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C-51 West Sub-basin
Updated Analysis of Flow and Phosphorus Data

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Executive Summary. Recent flow and phosphorus data from the C-51 West Basin were analyzed in order to improve the reliability of estimated inflow to Stormwater Treatment Area 1 East (STA-1 East) and Stormwater Treatment Area 1 West (STA-1 West). Using a 4-year period of data, the average annual runoff from the C-51W Basin was estimated to be 128,000 acre feet per year (ac-ft/yr), with a flow-weighted mean phosphorus concentration of 151 parts per billion (ppb). A regression equation was developed for estimating daily phosphorus concentrations, and this was applied to the 31-year simulated runoff used in the Long-Term Plan, a document developed for achieving compliance with the phosphorus criterion. The resulting phosphorus levels were 38% lower (115 ppb compared to 185 ppb) than the estimates used in developing the STA performance projections associated with the Long-Term Plan.

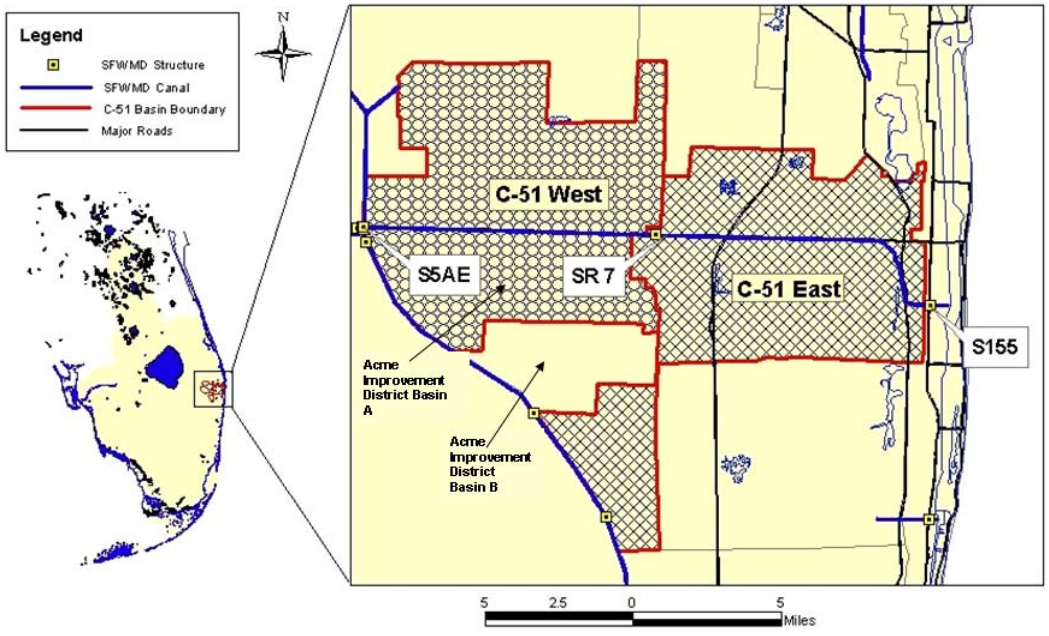
1.0 Introduction

Water quality performance projections for Everglades restoration efforts depend on understanding water movement and nutrient loadings from multiple watersheds. The projections utilize models that are calibrated from flow and water quality data collected at representative sites throughout the region. In 1994, when the Everglades Protection Project Conceptual Design (*Conceptual Design*) was compiled, there was an acknowledged uncertainty in the relationship between discharge volumes and total phosphorus (TP) from the C-51 West basin (Burns and McDonnell, 1994). This uncertainty remained when the 2002 basin-specific feasibility study for the Everglades Construction Project was completed (Burns and McDonnell, 2002). A recommendation from the *Everglades Protection Area Tributary Basins Long-Term Plan for Achieving Water Quality Goals* was to update the estimates of flow and TP for the C-51 West sub-basin (Burns and McDonnell, 2003). This report documents an updated data analysis in accordance with that recommendation.

The C-51 West sub-basin is part of the larger C-51 Basin, which is bordered on the west by the S-5AE structure and on the east by the S-155 coastal structure. The C-51 Basin is made up of two sub-basins, the C-51 West and the C-51 East sub-basins, divided by the gated structure S-155A located on the C-51 Canal at State Road 7 (SR7) (Burns and McDonnell, 1994). The focus of this analysis is on the flow and TP loading leaving the C-51 West sub-basin.

The C-51 West sub-basin has an area of about 75 square miles, is bisected by the C-51 canal, and is bordered on the east by the S-155A control structure and on the west by the S-5AE structure. The sub-basin includes the Acreage, the Village of Royal Palm Beach, and the Village of Wellington (**Figure 1**) housing developments, collectively referred to as the Acme Improvement District.

Figure 1. Map showing the configuration of the C51 West sub-basin



In the 1994 *Conceptual Design*, the TP concentration that was used for the C-51 West sub-basin relied on a small number of data points (n=14) that were collected at station S-5AE (**Table 1**). Since 1994, there has been additional water quality and flow data collected at S-5AE and other water control stations located along the C-51 Canal. To better estimate the flow and TP loading and concentrations coming out of the C-51 West sub-basin, an analysis of the flow and water quality collected at stations S-5AE, SR7, and S-155 was done. This updated evaluation of the data from the C-51 West sub-basin is important for use in future model predictions.

Table 1. Summary of Total Phosphorus and Flow Data used in 1994 Conceptual Design

Date	TP (ppb)	Flow (acre feet)	TP Load (kg)
03/24/82	*96*	*736*	*87*
03/25/82	*52*	*764*	*49*
03/30/82	*318*	*1,743*	*684*
06/01/82	*161*	*1,065*	*212*
06/08/82	*170*	*1,186*	*249*
06/22/82	*230*	*159*	*45*
06/24/82	*215*	*1,049*	*278*
06/25/82	*318*	*718*	*282*
11/09/82	*45*	*1,267*	*70*
10/18/83	*98*	*432*	*52*
10/16/84	*195*	*52*	*12*
06/25/85	*63*	*817*	*64*
07/24/85	*560*	*661*	*456*
09/17/85	*66*	*762*	*62*
Total	**185**	**11,411**	**2,602**

1.1 Background

For the 1994 *Conceptual Design*, a 24 year (1961 – 1985) database was used. Because there was little to no measured data available, a model was used to estimate the runoff from the C-51 West sub-basin. The flow data that was used for the C-51 West sub-basin was generated by the U. S. Army Corps of Engineers Jacksonville District, using a simulated model that was calibrated to available gage data measured in the entire C-51 basin. The flow estimates show that three separate hydrologic regimes were used in the sub-basin, reflecting the different water management strategies that were used over that time period (**Table 2**). The projected average runoff from the C-51 West sub-basin was expected to be stable throughout the 25-year period, with average annual runoff calculated to be 119,002 acre-ft/year. This model simulation runoff estimate included contribution from part of the Acme Improvement District Basin (Basin A was included but not Basin B) (**Figure 1**). Additionally, for the Conceptual Design, it was assumed that 11,500 acre feet per year of C-51W sub-basin runoff would be diverted to STA-1W, and that approximately 31,000 acre feet per year of S-5A basin runoff would be diverted to STA-1E.

The original estimate of the flow-weighted mean (FWM) TP concentration coming from the C-51 West sub-basin was initially going to be based on the data collected from station SR7, located about 10 miles east of S-5AE on the C-51 canal. But, because there was a very limited amount of data available at SR7 and the dataset consisted of only 6 data points heavily influenced by a single data point, the resulting TP concentration of 276 ppb was not used. Instead a single FWM TP concentration based on data collected from S-5AE during negative flow events, i.e., flow leaving the sub-basin, was used. S-5AE had a slightly greater number of data points (n = 14) and the calculated FWM TP concentration of 185 ppb was used to estimate loading coming from the C-51 West sub-basin (**Table 1**). A long-term average annual load of 27,156 kg/yr was estimated for the C-51W sub-basin.

For the basin-specific feasibility studies leading to the Long-Term Plan, the South Florida Water Management Model (SFWMM) simulated a 31-yr average annual runoff from the C-51W basin of 105,202 acre feet per year (Goforth and Piccone 2001). A flow-weighted mean concentration of 185 ppb was applied to the daily runoff estimates to generate an estimate of phosphorus load of 24,009 kg/yr to STA-1E.

Table 2: Data that was used to estimate flow for C-51 West basin for 24 base year (1961 – 1985). The data was generated by the Jacksonville District Corps of Engineers using a simulation model. Three different water regimes were used in the C-51 Basin. From: "Everglades Protection Project, Conceptual Design, February 15, 1994, Burns & McDonnell.

Period		**Discharge at S-5AE**				**Hydrologic Regime**
	C-51 West Basin Runoff (ac-ft/yr)	**Inflow (ac-ft/yr)**	**Outflow (ac-ft/yr)**	**Net (ac-ft/yr)**	**Discharge at SR7 (ac-ft/yr)**	
1961-1970	120,883	191,021	1,184	189,837	310,720	C&SF Project in place
1971-1978	112,491	27,906	3,100	24,806	137,297	WPB M-Canal system in place
1979-1985	123,754	96.968	9,994	86,974	210,788	Lake Okeechobee Interim Action Plan in Place

2.0 Data Update Methodology

The goal of this analysis is to recommend an updated relationship between TP and flow for the C-51 West sub-basin to be used in the refined data sets used to predict the performance of STA-1 East. To achieve this goal, available flow and TP data from the C-51 West sub-basin were analyzed to better estimate the TP loading and concentrations leaving the sub-basin. The available data were retrieved from the South Florida Water Management District (SFWMD) database; flows, TP loads and concentrations were calculated; annual statistics were generated; and an overall relationship between TP concentration and flow for the C-51 West sub-basin was determined.

The database was queried in order to identify all of the available data within the entire C-51 West sub-basin. A broad query requesting flow from the hydrology database (DBHYDRO) for the sub-basins named C51, C51E, C-51 West sub-basin was done. The stations that were returned from the query of the hydrological database were: Acme, C51SR7, LWD, S155, S5AE, S5AS. The water quality data base was also queried, requesting the stations that had C51 in their name: C51-12.0, C51-22.0, C51FORST. C51JOG, C51KIRK, C51S155, C51S5!, C51S51AE, C51SR7, C51SR809, C51SUMIT, S5AE. Most of these stations were used for pesticide monitoring and TP was measured only at stations S5AE, C51S5AE, C51SR7, C51S155. Those sites that add nutrients to the basin, such as Acme and LWD, were not considered because they are internal contributions and only the water quality leaving the sub-basin was analyzed. A listing of the station names and database query keys that were used in this analysis is found in **Table 3**. The “EMA Load Program, 3/03” was used to retrieve the flow and water quality data from the databases.

After flow and load calculations were conducted, time series plots of the resulting flow, load, and FWM TP were created.

2.1 S-5AE Data Analysis Method

Water flow can move in two directions at structure S-5AE; positive flow indicates water moving into the sub-basin from sources to the west, including the L-8 basin, Lake Okeechobee, the Arthur R. Marshall Loxahatchee National Wildlife Refuge, and in some circumstances, the Everglades Agricultural Area (EAA). Negative flow indicates water moving out of the sub-basin. Water quality samples for S-5AE were collected under 2 separate projects for part of the data

record, from 1997 – 2001 (**Table 4** and **Figures 2 and 3**). Because both negative and positive flow at S-5AE triggered sample collection at the autosampler, the samples contained a mixture of flow from the basin, as well as flow leaving the basin and there was no way to differentiate the sample; hence, the autosampler TP data was not used. Instead, the grab sample TP values were used and the values were averaged, by date, then merged together. To estimate the TP load and concentrations leaving the C-51 West sub-basin through S-5AE, grab sample TP data, collected only when flow was negative, was used. There were some years when there was not any negative flow measured at S-5AE. During the years when there was negative flow, there were some years (1986, 1987, 1990, 1991, and 1995) when there were no grab samples collected simultaneously during the flow events. In those years when there was a matched TP sample to negative flow, the number of TP samples that were collected annually during the negative flow events ranged from a single sample in 1983, 1984, and 2001 up to 12 samples in 1999 (**Table 4**). In total, there were 29 TP data values with negative flow at S-5AE.

The FWM TP concentrations leaving the C-51 West sub-basin at S-5AE were calculated using the same methodology that was used in the 1994 *Conceptual Design*. First the load was calculated using grab sample data collected during negative flow events (concurrent data). From the point by point TP load estimates, the FWM TP was calculated. Then, as a refinement to the methodology used in the 1994 *Conceptual Design*, the point by point FWM TP was applied to the total amount of negative flow on an annual basis to calculate a total TP load over the period of record. Then, from this total TP load, a period of record FWM TP for water leaving the sub-basin was calculated.

In addition to calculating the loads and FWM TP leaving the sub-basin, the TP load and FWM concentrations of water entering into the C-51 West sub-basin through S-5AE was also calculated. Again, the point by point methodology was used to estimate TP loads when there was positive flow through S-5AE, using grab sample TP data. The FWM TP that was calculated was then applied to the total amount of positive flow in order to estimate the total amount of load and FWM TP entering the sub-basin.

Table 3: A listing of the DBKEYS and water quality stations queried from the District database to calculate TP loads coming from the C-51 West sub-basin.

	Hydrology			**Water Quality**			
Site	**Station Name**	**DBKEY**	**Period of Record**	**Project**	**Station Name**	**Type & Frequency**	**Period of Record**
S-5AE	S5AE_C	P1018 (Mod1)	01/01/78 – 12/31/00	ST1E	C51S5AE	A/S, G	08/01/97 – 07/22/01
		L7443	11/30/99 – 03/03/04	CAMB	S5AE	G; bi-weekly	03/24/82 – 12/31/03
SR7	C51SR7_O	FI280	07/24/97 – 07/05/01	LATE, ST1E	C51SR7	A/S, G; weekly	07/24/97 – 07/05/01
S-155	S155_S	P0963 (Mod1)	01/01/78 – 12/31/00	WQM	C51S155	G; monthly	03/18/82 – 12/31/03
		03680	02/19/86 – 02/29/04				

Table 4. Summary of S-5AE Flows and TP Loads (period of record: 3/1982 - 12/2003)

		Entering the C-51 West sub-basin							Leaving the C-51 West sub-basin						
Year	Combined Flow acre feet	Flow acre feet	Number of TP Samples	Flow with TP Grab Samples acre feet	Concurrent TP Load kg	Concurrent TP ppb	TP Load with All Flow (See Note 1) kg	TP with All Flow (See Note 1) ppb	Total Flow acre feet	Number of TP Samples	Flow with TP Grab Samples acre feet	Concurrent TP Load kg	Concurrent TP ppb	TP Load with All Flow (See Note 1) kg	TP with All Flow (See Note 1) ppb
***1982**	117,936	85,572	13	4,108	307	61	6,390	61	32,364	9	8,688	1,956	182	7,286	182
1983	240,667	231,034	22	17,223	2,669	126	35,808	126	9,634	1	432	52	98	1,165	98
1984	180,990	178,681	18	14,009	2,051	119	26,154	119	2,309	1	52	12	195	555	195
1985	36,674	16,981	7	916	95	84	1,761	84	19,692	3	2,239	582	211	5,116	211
1986	68,947	67,476	13	3,925	678	140	11,660	140	1,472	0	0	0		0	
1987	70,300	69,010	12	4,629	452	79	6,735	79	1,289	0	0	0		0	
1988	86,055	86,055	11	3,929	527	109	11,536	109	0	0	0	0		0	
1989	18,207	18,207	11	823	96	94	2,121	94	0	0	0	0		0	
1990	18,059	15,237	8	625	85	111	2,080	111	2,822	0	0	0		0	
1991	3,030	1,365	1	0	0		0		1,666	0	0	0		0	
1992	144,229	144,229	8	5,694	465	66	11,769	66	0	0	0	0		0	
1993	90,860	90,860	8	5,550	292	43	4,780	43	0	0	0	0		0	
1994	82,027	82,027	1	1,597	61	31	3,137	31	0	0	0	0		0	
1995	286,560	286,088	10	9,935	1,280	104	36,848	104	472	0	0	0		0	
1996	141,959	141,959	15	8,025	719	73	12,719	73	0	0	0	0		0	
1997	64,989	64,989	29	13,940	1,192	69	5,557	69	0	0	0	0		0	
1998	211,149	216,119	63	43,894	3,206	59	15,783	59	4,971	2	1,123	59	43	263	43
1999	119,198	149,586	56	32,073	3,203	81	14,941	81	30,388	12	6,720	753	91	3,407	91
2000	42,381	42,456	57	7,289	991	110	5,772	110	75	0	0	0		0	
2001	36,460	36,603	37	2,847	175	50	2,249	50	143	1	143	26	145	26	145
2002	127,509	127,509	15	9,037	922	83	13,012	83	0	0	0	0		0	
2003	268,222	268,222	22	18,881	2,147	92	30,507	92	0	0	0	0		0	
Total	**2,312,969**	**2,420,267**	**437**	**208,948**	**21,612**	**84**	**261,318**	**88**	**107,298**	**29**	**19,397**	**3,440**	**144**	**17,817**	**135**
Annual Average	**106,343**	**111,277**					**12,015**		**4,933**					**819**	
Minimum	3,030	1,365	1	0	0	31	0		0	0	0	0	43	0	43
Maximum	286,560	286,088	63	43,894	3,206	140	36,848		32,364	12	8,688	1,956	211	7,286	**182**

*** Flow and water quality measurements began in March, 1982.**

Note 1. Annual load calculated using the total flow and the annual FWM TP concentration based on days with concurrent flow and grab samples.

Figure 2: Time series plot of S-5AE flow.

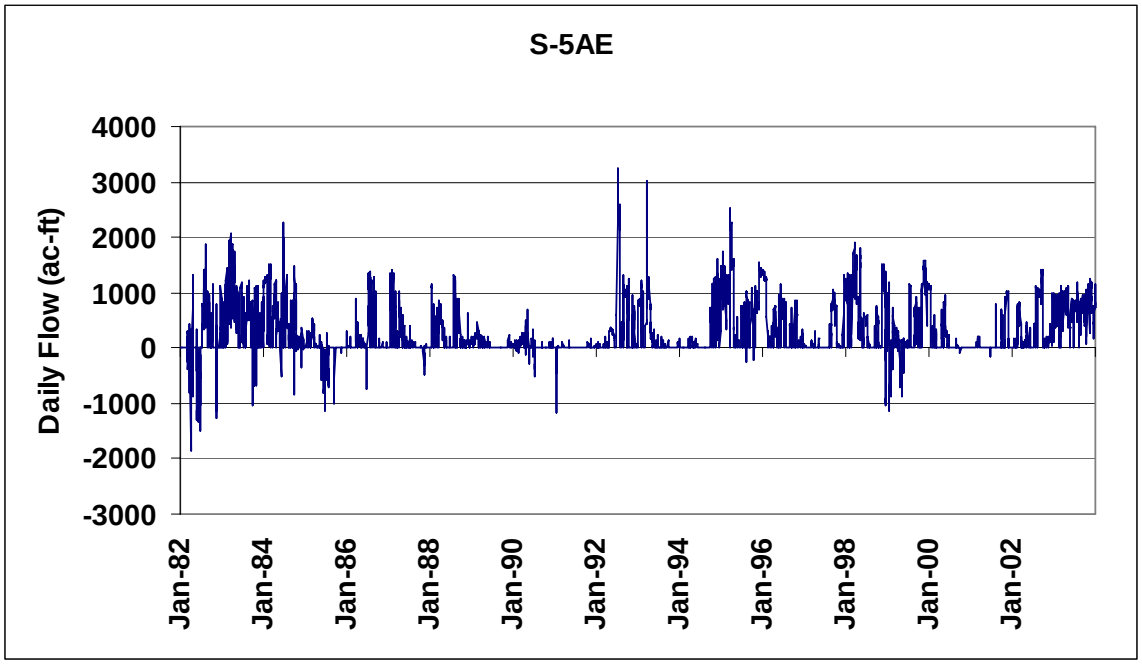


Figure 3.Time series plot of S-5AE TP grab sample data.

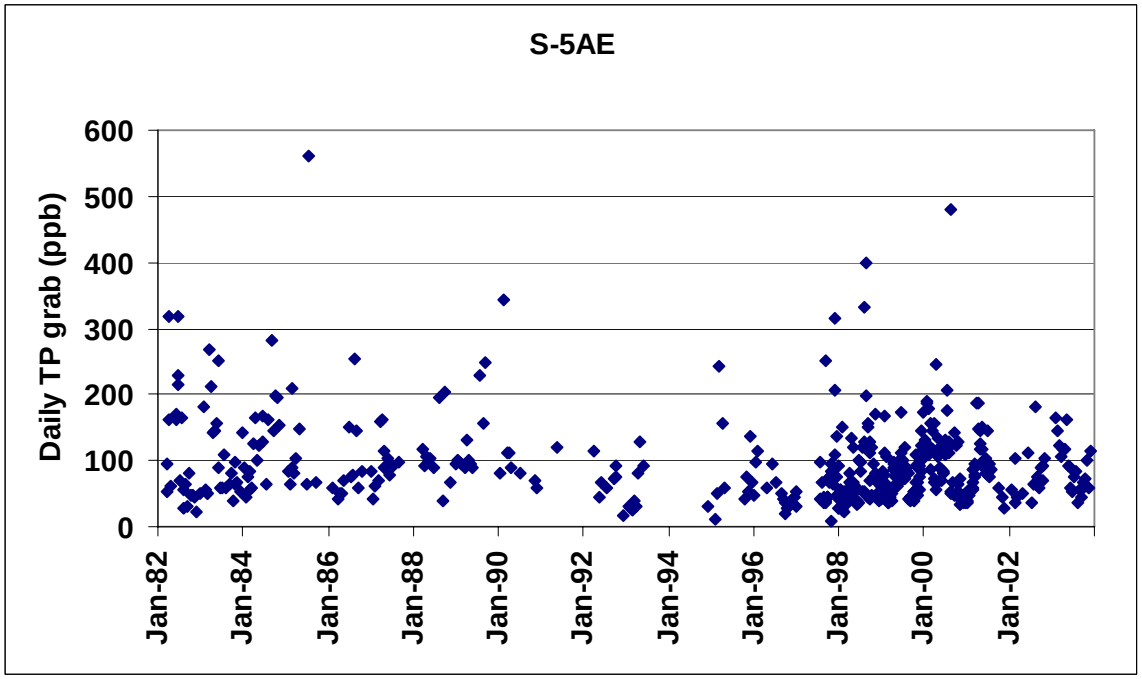


Figure 4. Summary of Annual Flow at S-5AE.

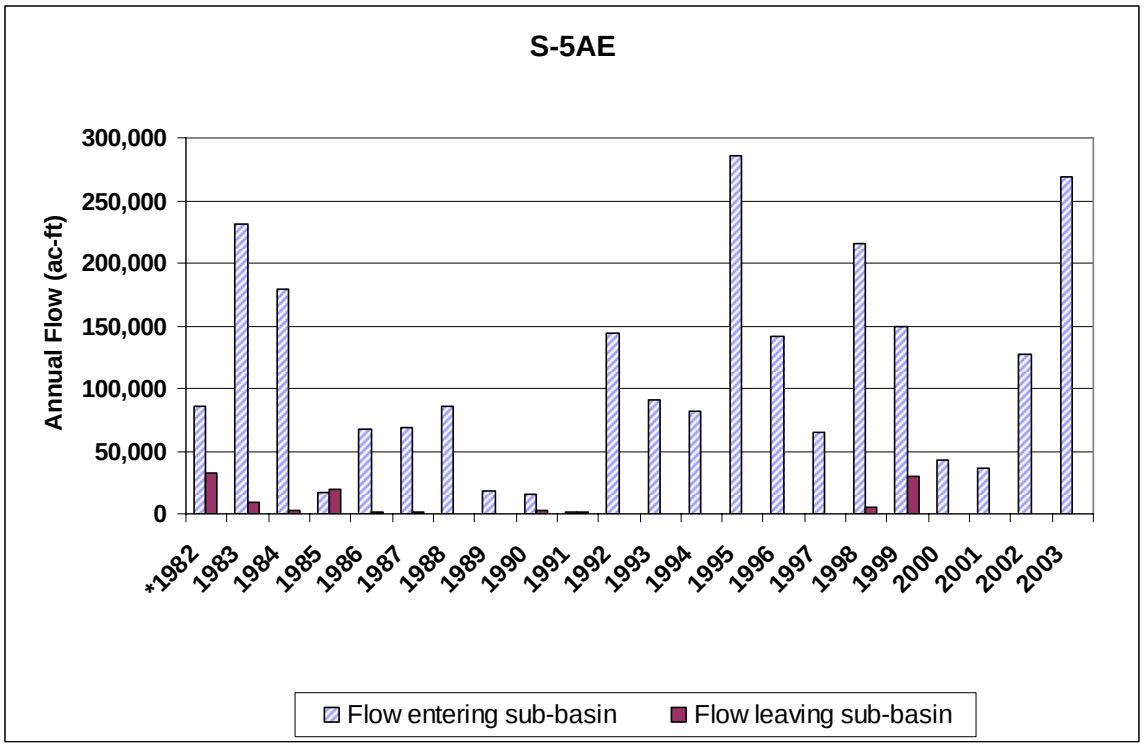
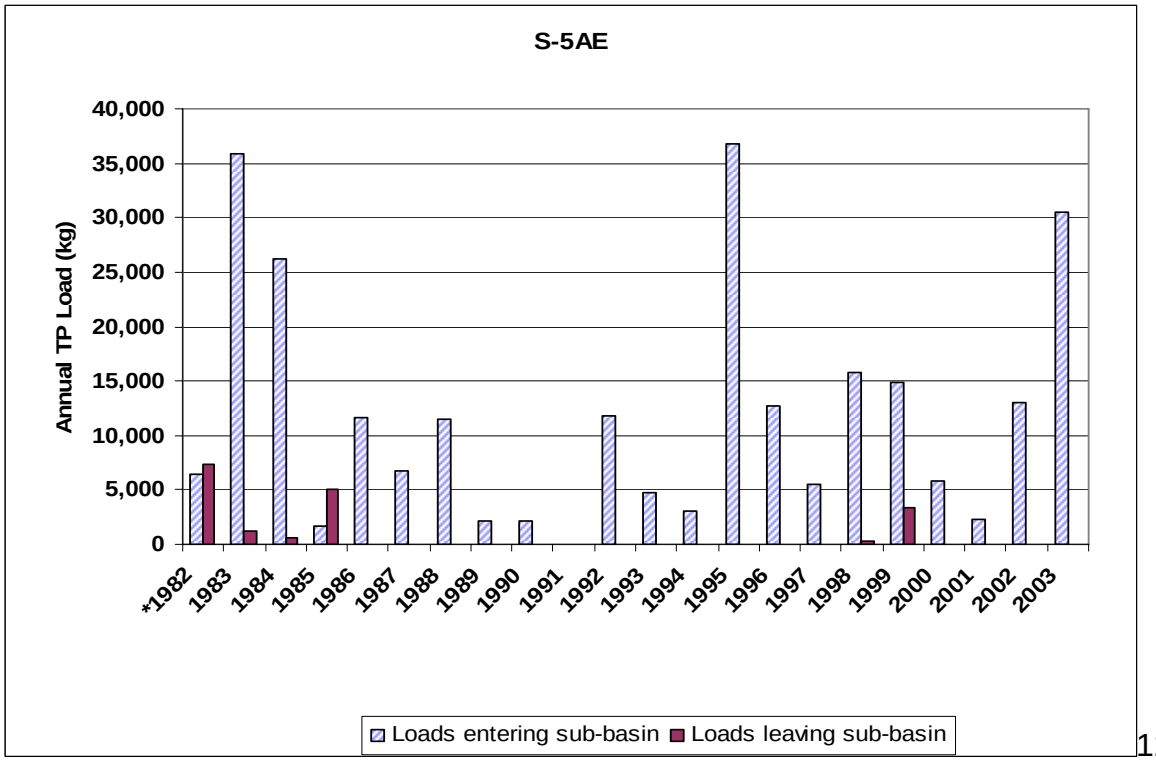


Figure 5. Summary of Annual TP Loads at S-5AE.



2.2 State Road 7 Data Analysis Method

Flow and TP data were collected at State Road 7 (SR7) between August 1997 and July 2001 (**Figures 6 and 7**). However, the amount of water leaving the sub-basin to the east at SR7 is overestimated by the SR7 data because the flow measurements include pass-through water from the west as well as unquantified discharges from the north (Indian Trail Water Control District). This pass-through water originates as either runoff from the L-8 or EAA basin, or as Lake Okeechobee or Refuge releases. The amount of net flow crossing under SR7 was calculated by subtracting out the pass-through water, measured at the S-5AE structure as positive flow, from the total flow measured at SR7, if both occurred on the same day. Although most often the flow at SR7 was positive, indicating flow moving to the east, there were a few instances where there was negative flow values measured at SR7. To determine how much impact these negative flows had on the dataset, the percentage of negative to positive flow was calculated. In 1998 and 2000, the percentage of negative flow was less than 1%; in 2001 only about 4% of the flow was negative; and in 1997 or 1999, there was no negative flow measured. Most likely, these negative flows represent localized wind disturbances. Because there was only a small amount of negative flow, the days when there was negative flow were not included in the analysis.

The net phosphorus loads leaving the basin at SR7 were also calculated by subtracting estimated pass through loads from the S-5AE structure. Daily loads passing through S-5AE were calculated by applying the average annual flow-weighted mean concentration (based on days with concurrent flow and TP samples) within each calendar year. These pass-through loads were subtracted from the loads calculated at SR7, calculated from using the daily SR7 flows and interpolated autosampler values. The “EMA Load Program” using a 14-day interpolation methodology (EMA Load Program, 2003) was used for the interpolation.

Figure 6.Time series plot of State Road 7 flow.

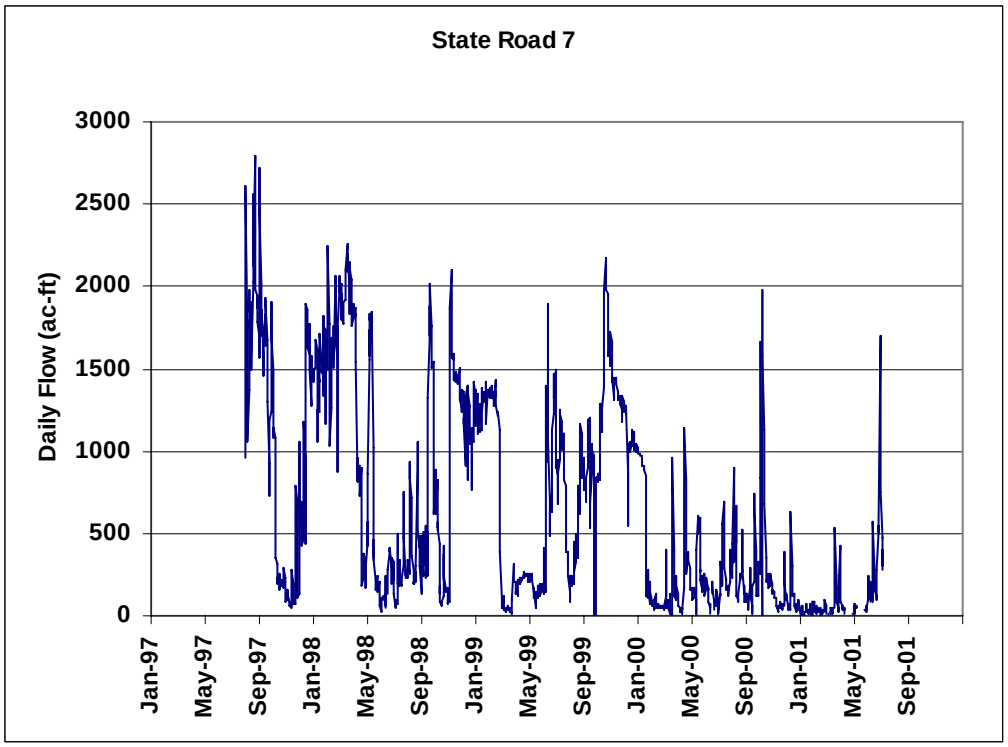


Figure 7. Time series plot of SR7 TP grab and autosampler data.

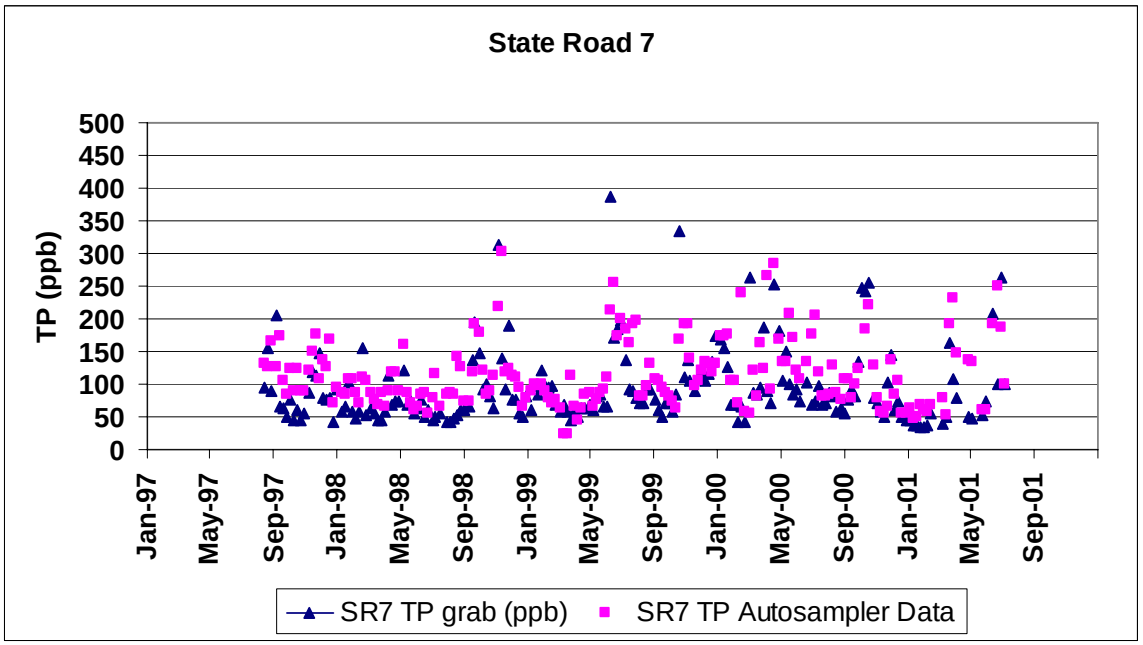


Figure 8. Summary of Annual Flow at State Road 7.

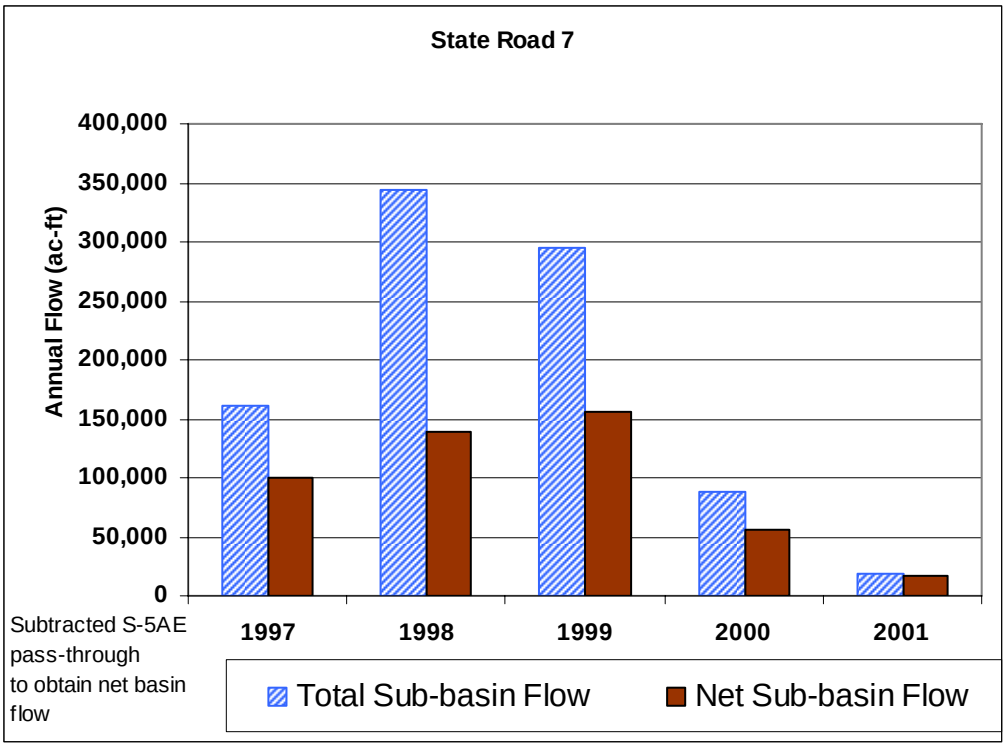
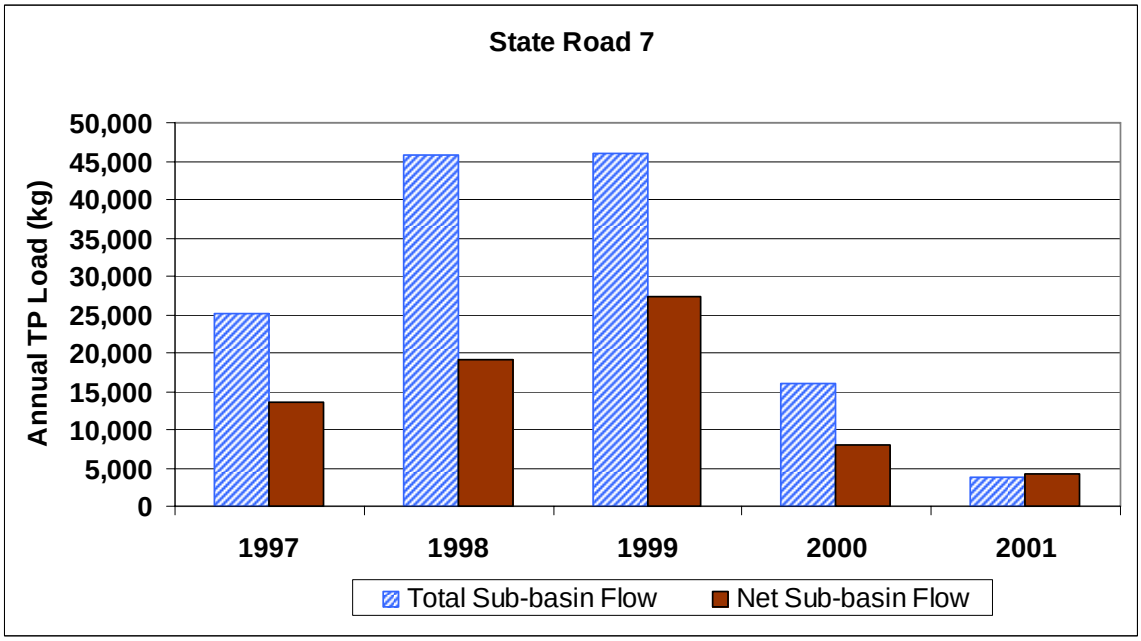


Figure 9. Summary of Annual TP Loads at State Road 7.



2.3 S-155 Data Analysis Method

The flow and load calculations for S-155 were made using the EMA load program. At S-155, only grab TP samples were collected (**Figures 10 and 11**). The EMA load program linearly interpolates the grab sample TP data between collection dates to estimate daily loading and FWM TP concentrations.

Figure 10. Time series plot of S-155 flow.

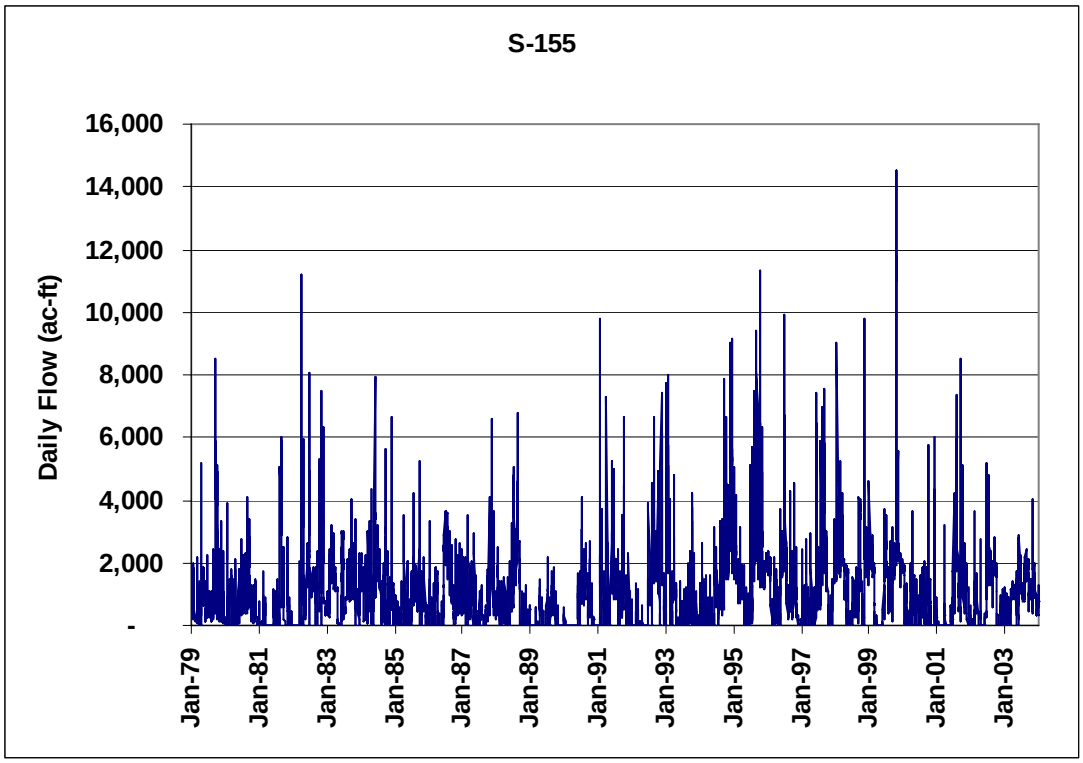


Figure 11. Time series plots of S-155 TP grab sample data.

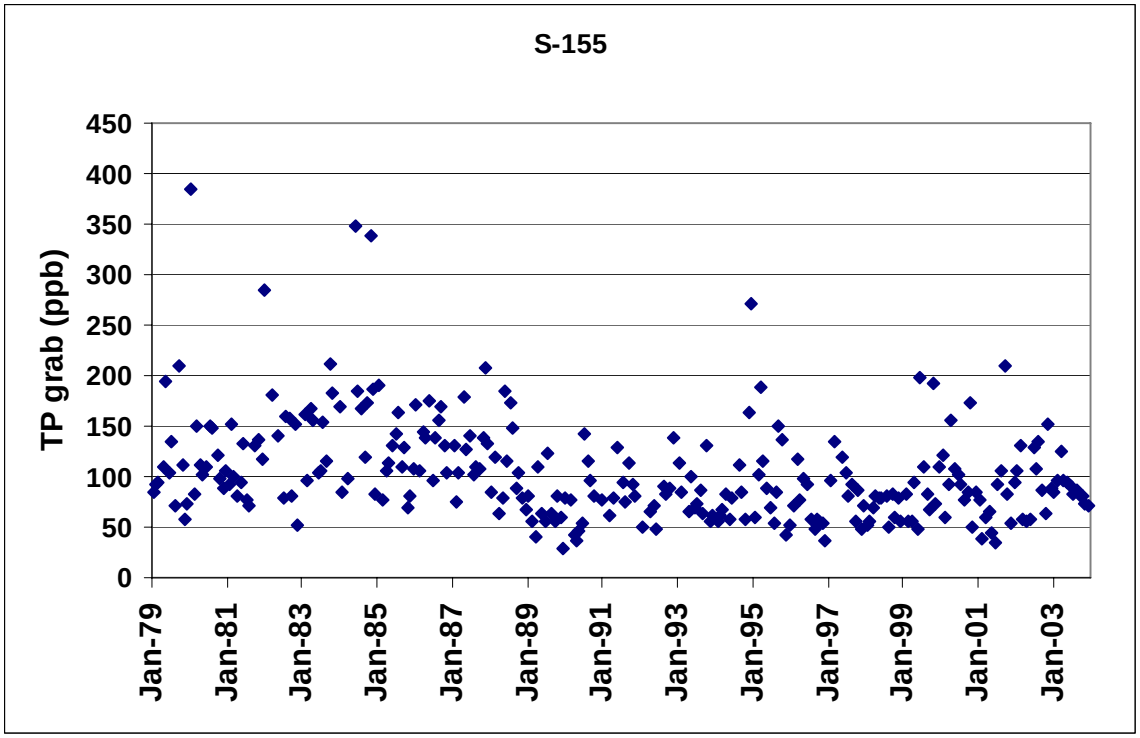


Figure 12. Summary of Annual Flows at S-155.

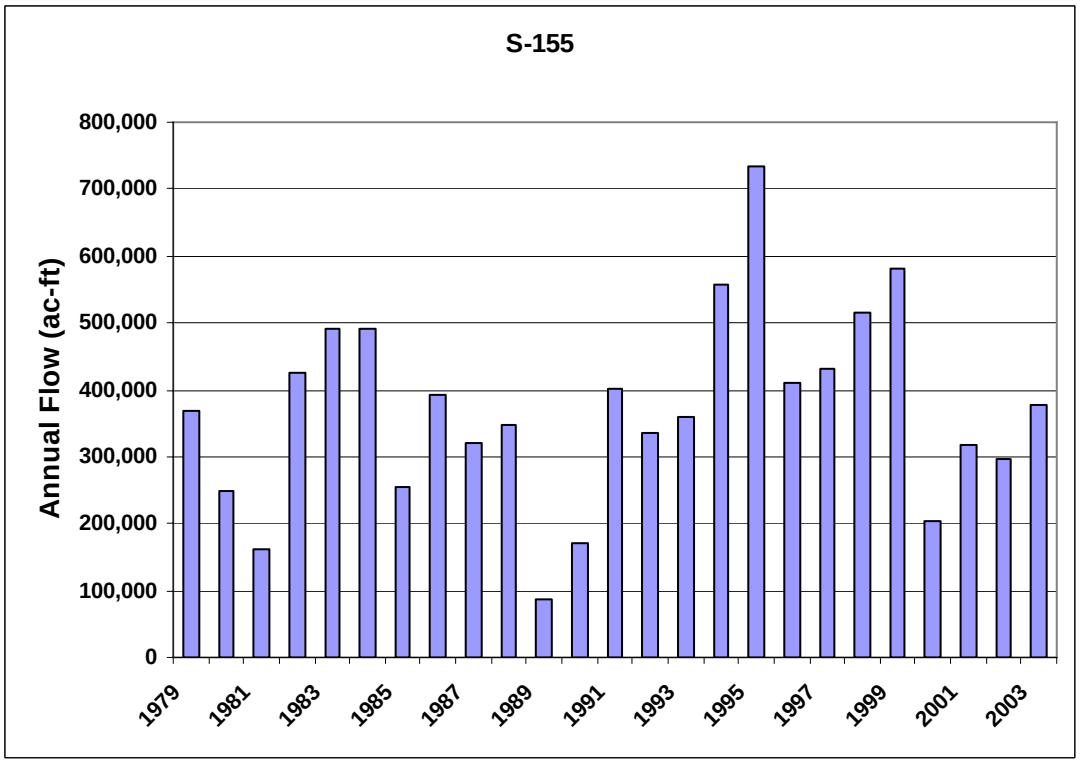
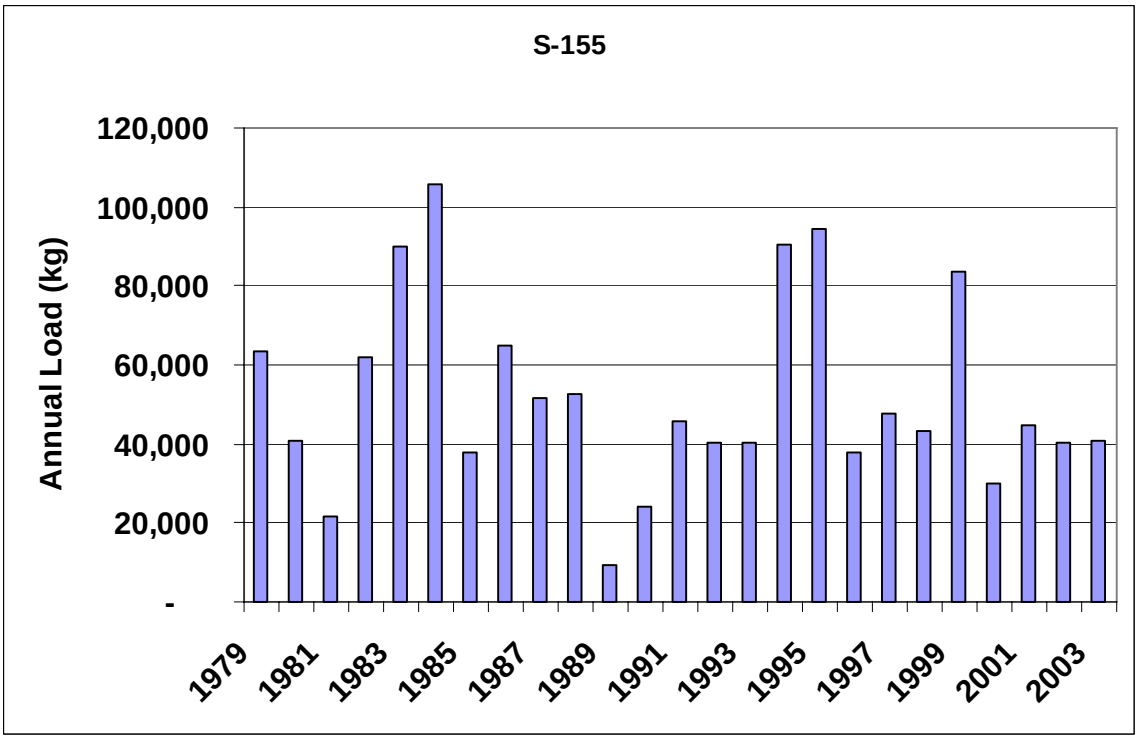


Figure 13. Summary of Annual TP Loads at S-155.



2.4 Regression Analysis

A multiple linear regression analysis was performed on grab sample data collected during flow events at S-5AE and SR7 in order to determine if the regression equation or the period of record FWM TP concentration is a better predictor of TP concentration. The regression analyzed the correlation of flow and time of year as predictors of TP concentration. The analysis was done using the Microsoft Excel LINEST function.

3.0 Data Analysis

3.1 S-5AE Results

A 21.75-year record for flow and water quality data for S-5AE, from March 1982 through December 2003, was analyzed. Over the entire period, the gross amount of flow measured at S-5AE averaged 106,343 ac-ft/yr and ranged from

3,030 ac-ft/yr in 1991 to 286,560 ac-ft/yr in 2003. Of this total, the amount of flow that entered into the C-51 West sub-basin averaged 111,277 ac-ft/yr with the smallest amount of flow (1,365 ac-ft/yr) occurring in 1991 and the greatest amount of flow occurring in 2003 (286,088 ac-ft/yr). The amount of flow leaving the C-51 West sub-basin through S-5AE was much lower than what entered the sub-basin. For many of the years there was not any flow leaving the sub-basin through S-5AE. In those years that did have flow, the annual flow averaged 4,933 ac-ft/yr, ranging from a low of 75 ac-ft/yr in 2000 up to a high of 32,364 ac-ft/yr in the partial year in 1982 that began in March. Results are shown in **Table 4** and **Figure 4**.

The total amount of TP load entering into the C-51 West sub-basin through S-5AE was 261,318 kg, averaging 12,015 kg/year. The amount of TP leaving the sub-basin totaled 17,817 kg, averaging 819 kg/year. Over the entire 21.75-year period of record, the FWM TP entering into the sub-basin was 84 ppb using the concurrent data and 88 ppb using the total flow. Using the concurrent method, the FWM TP leaving the sub-basin through S-5AE was 144 ppb, and 135 ppb using the total flow method. Results using the total flow method are shown in **Table 4** and **Figure 5**.

3.2 SR7 Results

A four-year record for flow and water quality, from August 1997 – July 2001, was available for SR7. Over this period, a total of 906,398 ac-ft/yr was estimated at SR7. Subtracting out the amount of pass-through water contributed by S-5AE, the net amount of basin flow through SR7 was about half of the combined flow, totaling 467,902 ac-ft and averaging 119,975 ac-ft/yr. Subtracting out the pass-through phosphorus loads from S-5AE yielded a flow-weighted mean concentration of 156 ppb phosphorus leaving the basin at SR7. Results are shown in **Table 5** and **Figures 8 and 9**.

Table 5. Summary of State Road 7 Flows and TP Loads (period of record: 8/1/1997 - 7/5/2001)

	Combined Flow and Load Record (See Note 1)			Pass Through from S-5AE (See Note 2 and Note 3)		Net Sub-Basin Flows and Loads		
Year	Total Sub-basin Flow	TP Load	TP	Flow	TP Load	Net Sub-basin Flow	TP Load with all flow (see Note 1)	Cumulative TP (see Note 2)
	acre feet	kg	ppb	acre feet	kg	acre feet	kg	ppb
1997 (P)	161,823	25,124	126	61,521	5,273	100,302	19,851	160
1998	343,733	45,715	108	216,119	15,783	138,201	28,419	167
1999	294,763	46,093	127	149,586	14,941	155,417	28,385	148
2000	87,761	16,025	148	42,456	5,772	56,204	9,660	139
2001 (P)	18,319	3,870	171	2,862	282	17,778	3,824	174
Total	**906,398**	**136,826**	**122**	**472,546**		**467,902**	**90,139**	**156**
Average	**232,410**	**35,084**		**121,166**		**119,975**	**23,113**	

Note 1. Interpolated autosample data used for SR7 concentrations.
Note 2. Annual flow-weighted mean TP used for S-5AE loads.
Note 3. Net flows and loads set to zero if S-5AE pass-through exceeded SR7 flows and loads, and S-5AE pass-through reduced accordingly.

3.3 S-155 Results

For station S-155, there was a continuous period of record, from 1979 through 2003. Over the 25 year period, a total of 9,284,188 ac-ft of flow was measured at S-155, averaging 371,368 ac-ft/yr and ranging from a low of 87,257 ac-ft/yr in 1989 up to a high of 733,344 ac-ft/yr in 1995. The total amount of TP load was 1,303,376 kg, averaging 52,135 kg/year and ranging from 9,255 kg/year up to 105,513 kg/year. The average FWM TP concentration was 114 ppb, ranging from 68 ppb up to 174 ppb. Results are shown in **Table 6** and **Figures 12 and 13**.

The amount of flow entering the C-51 East sub-basin at SR7 was about 57% of the flow measured leaving the sub-basin at S-155, ranging from 20% to 67%. Although the flow volume was less at SR7, the TP loads measured at SR7 did not always follow the same trend. At times, the TP load was higher at SR7 and other times lower, ranging from 106% in 1999 to 43% in 2002. During the period when there was an overlap of data collected from SR7, from August 1997 through July 2001, the FWM TP for SR7 (calculated using the combined flow at SR7), was 122 ppb while the FWM TP calculated for S-155 was 93 ppb.

Table 6. Summary of S-155 Flows and TP Loads (period of record: 1/1979-12/2003)

	S-155				State Road 7			
Year	Flow acre feet	TP Load (metric tons)	TP Load kg	TP ppb	Flow acre feet	Percentage of S-155 Flow %	TP Load kg	Percentage of S-155 Load %
1979	369,955	64	63,510	139				
1980	249,538	41	40,579	132				
1981	161,638	22	21,684	109				
1982	425,863	62	62,109	118				
1983	490,832	90	90,106	149				
1984	490,780	106	105,513	174				
1985	254,602	38	38,057	121				
1986	391,591	65	64,956	134				
1987	321,847	52	51,729	130				
1988	348,420	53	52,681	123				
1989	87,257	9	9,255	86				
1990	172,190	24	23,992	113				
1991	401,748	46	45,957	93				
1992	336,527	40	40,387	97				
1993	358,228	40	40,475	92				
1994	557,096	90	90,437	132				
1995	733,344	94	94,315	104				
1996	411,154	38	37,765	74				
1997	431,748	48	47,589	89	161,823	62%	25,124	101%
1998	516,014	43	43,045	68	343,733	67%	45,715	106%
1999	580,153	83	83,452	117	294,763	51%	46,093	55%
2000	203,415	30	29,961	119	87,761	43%	16,025	53%
2001	318,166	45	44,737	114	18,319	20%	3,870	43%
2002	295,771	40	40,197	110				
2003	376,312	41	40,886	88				
Total: 1/1/79 - 12/31/03	**9,284,188**	**1,303**	**1,303,376**	**114**				
Total: 8/1/97 - 7/5/01	**1,593,548**	**184**	**183,697**	**93**	**906,398**	**57%**	**136,826**	**74%**
Average	**371,368**	**52**	**52,135**	**114**				
Minimum	**87,257**	**9**	**9,255**	**68**				
Maximum	**733,344**	**106**	**105,513**	**174**				

Note: For 1997 and 2001 partial years shown for SR 7 and comparisons

3.4 Regression Analysis

A single flow and TP data set for the C-51 West sub-basin was compiled by combining the grab and concurrent flow data for S-5AE and SR-7. For days with flow measured at both sites, cumulative values of flow and TP were developed. The multiple linear regression analysis was modeled after Walker and Havens (2003), and indicated a reasonable relationship of TP concentration to flow and time of year, with 16% of the variation in TP values explained by variations in flow and season. The resulting least-squares regression equation is

$$\text{Ln[TP (ppb)]} = 3.883 + 0.118*\text{Ln[flow(cfs)]} + 0.003*\sin(2*PI*\text{day}/365) - 0.171*\cos(2*PI*\text{day}/365)$$

To minimize any potential bias in the method resulting from transforming the data using logarithms, a flow-weighted coefficient was derived to ensure the mean load estimate is unbiased. This was calculated as

F = Sum (P concentration observed / P concentration predicted)

Where

Sum = sum over calibration dates

P concentration observed = daily observed P concentration

P concentration predicted = daily concentration predicted by the regression equation

For the combined S-5AE and SR7 data set, the value of F was calculated to be 1.142.

4.0 Summary and Recommendations

A summary of annual flows and loads for the C-51 West sub-basin using the total flow method for the 4 years of overlapping data (August 1997 – July 2001) is presented in **Table 7**. For this time period, the estimated average annual flow leaving the C-51 West sub-basin was 128,063 acre feet per year. This 4-yr annual value is 9,057 acre feet per year above the long-term value estimated in the 1994 *Conceptual Plan*. The method used overestimates the C-51W basin runoff, as the flows leaving SR7 contain some unquantified discharges from the Indian Trails Water Control District. With the construction of STA-1E, approximately 6,560 acres of the 79.5 square mile C-51W basin will no longer contribute runoff. Adjusting for this reduction yields an estimate of approximately 111,552 acre-feet per year and an average annual load of 20,785 kg/yr. This is about 6,350 acre feet per year above the estimated flows used in the basin-specific feasibility studies and *Long-term Plan (105,202 AF/yr)*. The updated annual FWM concentration of 151 ppb is approximately 18% below the estimated level (185 ppb) used in the 1994 *Conceptual Plan* and *Long-term Plan*, so the resulting updated 4-year TP load is about 12% less than estimated in the 1994 *Conceptual Plan*, and about 13% less than was estimated for the basin-specific feasibility studies and Long-term Plan.

However, recognizing that the short-term period of overlapping record does not cover the anticipated hydrologic range and phosphorus levels for the C-51 West sub-basin in the future, the multiple linear regression equation developed for the 4-year period is recommended for use when updating the input data sets for STA-1 East. By way of comparison, using the regression equation on the simulated C-51W sub-basin flows yielded a 31-yr flow-weighted mean concentration of 115 ppb with an average annual load of 14,925 kg. These

values suggest a 35% reduction compared to the Long-Term Plan estimates (22,861 kg/yr).

Furthermore, additional TP data will be collected at S-319, the new inflow pump station for STA-1E beginning in 2004, and this data will provide additional information on the TP levels in the C-51 West sub-basin.

Table 7. Summary of C-51 West Sub-Basin Flows and Loads (period of record: 8/1997 - 7/2001)

	Leaving Basin through S-5AE			Leaving Basin at State Road 7			Total Leaving Basin		
Year	**Flow acre feet**	**TP kg**	**TP ppb**	**Flow acre feet**	**TP kg**	**TP ppb**	**Flow acre feet**	**TP kg**	**TP ppb**
1997 (P)	0	0		100,302	19,851	160	100,302	19,851	160
1998	4,971	263	43	138,201	28,419	167	143,172	28,681	162
1999	30,388	3,407	91	155,417	28,385	148	185,806	31,792	139
2000	75	0		56,204	9,660	139	56,280	9,660	139
2001 (P)	143	0	145	17,778	3,824	174	17,921	3,824	173
Water Year									
WY98 (P)	0	0		157,401	30,068	155	157,401	30,068	155
WY99	29,379	3,028	84	142,563	24,921	142	171,942	27,949	132
WY00	5,980	646	88	105,581	24,433	188	111,561	25,079	182
WY01	75	0		48,989	7,637	126	49,064	7,637	126
WY02 (P)	143	0		13,368	3,080	187	13,512	3,080	185
Total (8/1/97-7/5/01)	***35,578***	***3,673***	***84***	***467,902***	***90,139***	***156***	***503,480***	***93,813***	***151***
Average (AF/yr)	***9,049***	***934***		***119,013***	***22,927***		***128,063***	***23,862***	
% of Basin Total	***7.1%***	***3.9%***		***92.9%***	***96.1%***				
1994 Conceptual Design							119,006	27,159	185
Difference							9,057	-3,297	-34
							-8%	12%	
Basin Specific Feasibility Study							105,202	24,009	185
Difference							-22,861	147	-34
							-22%	1%	

Water Year is April - May

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