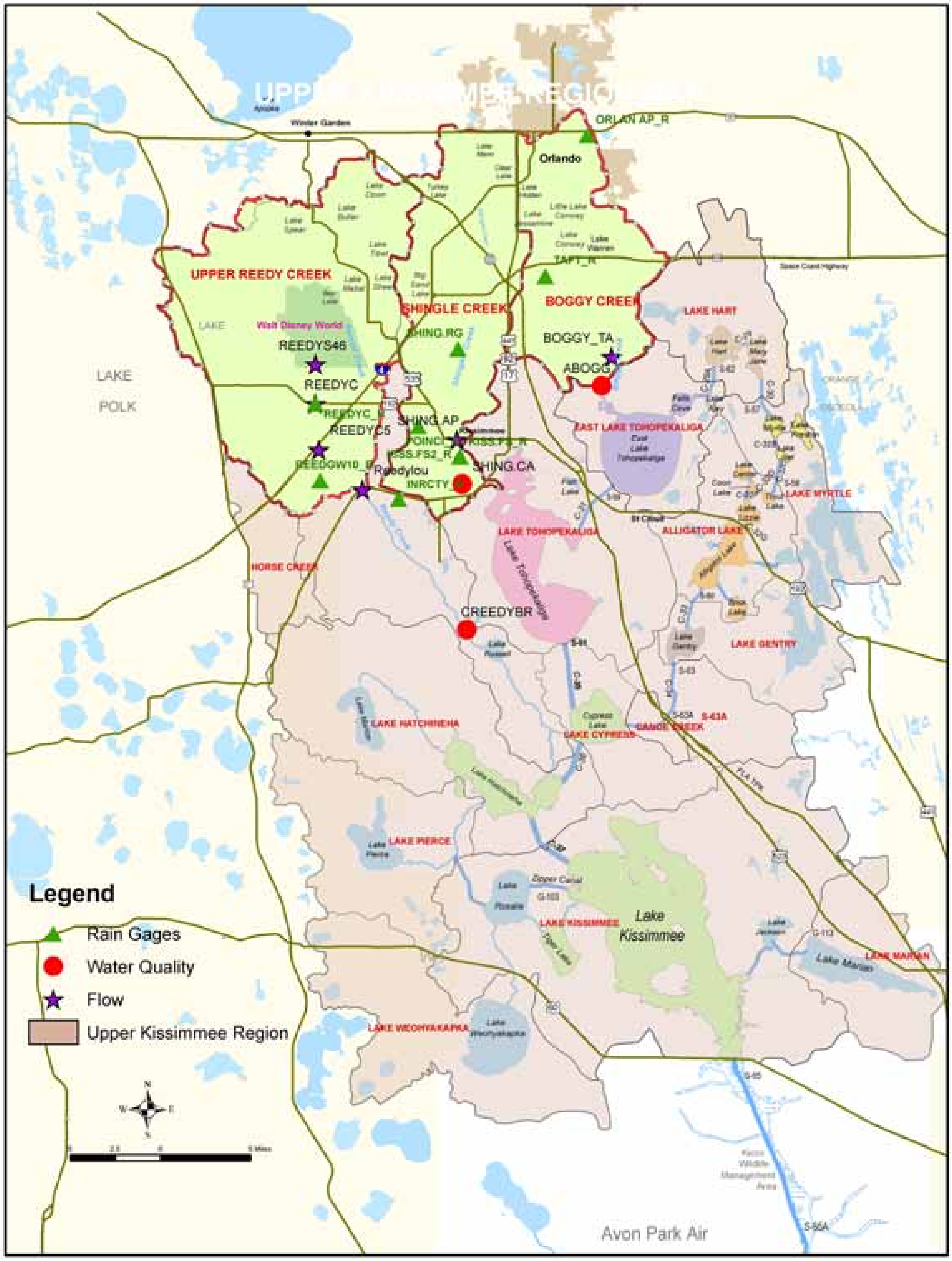

Figure 2-1: Upper Kissimmee Region Map
(Modified from Upper Kissimmee Basin Map, the Kissimmee Division, January 2008)

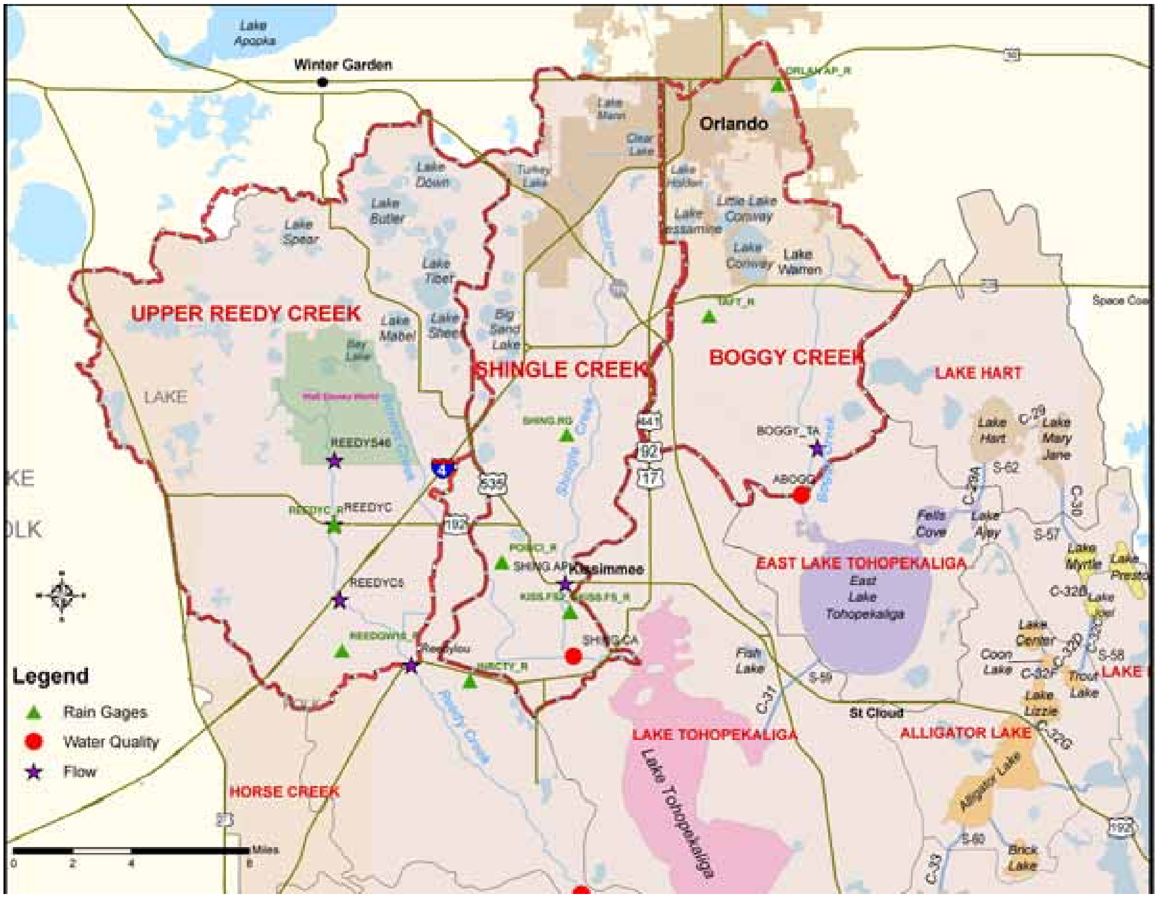

Figure 2-2: Upper Reedy, Shingle Creek and Boggy Creek Basins Drainage Map

III. Data Preparation

Inputs for the CREAMS-WT include soil, weather, and land use information (described below). Weather data includes rainfall, temperature and solar radiation. The observed flow and water quality data are use to calibrate and validate the model.

1. Soil Data

The U.S. General Soil Map (USGSM) consists of general soil association units. It was developed by the National Cooperative Soil Survey (NCSS) and supersedes the State Soil Geographic (STATSGO) dataset published in 1994. The soil data for Florida was downloaded from NCSS. Spatial data are available in ESRI® shape file format. Tabular data are available as text files in ASCII. A Microsoft Access template database has been prepared for use with the U.S. General Soil Map tabular data (NCSS, 2006).

Based on the USGSM, the Upper Kissimmee Region contains 16 primary soil associations. Fifteen of these associations were classified into groups as specified in the

Lake Okeechobee watershed study (Zhang et al., 1999). The remaining soil association, Candler-Astatula, was previously identified as a minor soil association in the Lake Okeechobee watershed study and grouped under soil association Zolfo-Tavares. In the Upper Kissimmee Region, this soil association covers approximately 18% of the drainage area, and is listed as an independent group, CAN-AS. These sixteen soil associations were grouped into six CREAMS-WT soil associations. The soil file name, the related soil associations in the CREAMS-WT model, and the soil association name as appears in the USGSM database are listed in Table 3-1. The soil parameter file for the new soil association CAN-AS is named as Sol-as14.

Table 3-1: Soil Association in the Upper Kissimmee Region

Soil ID	Soil Association	Area (acres)	Percentage (%)	Soil Association Names in USGSM
Sol-as1	Urban land-Basinger	26,825	2.6	Immokalee-EauGallie-Basinger, Urban land-Basinger, Urban land-Smyrna-Myakka
Sol-as2	Felda-Chobee	47,054	4.6	Kaliga-Floridana-Felda-Chobee
Sol-as3	Floridana-Riviera	56,820	5.6	Riviera-Copeland-Boca, Riviera-Pineda-Felda, Terra Ceia-Riviera-Floridana
Sol-as7	Smyrna-Immokalee	473,377	46.3	Smyrna-Immokalee-Basinger, Smyrna-Myakka-Immokalee, Waveland-Pomello-Myakka-Immokalee, Popash-Pomona-Myakka-Malabar-EauGallie
Sol-as9	Terra Ceia Samsula	110,387	10.8	Samsula-Hontoon-Everglades, Tomoka-Terra Ceia-Samsula-Hontoon, Water-Udorthents-Neilhurst-Hydraquents-Arents
Sol-as14	Candler-Astatula	184,262	18.0	Candler-Astatula, Candler-Astatula-Arredondo
Water	Water	122,829	12.0	
Total		1,021,554	100	

The USGSM database for Florida was downloaded from the NCSS website, http://soils.usda.gov/survey/geography/statsgo/. The soil parameters for Sol-as14 were calculated based on the USGSM database. The USGSM database has a wealth of information with over 130 tables. These tables are woven together in a very complex web of relationships. For the purpose of CREAMS-WT model simulation, pertinent information is included in four tables (Figure 3-1):

- mapunit: identifies the map units included in the referenced legend
- chorizon: lists the horizon(s) and related data for the referenced map unit component.
- component: lists the map unit components identified in the reference map unit and the selected properties of each component.
- muaggat: records a variety of soil attributes and interpretation that have been aggregated from the component level to a single value at the map unit level.

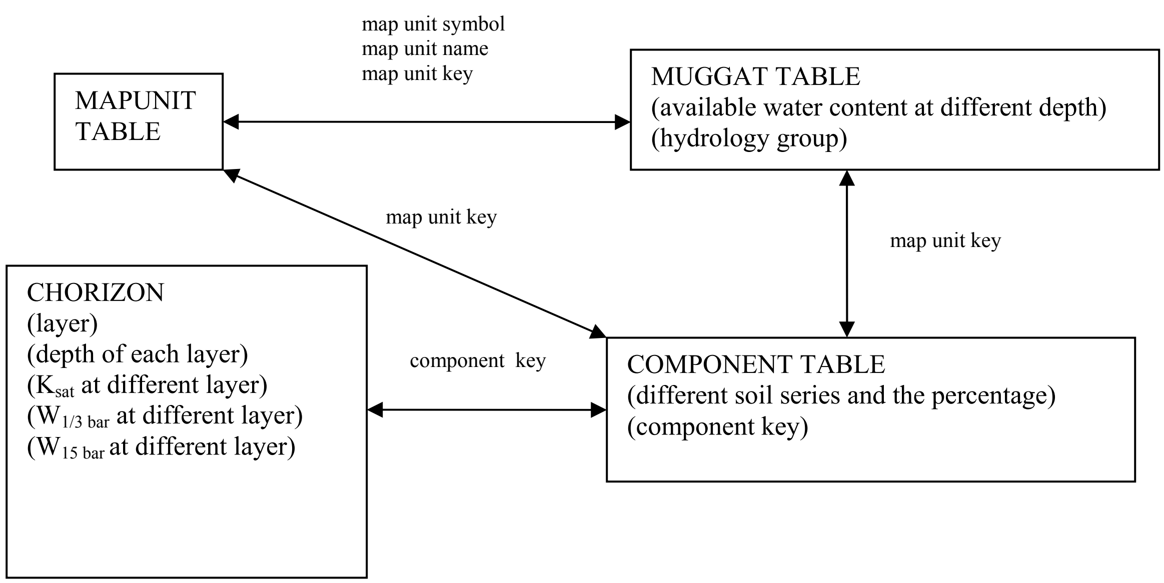

Figure 3-1: Relationships among Four U.S. General Soil Tables

The Sol-as14 soil parameter file includes 20 parameters (Table 3-2). The saturated conductivity assumed that the smallest layer value had the most effect on water movement and uptake. The rooting depth was estimated by spodic layer depth. The average field capacity and wilting point (BR15) values for each soil were weighted by the layer depth. The plant available soil water storage for each of seven layers was calculated based on the data from the soil database. The detailed calculation method for available soil water storage was documented by Kiker et al. (1992). This Sol-as14 soil association is found to the west and north side of the study area (Figure 3-2). The new soil data association was used in the model development for the three basins: Upper Reedy Creek, Shingle Creek, and Boggy Creek.

Table 3-2: Soil Parameters for CANDLER-ASTATULA Association

Parameter	**Explanation**	CANDLER-ASTATULA
label	file label	CAN-AS
rd	maximum rooting depth (inches)	36
Dsp	deep percolation rate (inches/day); same as DSP in model description	0.005
porsub	sub-surface porosity (-); same as PORS in model description	0.08
rxp	exponent for water table recession curve (-); same as k in model description	To be calibrated
rc	effective saturated soil conductivity (inches/hour)	11
fc	field capacity of active layer in nutrient simulations (-); same as FC in model description	0.081
ful	fraction of pore space filled at field capacity in hydrology simulations (-)	0.132
bst	fraction of plant-available water storage filled when simulation begins (-)	0.5
cona	soil evaporation parameter (-)	3.3
poros	soil porosity of active layer in nutrient simulations (-); same as POR in model description	0.45
br15	soil water content at wilting point (-)	0.025
sia1	initial abstraction coefficient for SCS curve number method	0.2
chs	channel slope (-)	0.01
wlw	watershed length/width ratio (-)	2
ul[1 to 7]-1	plant available soil water storage for layers one through seven (inches)	0.064
ul[1 to 7]-2		0.281
ul[1 to 7]-3		0.343
ul[1 to 7]-4		0.348
ul[1 to 7]-5		0.351
ul[1 to 7]-6		0.352
ul[1 to 7]-7		0.352
om	organic matter available for denitrification (% of soil mass)	1.49
an	enrichment coefficient for nitrogen in the sediment (-)	8
bn	enrichment exponent for nitrogen in the sediment (-)	-0.2
ap	enrichment coefficient for phosphorus in the sediment (-)	8
bp	enrichment exponent for phosphorus in the sediment (-)	-0.2

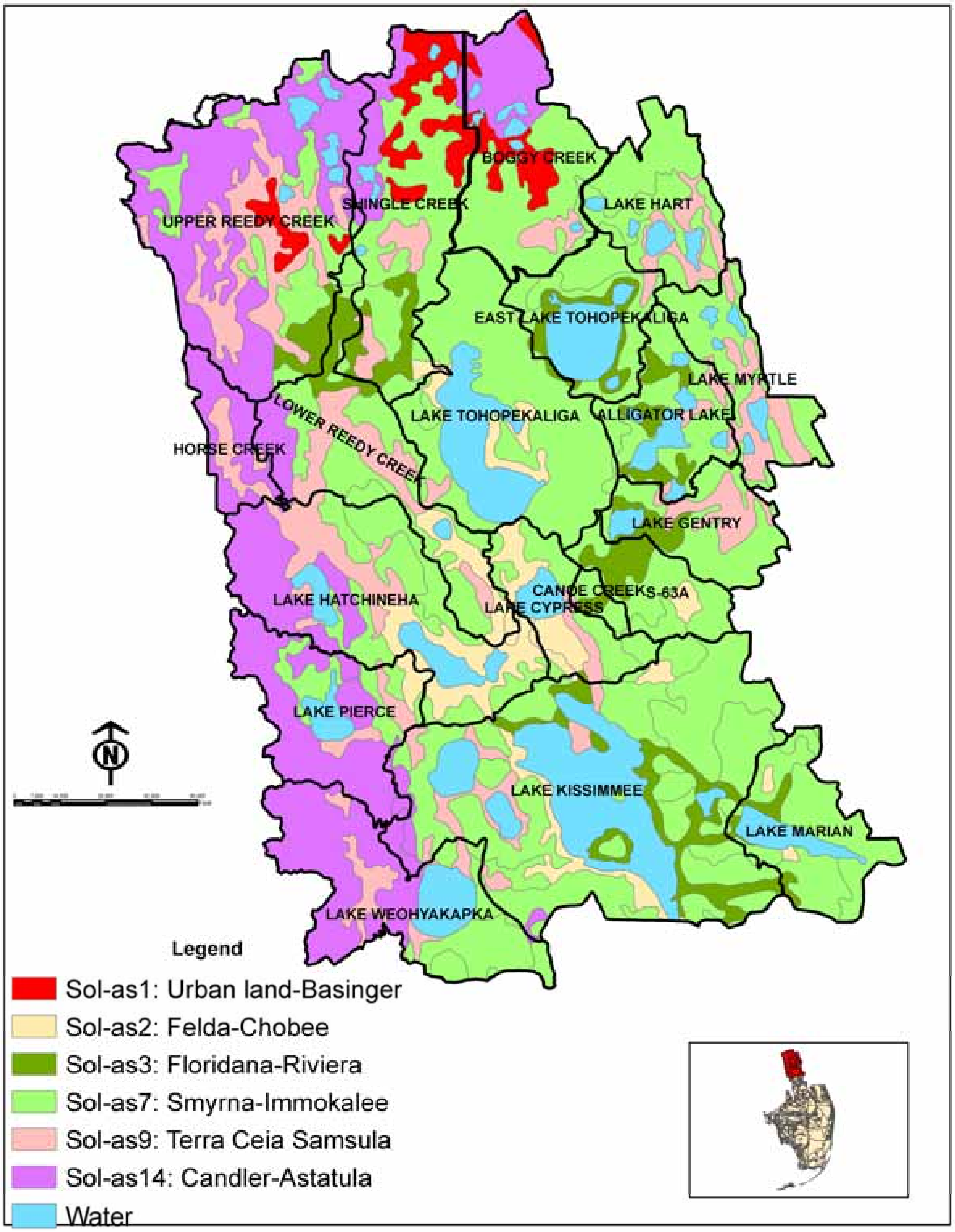

Figure 3-2: Soil Association Distribution in the Upper Kissimmee Region

2. Land Use Data

The 2006 Upper Kissimmee Region landuse data were analyzed to develop land use types at these three basins. This file is accessible via this link, (\\ad.sfwmd.gov\dfsroot\data\iz_support\LOPP\Landuse\Uk_Landuse06.shp).

For the purpose of simulation, the land use types are summarized into 12 categories (Tables 3-3 and 3-4). The PCP parameter files were developed during the LOADSS study (Kiker et al., 1992) and updated by Zhang et al. (1999). These files were initially used in the model simulation. The extraction coefficient for phosphorus into flow (EXKP) was further adjusted for better calibration results.

Table 3-3: Land Use Categories and Phosphorus Application Rate Assumptions

Land Use Category	FLUCCS3 code	FLUCCS3 Description	Land Use and Its Phosphorus Application Rate	File Name in CREAMS-WT Model
Urban	1009, 1100- 1800	residential, recreation, industrial, mobile home, institutional, commercial and services, recreational	4.4 lbs P/ac/yr fertilizer	res01000
Improved Pastures	2100, 2110, 2510	improved Pastures,	Improved pasture; no P fertilizer	nip01000
Unimproved Pastures	2120	unimproved pastures,	Unimproved pasture; no P fertilizer	nup0000
Forest	4400, 4000	upland forest, tree plantations,	Commercial forestry; normal management; no fertilizer	nfo01000
Natural Area	7000, 1900	barren land, open land, land in transition	Natural area no fertilizer	nna01000
Transportation	8000	Highway and road, utilities, communications	no fertilizer	ntr01000
Citrus	2210	Citrus	Mature citrus; 9 lbs P/ac/yr fertilizer	nct01000
Sod Farm	2420	sod farm	53 lbs P/ac/yr fertilizer	nsf01000
Ornamentals	2430	Ornamentals	42 lbs P/ac/yr fertilizer	nor01000
Row Crops	2140	row crops	98 lbs P/ac/yr fertilizer	ntc01000
Wetland	6000	mixed wetland hardwoods, wetland coniferous forest, wetland forest mixed, vegetated Non-forest wetlands, wet prairies	no fertilizer	not simulated
Water	5000	Water	no fertilizer	not simulated

Table 3-4: Land Use Distribution in the Three Modeled Basins

Land Use Category	Boggy Creek Basin		Upper Reedy Creek Basin		Shingle Creek Basin	
	Area (acres)	Percentage (%)	Area (acres)	Percentage (%)	Area (acres)	Percentage (%)
Citrus	434	0.78	8,791	7.71	486	0.68
Forest	3,083	5.55	15,098	13.23	6,472	9.08
Improved Pasture	4,104	7.38	3,133	2.75	2,709	3.80
Ornamentals	12	0.02	20	0.02	17	0.02
Sod	522	0.94	0	0.00	325	0.46
Row Crops	0	0.00	638	0.56	27	0.04
Unimproved Pastures	328	0.59	183	0.16	368	0.52
Natural Area	1,488	2.68	3,796	3.33	6,775	9.50
Urban & Residential	27,502	49.46	32,051	28.09	35,928	50.38
Transportation and Utility	7,085	12.74	4,297	3.77	937	1.31
Water	4,407	7.93				
Wetland	6,636	11.93	46,092	40.40	17,262	24.21
Grand Total	55,600	100	114,101	100	71,307	100

3. Rainfall Data

Daily average rainfall was estimated based on Thiessen weights, the weighted area percentage of the rain gage in relation to the particular basin (Table 3-5, Figure 3-3). When there were missing data, the weights were adjusted proportionally. Annual rainfall did not vary considerably among these three basins (Figure 3-4).

Table 3-5: Flow, Water Quality and Rainfall Monitoring Sites

	Upper Reedy Creek Basin		Shingle Creek Basin		Boggy Creek Basin	
	Rain Gage ID	**Weight**	**Rain Gage ID**	**Weight**	**Rain Gage ID**	**Weight**
Rain Gage	REEDYC_R (00153)	0.88	SHING.RG (VN390)	0.76	ORLAN AP_R (06256)	0.24
	REEDGW10_R (05790)	0.12	POINCI_R (0602)	0.12	TAFT_R (06042)	0.76
			KISS.FS_R (06305)	0.12		
Flow	REEDYLOU (J6175, 00165)		SHING.AP (00118)		BOGGY_TA (00113)	
Water Quality	CREEDYBR		BWSHNGLE		ABOGG	

(Dbkeys are listed inside the parenthesis.)

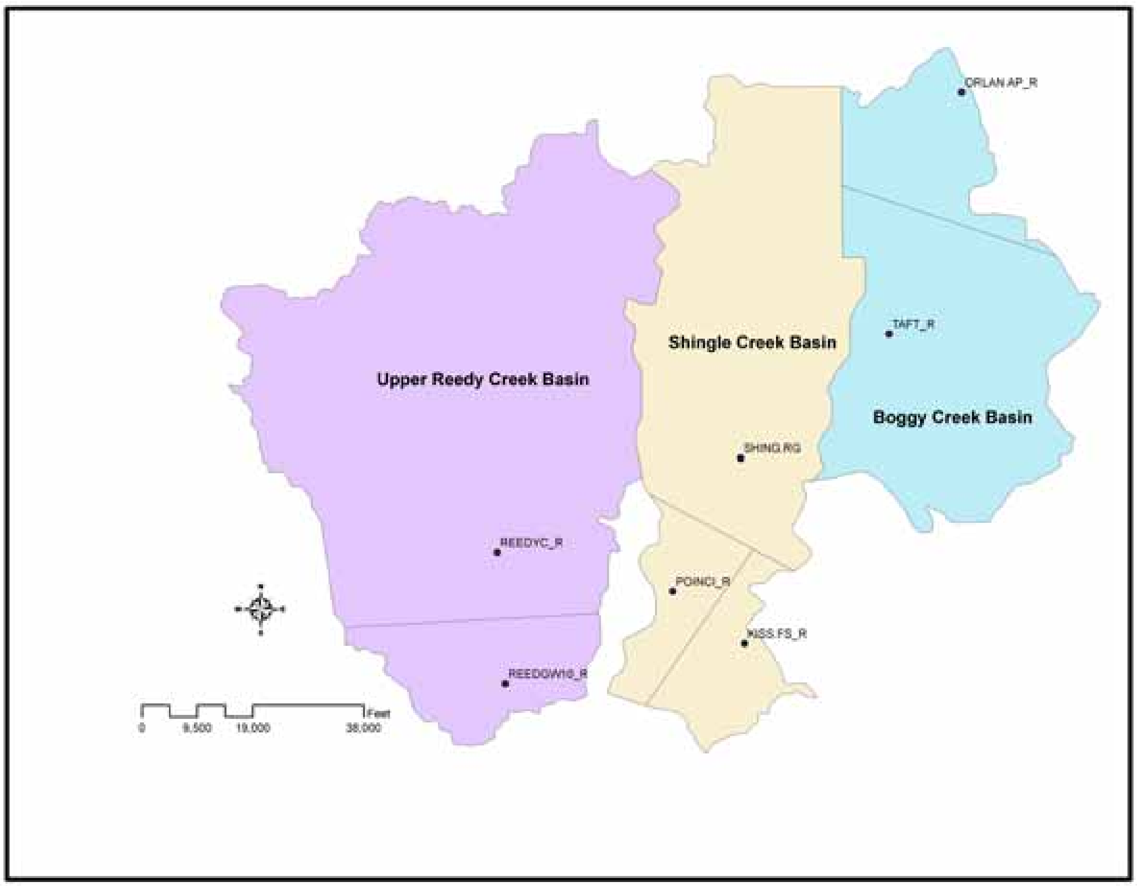

Figure 3-3: Thiessen Polygons for Area Average Rainfall Calculation

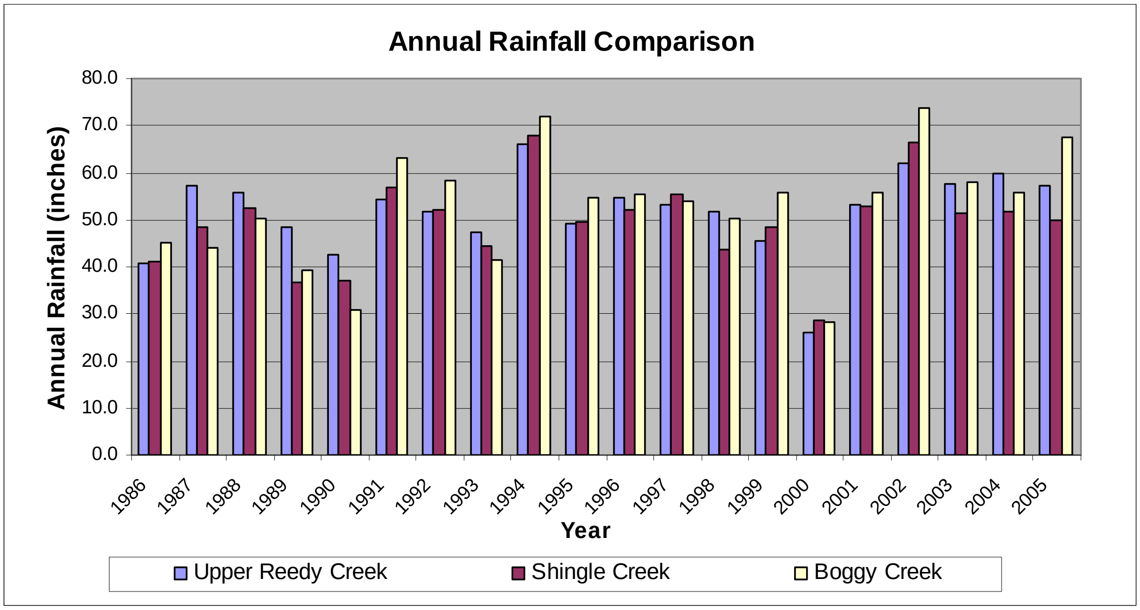

Figure 3-4: Annual Rainfall Comparison

4. Flow and Water Quality Data

For the Upper Reedy Creek basin, no water quality monitoring station is located near the USGS flow station REEDYLOU. The water quality data collected at the downstream station CREEDYBR is utilized. For Shingle Creek Basin, the water quality monitoring station is located about half mile downstream of the flow station SHING.AP. For Boggy Creek Basin, the water quality and quantity are monitored at the same location. The Nutrient Load Program developed by the District was used to retrieve data from DBHYDRO and calculate the loads.

5. Temperature and Radiation Data

In the Upper Kissimmee Region, the solor radiation data are limited. However, for this region, we don't expect large spatial variety on solar radiation. The closest sites to the study area for which data are available are S65CW and S65C. The solor radiation data as well as the temperature data from these two stations were used to calculate the potential evapotranspiration. These daily values were averaged monthly for input to CREAMS-WT. The records for years 1986 and 1987 are not available, so the records for 1988 and 1989 were adopted for years 1986 and 1987.

IV. Model Calibrations

The original CREAMS-WT program and the C_SHELL program (Kiker et al., 1992) were adopted for simulation with some manipulation of the management file. The calibration goals are to preserve the overall trend and accuracy for both annual flow and load on a long term basis. Some extreme events may not fit the model well. The statistical analysis will be conducted to quantify the calibration results by comparing simulated versus observed annual flow, load, and TP FWMC. Statistical analyses include the annual average error (AAE), the relative average error AAE%, and the correlation coefficient, R. These terms are defined below. The long term annual average value is an important factor that the regulatory program in the District used to evaluate a landuse change permit application. The AAE and AAE% provides good measures of the accuracy of the calibrated annual average values while R measures the relationship between simulated and observed time series.

$$AAE = \tilde{Y}_{obs} - \tilde{Y}_{sim} \tag{1}$$

$$AAE\% = AAE/\tilde{Y}_{obs} \tag{2}$$

$$R = S_{obs,\, sim} / S_{obs} \cdot S_{sim} \tag{3}$$

$$S_{obs} = \left(\sum_{i=1}^{20} (Y_{obs,i} - \tilde{Y}_{obs})^2/(n-1)\right)^{0.5} \tag{4}$$

$$S_{sim} = \left(\sum_{i=1}^{20} (Y_{sim,\,i} - \tilde{Y}_{sim})^2/(n-1)\right)^{0.5} \tag{5}$$

$$S_{obs,\, sim} = \sum_{i=1}^{20} (Y_{obs,i} - \tilde{Y}_{obs}) \cdot (Y_{sim,i} - \tilde{Y}_{sim})/(n-1) \tag{6}$$

Where $\tilde{Y}_{obs}$ is the observed averaged annual value, $\tilde{Y}_{sim}$ is the simulated averaged annual value, $Y_{obs,i}$ is the observed annual value in year *i*, $Y_{sim,i}$ is the simulated annual value in year i, n is the number of years, 20.

The CREAM-WT involves more than 100 parameters associated with soil data, landuse data, and weather factors. Due to the uncertainty and stochastic nature of a hydrologic system and the spatial and temporal uncertainty and variability associated with each hydrologic parameter, a perfect match is impossible. In this study, the calibration efficiency will be measured by one of three categories, excellent, satisfactory, and poor. The criteria for each category are defined below. These criteria also apply to the validation results.

Table 3-6: Model Evaluation Criteria

	AAE%	R
excellent	<10%	> 0.8
satisfactory	(10%, 30%)	(0.5, 0.8)
poor	>30%	<0.5

The 20-year calibration period is from 1986 to 2005. The rainfall, temperature, and solar radiation input files contained the data from 1981 to 2005. The first 5-year simulation is to a warm-up period to minimize the effect of the initial conditions. The wetland and water body categories were not included in the simulation since the evaporation and rainfall are approximately the same for these two land use categories in South Florida, and no flow was produced.

Most of the parameters in a CREAMS-WT model are physically based. This study tried to minimize the parameter calibration and preserve the values that were previously calibrated. The calibrations were concentrated on phosphorus extraction coefficient (EXKP) and the exponent for water table recession curve (RXP) for the new soil association, CANDLER-ASTATULA. These two parameters were selected based on a previous sensitivity analysis conducted by Haan and Zhang (1996) for the Lake Okeechobee Watershed.

The parameter EXKP is the extraction coefficient for phosphorous into flow. It relates the phosphorus concentration in the flow to the soluble phosphorus in the surface soil layer. Exact values of EXKP are unknown and may be related to legacy phosphorus in the region. Legacy phosphorus is defined as phosphorus resulting from anthropogenic activities and has transport potential to the drainage canal. A value of EXKP equal or less than 0.25 is recommended (Knisel, 1980). The value of 0.25 is used in Lake Okeechobee Watershed. In this study, the calibrated EXKP values are on the lower side (Table 4-1). With these low values, the simulated phosphorus concentration and load for these land uses are generally lower than the values found in the Lake Okeechobee watershed.

Table 4-1: Calibrated Phosphorous Extraction Coefficient, EXKP

Land Use Category	Upper Reedy Creek Basin EXKP	Shingle Creek Basin EXKP
Citrus	0.04	0.04
Forest	0.03	0.03
Improved Pasture	0.03	0.03
Ornamental	0.04	0.04
Sod	0.04	0.04
Row Crop	0.03	0.03
Unimproved Pasture	0.03	0.03
Natural Area	0.03	0.03
Urban and Residential	0.01	0.02
Transportation and Utility	0.01	0.02

Most of the soil series included in the soil association CANDLER-ASTATULA are excessively drained sandy soils in the form of thick sandy marine deposits. Excessive seepage is expected. The calibrated exponent for water table recession curve RXP is 0.54. This value is 50% higher than the poorly drained organic soil series like Samsula-Hontoon-Everglades, which belongs to Terr Ceia Samsula soil association. All other parameters related to this soil association were based on the physical calculation or extracted from the USGSM database.

The impervious area ratio is another factor adjusted during the model calibarion. For urban and transportation land use categories, majority of the rainfall that occurs upon the impervious areas becomes flow. So, flow from impervious area was calculated separately based on annual rainfall amount. This assumption also was adopted in the Lake Okeechobee Watershed CREAMS-WT model study. It is further assumed the impervious area percentage for the urban and transportation land use categories is 10%.

For the calibration results, visually, the calibrated and observed 20-year annual flow, load, and FWMC compare reasonably well. The trends and accuracy in both annual flow and annul load series were well preserved. Both basins demonstrate some deviations for year 2004 and 2005. These deviations can be explained by the hurricane impacts. In 2004, three strong hurricanes hit these three basins directly which brought high intensity rainfall to the basins. In 2005, even though these basins were not hit directly by hurricanes, they were impacted by the increased rainfall due to hurricanes. Hurricanes impact the annual flow and load from two perspectives. First, hurricanes brought significant high intensity rainfall to the basin, which generated high flow. Second, the strong wind caused the loss of top layer soil and the disturbance of sediment, which normally produced high TP concentration materials.

The calculated statistical terms were summarized in the Table 4-2. For the Upper Reedy Creek basin (Figures 4-1), both the calibrated annual flow and load are satisfactory. The calibrated flow weighted mean concentration (FWMC) is poor. The observed annual loads for 2003 are significantly higher than the simulated value. The high loads in 2003 can be explained by the simultaneous occurrence of high flow and high TP concentration. In this year, the observed TP concentration data on August 6 and September 15 are 150 ppb and 180 ppb, which are significantly higher than the annual average FWMC of 116 ppb. At the same period, the observed flow is more than 60,000 ac-ft, which is 59% of the annual flow.

For Shingle Creek Basin, both calibrated annual flow and load series are satisfactory. The calibrated annual FWMC series is poor. The simulated 1986 annual load is significantly lower than the observed value. The large difference can be explained by the high annual TP FWMC, 188 ppb, which is the highest value during the 20-year simulation period. The high FWMC in 1986 was caused by the two large Orange County municipal wastewater treatment plants. These two treatment plants discharged treated effluent into the creek until January 1987. The decreases in mean P concentrations that occurred after the removal of wastewater discharges from the creek at the end of 1986 were found to be statistically significant (O'Dell, 1994).

Table 4-2: Statistical Analysis for Calibration Results

	Reedy Creek Basin			Shingle Creek Basin		
	Flow (ac-ft)	**load (lb)**	**TP FWMC (ppb)**	**Flow (ac-ft)**	**load (lb)**	**TP FWMC (ppb)**
Observed Annual Average	44,160	13,807	52	70,008	18,663	45
Simulated Annual Average	50,390	11,238	37	64,426	15,774	41
Annual Average Error	-6,230	2,570	15	5,582	2,889	4
Annual Absolute Error %	-14	19	29	8	15	9
Correlation Coefficient, R	0.70	0.57	0.14	0.61	0.67	0.36

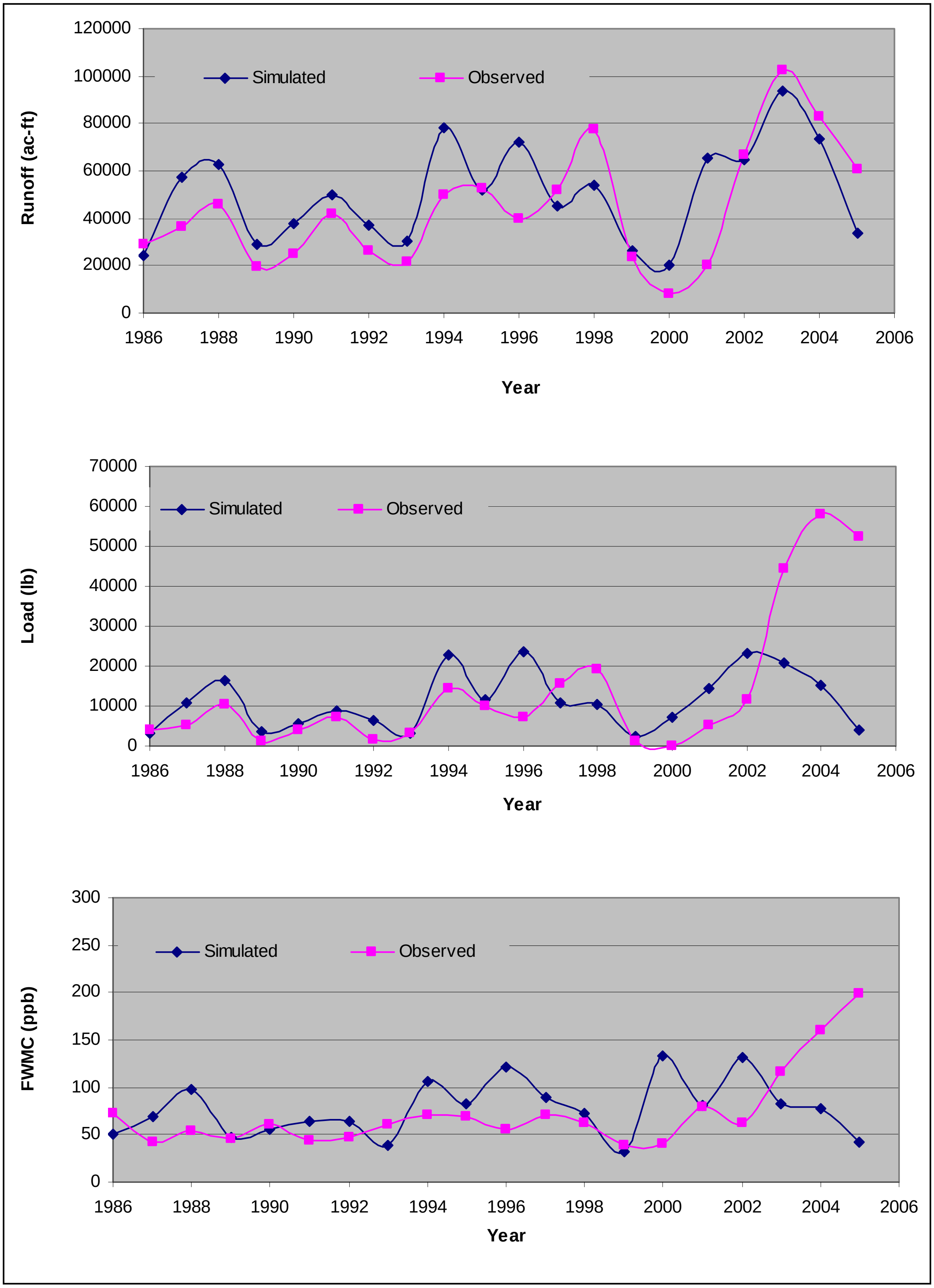

Figure 4-1: Upper Reedy Creek Basin Simulated and Observed Annual Runoff, Load and TP FWMC

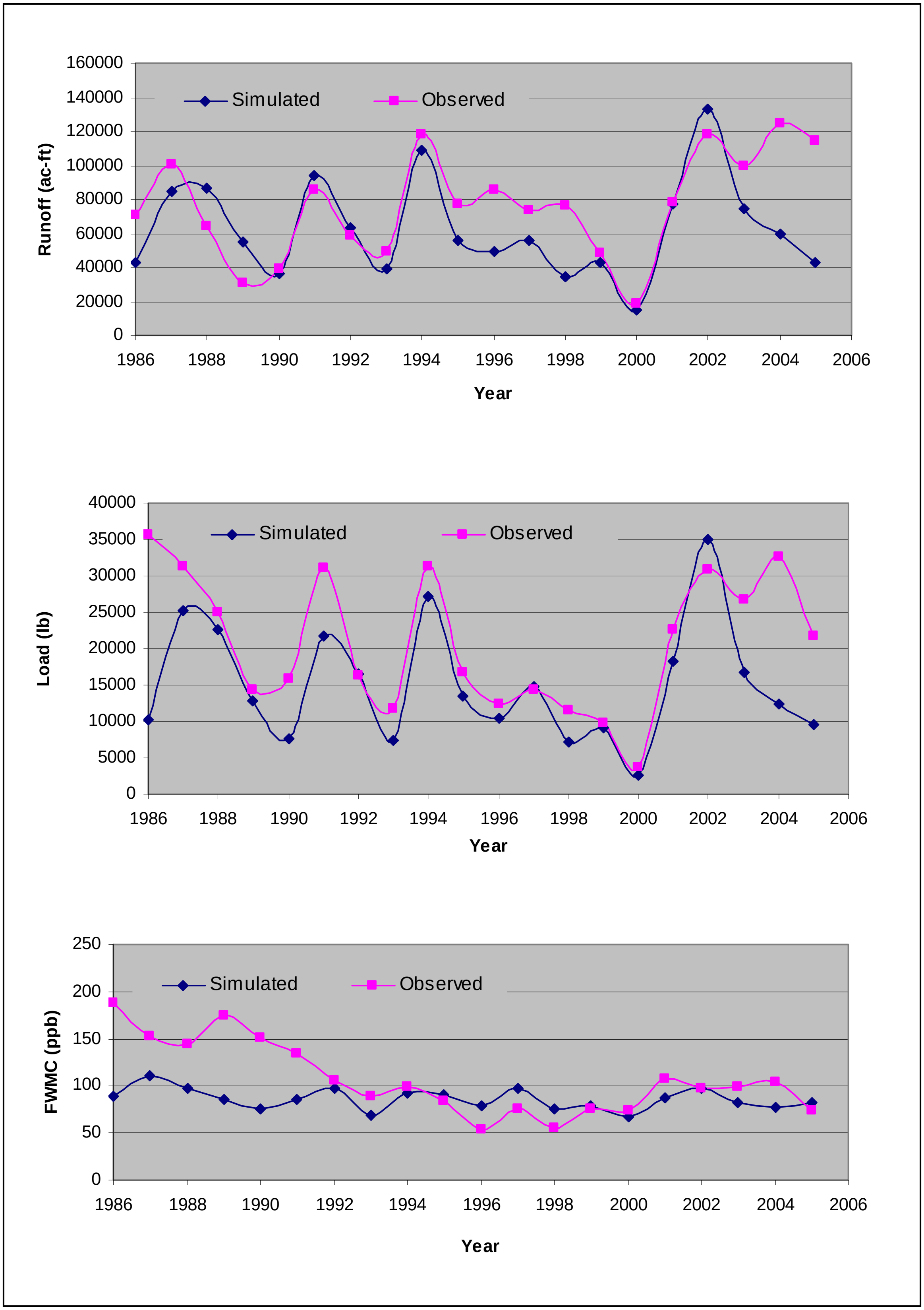

Figure 4-2: Shingle Creek Basin Simulated and Observed Annual Runoff, Load and TP FWMC

V. Model Validation

Boggy Creek Basin was selected for model validation. Model validations of flow and load were conducted for both long term annual series and the long term annual average value.

First, the calibrated CREAMS-WT model input parameter files combined with the Boggy Creek rainfall file were used to simulate the basin long term annual flow and load series. The calibrated EXKP values for the urban/residential and transportation/utilities land use categories were 0.01 for Upper Reedy Creek Basin and 0.02 for the Shingle Creek Basin. Therefore, an average value of 0.015 was applied for the Boggy Creek basin simulation. The simulated annual flows and loads series compare satisfactorily with the observed values in both the trend and the accuracy (Figures 5-1). The simulated 1994 and 2002 annual loads are higher than the observed values. The large difference can be explained by the high annual rainfall amount. For both years, the annual rainfall is more than 70 inches, the highest values in the 20-year simulation period.

Second, validation was conducted by predicting Boggy Creek Basin long term annual average flow and load. Based on the calibration results from Reedy Creek and Shingle Creek basins, the simulated annual averaged, 20th and 80th percentile unit flow and load corresponding to common combinations of soil and land use types in both basins were estimated (Tables 5-2 to 5-3). These estimates were applied to predict the long term annual average flow and load for Boggy Creek Basin. The predicted annual average flow and load were 52,305 ac-ft and 9,440 lb, respectively. For the period of 1986 to 2005, the observed annual average flow and load were 62,651 ac-ft and 10,611 lb, respectively. The relative errors for annual average flow and load are 17% and 11%. These relative errors are acceptable considering the spatial and temporal uncertainty and variability.

Statistical analysis was further conducted to quantity the validation results by comparing simulated versus observed annual flow and load. The calculated AAE, AAE%, and R were summarized in the Table 5-1. For both flow and load, the values of AAE% are less than 15%; the Rs for both flow and load are greater than 0.7. According to the criteria defined in Table 3-6, both validated annual flow and load series are satisfactory. The validation result for TP FWMC is better than calibration results. The TP FWMC can also be predicted based on the long term simulation or the unit flow and load values. The predicted TP FWMC values are also summarized in Table 5-1. The AAE% is 9% by long term trend simulation and -9% by predicting through unit flow and load values. These validation results are satisfactory based on the criteria specified in Table 3-6.

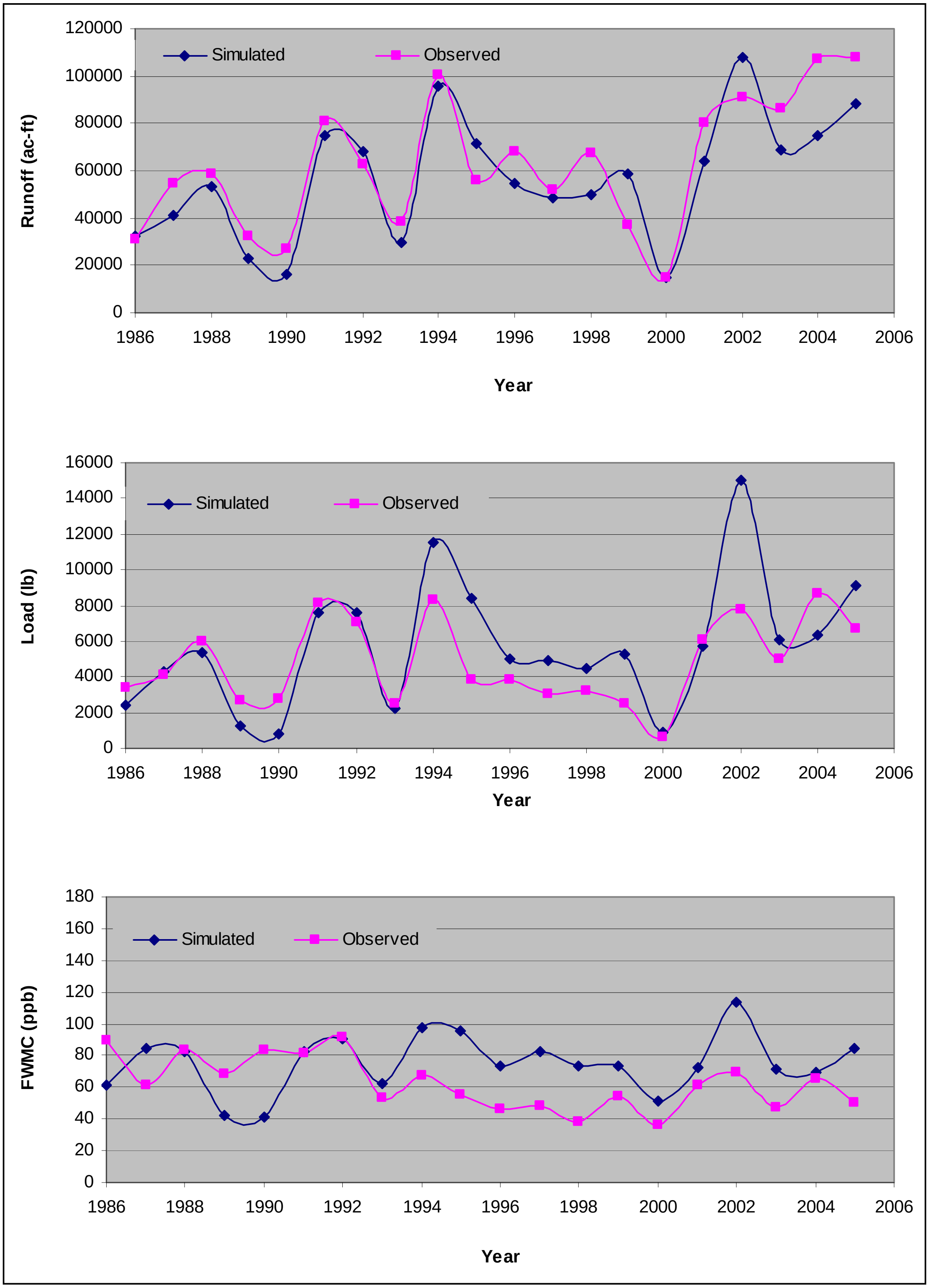

Figure 5-1: Boggy Creek Basin Simulated and Observed Annual Runoff, Load, and TP FWMC

Table 5-1: Statistical Analysis for Validation Results

Validation	Statistical Term	Boggy Creek Basin		
		Flow (ac-ft)	Load (lb)	TP Flow Weight Mean Concentration
I: Validation by Simulating Long Term Time Series	Observed Annual Average	62,651	10,611	28
	Simulated Annual Average	69,780	10,712	26
	Average Annual Error	-7,129	101	2
	Average Annual Error %	11.4	1.0	9
	Correlation Coefficient, R	0.88	0.77	
II: Validation by Using Unit Flow and Load	Predicted Average	52,305	9,440	30
	Average Annual Error	10,346	1,171	-2
	Average Annual Error %	17	11	-9

Unit model output for calibration and validation were averaged to develop recommended flow and load for different combination of land use and soil. (Tables 5-4 to 5-5). Two soil associations, Urbanland-Basinger and Felda-Chobee, do not appear in Boggy Creek Basin. So the values for these two soil associations are identical as the values listed in Tables 5-2 to 5-3. Tables 5-4 to 5-5 also presents the estimate of 20th and 80th percentiles which provide the variability measurement associated with each value.

Table 5-2: Simulated Unit Annual Flow for Different Soil/Land Use Combinations Based on the Calibration Results from Reedy Creek and Shingle Creek Basins (in/acre)

Land Use Type	**Improved Pasture**						**Citrus**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	13.96	12.09	11.04	13.72	11.35	6.95	8.72	7.05	4.95	9.50	1.80	2.48
20th percentile	9.46	5.62	5.97	7.12	7.99	0.59	3.31	1.09	0.28	3.63	0.35	0.16
80th percentile	18.05	18.65	15.73	18.21	16.09	13.76	13.73	12.20	8.80	14.89	3.28	4.51
Land Use Type	**Unimproved Pasture**						**Natural Area**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	14.37	12.68	11.51	13.92	13.51	11.60	13.75	11.90	11.38	13.59	9.24	11.48
20th percentile	9.70	7.56	7.20	7.32	9.60	7.53	9.44	5.65	6.07	7.28	6.01	7.12
80th percentile	18.56	19.01	16.08	18.77	18.93	16.10	17.90	18.46	15.99	18.12	12.21	16.96
Land Use Type	**Sod Farm**						**Upland Forest**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	8.66	7.00	4.84	9.09	1.51	1.90	8.79	7.18	5.44	9.76	4.18	3.24
20th percentile	0.00	1.29	0.14	3.44	0.12	0.09	3.36	1.44	1.21	3.82	1.69	1.07
80th percentile	0.00	11.39	8.53	14.10	2.32	3.20	13.59	11.46	8.92	15.09	6.60	4.72
Land Use Type	**Ornamental**						**Row Crop**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	10.80	8.80	6.98	11.14	5.20	4.68	16.06	13.44	12.45	16.04	9.42	11.55
20th percentile	5.74	3.22	2.92	5.53	2.78	2.05	10.87	6.53	7.58	10.73	5.67	6.53
80th percentile	15.49	14.49	10.79	16.11	7.95	6.92	22.46	20.28	18.26	22.49	13.45	17.80
Land Use Type	**Urban**						**Transportation**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	9.08	13.25	9.07	12.24	9.75	7.75	13.81	11.95	11.27	13.63	9.63	11.51
20th percentile	3.76	9.08	3.57	6.99	3.32	2.32	9.46	5.40	6.17	7.25	6.21	6.81
80th percentile	14.10	18.84	11.35	15.95	14.15	11.62	17.96	18.51	16.01	18.14	14.05	17.32

Table 5-3: Simulated Unit Annual Load for Different Soil/Land Use Combinations Based on the Calibration Results from Reedy Creek and Shingle Creek Basins (lb/acre)

Land Use Type	**Improved Pasture**						**Citrus**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	0.62	0.52	0.45	0.62	0.47	0.51	0.48	0.43	0.29	0.55	0.12	0.09
20th percentile	0.41	0.28	0.26	0.31	0.35	0.28	0.15	0.09	0.01	0.23	0.02	0.01
80th percentile	0.81	0.76	0.72	0.81	0.67	0.76	0.70	0.59	0.45	0.80	0.13	0.10
Land Use Type	**Unimproved Pasture**						**Natural Area**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	0.34	0.29	0.26	0.33	0.31	0.26	0.15	0.12	0.11	0.15	0.07	0.11
20th percentile	0.21	0.17	0.16	0.17	0.22	0.16	0.09	0.05	0.05	0.06	0.04	0.05
80th percentile	0.47	0.42	0.36	0.48	0.45	0.35	0.22	0.18	0.16	0.22	0.10	0.16
Land Use Type	**Sod Farm**						**Upland Forest**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	1.60	1.55	0.83	1.75	0.13	0.20	0.20	0.16	0.11	0.22	0.08	0.06
20th percentile	0.67	0.14	0.01	0.81	0.01	0.01	0.07	0.03	0.02	0.08	0.04	0.02
80%	1.93	2.93	1.54	3.06	0.16	0.21	0.30	0.26	0.18	0.33	0.13	0.09
Land Use Type	**Ornamental**						**Row Crop**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	2.17	1.92	1.03	2.86	0.70	0.57	2.71	2.74	2.57	3.31	2.74	3.48
20th percentile	0.76	0.40	0.33	1.12	0.34	0.19	0.84	0.61	0.63	1.02	0.89	1.12
80th percentile	3.03	2.28	1.26	4.07	1.00	1.04	6.05	5.93	5.30	6.94	3.62	5.82
Land Use Type	**Urban**						**Transportation**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	0.18	0.15	0.12	0.18	0.13	0.09	0.15	0.12	0.11	0.15	0.07	0.11
20th percentile	0.05	0.11	0.06	0.10	0.06	0.04	0.09	0.05	0.05	0.06	0.04	0.05
80th percentile	0.28	0.19	0.17	0.28	0.17	0.13	0.22	0.18	0.16	0.22	0.10	0.15

Table 5-4: Recommended Unit Annual Flow for Different Soil/Land Use Combinations at Upper Kissimmee Region (in/acre)

Land Use Type	**Improved Pasture**						**Citrus**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	13.96	12.09	11.04	14.37	11.87	8.87	8.72	7.05	4.95	10.03	2.10	2.48
20th percentile	9.46	5.62	5.97	6.99	7.73	0.96	3.31	1.09	0.28	3.63	0.35	0.16
80 th percentile	18.05	18.65	15.73	20.46	16.85	15.35	13.73	12.20	8.80	15.10	4.10	4.51
Land Use Type	**Unimproved Pasture**						**Natural Area**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	14.37	12.68	11.51	14.48	12.71	12.01	13.75	11.90	11.38	14.25	9.86	11.93
20th percentile	9.70	7.56	7.20	6.97	7.64	6.53	9.44	5.65	6.07	7.00	6.01	6.46
80 th percentile	18.56	19.01	16.08	20.39	18.40	17.63	17.90	18.46	15.99	20.37	15.42	17.82
Land Use Type	**Sod Farm**						**Upland Forest**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	8.66	7.00	4.84	9.70	1.83	2.32	8.79	7.18	5.44	10.31	4.66	3.75
20th percentile	0.00	1.29	0.14	3.25	0.12	0.10	3.36	1.44	1.21	3.78	1.71	1.08
80 th percentile	0.00	11.39	8.53	14.41	3.04	4.24	13.59	11.46	8.92	15.35	7.39	6.26
Land Use Type	**Ornamental**						**Row Crop**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	10.80	8.80	6.98	11.68	5.66	5.22	16.06	13.44	12.45	16.73	10.00	12.04
20th percentile	5.74	3.22	2.92	5.45	2.73	1.95	10.87	6.53	7.58	10.07	5.79	5.96
80%	15.49	14.49	10.79	16.53	8.78	8.10	22.46	20.28	18.26	23.24	14.48	18.27
Land Use Type	**Urban**						**Transportation**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	9.08	13.25	9.07	13.55	11.62	9.55	13.81	11.95	11.27	14.47	11.53	12.05
20th percentile	3.76	9.08	3.57	7.42	5.14	3.27	9.46	5.40	6.17	7.61	6.64	6.81
80 th percentile	14.10	18.84	11.35	18.56	19.11	15.68	17.96	18.51	16.01	20.36	16.71	18.25

Table 5-5: Recommended Unit Annual Load for Different Soil/Land Use Combinations at Upper Kissimmee Region (lb/acre)

Land Use Type	**Improved Pasture**						**Citrus**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	0.62	0.52	0.45	0.77	0.59	0.62	0.48	0.43	0.29	0.57	0.13	0.12
20th percentile	0.41	0.28	0.26	0.32	0.37	0.32	0.15	0.09	0.01	0.20	0.02	0.01
80 th percentile	0.81	0.76	0.72	1.13	0.80	0.91	0.70	0.59	0.45	0.83	0.16	0.12
Land Use Type	**Unimproved Pasture**						**Natural Area**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	0.34	0.29	0.26	0.35	0.28	0.27	0.15	0.12	0.11	0.15	0.07	0.11
20th percentile	0.21	0.17	0.16	0.16	0.17	0.15	0.09	0.05	0.05	0.06	0.04	0.04
80 th percentile	0.47	0.42	0.36	0.50	0.40	0.40	0.22	0.18	0.16	0.22	0.11	0.17
Land Use Type	**Sod Farm**						**Upland Forest**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	1.60	1.55	0.83	1.90	0.16	0.32	0.20	0.16	0.11	0.23	0.09	0.07
20th percentile	0.67	0.14	0.01	0.78	0.02	0.01	0.07	0.03	0.02	0.07	0.04	0.02
80 th percentile	1.93	2.93	1.54	3.22	0.26	0.39	0.30	0.26	0.18	0.34	0.14	0.12
Land Use Type	**Ornamental**						**Row Crop**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	2.17	1.92	1.03	2.76	0.74	0.62	2.71	2.74	2.57	3.59	2.84	3.56
20th percentile	0.76	0.40	0.33	0.99	0.34	0.16	0.84	0.61	0.63	1.02	0.89	1.12
80 th percentile	3.03	2.28	1.26	4.19	1.29	1.11	6.05	5.93	5.30	6.80	3.82	5.82
Land Use Type	**Urban**						**Transportation**					
Soil Association	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula	Urbanland-Basinger	Felda-Chobee	Floridana-Riviera	Smyrna-Immokalee	Terra Ceia-Samsula	Candler-Astatula
mean	0.18	0.54	0.32	0.45	0.46	0.36	0.15	0.12	0.11	0.15	0.09	0.11
20th percentile	0.05	0.39	0.07	0.16	0.11	0.07	0.09	0.05	0.05	0.06	0.05	0.04
80 th percentile	0.28	0.65	0.52	0.64	0.76	0.57	0.22	0.18	0.16	0.22	0.14	0.16

VI. Summary and Discussion

Results of this study include:

1. Discovered a new soil association, Candler-Astatula, and developed corresponding soil parameter file.
2. Calibration of the CREAMS-WT model for Upper Reedy Creek and Shingle Creek basins based on the 20-year period of observed data from 1986 to 2005.
3. Validation of the Upper Kissimmee Basin CREAMS-WT model by simulating Boggy Creek long term annual flow and load series. The simulated long term annual flow and load series compare closely with the observed flow and load series. The unit flow and load data sets were also validated by successfully predicting Boggy Creek Basin long term annual average flow, load, and TP concentration.
4. Based on both the calibration and validation results, datasets for unit flow and unit load for different combinations of soil, and land use practice were developed (Tables 5-4 to 5-5).

Based on these results, two recommendations are made. First, the calibrated CREAMS-WT model should be applicable to simulate the long term annual flow and load series for other basins in the Upper Kissimmee Region by combining with local rainfall data. Second, within the Upper Kissimmee Region, for basins or land parcels without observed local rainfall data, the average values of unit flow and load shown in Tables 5-4 to 5-5 are applicable to predict the long term annual average flow and load. One parameter needs additional discussion is the impervious area ratio. In this study, the calibrated impervious area ratio for urban and residential and transportation and utility landuse categories is 10%. During the application, the impervious area ratio shall be adjusted based on the actual measurement. This recommendation is consistent with the current application at the Lake Okeechobee Watershed.

An extensive model sensitivity analysis was conducted by Haan and Zhang (1996) for the Lake Okeechobee Watershed. In the 1996 study, the most sensitive parameters were identified, including EXKP, RXP, curve number (CN), depth of active soil zone (DEPTH), EXKP1, and LAI. Such an analysis would be a useful next step.

In this study, rainfall was estimated from two or three gages for each basin based on a Thiessen polygon method. Higher resolution rainfall data (2 km by 2 km) based on NEXRAD is available since January 1, 2002. A simulation, using this higher resolution data will better represent the spatial distribution of rainfall. Periodic updates based on new flow, water quality and land use data are recommended every 5 years.

Acknowledgements

The authors thank Yao Yan for provided support to resolve technical issues related with GIS. We also thank David Anderson and Odi Villapando for helpful discussions, respectively, regarding monitoring stations for the Upper Kissimmee Region and the University of Florida soil database. The authors thank Stuart VanHorn, Jun Han, Eric Flaig, David Anderson, Chad Rucks, and Kelly Cranford for their review of a previous version of this technical memo.

References

1. Guardo, M. 1992. An Atlas of the Upper Kissimmee Surface Water Management Basins. South Florida Water Management District, West Palm Beach, Florida.

2. Haan, C.T. and J. Zhang. 1996. Impact of Uncertain Knowledge of Model Parameters on Estimated Flow and Phosphorus Loads in the Lake Okeechobee Basin. Transactions of the American Society of Agricultural Engineers. 39: 511-516.

3. Heatwole, C.D. 1986. Field and Basin Scale Water Quality Models for Evaluating Agricultural Nonpoint Pollution Abatement Programs in a South Florida Flatwoods Watershed. Ph.D. Dissertation. University of Florida, Gainesville.

4. Kiker, G.A., K.L. Campbell, J. Zhang. 1992. CREAMS-WT Linked With GIS to Simulate Phosphorus Loading. ASAE Paper No. 92-2016. Presentation at the 1992 International Summer Meeting, ASAE.

5. Knisel, W.G., editor. 1980. CREAMS, A Field Scale Model for Chemicals, Flow, and Erosion From Agricultural Management Systems. U.S. Department of Agriculture, Science and Education Administration. Conservation Research Report No. 26. USDA Science and Education Administration. Washington D.C.

6. National Cooperative Soil Survey, 2006. The U.S. General Soil Map. Natural Resources Conservation Services.

7. Negahban, B., C. Fonyo, W. G. Boggess, J. W. Jones, K. L. Campbell, G. Kiker, E. Flaig and H. Lal. 1995. LOADSS: A GIS-based Decision Support System for Regional Environmental Planning. Ecological Engineering 5:391-404.

8. O'Dell, K. M. 1994. Water Quality in the Shingle Creek Basin, Florida, before and after Wastewater Diversion, Journal of Environmental Quality, 3:_563-571.

9. South Florida Water Management District, 2003. Application of the CREAMS-WT Computer Model for Assessing the Impact of Land Use Change on Phosphorus Loads Leaving a Land Parcel, West Palm Beach, Florida.

10. United States Department of Agriculture. 1979. Soil Survey of Osceola County Area, Florida. Gainesville, Florida.

11. Wagner, R. A., T. S. Tisdale and J. Zhang. 1996. A framework for Phosphorus Transport Modeling in the Lake Okeechobee Watershed. Water Resources Bulletin 32: 1-17.

12. Zhang, J., T. S. Tisdale and R. A. Wagner. 1996. A Basin Scale Phosphorus Transport Model for South Florida. Applied Engineering in Agriculture 12: 321-327.

13. Zhang, J., B. Negahban, A. B. Bottcher, C. F. Boggess, B. Jacobson. 1999. Update and Verification of the Lake Okeechobee Agricultural Decision Support System. ASCE 1999 International Water Resources Engineering Conference, Seattle, Washington.

14. Zhang, J., S.A.F. Ray, and A. Steinman. 2002. Potential Phosphorus Load Reductions under the Lake Okeechobee Regulatory Program. Journal of the American Water Resources Association. 38: 1-12.