FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Water Resource Management, Bureau of Watershed Management

CENTRAL DISTRICT • MIDDLE ST. JOHNS RIVER BASIN

TMDL Report
Dissolved Oxygen TMDL for Crane Strand Drain (WBID 3014)

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TMDL Program

http://www.dep.state.fl.us/water/tmdl/index.htm

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STORET Program

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2000 305(b) Report

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Chapter 1: INTRODUCTION

1.1 Purpose of Report

This report presents the Total Maximum Daily Load (TMDL) for pollutants (Biochemical Oxygen Demand and Total Nitrogen) that cause low Dissolved Oxygen (DO) concentrations in the Crane Strand Drain, a canal located in the southern section of the Middle St. Johns River Basin. The Crane Strand Drain, known locally as the Crane Strand Canal, was verified as impaired for DO based on the results of sampling and analysis carried out between 1996 and 2002. These results revealed that 25% of the DO values measured during the planning period and 37% of the DO values measured during the verified period were below the Class III DO criterion of 5 mg/L. The Crane Strand Drain was subsequently included on the Verified List of Impaired Waters that was adopted by Secretarial Order in May 2004. The TMDL for the Crane Strand Drain establishes the allowable loadings that would restore the waterbody, so that it meets its applicable water quality criteria for DO.

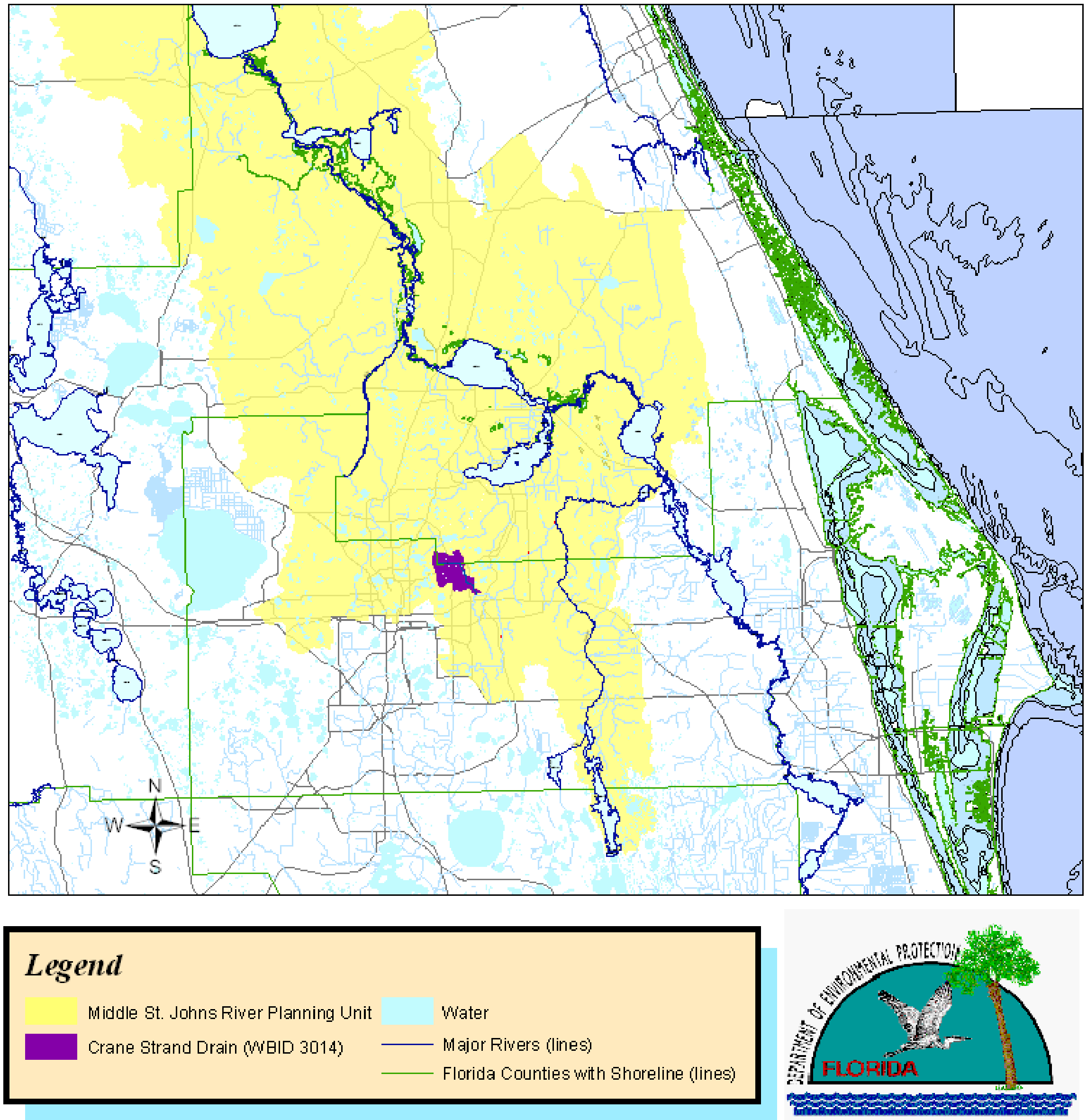
1.2 Identification of Waterbody

The Crane Strand Drain sub-basin is located in central Florida, approximately 2 miles northeast of the city of Orlando (**Figure 1.1).** It is part of the Econlockhatchee River Planning Unit of the Middle St. Johns River Basin. The Crane Strand Drain flows east for approximately 1.6 miles before making an almost 90 degree bend, and then travels an additional 4 miles in a south and southeasterly direction. It is a tributary of the E-4 Canal in the Crane Strand sub-basin, which flows east into the northeastwardly flowing Little Econlockhatchee River. The Little Econlockhatchee River is approximately 14.8 miles long, with a drainage area of 45,420 acres. It is the longest tributary of the 35.8 mile-long Econlockhatchee River (FDEP, 2003).

Seventy five percent (75%) of the 7.66-square-mile (mi^2) drainage area of the Crane Strand Drain is located in Orange County, and the remaining 25% (the central-north and northeast corner) is in Seminole County **(Figure 1.2).** The Crane Strand Canal originates as a channel in a 0.7 square mile channelized wetland area in the northwest section of the sub-basin. The northern half of this former wetland is in Seminole County, with the Crane Strand Canal partitioning it on the county line. No major population jurisdictions are completely within this sub-basin, but it includes parts of Casselberry, a city with a total population 22,629, and Winter Park, a city of 24,090, which extends down the sub-basin's west side. At the northeast corner of the basin is Goldenrod, a census designated place with a population of 12,871. The Crane Strand Drain watershed contains 3.6% of Casselberry, 14% of Winter Park, and 46% of Goldenrod's land areas. Proximity to the city of Orlando is a major factor contributing to the sub-basin's high level of development.

For assessment purposes, the Department has divided the Middle St. Johns River Basin into water assessment polygons with a unique **W**ater**b**ody **Id**entification (WBID) number for each watershed or stream reach. Crane Strand Drain lies within WBID 3014. There are a total of 361 WBIDs in the Middle St. Johns River Basin; this TMDL only addresses WBID 3014.

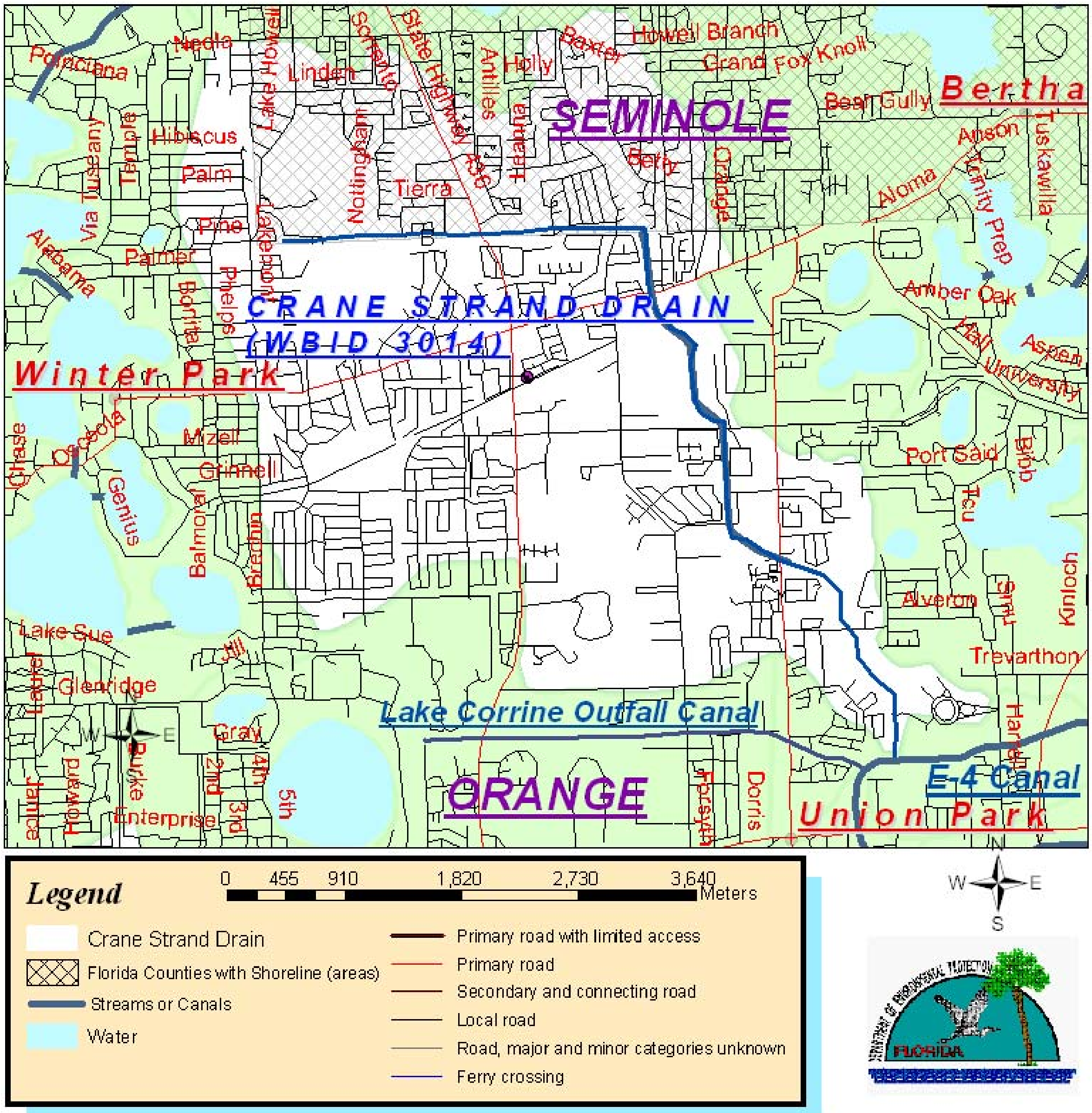
Figure 1.1. Location of Crane Strand Drain (WBID 3014)



1.3 Background

This report was developed as part of the Florida Department of Environmental Protection's (Department) watershed management approach for restoring and protecting state waters and addressing TMDL Program requirements. The watershed approach, which is implemented using a cyclical management process that rotates through the state's fifty-two river basins over a five-year cycle, provides a framework for implementing the TMDL Program–related requirements of the 1972 federal Clean Water Act and the 1999 Florida Watershed Restoration Act (FWRA, Chapter 99-223, Laws of Florida).

Figure 1.2 Crane Strand Drain (WBID 3014) and local canals, streams, and lakes



A TMDL represents the maximum amount of a given pollutant that a waterbody can assimilate and still meet water quality standards, including its applicable water quality criteria and its designated uses. TMDLs are developed for waterbodies that are verified as not meeting their water quality standards. TMDLs provide important water quality restoration goals that will guide restoration activities.

This TMDL Report will be followed by the development and implementation of a Basin Management Action Plan, or BMAP, to increase the amount of Dissolved Oxygen and reduce causative pollutants responsible for the verified impairment of Crane Strand Drain (WBID 3014). These activities will depend heavily on the active participation of the St. Johns River Water

Management District, local governments, businesses, and other stakeholders. The Department will work with these organizations and individuals to undertake and continue reductions in the discharge of pollutants and achieve the established TMDL for this waterbody.

1.3.1 Development of TMDL

This TMDL was developed in cooperation with the St. Johns River Water Management District, Orange County Public Works Department, Seminole County Public Works, and the City of Winter Park. There was also active coordination with a variety of local stakeholders throughout the TMDL development process. This included meetings and teleconference discussions between the Orange County Storm Water Management Division and FDEP's Watershed Planning and Coordination Section. There were also regular meetings between DEP officers, Seminole County officials, Environmental Advocacy Groups, consultants, and other stakeholders who volunteered to participate or whose participation was requested

The major issue related to the Crane Strand Drain throughout the TMDL development process was whether it should be classified as an 'urban ditch,' and whether such a classification would result in a TMDL no longer being required. The question was primarily related to whether an urban ditch was a 'water of the state.' The conclusion was that because the Crane Strand Drain is not separated from the Little Econlockhatchee River system by a control structure, it must be considered as a water of the state of Florida.

Chapter 2: DESCRIPTION OF WATER QUALITY PROBLEM

2.1 Statutory Requirements and Rulemaking History

Section 303(d) of the Federal Clean Water Act requires states to submit to the EPA a list of surface waters that do not meet applicable water quality standards (impaired waters) and establish a TMDL for each pollutant source in each of these impaired waters on a schedule. The Department has developed these lists, commonly referred to as 303(d) lists, since 1992. The list of impaired waters in each basin is also required by the FWRA [Subsection 403.067(4), Florida Statutes (F.S.)], and the list is amended annually to include updates for each basin statewide.

Florida's 1998 303(d) list included 24 waterbodies in the Middle St. Johns River Basin.However, the FWRA (Section 403.067, F.S.) stated that all previous Florida 303(d) lists were for planning purposes only and directed the Department to develop, and adopt by rule, a new science-based methodology to identify impaired waters. After a long rule-making process, the Environmental Regulation Commission adopted the new methodology as Chapter 62-303, Florida Administrative Code (F.A.C.) (Identification of Impaired Surface Waters Rule, or IWR), in April 2001. The list of waters for which impairments have been verified using the methodology in the IWR is referred to as the Verified List.

2.2 Information on Verified Impairment

The Department has used the IWR to assess water quality impairments in the Crane Strand Drain (WBID 3014) and has verified the impairments for low DO, with BOD as the causative pollutant (**Tables 2.1** and **2.2**). The Crane Strand Drain stream was verified as impaired for DO because, based on the analysis results, there is at least 90% confidence that the exceedance rate is greater than or equal to 10 percent. The data are based on samples collected between the years of 1999 and 2002. The BOD criteria for Class III fresh water is that BOD shall not be increased so as to cause DO to be depressed below the applicable DO criterion, and in no case, shall it be great enough to cause nuisance conditions. The existence of elevated BOD (mean and median values > 2.0 mg/L) led to the conclusion that BOD levels were a major negative influence on the DO concentrations.

Table 2.1 Verified Impaired Segments in the Crane Strand Drain

WBID	Waterbody Segment Name	Parameters Identified Using the Impaired Waters Rule (IWR)	Concentration Causing Impairment	Priority for TMDL Development	Projected Year for TMDL
3014	Crane Strand Drain	Dissolved Oxygen and BOD	DO > 5.0 mg/l BOD = 2.25 mg/l	High	2004
3014	Crane Strand Drain	Fecal Coliform Bacteria	> 400 per 100 ml	High	2004
3014	Crane Strand Drain	Total Coliform Bacteria	> 2400 per 100 ml	High	2004

Note: The parameters listed in Table 2.1 provide a complete picture of the impairment in the Crane Strand Drain, but this TMDL only addresses the DO and BOD impairment.

Table 2.2. Summary of Dissolved Oxygen Data for Crane Strand Drain, WBID 3014

Parameter of Concern	Number of Samples	Number of Exceedances	Summary of Analysis Concentrations, mg/L			
			Minimum	Maximum	Mean	Median
Dissolved Oxygen	30	11	2.87	10.95	6.11	5.95
BOD	14		1.0	4.7	2.65	2.25

Chapter 3. DESCRIPTION OF APPLICABLE WATER QUALITY STANDARDS AND TARGETS

3.1 Classification of the Waterbody and Criteria Applicable to the TMDL

Florida's surface waters are protected for five designated use classifications, as follows:

Class I	**Potable water supplies**
Class II	**Shellfish propagation or harvesting**
Class III	**Recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife**
Class IV	**Agricultural water supplies**
Class V	**Navigation, utility, and industrial use (there are no state waters currently in this class)**

3.1.1 Applicable Water Quality Standards and Numeric Water Quality Target

3.1.1.1 Interpretation of Narrative Nutrient Criterion

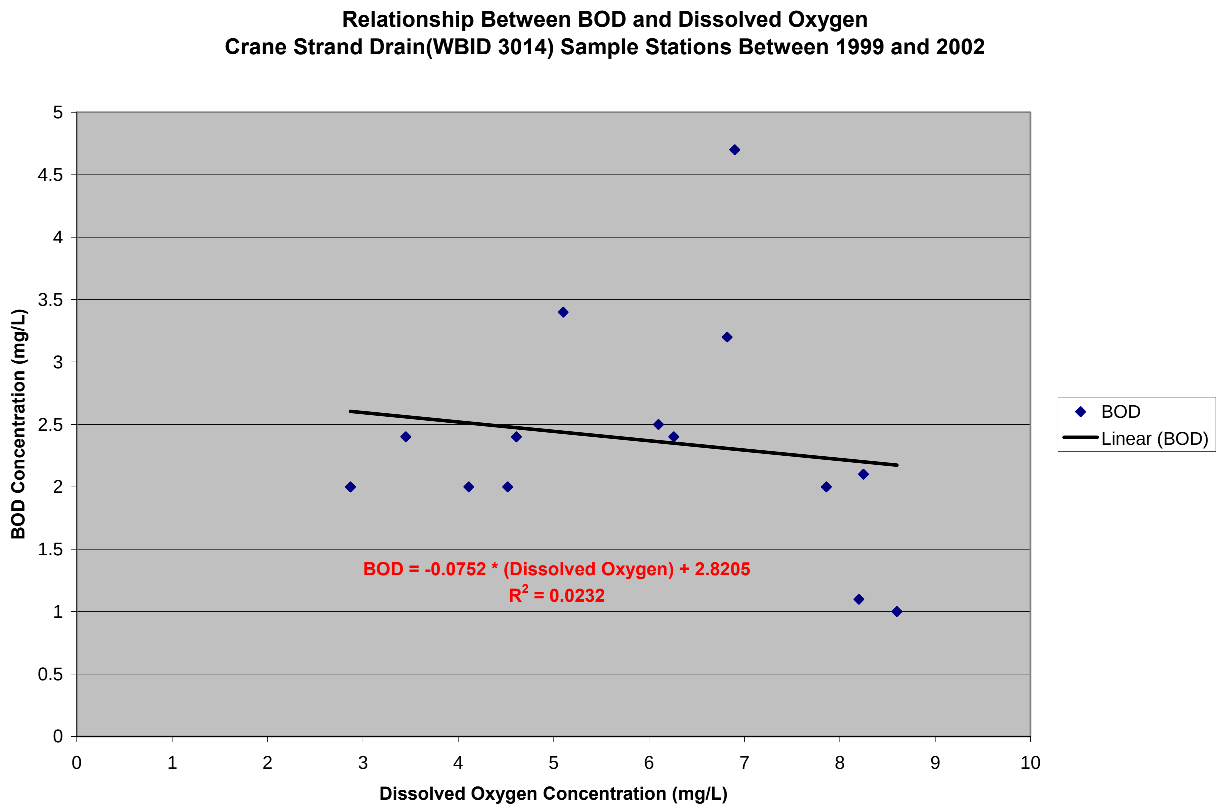
Crane Strand Drain (WBID 3014) is considered a Class III waterbody, with a designated use of recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criterion applicable to the impairment addressed by this TMDL is that dissolved oxygen shall not be less than 5.0 mg/L, with normal daily and seasonal fluctuations above these levels maintained. The BOD (Biochemical Oxygen Demand) shall not be increased to exceed values that would cause the dissolved oxygen to be depressed below the established DO limit, and in no case shall it be great enough to produce nuisance conditions.

3.1.1.2 Relationship between DO, Nutrients, and BOD

After verification of the low dissolved oxygen in Crane Strand Drain, the Department identified the causative pollutants by investigating those parameters typically responsible for depressed DO. These include nutrients (nitrogen and phosphorus) and biochemical oxygen demand (BOD). Although there is an expectation that one should find a relationship between the causative pollutants and DO data, it is difficult to establish such a relationship with some parameters without extensive data collection.

There is a known inverse relationship between average BOD and DO (with an elevated average BOD one would expect to see depressed DO concentrations in a stream). However, there are many other factors responsible for temporal and spatial variation in DO (atmospheric interchange, plant respiration, mud respiration, and plant photosynthesis) and BOD concentrations. This is likely the reason why there was no statistically significant relationship between DO and BOD when looking at a sample by sample analysis of the Crane Strand Drain sample data **(Figure 3.1)**. Even a sudden drop in BOD is not always matched by a corresponding increase in DO (Gray, 2004). The limited amount of samples collected (and lack of continuous sampling throughout the day) in the Crane Strand Drain also made it more difficult to observe a correlation.

Figure 3.1. Relationship between DO and BOD



To identify causative pollutants, the Department uses screening level concentrations set at the 70th percentile of STORET data from 1970 to 1987. The screening levels for streams are 2.0 mg/L for BOD5, 1.6 mg/L for Total Nitrogen and 0.22 mg/L for Total Phosphorus. For the reason outlined above, even though no specific relationship between BOD and DO was observed, it is well established that high BOD is associated with depressed dissolved oxygen. Thus, the fact that the median BOD concentration of the Crane Strand Drain exceeded the screening level of 2 mg/L provides evidence that BOD was a factor in the low DO levels. It is thus determined that the screening level of less than 2 mg/L BOD should be the target for sub-basin remediation.

Figure 3.2. Relationship between DO and Total Phosphorus

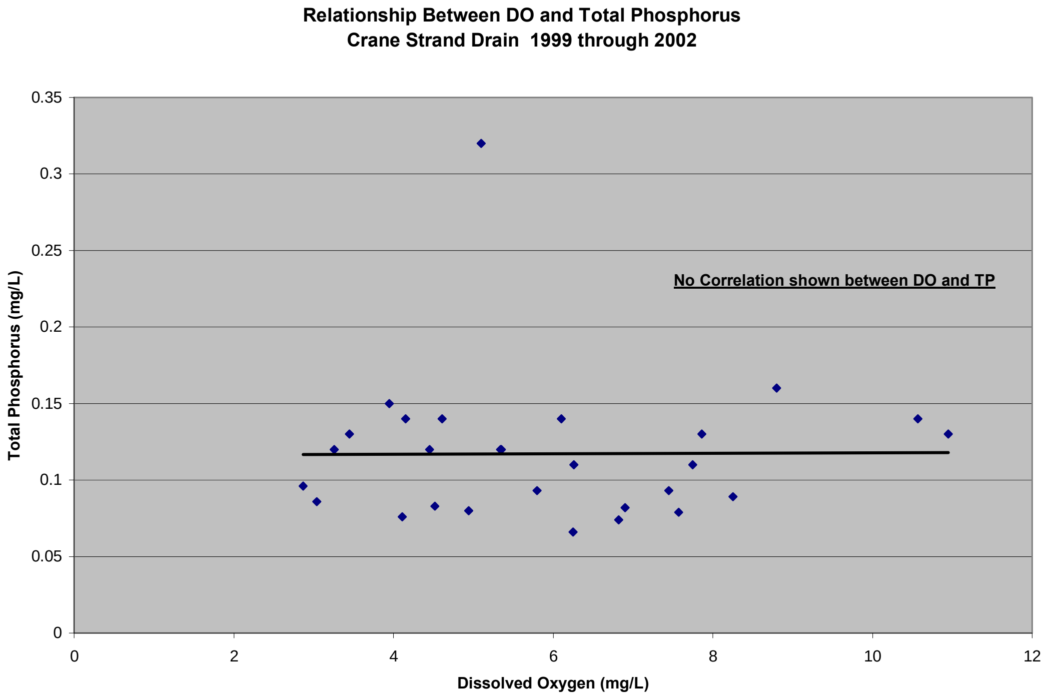
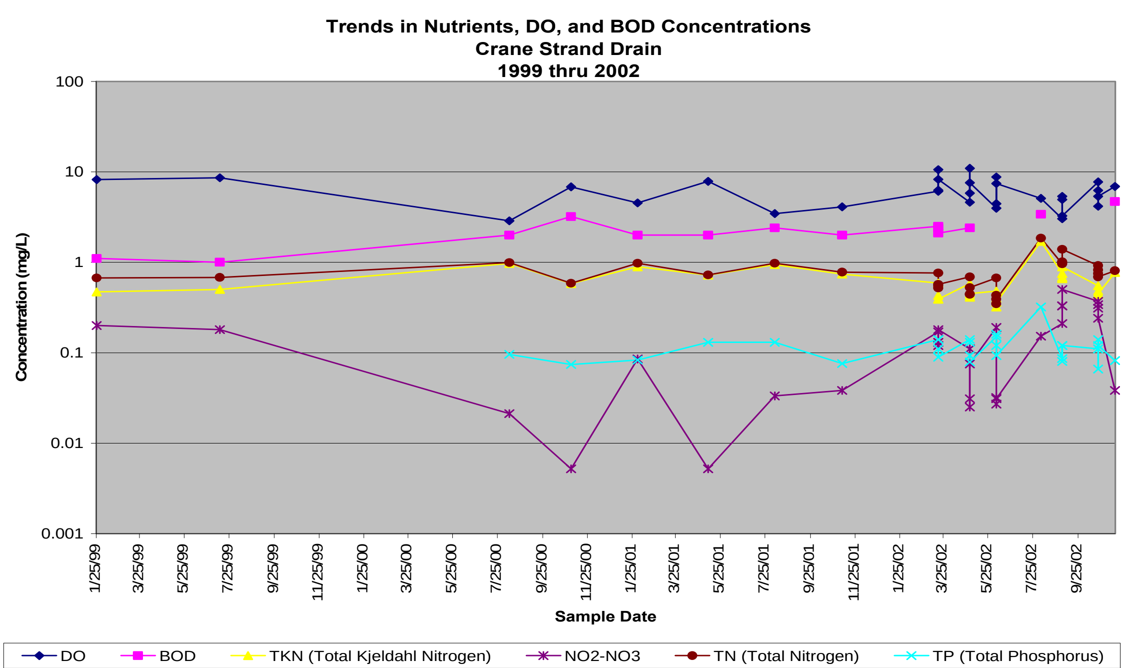
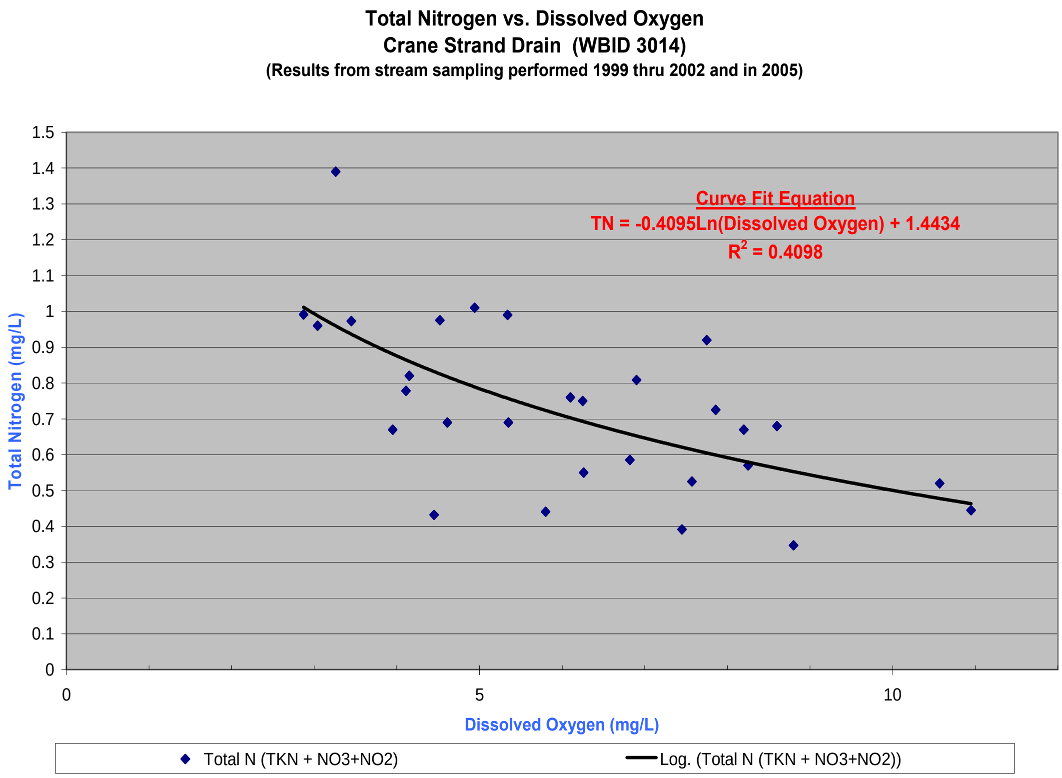


Figure 3.3. Trends in Nutrient, DO, and BOD Concentrations, Crane Strand Drain



Note: Multiple data points on a given day indicate several samples taken at various sample stations on Crane Strand Canal.

Figure 3.4. Relationship between DO and Total Nitrogen



There was also no observed relationship between DO and Total Phosphorus **(Figure 3.2)**. However, there is an inverse relationship between dissolved oxygen and Total Nitrogen **(Figure 3.3)**. Although correlation between individual DO and TN samples **(Figure 3.4)** is much stronger than between DO and BOD or between DO and Total Phosphorus, the coefficient of determination (R^2 of **Equation 3.1**) of approximately 0.4 indicates that other variables affect DO levels in the creek. Of the components of Total Nitrogen, there is relatively little correlation observed between Nitrate and DO **(Figure 3.5),** while the relationship between TKN and DO is slightly better than that with TN **(Figure 3.6)**

Equation 3.1 $TN = -.4095\ LN\ (DO) + 1.4434 \quad R^2 = .4098$

Where, TN = Total Nitrogen Concentration (mg/L), and
DO = Dissolved Oxygen Concentration (mg/L)

Solving the above equation at the Class III freshwater criterion (a DO of 5 mg/L) gives a resulting TN concentration = 0.784 mg/L. By performing a similar analysis with the TKN regression equation, we find that TKN equals 0.623 mg/L at DO = 5. It should be noted that these target TN and TKN values are below the Department's screening level for TN (1.6 mg/L). However, based on data collected in Crane Strand Drain, a Total Nitrogen concentration of 1.6 mg/L would result in DO levels in Crane Strand Drain significantly below the DO criterion. Thus, the Department set the target TN load at 0.78 mg/L.

Figure 3.5. Relationship between DO and Nitrite-Nitrate

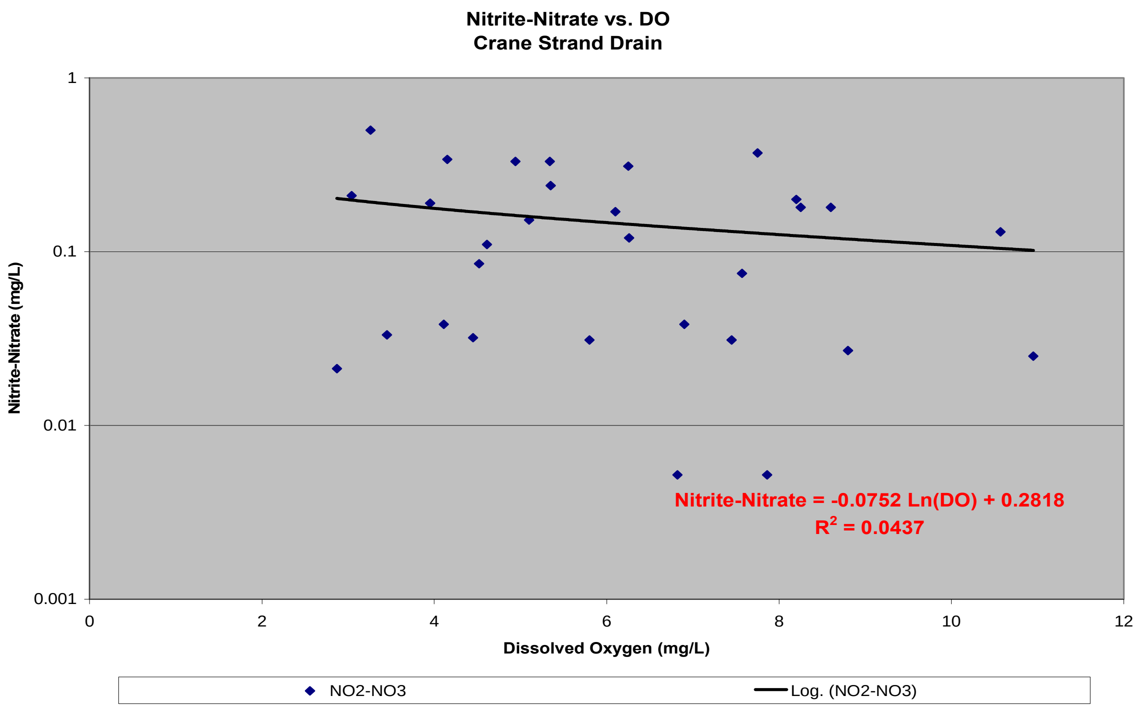
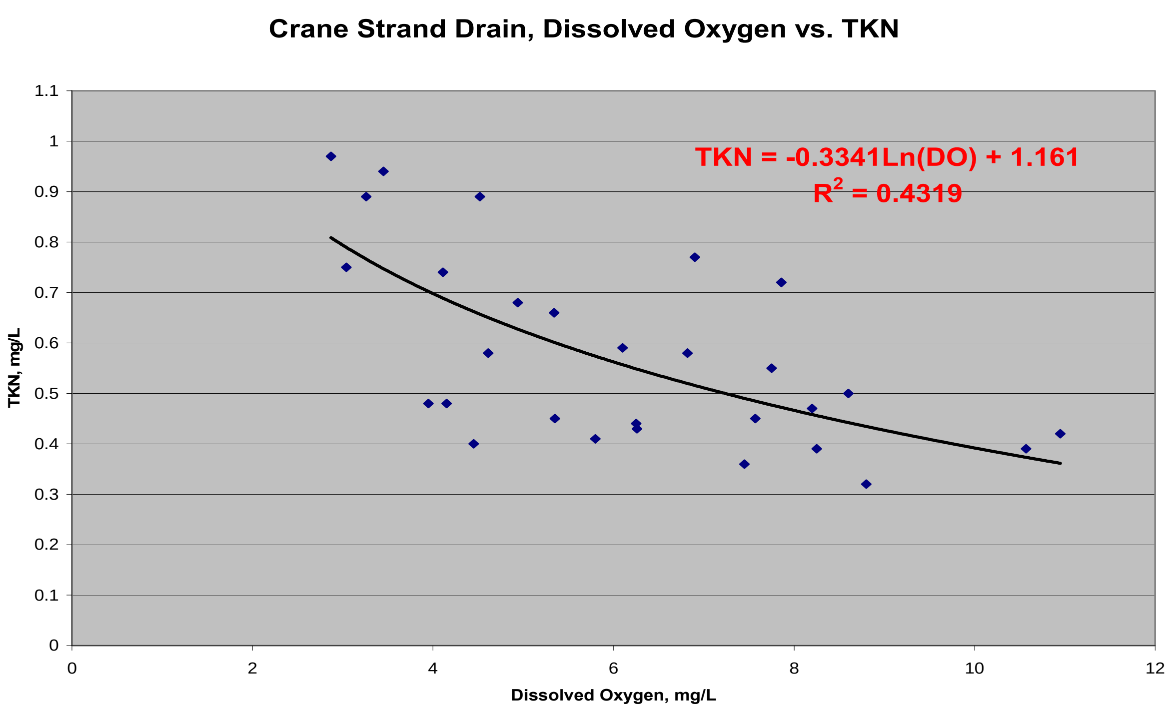


Figure 3.6. Relationship between DO and TKN



Chapter 4: ASSESSMENT OF SOURCES

4.1 Types of Sources

An important part of the TMDL analysis is the identification of pollutant source categories, source subcategories, or individual sources of low dissolved oxygen in the watershed and the amount of pollutant loading contributed by each of these sources. Sources are broadly classified as either "point sources" or "nonpoint sources." Historically, the term point sources has meant discharges to surface waters that typically have a continuous flow via a discernable, confined, and discrete conveyance, such as a pipe. Domestic and industrial wastewater treatment facilities (WWTFs) are examples of traditional point sources. In contrast, the term "nonpoint sources" was used to describe intermittent, rainfall driven, diffuse sources of pollution associated with everyday human activities, including runoff from urban land uses, agriculture, silviculture, and mining; discharges from failing septic systems; and atmospheric deposition.

However, the 1987 amendments to the Clean Water Act redefined certain nonpoint sources of pollution as point sources subject to regulation under the EPA's National Pollutant Discharge Elimination Program (NPDES). These nonpoint sources included certain urban stormwater discharges, including those from local government master drainage systems, construction sites over five acres, and a wide variety of industries (see **Appendix A** for background information on the federal and state stormwater programs).

To be consistent with Clean Water Act definitions, the term "point source" is used to describe traditional point sources (such as domestic and industrial wastewater discharges) and stormwater systems requiring an NPDES storm water permit when allocating pollutant load reductions required by a TMDL. However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES stormwater discharges and non-NPDES stormwater discharges, and as such, this source assessment section does not make any distinction between the two types of stormwater.

4.2 Potential Sources of BOD and Low DO in Crane Strand Drain (WBID 3014) Watershed

4.2.1 Point Sources

There are four permitted wastewater facilities located in Crane Strand Drain (WBID 3014) including one domestic wastewater treatment facility, two industrial wastewater facilities, and one ground water remediation plant **(Table 4.1).** However, only two of the facilities (City Industries Groundwater Extraction and Treatment Plant and CEMEX/Goldenrod Concrete Batch Plant) are authorized to discharge to surface waters. City Industries Groundwater Extraction and Treatment Plant is authorized to discharge into the drain at the eastern boundary of the Sears property and is required to provide extensive effluent analyses (Black and Veatch, 2004)**.** CEMEX/Goldenrod Concrete Batch Plant is the other NPDES faclitiy, and is authorized to under a general permit for concrete batch plants. Based on discussion with permitting staff, neither wastewater facility is expected to discharge significant concentrations of nutrients or BOD.

Table 4.1. Point Sources in Crane Strand Drain (WBID 3014)

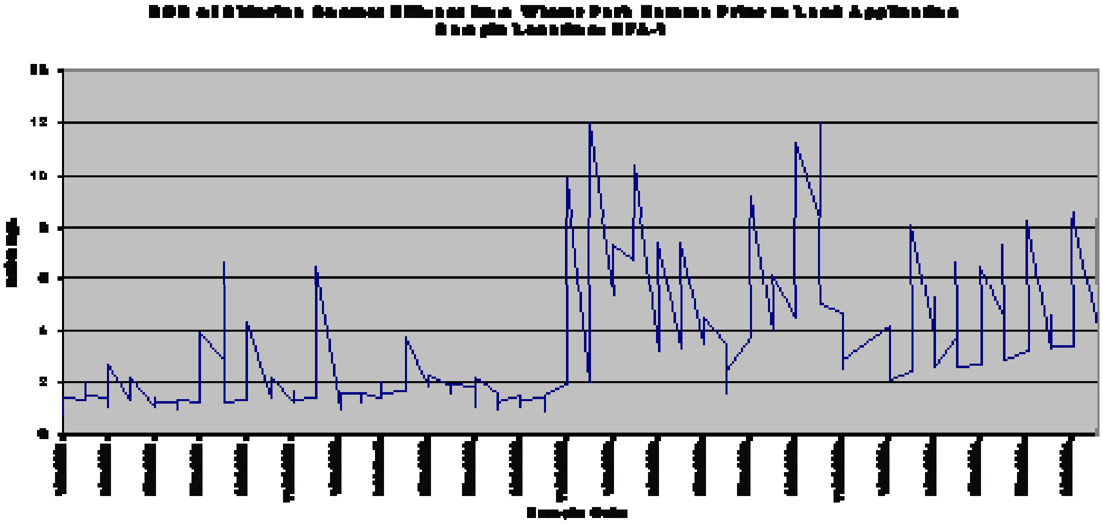
Facility Name	Type	Permit
Winter Park Estates 2655 Bongart Road, Winter Park, 32789	Municipal WWTF	FLA010819 WAFR Facility # 10819, 2 permits 1. Winter Park/Showalter Background, MW 2. Interlachen Golf Course/Compliance MW-3
Rinker Materials 4010 Forsyth Road, Winter Park	Industrial Concrete Batch Plant,	FLA010820 WAFR Facility # 10820
CEMEX/Goldenrod Concrete Batch Plant 4000 Forsyth Rd & SCL Railroad, Orlando	Industrial Concrete Batch Plant	FLG110401 WAFR Facility # 10832 (NPDES)
City Industries 3825 Forsyth Road (Behind Sears) Winter Park 32792	Remediation	FL0043265 WAFR facility # 16186 (NPDES)

The only domestic wastewater discharge in the basin is the Winter Park Estates Wastewater Treatment facility. The Winter Park Estates treatment facility is an extended aeration facility, which is a type of secondary (biological) treatment. While reclaimed water from this plant is reused as irrigation water, the reclaimed water is a potential nonpoint source to the drain because three of its four irrigation sites are in Crane Strand Drain **(Table 4.2)**. One of these sites, the Interlachen Country Club, is a channelized wetland where it is possible that some of the applied effluent reaches the Crane Strand Canal through means of interflow and surface runoff. The results of chemical analyses of the Winter Park Wastewater Treatment Facility's reclaimed irrigation water show the BOD load is below regulatory limits. However, it should be noted that there has been a significant increase in reclaimed water BOD since October 2002 **(Figure 4.1** and **Table 4.3).** More analysis of the watershed system is required to determine if reclaimed water makes any contribution to the depressed DO in the Crane Strand Drain.

Table 4.2. Reclaimed Water Irrigation in Crane Strand Drain (WBID 3014)

Locations Receiving Reclaimed Water Irrigation from Winter Park Estates Treatment Plant
1. Interlachen Country Club (This is the Large Crane Strand Drain Golf Course): Permitted for 0.190 Million Gallons per Day (MGD)
2. Winter Park Pines Golf Course (It is ½ mile South of treatment plant. It is in Lake Baldwin Outfall WBID, 3023A): Permitted 0.155 MGD
3. Cadyway/Showalter Field (this is a park South of Interlachen golf course, a few blocks South of Aloma Avenue): Permitted for .120 MGD
3. Glen Haven Memorial Park Cemetery (In Crane Strand Drain just northwest of the Interlachen golf course) Permitted for 0.150 MGD

Figure 4.1   BOD Trends in BOD Land Applied Reclaimed Water, Crane Strand Drain



4.2.1.1 Estimating Point Source Loads

Based on past records, there are no wastewater discharges from permitted facilities that would be expected to decrease dissolved oxygen.

4.2.1.2 Municipal Separate Storm Sewer System Permittees

The stormwater collection systems owned and operated by Orange County Public Works [with Florida Department of Transportation (DOT) as the co-permitee] and Seminole County Public Works Department are covered by separate NPDES municipal storm sewer system (MS4) permits.   There are no Phase 2 MS4 permittees in the sub-basin.

4.2.2 Land Uses and Nonpoint Sources

Because land uses in Crane Strand Drain are essentially urban in nature, most of the nonpoint source runoff is consistent with an urban environment. With the only agriculture existing in the form of seven acres (0.14% of the sub-basin) devoted to citrus crops, there are almost no nonpoint sources of BOD or TN from production agriculture (horticulture, food crops or livestock) in the basin. The main nonpoint sources include runoff and erosion from developed areas, small-scale construction, residential and commercial fertilizer use, pets, and residential septic failure or poor design.

Table 4.3 Concentrations of BOD of Land Applied Effluent

Concentrations of BOD (mg/L), Winter Park Estates Treatment Plant							
Sample Date	Result	Sample Date	Result	Sample Date	Result	Sample Date	Result
1/31/2001	0.78	12/31/2001	1.4	11/30/2002	1.9	10/31/2003	12
1/31/2001	1	12/31/2001	2.7	11/30/2002	7	10/31/2003	5
1/31/2001	1.4	12/31/2001	6.4	11/30/2002	9.9	11/30/2003	4.7
2/28/2001	1.36	1/31/2002	1	12/31/2002	2	11/30/2003	2.5
2/28/2001	2	1/31/2002	1.1	12/31/2002	4	11/30/2003	2.9
2/28/2001	1.5	1/31/2002	1.6	12/31/2002	12	1/31/2004	4.2
3/31/2001	1.4	2/28/2002	1.6	1/31/2003	5.4	1/31/2004	2.5
3/31/2001	1.1	2/28/2002	1.2	1/31/2003	5.4	1/31/2004	2.1
3/31/2001	2.7	2/28/2002	1.6	1/31/2003	7.3	2/29/2004	2.4
4/30/2001	1.3	3/31/2002	1.4	2/28/2003	6.7	2/29/2004	4.8
4/30/2001	1.4	3/31/2002	2	2/28/2003	8	2/29/2004	8.1
4/30/2001	2.2	3/31/2002	1.6	2/28/2003	10.4	3/31/2004	3.8
5/31/2001	1.1	4/30/2002	1.7	3/31/2003	3.2	3/31/2004	5.3
5/31/2001	1.4	4/30/2002	2.4	3/31/2003	5	3/31/2004	2.6
5/31/2001	1.2	4/30/2002	3.7	3/31/2003	7.4	4/30/2004	3.7
6/30/2001	1.2	5/31/2002	1.8	4/30/2003	3.3	4/30/2004	6.6
6/30/2001	1	5/31/2002	2.1	4/30/2003	4.8	4/30/2004	2.6
6/30/2001	1.3	5/31/2002	2.3	4/30/2003	7.4	5/31/2004	2.7
7/31/2001	1.2	6/30/2002	1.8	5/31/2003	3.5	5/31/2004	3.6
7/31/2001	2	6/30/2002	1.6	5/31/2003	4.5	5/31/2004	6.4
7/31/2001	3.9	6/30/2002	1.9	6/30/2003	3.5	6/30/2004	4.5
8/31/2001	2.9	7/31/2002	1.8	6/30/2003	1.6	6/30/2004	7.3
8/31/2001	6.6	7/31/2002	1.1	6/30/2003	2.4	6/30/2004	2.9
8/31/2001	1.2	7/31/2002	2.2	7/31/2003	3.7	7/31/2004	3.2
9/30/2001	1.3	8/31/2002	1.6	7/31/2003	5.4	7/31/2004	5.3
9/30/2001	2.4	8/31/2002	1	7/31/2003	9.2	7/31/2004	8.2
9/30/2001	4.3	8/31/2002	1.2	8/31/2003	4	8/31/2004	3.3
10/31/2001	1.4	9/30/2002	1.5	8/31/2003	4.3	8/31/2004	4.6
10/31/2001	1.7	9/30/2002	1.1	8/31/2003	6.1	8/31/2004	3.4
10/31/2001	2.2	9/30/2002	1.3	9/30/2003	4.5	9/30/2004	3.4
11/30/2001	1.2	10/31/2002	1.4	9/30/2003	8.7	9/30/2004	4.3
11/30/2001	1.7	10/31/2002	0.9	9/30/2003	11.3	9/30/2004	8.6
11/30/2001	1.3	10/31/2002	1.5	10/31/2003	8.3	10/31/2004	4.1
						10/31/2004	7.1

4.2.2.1 Land Uses

Land use categories in the Crane Strand Drain watershed were aggregated using the simplified Level 1 codes (Table 4.4). By far the largest Level 1 land use is “Urban and Built-up” (81%). Based on Level 2 codes (Table 4.5), urban and built-up land uses are comprised of (in order of highest to lowest) High Density Residential (44%), Commercial (12%), Medium Density

Residential (11%), Industrial (6%), Institutional (4.18%), and Low density Residential (1.34%). If the Level 1 Category of Transportation, Communication, and Utilities (3%) is added to the "Urban and Built-up," primarily human land uses constitute over 84% of the basin.

Table 4.4 Level 1 Land Uses in Crane Strand Drain

Table 4.4 Level 1 Landuse for WBID 3014	Area	
Description	**Acres**	**%**
1000: Urban and Built-up	3,981.1	81.18%
6000: Wetland	431.2	8.79%
8000: Transportation, Communication, and Utilities	150.8	3.08%
4000: Upland Forests	128.9	2.63%
5000: Water	105.3	2.15%
3000: Rangeland	90.3	1.84%
7000: Barren Land	9.5	0.19%
2000: Agriculture	7.1	0.14%
Total	**4,904.1**	**100%**

Primarily non-human land use includes wetland (9%), upland forest (2.63%), rangeland (1.84%), barren land (0.19%) and citrus tree agriculture (0.14%). "Wetland" is ranked highest in the sub-basins' primarily non-human land-use, indicative of the fact that much of the sub-basin was developed around a wetlands **(Figures 4.2, 4.3, and 4.4)**. Based on an analysis of Land Use percentages for the sub-basin and the corresponding Event Mean Concentrations **(Table 4.6)**, the three largest land use contributors of both BOD and Total Nitrogen from storm runoff are high density residential, commercial, and medium density residential.

Table 4.5 Classification of Level 2 Land Use Categories in Crane Strand Drain (WBID 3014) Watershed

Level 2 Landuse	AREA	
Code and Description	**Acres**	**%**
1300: Residential, High Den.	2139.5	43.6
1400: Commercial	566.7	11.5
1200: Residential, Med. Den	516.4	10.5
1500: Industrial	316.2	6.4
6100: Wetland hardwood for	256.1	5.22
1700: Institutional	205.0	4.18
1800: Recreation	142.8	2.91
8100: Transportation	133.0	2.71
6400: Veg. Nonfor. Wetland	123.8	2.52
4300: Upland Mixed Forest	99.8	2.04
5300: Reservoirs	97.0	1.98
1100:Residential, Low Den.	65.7	1.34

Level 2 Landuse	AREA	
Code and Description	**Acres**	**%**
3200: Shrub and Brushland	58.1	1.18
6300: Wetland Forest Mixed	31.9	0.65
1900: Openland	28.8	0.59
3100: Herbaceous	27.8	0.57
4100: Upland Coniferous	25.4	0.52
6200: Wetland Coniferous	19.3	0.39
8300: Utilities	14.8	0.30
7400: Disturbed land	9.5	0.19
2200: Treecrops	7.1	0.14
5200: Lakes	4.4	0.09
3300: Mixed Rangeland	4.4	0.09
5100: Streams, Waterways	3.8	0.08
4200: Upland Hardwood	3.7	0.07
8200: Communication	3.0	0.06
Total	**4904.1**	**100**

Table 4.6 Land Use Categories for Modeling and Corresponding Relative EMC Pollutant Contributions

Crane Strand Drain Land Uses	AREA		BOD EMCs (mg/L)	Landuse % BOD load	TN EMC (mg/L)	Landuse % TN load
	Acres	%				
A. Forest/Rural Open	390.7	7.97%	1.23	1%	1.09	4%
B. Urban Open	9.5	0.19%	0.5	0%	1.09	0%
C. Agriculture/Pasture	7.1	0.14%	2.55	0%	2.24	0%
D. Low Density/Residential	65.7	1.34%	4.3	1%	1.64	1%
E. Medium Density/Residential	516.4	10.53%	7.4	10%	2.18	11%
F. High Density/Residential	2139.5	43.63%	11	61%	2.42	51%
G. Commercial	771.7	15.74%	7.4	15%	1.98	15%
H. Industrial	334.0	6.81%	9.6	8%	1.79	6%
I. Highways	133.0	2.71%	6.7	2%	2.23	3%
J. Water/Wetland	536.4	10.94%	1.6	2%	1.6	8%
	4904.1	100.00%				

4.2.3 Modeling Nonpoint Source Loading

4.2.3.1 Estimating Flow

The determination of nonpoint source loading requires an estimation of stream flow rate as well as the concentration of pollutant. Although there has been no continuous flow monitoring of the Crane Strand Drain, flow measurements were recently made at two STORET sampling stations in the sub-basin. In addition, a United States Geological Survey (USGS) gage station downstream of the confluence of the Crane Strand Drain with the E-4 canal proved extremely useful in estimating historical flow within the Crane Strand Drain. This method of estimation was tested utilizing other downstream gages. This was done by comparing the regression predicted flow with recorded flow from three USGS gage stations located within the Little Econlockhatchee River basin **(Figure 4.5b)**. The stream flow estimates were derived as follows.

Flow measurements were made at four stations on February 24, 2005, using a wading rod and flow meter. The flow at an upstream STORET site (20010196) and a downstream STORET site (20010393) on Crane Strand Drain were measured as 2.13 and 4.94 cfs, respectively. In addition, flow was measured at Lake Corrine Outfall (LCO) Canal (a tributary of the E-4 Canal) and Azalea Park/Colonial Blvd (upstream on the E-4 Canal, before it joins with the Crane Strand Drain and the Lake Corrine Outfall Canal). These flows were measured as 1.03 and 3.41 cfs, respectively.

Figure 4.2 Northwest Crane Strand Drain (WBID 3014) sub-basin in 1940

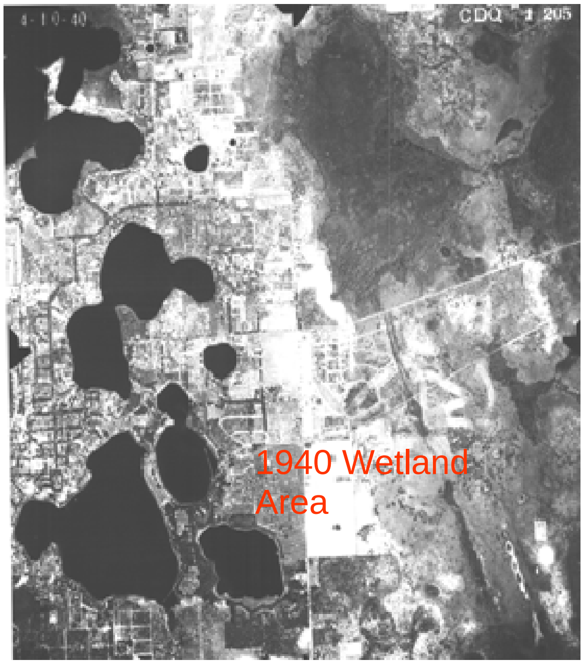
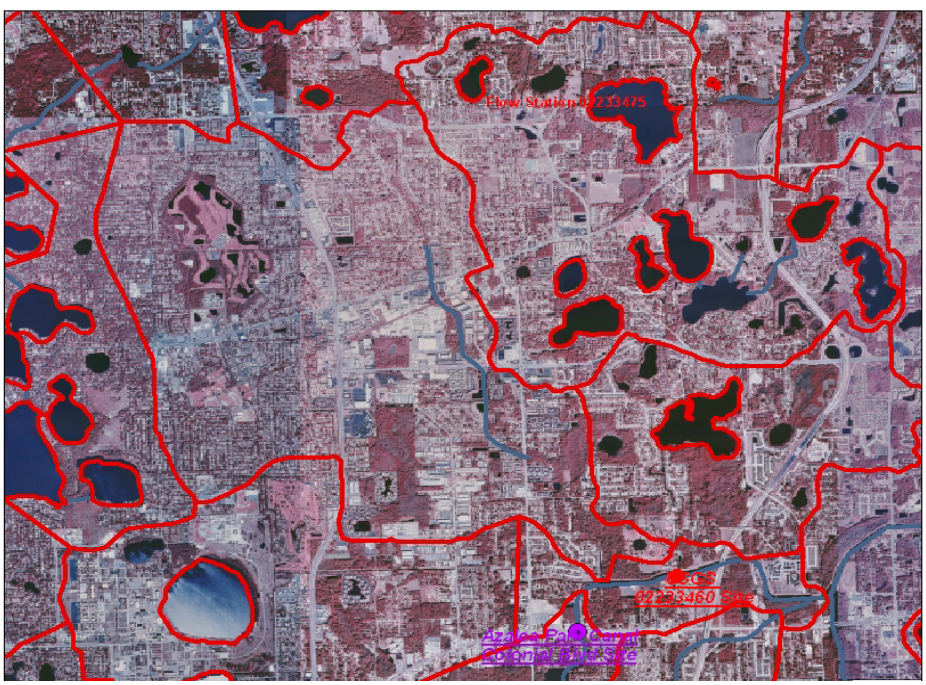


Figure 4.3 Northwest Crane Strand Drain (WBID 3014) sub-basin in 1966

Figure 4.4 Northwest Crane Strand Drain (WBID 3014) sub-basin with Northwest channelized wetland in 1999



On this same day, the gaged flow at the USGS Banner Dam Station (STA 2233460) was recorded as 11 cfs **(see Figures 4.5a and 4.5b).** The sum of the flows at STORET site 20010393, the LCO Canal, and Colonial Blvd E-4 is 9.4 cfs. Because there were no substantial rainfall prior to or on the day of monitoring, the difference can be attributed to the contributions from the drainage areas between where the flow measurements were made. The distance between STORET 20010196, LCO Canal, and the Colonial Blvd E-4 field measurements and the Banner Dam Gage Station are 1.7, 0.8 and 0.9 miles, respectively.

There was also an obvious relationship observed between drainage areas and flows, which was validated through regression analysis. Such relationships have been extensively observed for low flow conditions in Florida (Rumenik and Grubbs, 1996). Thus, a relationship between drainage area and flow within the basin was established based on the flow measurements taken on 2/24/05. Utilizing the flows and areas listed in **Table 4.7a** resulted in regression equations 4.1 and 4.2, with excellent coefficient of determinations (R^2) **(Figure 4.6a).**

The regression equations developed were tested on USGS stations where continuous data have been collected continuously for over a year. This was possible with USGS station 2233475 (with 9 years of collected daily flow) and Banner Dam (USGS station 2233460), with 3 years of collected daily flow. The distance between these two stations is 6.5 miles. Because the comparison was limited by the duration of data collection at Banner Dam, it was decided to carry out the comparison for the three-year period between 3/31/02 and 3/30/05. The predicted flow at STA 2233460 (Banner Dam) was determined utilizing a linear regression (Equation 4-1) in combination with the measured flow at STA 2233475. The predicted Banner Dam flow was compared to the actual measured flow **(Table 4.7b)**. **Figure 4.6b** illustrates that the percentage and values at low flow matched better than flows above the 60 percentile range. Although there was a difference in total flow of -6% over the three-year period, the errors for the individual

Figure 4.5a STORET sample sites and Flow Measurement Sites on 2/24/05 (Flow meter and USGS gage)

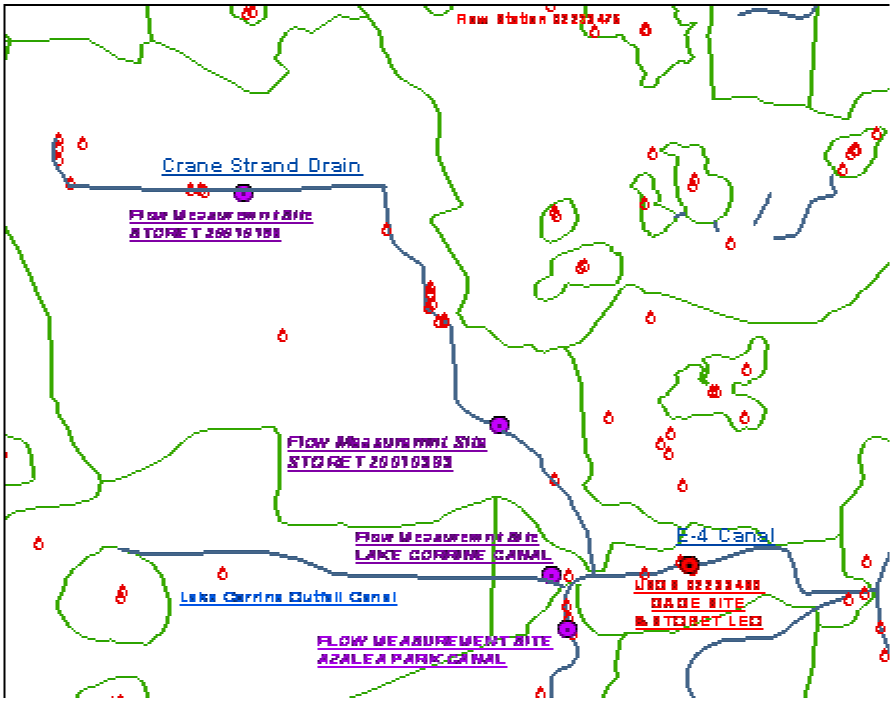


Figure 4.5b USGS Gage Stations in the Little Econlockhatchee Basin

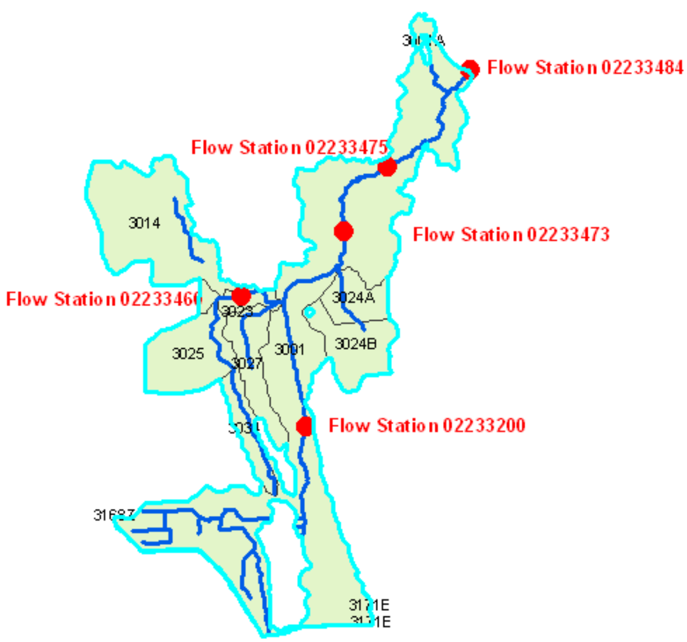


Figure 4.6a Regression relationship between Flow Data and Drainage Area

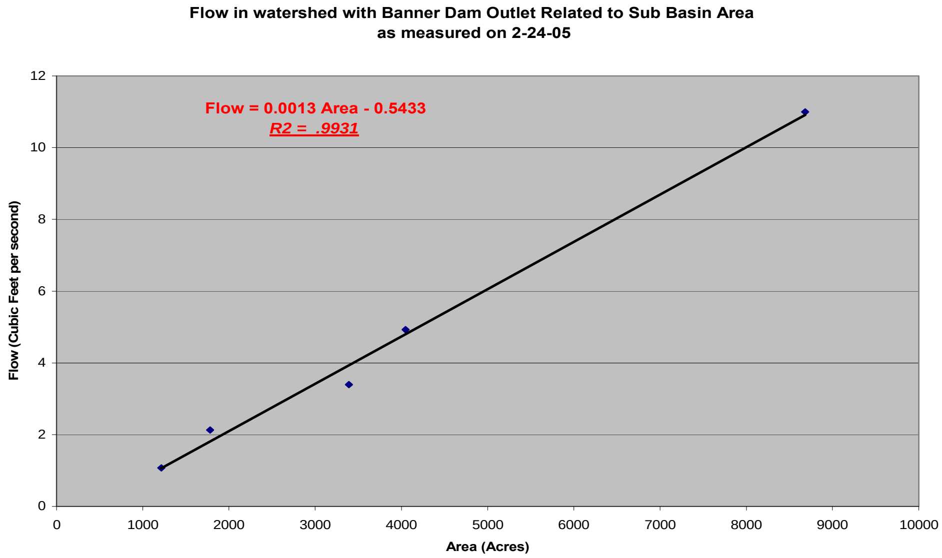


Table 4.7a Estimation of Crane Strand Drain Flow Based on downstream USGS Station flow

Flow Measurements vs Calculated

Flow Monitoring Station	Type of Data Available	Drainage Basin Area (acres)	USGS Flow CFS measurement, 2-24-05	FDEP Flow Measurement, 2-24-05	Predicted Flow based on Flow-Area Regression Equation (CFS)	Regression Equation without Station 02233475 (CFS)	Predicted Flow based on Direct Ratio (CFS)
Crane Strand Drain STORET station 2010393 Lat: 28 35 16 Long: 81 17 12	One time	4047.38		4.93	4.81	4.80	5.10
Crane Strand Drain STORET Station 2010196 Lat: 28 36 37 Long: 81 18 35	One time	1582		2.12	1.74	1.81	2.24
Crane Strand (WBID 3023) Puritan St. Station	One time	1215.8		1.07	0.97	1.06	1.53
Azalea Park Canal at Colonial Blvd	One time	3392		3.39	3.92	3.93	4.27
Banner Dam in Crane Strand Lat: 28 34 26 Long: 81 16 09	daily	8733	11		11.17	10.98	11
USGS Gage Station 02233475 Lat: 28 36 37	daily	35,841	48		47.96	46.73	45.15

Long: 81 12 28							
Crane Strand Drain (WBID 3014) outlet	No Measurement	4904.1			5.98	5.92	6.17

years were -9.8%, -29.7%, and +10.7%. Most of the error is associated with high flow conditions.

Equation 4-1 Flow (cfs) = 1.357 * 10^{-3} x Area (Acres) - .67886 with an R^2 = .9997.

Because of the proximity of the Banner Dam station to the stations we wished to simulate in Crane Strand Drain, the Banner Dam Station was used to predict flow in Crane Strand Drain and the flow at STA 2233475 was not included in the regression equation. In an attempt to include only local stations that have a greater chance of having experienced the same precipitation events, the revised regression equation **(Equation 4.2)** used for Crane Strand Drain flow did not utilize flow rates further downstream. Because the average distances between stations is less than 1/3 the distance between the tested USGS Stations 2233475 and 2233460 (Banner), it is believed that the error will be much lower.

Equation 4-2 Flow (cfs) = 1.319 * 10^{-3} x Area (acres) - .54327 with an R^2 = .9931

Figure 4.6b Analysis of 3 years of Predicted versus Actual Flow at STA 2233460 (Banner Dam).

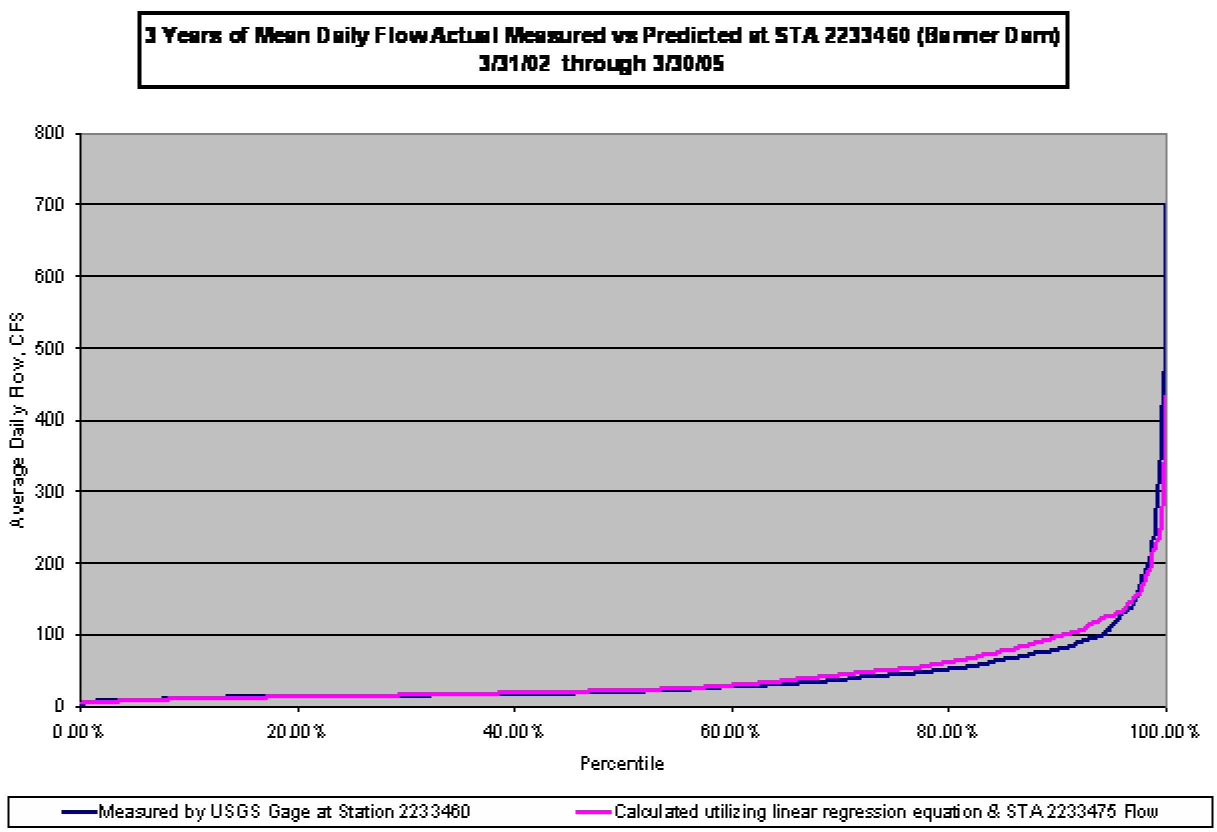


Table 4.7b Error associated with Extended Period Flow Estimation using regression equation.

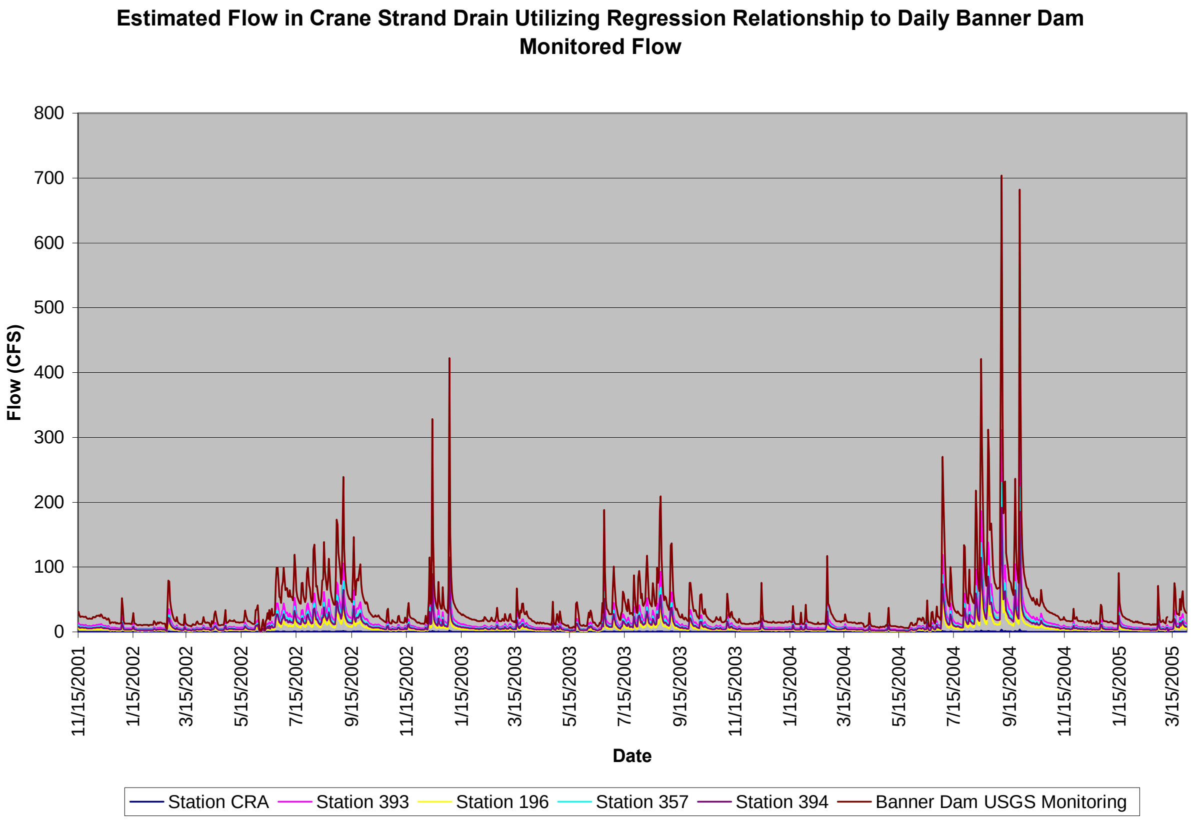
Total 3 yr Measured Flow (Million Cubic Feet) at STA 2233460 (based on average daily CFS)	Total 3 yr Predicted Flow in Million Cubic Feet (Based on STA 2233475 average daily CFS)	ERROR AS PERCENTAGE OF ACTUAL FLOW
3,671,542,080	3,900,940,956	-6.25%

It is believed that peak flows associated with high intensity storms, especially those of short duration, will deviate from this formula, but because of the proximity of the USGS gage station to the Crane Strand Drain, the estimates should still remain acceptable. The errors in the empirical equations exist because these equations do not explicitly contain terms for important factors such as land use, land management, soil types, slopes, surface storage, antecedent moisture condition, surface roughness, and length of flow. But, because they are based on known flows in the same region with similar physical characteristics, some of the listed factors are handled implicitly.

It should be noted that this equation's usefulness is to provide an approximate continuous flow for Crane Strand Drain for model simulation, with emphasis on low flow conditions (which was the condition on 2-24-05). The proportionality between areas and peak flows has not been established and empirical equations are likely more complex (e.g., would include slope and other factors). Although these area-based empirical equations provide useful flow estimates for ungaged streams, the Department acknowledges that the best understanding of the basins require physical monitoring of streams and actual measured flows. It is recommended that measurements be taken on a regular basis within the sub-basin to further establish relationships between flows within the basin, as well as establish a site-specific database.

Because stream flow at the USGS Banner Dam station was available beginning in late 2001, only three years of stream flow at the Crane Strand Drain sample stations was simulated **(Figure 4.7).** But, as was indicated in the section above, STA 2233460 could be predicted for earlier years utilizing STA 2233475 data (which is available for years 1996 through present) and longer simulations can be performed with the additional error associated with predicted data.

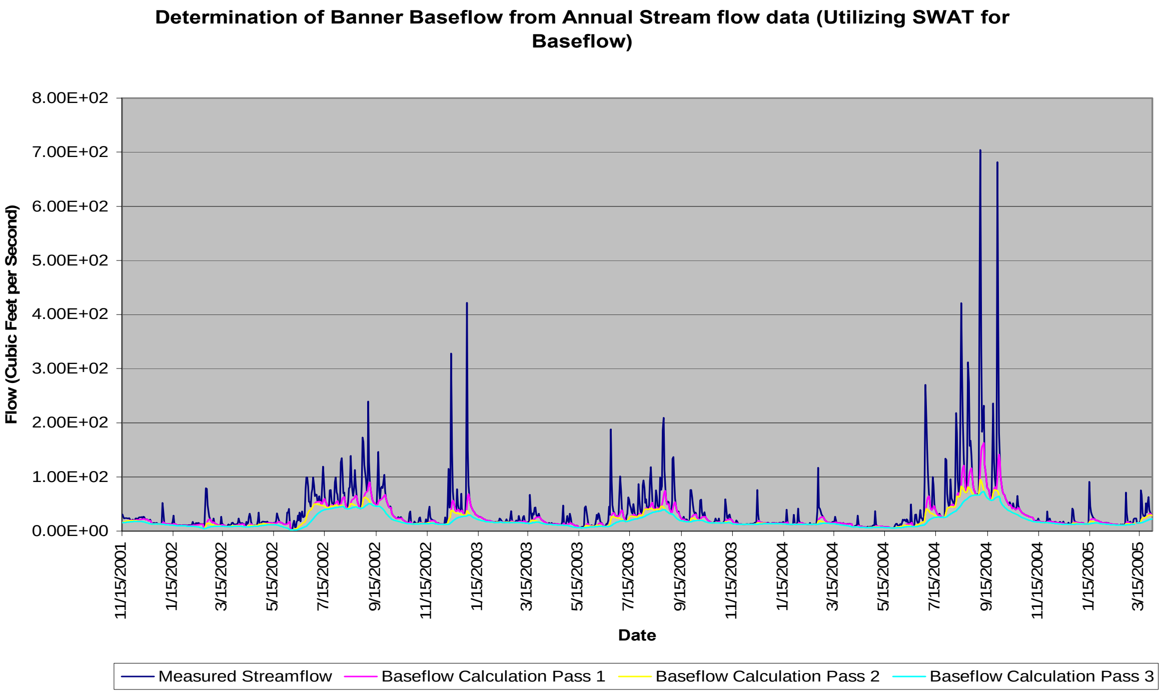
Figure 4.7   Utilizing Flow Data from USGS gage Station to generate 3 years of flow data for sampling stations within the Crane Strand Drain.



4.2.3.1.1 Estimating Base Flow

Base flow was estimated for the stations within Crane Strand Drain by first predicting base flow for USGS STA 2233460 with the use of the computer program 'Baseflow for SWAT,' From the base flow of STA 2233460, the previously developed regression equation was used to determine the flow within Crane Strand Drain on a daily basis **(Figures 4.8 and 4.9).** The successful estimation of total stream flow in the Crane Strand Canal provided a means of calibrating and validating the computer model used to simulate the sub-basin hydrology. The base flow is utilized as an input time series in the SWMM model.

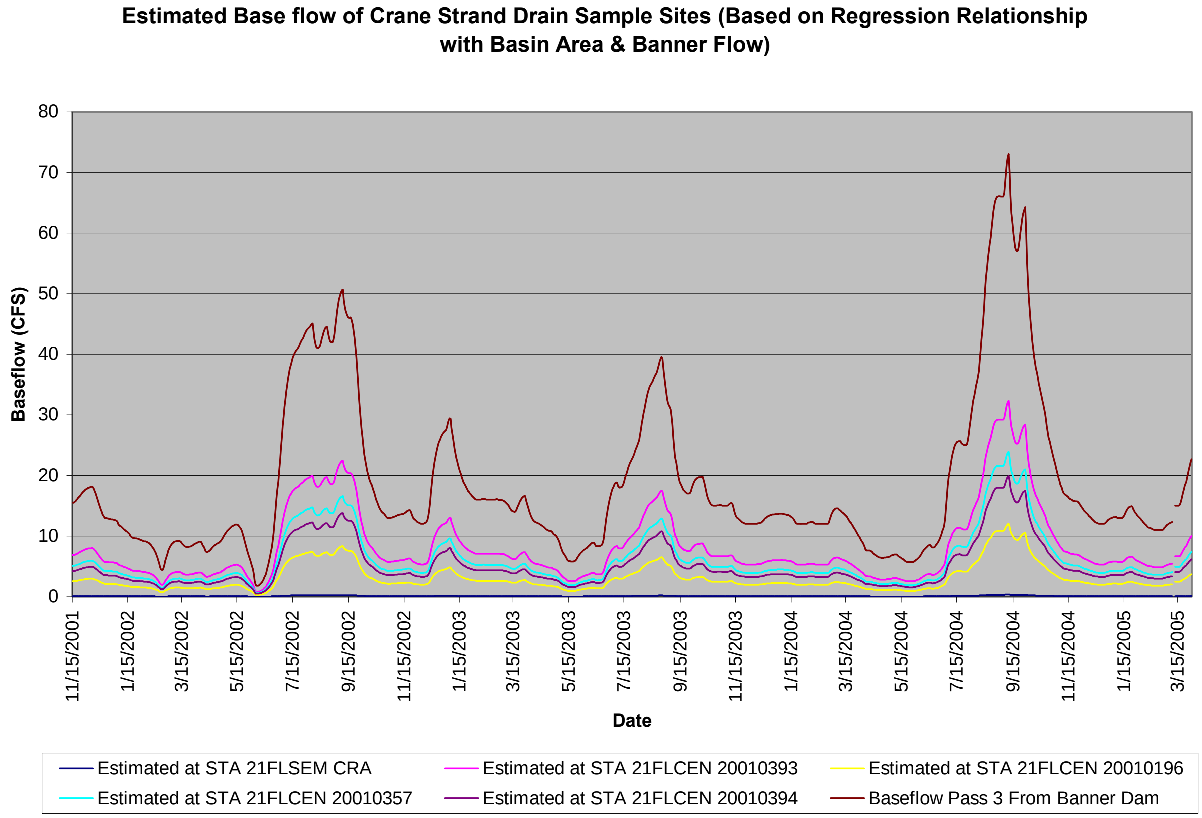
Figure 4.8. Base flow data obtained from Banner Dam USGS data, utilizing the SWAT Baseflow program.



4.2.3.2 SWMM Model

The Storm Water Management Model (SWMM), Version 5.0 was used to simulate the Crane Strand Drain's water quantity and quality. SWMM can simulate individual storm events with a time step of a few minutes, or a continuous simulation over an extended period of time (USEPA, 1997). SWMM includes the hydrologic processes of rainfall, surface and subsurface runoff, flow routing through a drainage network, storage and treatment. SWMM is composed of three groups of elements: hydrologic, hydraulic, and quality. The hydrologic elements include rain gages, subcatchments, aquifers, and snow packs. The hydraulic elements include vehicles to move and store water and are grouped into links or nodes. Links (which handles flow

Figure 4.9. Base flow data obtained generated for Crane Strand Drain Sample Stations utilizing established flow relationship with Banner Dam flow.



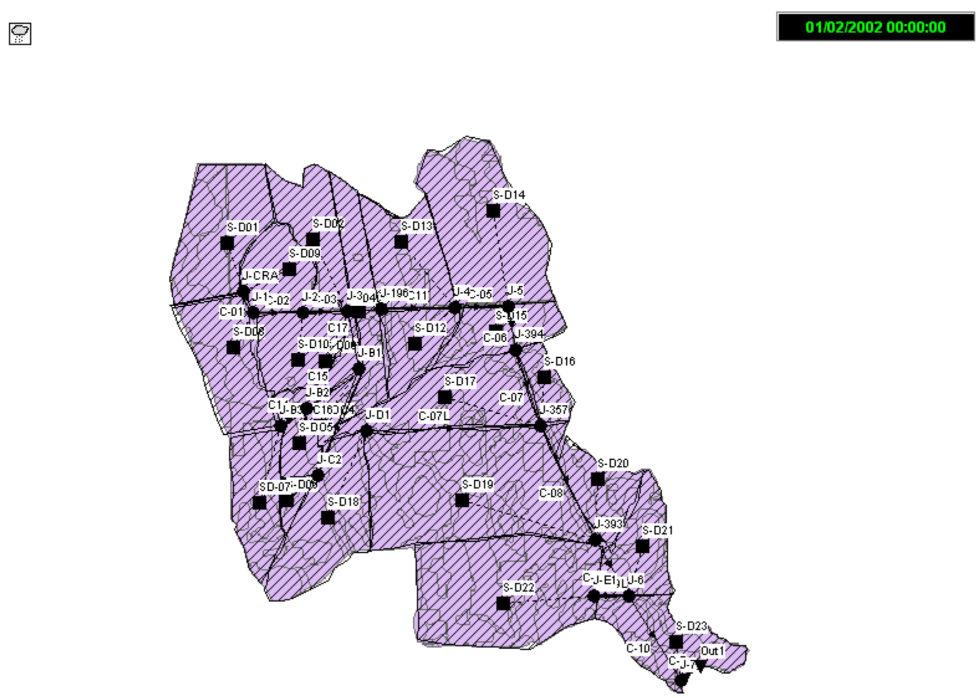
mechanisms) include conduits (streams and pipes), pumps, orifices, weirs, and outlets. Nodes (which are turning points, storage points, receiving or discharge points) include junctions, outfalls, dividers, and storage units. The SWMM computer model requires the subcatchment properties of percent imperviousness, infiltration rate, depression storage, and surface roughness (USEPA, 1988). It also requires other inputs such as stream or conduit geometry (shape, width, depth, side slopes), landuses, base flow, base flow concentrations, and Event Mean Concentrations (EMCs) by landuse. These basic components were used to represent the Crane Strand Drain, and are shown **(Figure 4.10**) as they appear in the Windows-based SWMM (USEPA, 2005), with a backdrop transferred from GIS Arcmap. Input data for the simulations are shown in **Appendix E.**

Although the sub-basin was initially divided into only four sections (or subcatchments), it was eventually divided into what would become 23 subcatchments for the reasons listed below:

- A greater number of subcatchments provide greater opportunities to utilize internal mechanisms to create storage and delay flow within the modeled basin. This more accurately simulate long-term storm effects and gives width to the flow hydrograph.
- Instead of lumping and averaging all properties within larger subcatchments, for each smaller subcatchment you can specify such parameters as area, infiltration rate, percent impervious area, slope, point of entry into conduit (stream), ground water characteristics, and landuses.

Given that the SWMM model lumps the properties of each subcatchment, the best way to model an individual subcatchment with different characteristics is to create a new subcatchment. Of course, there is a balance between making subcatchment divisions and the time required to define each subcatchment. The benefits are also proportional to the degree of detail that you can describe for the different parameters related to each subcatchment. Other data inputs include stream widths and depths (from information obtained during stream flow measurements), surface slopes, areas, soils, landuse (information obtained from GIS shape files and maps), and rainfall data. **Table 4.8** displays the imperviousness factors associated with each landuse.

Figure 4.10 Basic Components of SWMM applied to Crane Strand Drain



Data Required for Estimating BOD and TN Loadings. To estimate TN and TP loadings from the Crane Strand Drain watershed using SWMM, the following data were collected:

A. Rain precipitation data were obtained from the weather stations located in Orange County, Orlando WSO Airport, (086638) and the Michael Dam Weather Station. **Table 4.9** depicts monthly average precipitation between 1971 and 2000, and **Figure 4.11** displays daily precipitation over a three-year period at the Orlando Airport Station. Because the Orlando Airport station is located over two miles from Crane Strand Drain, it was decided to also simulate the sub-basin with data from a nearer station (Michael dam). Unfortunately, only 2004 data were obtained from the Michael Dam station, and there were no data available during the period when the Crane Strand Drain sampling occurred. **Figure 4.12** shows the difference between the two stations for the year 2004.

Table 4.8 Directly Connected Impervious Areas used in SWMM Model Simulation

Land Use Categories	*DCIA*	*Reference*
Forest/Rural Open	0.5%	CDM, 1998. WMM User's Manual.
Urban Open	0.5%	CDM, 1998. WMM User's Manual.
Agriculture/Rangeland	3.7%	Brown, 1995
Low Density Residential	12.4%	Brown, 1995
Medium Density Residential	18.7%	Brown, 1995
High Density Residential	29.6%	Brown, 1995
Commercial	57.0%	Singhofen, 2001
Industrial	57.0%	Singhofen, 2001
Communication and Transportation	36.2%	Brown, 1995
Water/Wetlands	30.0%	Harper and Livingston, 1999

Table 4.9 Monthly Average Precipitation, Maximum and Minimum Temperatures at Orlando WSO Airport Weather STA 086638 for period 1971 through 2000

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	75.9	74.1	79.4	83.2	88.3	91.2	92.2	91.2	89.8	85.8	77	76.2	83.9
Average Min. Temperature (F)	54.8	51.6	56.5	60.8	67.8	73	74.5	74	73.2	68.7	58.1	56.3	64.3
Average Total Precipitation (in.)	2.31	2.98	2.84	2.61	4.21	5.85	6.74	8.85	5.47	2.82	1.81	2.07	48.56

The data show that there are distinct differences, but as would be expected, because high intensity storms can be very local in nature, some storms appear to have been missed by one or the other stations. Because the Michael STA is closer, it would be preferable to utilize the Michael data if they are of equal reliability. In any case, both stations should provide data to produce a reasonable simulation and mass balance. For the simulation, Orlando data were used for the years 2002 – 2003, and Michael Dam data were used for the year 2004.

Figure 4.11 Daily Rainfall at Orlando WSO Airport (086638)

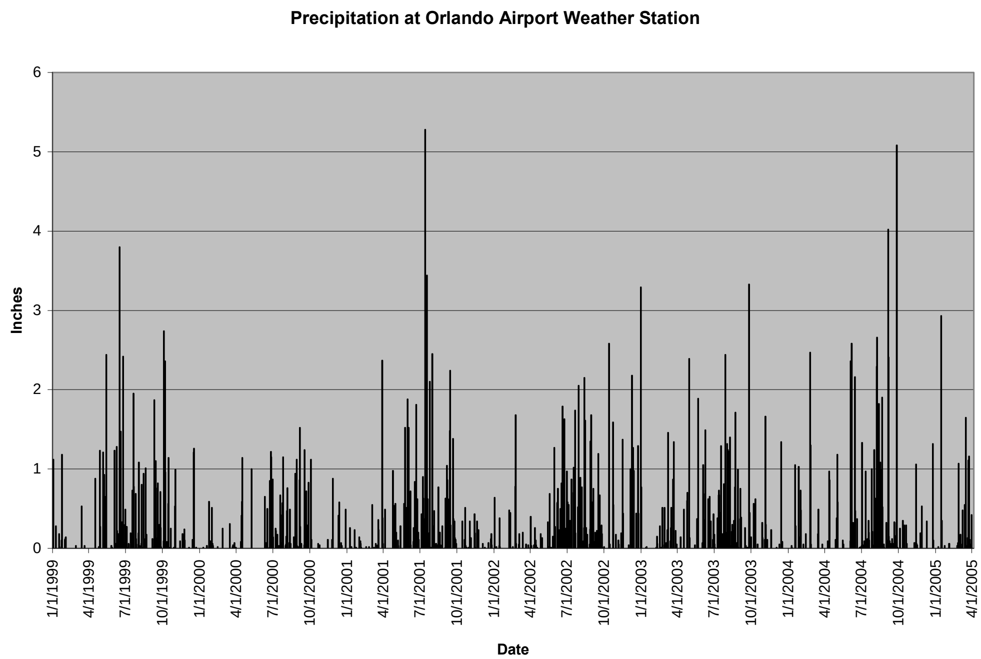
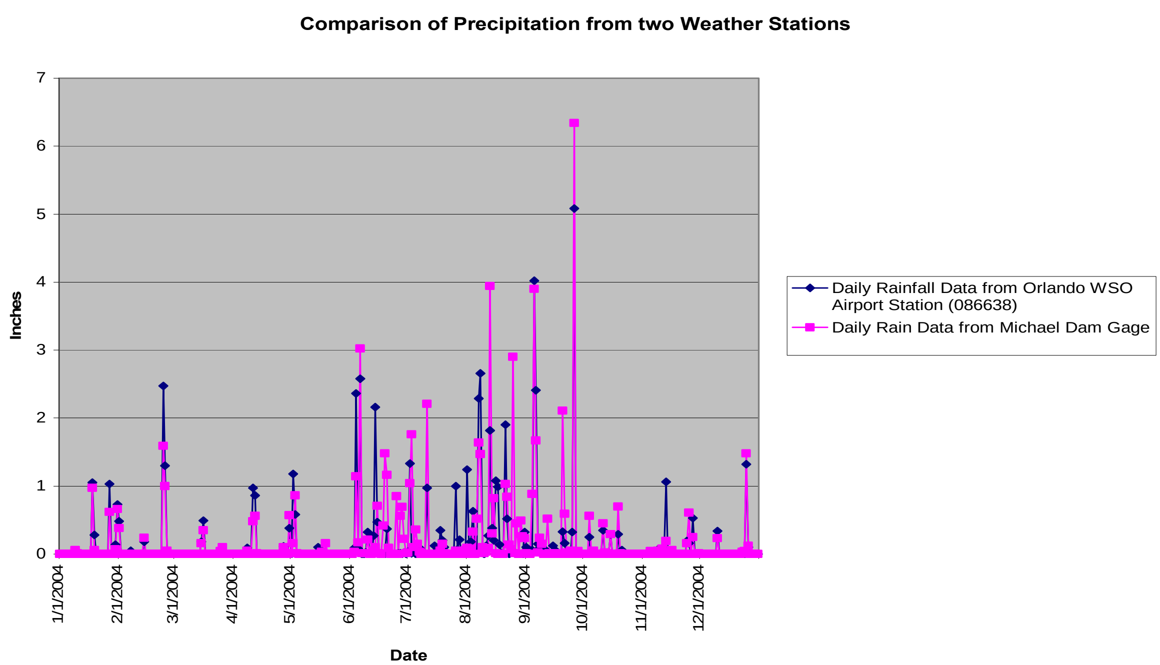


Figure 4.12 Comparison between weather data from Michael Dam and Orlando Airport Stations



B. *Areas of different land use categories* in the Crane Strand Drain (WBID 3014) were obtained by aggregating GIS land use coverage based on the simplified Level 1 codes, as well as Level 2 code. These were applied to the sub-basin as a whole and to the divisions. These areas are listed in **Table 4.4 and Table 4.5** (for the entire watershed) and **Table 10** (examples for the watershed divisions required for the SWMM model). These tables shows percent distributions of each land use category in the watershed.

Table 4.10 Table Illustrating DCIA Calculations for Crane Strand Drain Drainage Area Sections (Used in the SWMM computer model)

Crane Strand Drain Section Number>>	17	18	19	20	21	22	23	TOTAL
Area (acres)	361.6	225.0	511.5	152.3	178.9	480.8	195.2	4904.1
Forest Rural Open	15.3%	0.0%	4.2%	6.6%	14.8%	8.4%	14.6%	7.97%
Urban Open	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.19%
Agriculture/ Pasture	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.14%
Low Density Residential	0.0%	0.0%	1.3%	17.9%	14.3%	0.2%	2.9%	1.34%
Medium Density Residential	0.0%	0.0%	4.2%	0.0%	0.0%	9.6%	0.0%	10.53%
High Density Residential	13.3%	89.2%	43.1%	49.9%	34.5%	23.2%	38.7%	43.63%
Commercial	30.1%	10.8%	24.4%	13.9%	1.2%	2.0%	17.0%	15.74%
Industrial	31.0%	0.0%	6.5%	0.0%	0.0%	33.6%	0.0%	6.81%
Highways	5.8%	0.0%	2.7%	3.9%	2.4%	2.1%	0.9%	2.71%
Water/Wetland	4.5%	0.0%	13.5%	7.8%	32.9%	20.8%	24.9%	10.94%
Directly Connected Impervious Area (DCIA) % Based on Land Use	42.3%	32.6%	36.4%	28.7%	23.5%	36.1%	29.4%	32.2%

Below is an example calculation of % Imperviousness for a Crane Strand Drain subcatchment section used in the SWMM model. The Landuse DCIA and the % of area in a given landuse were used in the calculation.

Sample Calculation: Based on Land Use for Section 20, the DCIA for section 20 is calculated below.
DCIA = (6.6% x 0.5%) + (17.9% x 12.4%) + (49.9% x 29.6%) + (13.9% x 57%) + (3.9% x 36.2%) + (7.8% x 30%)
DCIA = 28.7%

C. ***Percent impervious area of each land use category*** is a very important parameter in estimating surface runoff using the SWMM model. Nonpoint pollution monitoring studies throughout the United States over the past fifteen years have shown that annual per-acre discharges of urban stormwater pollution are positively related to the amount of imperviousness in land use (User's Manual: Watershed Management Model, 1998). Ideally, the *impervious area* is the area that does not retain water and therefore, 100 percent of the precipitation falling on the impervious area should become surface runoff. In practice, however, the runoff coefficient for impervious area typically ranges between 95 and 100 percent. Impervious runoff coefficients lower than this range were observed in the literature, but usually the number should not be lower than 80 percent. For pervious area, the runoff coefficient usually ranges between 10 and 20 percent. However, values lower than this range were also observed (User's Manual, 1998). In this study, the imperviousness was obtained by integrating information from **Tables 4.4 and 4.5, and 4.8** to develop a weighted average impervious figure, based on the relative landuses for the given WBID division.

It should be noted that the impervious area percentages do not necessarily represent the directly connected impervious area (DCIA). Using a single-family residence as an example, rain falls on rooftops, sidewalks, and driveways. The sum of these areas may represent 30 percent of the total area of the residential lot. However, much of the rain that falls on the roof drains to the grass and infiltrates to the ground or runs off the property, and thus does not run directly to the street. For the SWMM model DCIA was used to characterize Imperviousness according landuse (see **Table 4.8** for references).

To simulate infiltration, the SWMM model provides the user with the option of utilizing either the Horton Equation or the Green-Ampt Equation. The Green-Ampt equation was selected because the parameters required were more accessible. The parameters required by the Green-Ampt equation are the soil saturated hydraulic conductivity, the initial deficit (difference between initial moisture and soil porosity), and the soil suction (average values of soil capillary suction along wetting front). The GIS Soils Shape file (SSURGO Soils SJRWMD) was used to determine the percentage of the sub-basin soils in each of the area divisions. The required soil properties were calculated utilizing information from the NRCS Soils Manuals for Orange and Seminole Counties, as well as the GIS data files. The saturated hydraulic conductivity or permeability values were typically given in the form of a range, with final values estimated based on information about soil hydrologic group and drainage class. Based on the percentage of each soil in the sub-basin's section, weighted averages of these soil properties were calculated and these values were input to their respective subcatchment data file **(Table 4.11)**.

Table 4.11 Saturated Hydraulic Conductivities and Suction Heads used for Green-Ampt Infiltration Equation in SWMM

Table 4.11 Saturated Hydraulic Conductivities and Suction Heads								
Division	HYDCON	SUCT	Division	HYDCON	SUCT	Division	HYDCON	SUCT
1	6.64	2.64	9	0.63	4.41	17	3.87	3.36
2	0.71	4.28	10	3.19	2.74	18	7.79	2.31
3	3.42	2.79	11	1.45	3.94	19	6.43	2.35
4	3.07	3.09	12	4.58	2.77	20	5.31	2.45
5	4.79	2.61	13	1.20	3.99	21	3.84	2.78
6	10.39	1.89	14	1.83	3.95	22	5.29	2.73
7	14.29	1.77	15	4.59	2.52	23	5.16	2.64
8	6.65	2.44	16	7.32	2.30			

The Event Mean Concentrations used in the model (**Table 4.12**, ERD Report, 2003) were input into the "Landuse" section. The base flow concentrations for BOD, TN, and TP were determined by averaging the respective concentrations from the samples collected during the three "lowest flow" conditions **(Table 4.13).** The values obtained from this method compared well with the average ground water concentrations obtained for this WBID. For TP, the low flow average was 0.122 mg/L, whereas the ground water average was 0.115 mg/L. For TN the low flow average was 0.574 mg/L where the ground water average was 0.7 mg/L. These comparatively close values gave confidence that the BOD concentration, 1.63 mg/L, determined through the lowest flow method was a fair estimation (no ground water BOD data were available). The values also were in the range of literature **(Table 4.14, Duncan).** For the purpose of running the model, the individual base flow concentration of the sample station was modeled by inputting these base flows at the nodes representing those sample stations.

Table 4.12 Event Mean Concentrations Used in SWMM Model.
(Table from Harper, 2003).

Summary of Literature Based Runoff Concentrations For Selected Land Use Categories in Southwest Florida						
	Typical Runoff Concentrations (mg/L)				**PERCENT IMPERVIOUS (%)**	**RUNOFF COEFFICIENT**
Land Use Category	**Total N**	**Total P**	**BOD**	**TSS**		
Low Density Residential	1.64	0.191	4.3	16.9	14.7	0.268
Single-Family	2.18	0.335	7.4	26	28.1	0.33
Multi-Family	2.42	0.49	11	71.7	67	0.675
Low Intensity Commercial	1.12	0.18	7.4	72.8	91	0.857
High Intensity Commercial	2.83	0.43	17.2	94.3	97.5	0.887
Industrial	1.79	0.31	9.6	93.9	86.8	0.793
Highway	2.23	0.27	6.7	49.1	76.6	0.69
Agricultural						
a. Pasture	2.48	0.476	5.1	94.3	0	0.355
b. Citrus	2.24	0.183	2.55	15.5	0	0.401
c. Row Crops	2.88	0.638		20.4	0	0.204
d. General Agriculture	2.32	0.344	3.8	55.3	0	0.32
Undeveloped Rangeland Forest	1.09	0.046	1.23	7.8	1.5	0.163
Mining	1.18	0.15	9.6	93.9	23	0.361
Wetland	1.01	0.09	2.63	11.2	0	0.225
Open Water / Lake	1.6	0.067	1.6	3.1	100	0.5

Table 4.13 Values Used in Determination of Crane Strand Drain (WBID 3014) Base Flow Concentrations.

Date	STA	Flow (CFS)	DO	BOD	TKN	NO2-NO3	TN (Calc)	TP
6/5/02	196	0.41	3.95		0.480	0.190	0.670	0.150
3/18/02	196	1.59	6.10	2.50	0.590	0.170	0.760	0.140
2/24/05	196	2.12	7.10	0.51	0.580	0.220	0.800	0.110
6/5/02	357-University	0.82	8.80		0.320	0.027	0.347	0.160
3/18/02	357-University	3.17	10.57		0.390	0.130	0.520	0.140
2/23/05	357-University	3.92	9.10		0.400	0.150	0.550	0.120
6/5/02	393 - Goldenrod	1.11	4.45		0.400	0.032	0.432	0.120
3/18/02	393 - Goldenrod	4.29	6.26	2.40	0.430	0.120	0.550	0.110
2/24/05	393 - Goldenrod	4.90	6.99	0.89	0.510	0.120	0.630	0.110
6/5/02	394	0.68	7.45		0.360	0.031	0.391	0.093
3/18/02	394	2.64	8.25	2.10	0.390	0.180	0.570	0.089
2/23/05	394	3.26	9.85	1.40	0.510	0.160	0.670	0.120
Average For STA 196		1.37	5.72	1.51	0.550	0.193	0.743	0.133
Average For STA 357		2.64	9.49		0.370	0.102	0.472	0.140
Average For STA 393		3.43	5.90	1.65	0.447	0.091	0.537	0.113
Average For STA 394		2.19	8.52	1.75	0.420	0.124	0.544	0.101
Overall Average		**2.41**	**7.41**	**1.63**	**0.447**	**0.128**	**0.574**	**0.122**

Model output was transferred to an Excel spreadsheet and summarized in **Tables 4.15 and 4.16**. The results of the "water quantity" section of the model showed a good mass balance (a 5% difference in total flow between SWMM simulated stream flow and stream flow from the Banner Dam gage-based flow), **Table 4.16**. The cumulative flow matched well through the first months of simulation and began to deviate during the later months **(Figure 4.13)**. The flow hydrograph comparison **(Figure 4.14)** illustrates that there are multiple storm events where SWMM simulated higher flow than the gage, and there are a few gage-based storm flows that are much higher than the simulated SWMM simulation. The SWMM model was calibrated by changing the percent impervious areas input (there is a range of values available concerning impervious areas to be used for various land uses); the initial selected values that were on the high end of that range were replaced with lower ones to bring the peak flows from the SWMM simulation down. This is one of two parameters suggested by model developers for calibration to reduce peaks and volume of flow. Another parameter suggested for calibration is the width of overland flow path (reducing the width should increase the time span of the storm hydrograph). A factor that limits the impact of these calibration tools is the time step utilized in this application. Calibration has a greater impact where the time of concentration is larger than the modeled time step. For this modeling effort, the time step was fixed by the fact that daily rainfall data are used rather than a smaller time interval.

Table 4.14 Ranges of Base Flow Concentrations, Literature Summary / Hugh Duncan

Range of Baseflow Concentrations (mg/L)
(from Chapt. 3 Chart, "Urban Wastewater Pollutant Concentrations", Hugh Duncan)

	BOD				Total Phosphorus				Total Nitrogen			
	Sample Size	Min	Mean	Max	Sample Size	Min	Mean	Max	Sample Size	Min	Mean	Max
Urban	15	2	5	12	17	0.04	0.14	0.59	13	0.90	2.10	4.50
Rural	8	1	2.1	4	15	0.03	0.06	0.12	13	0.45	0.95	2.10

Figure 4.13 Modeling Cumulative Flow from Crane Strand Drain, 2002 through 2004

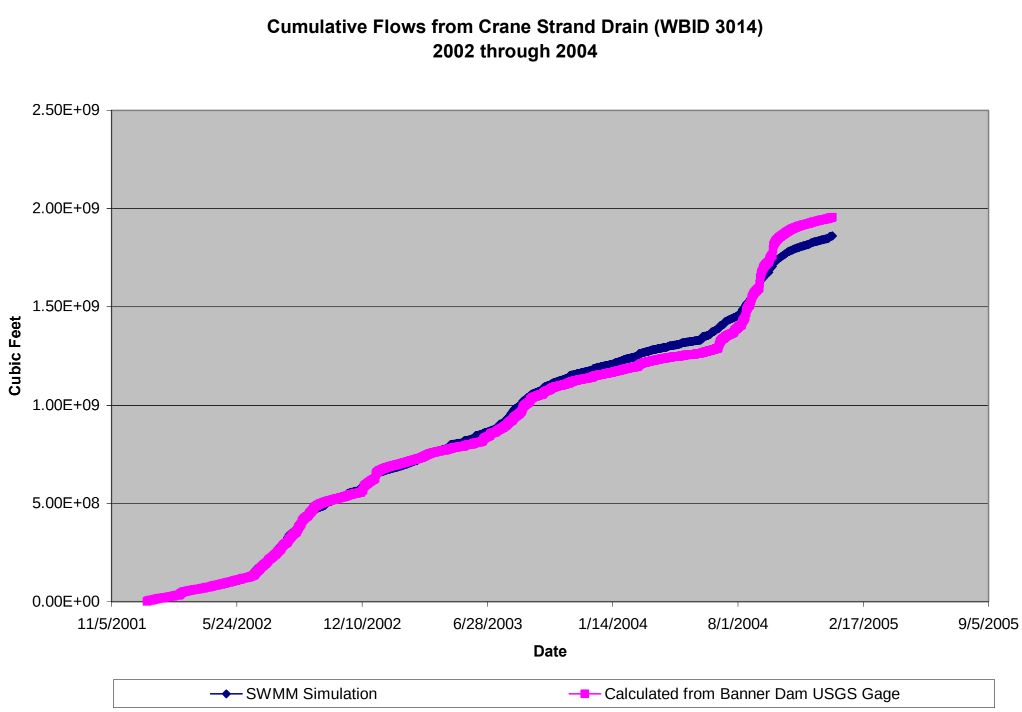


Table 4.15 SWMM Output Comparison Table

SWMM Simulation, utilizing Weather Data from Orlando WSO Airport Weather Station Flow in the last Section of Crane Strand Drain										
Date	***A SWMM Simulated Flow (CFS)***	***B BOD Concentration (mg/L)***	***C Total Nitrogen (mg/L)***	***D Total Phosphorus (mg/L)***	***E Flow Based on Banner Dam Gage***	***F BOD Load (LBS/DAY) A x B x 5.395***	***G TN load (LBS/DAY) A x C x 5.395***	***H TP load (LBS/DAY) A x D x 5.395***	***I BOD load limit A x 2.0 mg/L x 5.395***	***J TN load limit A x .784 mg/L x 5.396***
1/1/2002	8.02	1.54	0.5	0.11	7.55	66.63	21.63	4.76	86.54	33.92
1/2/2002	42.44	6.67	1.64	0.2	28.04	1527.19	375.50	45.79	435.03	171.72
1/3/2002	9.27	3.4	0.94	0.15	19.41	170.04	47.01	7.50	95.02	37.51
1/4/2002	7.63	1.75	0.56	0.12	8.63	72.04	23.05	4.94	78.21	30.87
1/5/2002	7.56	1.62	0.53	0.11	7.01	66.07	21.62	4.49	77.49	30.59
1/6/2002	7.49	1.61	0.53	0.11	7.01	65.06	21.42	4.44	76.78	30.31
1/7/2002	7.44	1.61	0.53	0.11	7.01	64.62	21.27	4.42	76.26	30.10
1/8/2002	7.35	1.61	0.53	0.11	7.01	63.84	21.02	4.36	75.34	29.74
1/9/2002	7.29	1.61	0.53	0.11	7.01	63.32	20.84	4.33	74.73	29.50
1/10/2002	7.21	1.61	0.53	0.11	7.01	62.63	20.62	4.28	73.91	29.17
1/11/2002	7.13	1.61	0.53	0.11	7.01	61.93	20.39	4.23	73.09	28.85
1/12/2002	7.08	1.61	0.53	0.11	6.47	61.50	20.24	4.20	72.57	28.65
1/13/2002	7.02	1.62	0.53	0.11	6.47	61.35	20.07	4.17	71.96	28.40
1/14/2002	23.31	5.76	1.44	0.18	9.71	724.36	181.09	22.64	238.94	94.32
1/15/2002	7.79	3.11	0.87	0.14	15.64	130.70	36.56	5.88	79.85	31.52
1/16/2002	6.67	1.72	0.56	0.12	7.55	61.89	20.15	4.32	68.37	26.99
1/17/2002	6.57	1.62	0.54	0.11	7.01	57.42	19.14	3.90	67.35	26.58
1/18/2002	6.46	1.62	0.53	0.11	6.47	56.46	18.47	3.83	66.22	26.14
1/19/2002	6.43	1.62	0.54	0.11	5.93	56.20	18.73	3.82	65.91	26.02
1/20/2002	6.4	1.62	0.54	0.11	5.34	55.94	18.65	3.80	65.60	25.90

Figure 4.14 Stream Flow From Crane Strand Drain (WBID 3014), Comparison between SWMM Simulation and Calculated flow based on Banner Dam, USGS Gage.

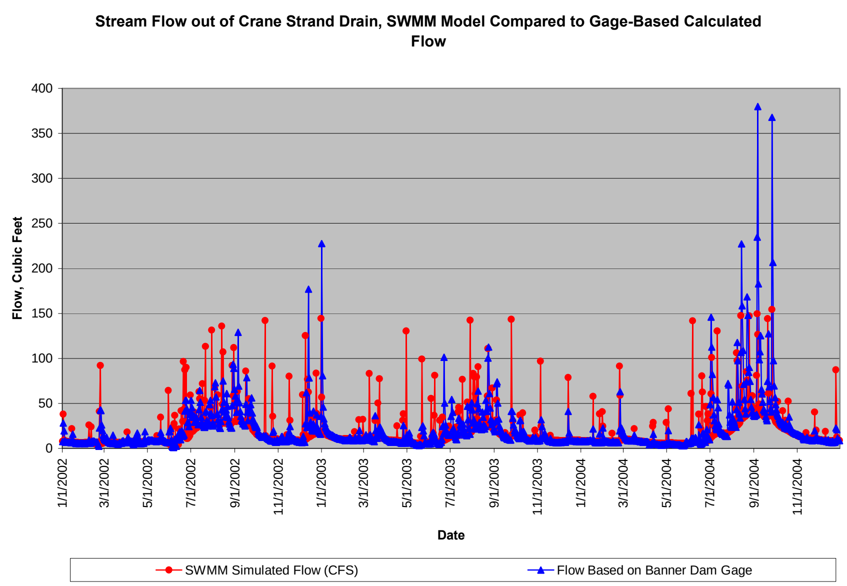


Table 4.16 SWMM Output Summary

SIMULATION SUMMARY OF THE CRANE STRAND DRAIN (WBID 3014)

CRANE STRAND DRAIN FLOW BETWEEN 1/1/2002 AND 12/31/2004

METHOD OF DETERMINATION	TOTAL 3-YR VOLUME (MILLION GALLONS)	FLOW (CUBIC FEET PER SECOND)			
		Average	Median	Maximum	Minimum
SWMM SIMULATION	14,476	20.5	10.7	156.2	3.2
AREA:RATIO CALCULATION	14,631	20.7	10.5	379.7	1.0
DIFFERENCE, SWMM & AREA RATIO METHODS	1.06%				

CRANE STRAND DRAIN LOADS, 1/1/2002 THROUGH 12/31/2004

SIMULATION SCENARIO	Load (LBS/YR)	Reduction Relative to Existing Load	
BOD		Pounds	Percent
SWMM SIMULATION OF EXISTING CONDITIONS	158,776	N/A	N/A
SWMM SIMULATION OF BOD LOAD AT 2.0 mg/L (SCREEN LEVEL)	80,553	78,223	49.3%
SWMM SIMULATION OF NATURAL CONDITIONS	57,281	101,495	63.9%
AVERAGE OF SCREENING LEVEL & BACKGROUND	68,917	89,859	56.6%
TOTAL NITROGEN			
SWMM SIMULATION OF EXISTING CONDITIONS	42,020	N/A	N/A
SWMM SIMULATION OF TN LOAD AT 0.784 MG/L	31,577	10,443	24.9%
SWMM SIMULATION OF NATURAL CONDITIONS	28,079	13,941	33.2%
AVERAGE OF 0.784 MG/L LOAD AND NATURAL CONDITIONS	29,828	12,192	29.0%

CRANE STRAND DRAIN POLLUTANT DAILY CONCENTRATION (mg/L)

BOD	Average	Median	Maximum	Minimum
SWMM SIMULATION OF EXISTING CONDITIONS, 02 - '04	2.40	1.63	7.69	1.54
FIELD SAMPLE ANALYSIS (14 GRAB SAMPLES, '99 - '01)	2.37	2.25	4.70	1.00
SWMM SIMULATION OF NATURAL CONDITIONS, '02 - '04	1.55	1.60	1.68	1.08
AVERAGE OF SCREENING LEVEL & NATURAL CONDITIONS	1.78	1.81	1.84	1.55
TOTAL NITROGEN				
SWMM SIMULATION OF EXISTING CONDITIONS, '02 - '04	0.71	0.54	1.87	0.50
FIELD SAMPLE ANALYSIS (30 GRAB SAMPLES, '99 - '01)	0.76	0.71	1.85	0.35
SWMM SIMULATION OF NATURAL CONDITIONS, '02 - '04	0.58	0.54	0.92	0.50
AVERAGE OF 0.784 MG/L AND NATURAL CONDITIONS	0.69	0.66	0.87	0.64

Chapter 5: DETERMINATION OF ASSIMILATIVE CAPACITY

5.1 Overall Approach

The overall approach is to model the existing BOD and Total Nitrogen loads utilizing the SWMM computer model, and then reduce loads of BOD and Total Nitrogen loads until the target DO would be expected to be met based on the target BOD and target TN. For BOD, that load will be set at the screening level for BOD (2.0 mg/L), and for Total Nitrogen it will be set at 0.784 mg/L consistent with its observed relationship to DO.

5.2 Relationship between Measured Flow and Nutrients, BOD, and DO

Attempts were also made to relate DO to stream flow. As has been found in other studies, low DO concentrations were consistent with low flow conditions. Using all of the individual data, there was no correlation between DO and flow rate of the Crane Strand Canal **(Figure 5.1).** However, there were some relationships between quarterly flow and DO values. For 2002 (2002 was chosen because that is the year when there is the most complete set of data for DO and flow) the DO was at its lowest average and median values during the third quarter, or the rainy season, when the flow is at its highest average and median values **(Figures 5.2 and 5.3)**. Unfortunately, there were not enough BOD data to evaluate quarterly averages during 2002. There were adequate Total Nitrogen data to evaluate quarterly averages, and the Total Nitrogen median and average quarterly concentrations were highest during the third quarter as well **(Figures 5.4 and 5.5).**

Figure 5.1. Relationship between DO and Flow Rate

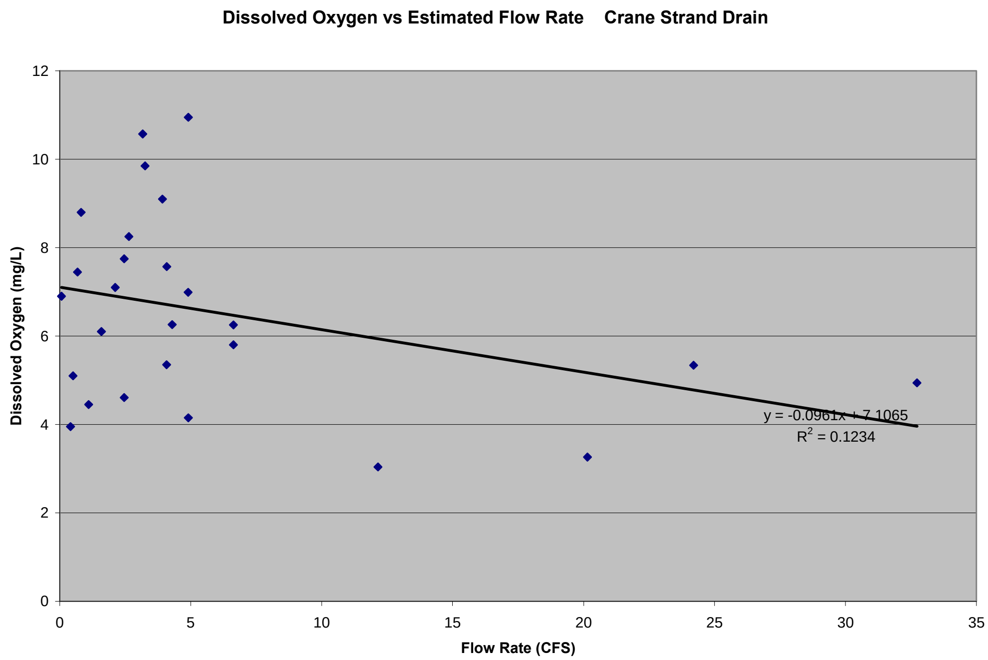


Figure 5.2. Relationship between Quarterly Average DO and Flow Rate

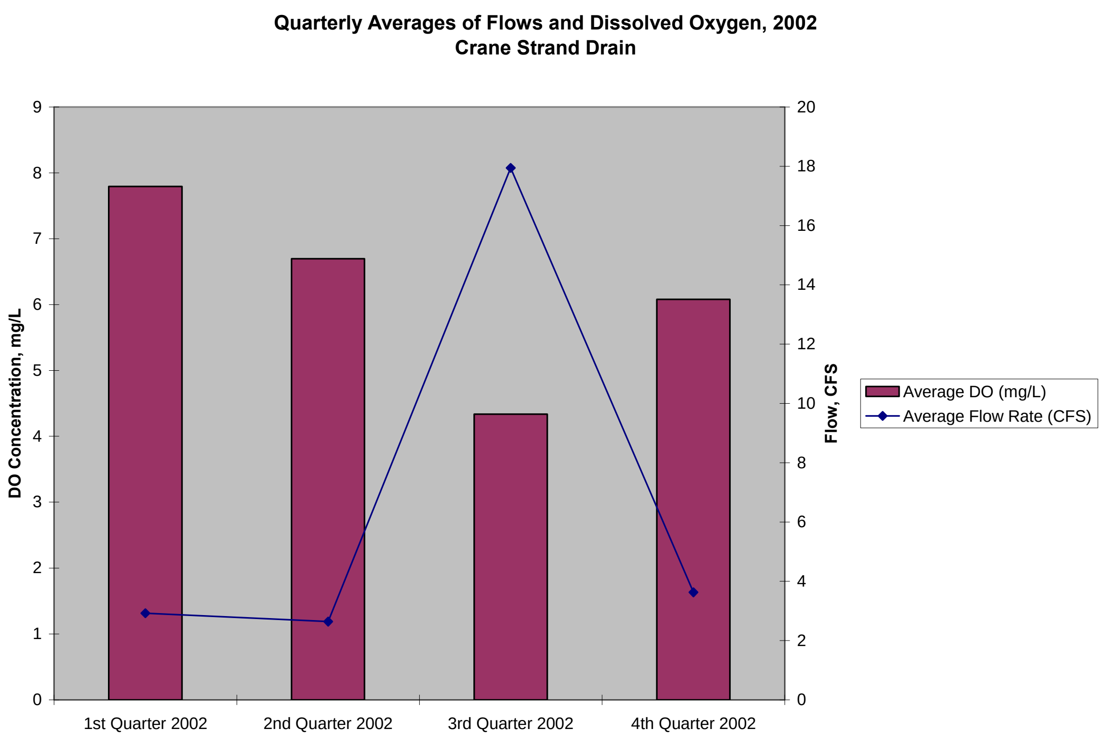


Figure 5.3. Relationship between Quarterly Median DO and Flow Rate

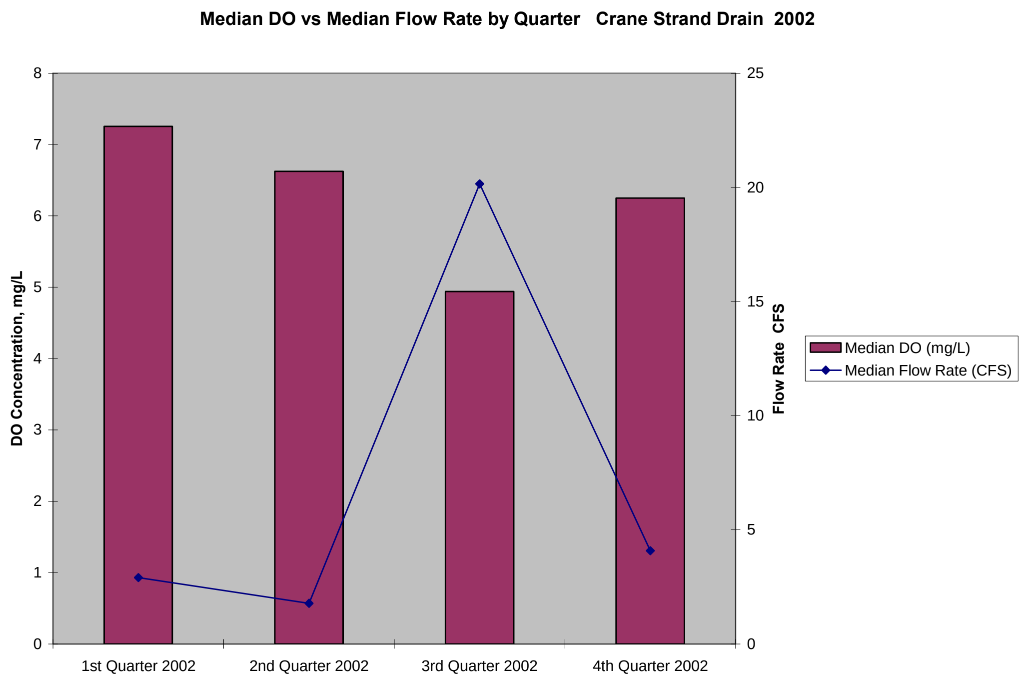


Figure 5.4. Relationship between Quarterly Average TN and Flow Rate

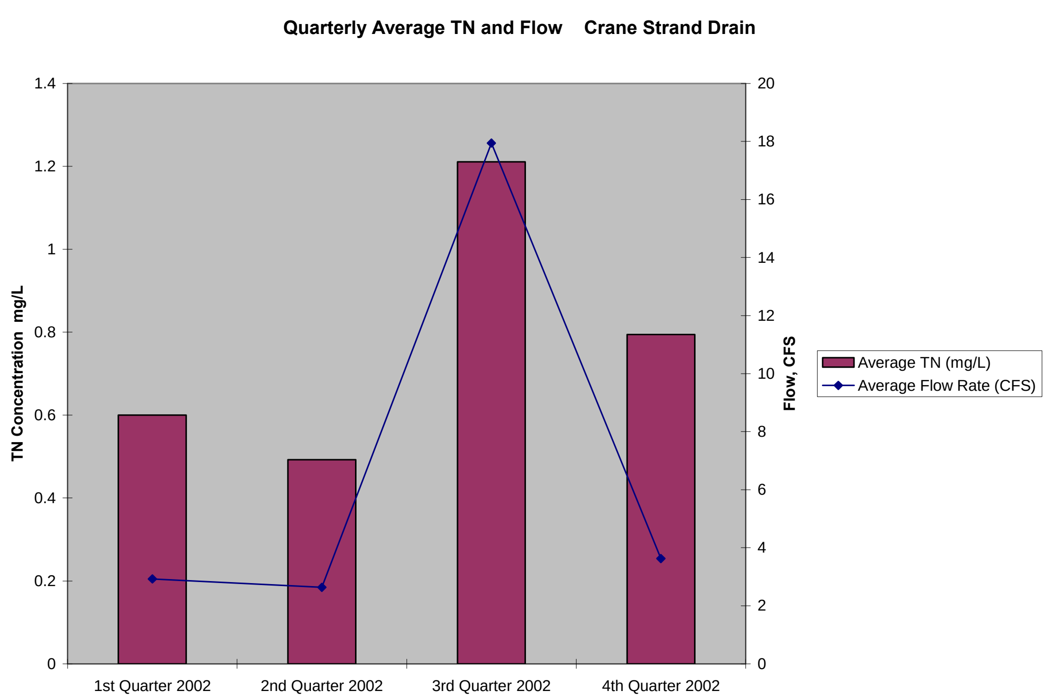
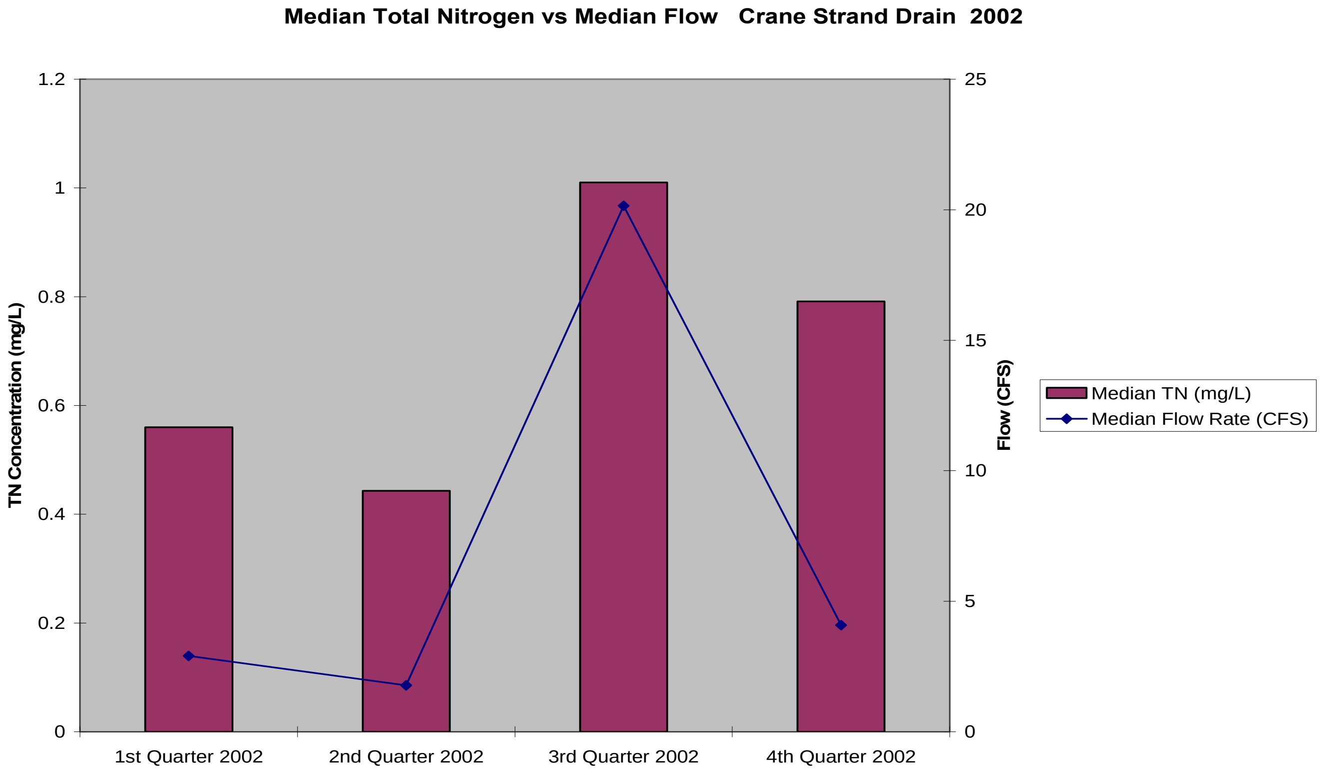


Figure 5.5.   Relationship between Quarterly Median DO and Flow Rate



The observation that the lowest DOs occur during the period of highest flows was not expected, based on other basin observations. This suggests that much of the low DO concentrations are related to wet season hydrology of higher runoff volumes, higher peak flows, and higher antecedent moisture conditions in the soil. Consistent with this, there appears to be a direct relationship DO concentrations in the Crane Strand Drain, the average monthly precipitation **(Figure 5.6),** and the average total precipitation **(Figure 5.7)**. Such a relationship is not present between BOD and these parameters **(Figure 5.8).** There is also an apparent correlation between Total Kjeldahl Nitrogen (TKN) concentrations and precipitation **(Figure 5.9).**

Figure 5.6.   Relationship Quarterly Mean Precipitation and Quarterly Mean Dissolved Oxygen, 1999 through 2002

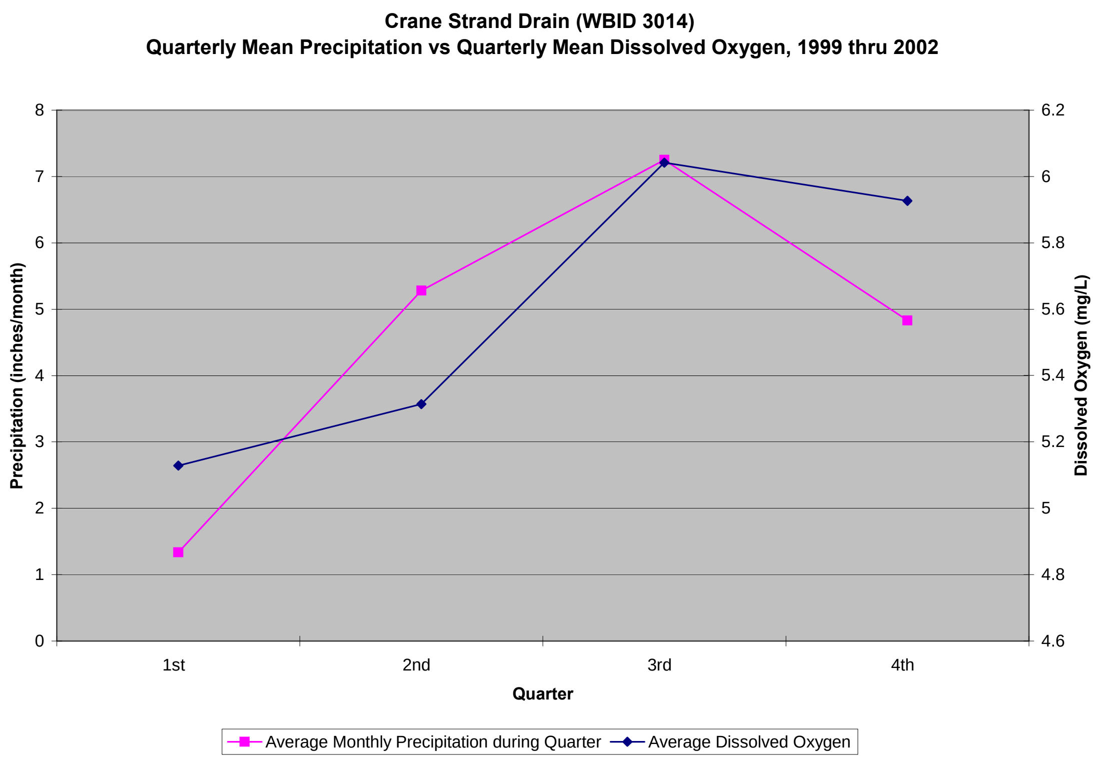


Figure 5.7.   Relationship Quarterly Total Precipitation and Quarterly Mean Dissolved Oxygen, 1999 through 2002

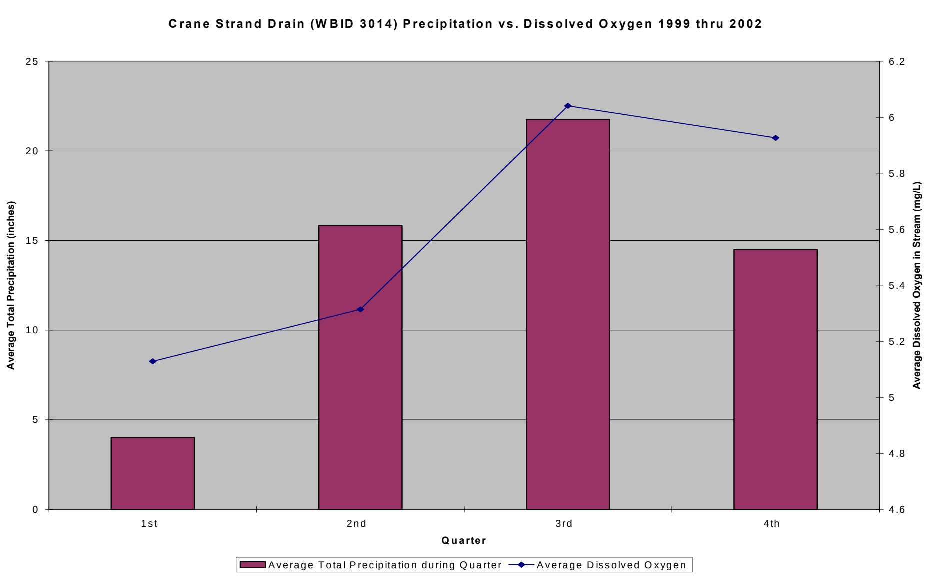


Figure 5.8. Relationship Quarterly Mean Precipitation and Total Precipitation and Quarterly Mean BOD, 1999 through 2002

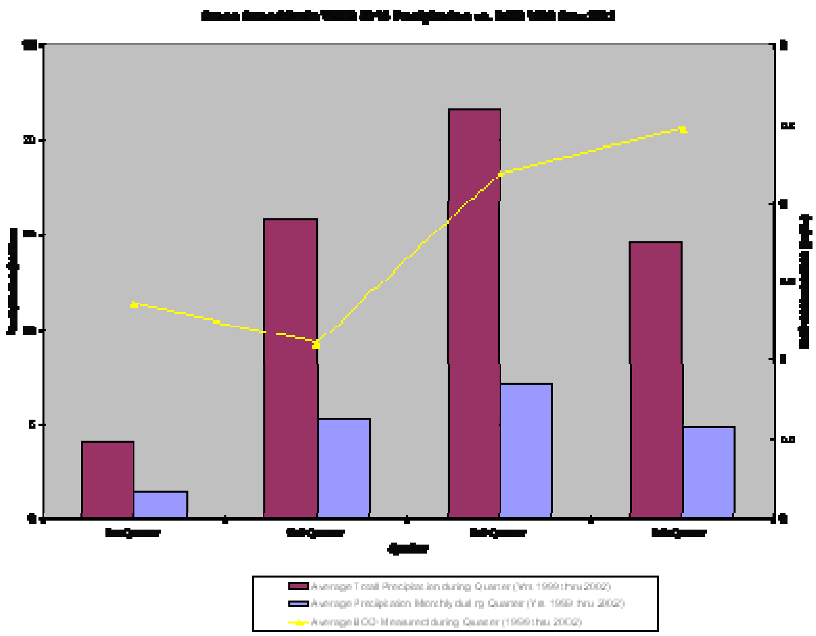
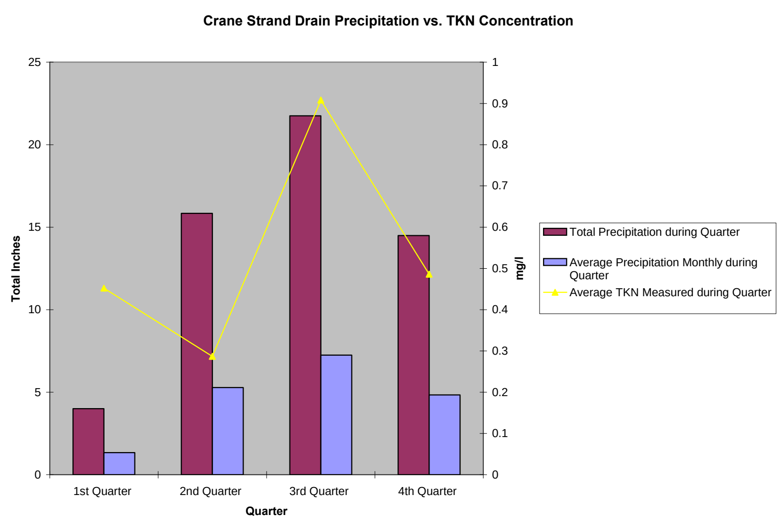


Figure 5.9. Relationship Quarterly Mean Precipitation and Total Precipitation and Quarterly Mean TKN, 1999 - 2002



5.4 Critical Conditions

The Crane Strand Drain TMDL was determined through the simulation of flow and pollutant loads during the entire year, rather than focusing on a critical "low flow" season or condition. Depressed dissolved oxygen levels have been observed in all flow conditions, with higher averages observed during high flow periods, and thus has not been solely related to seasonal or flow condition. There may be other as yet undetermined critical conditions related to low dissolved oxygen or elevated BOD, but based on current knowledge it was determined best to simulate the annual flows and concentrations and relate them to the target maximum loads.

The assimilative capacity for BOD must be sufficient to achieve the loads consistent with the screening level of 2.0 mg/L. However, it should be noted that the natural background BOD levels in some regions of Florida have been shown to be approximately 2.0 mg/L. In recognition of these two factors, the approach taken here will be to simulate and determine the natural background BOD load for the Crane Strand Drain, and set the BOD target to be midway between the load consistent with a 2.0 mg/L and the load associated with undeveloped land uses.

Based on the results of the SWMM model simulation for the years 2002 through 2004 (**Table 4.16**), the average BOD load in the Crane Strand Drain was 158,776 lbs BOD/year. The SWMM simulation results also indicate that the BOD load at the screening level of 2.0 mg/L would have been 80,553 lbs/year and the BOD load associated with natural undeveloped conditions is 57,281 lbs/year. The assimilative capacity for BOD is thus 68,917 lbs/year (the average of these two loads).

Similarly, the assimilative capacity for Total Nitrogen is the average of the load associated with the critical concentration related to dissolved oxygen (0.784 mg/L based on regression relationship) and the load associated with undeveloped landuse conditions. The SWMM model simulation results (**Table 4.16**) for the years 2002 through 2004 estimated the average Total Nitrogen (TN) load was 42,020 lbs/yr. At a load consistent with the concentration of 0.784 mg/L the total load would have been 31,577 pounds per year. Based on the SWMM model results, the Total Nitrogen load associated with natural undeveloped conditions is 28,079 lbs/year. The assimilative capacity is thus 29,828 lbs/year (the average of these two loads**).**

In modeling the natural undeveloped conditions, the base flow concentrations were left the same as the present conditions. In simulating natural conditions, all landuses for the sub basin were changed to upland forest, except the channelized wetland, which was converted to wetland. The TN and BOD reduced loads were thus associated with the reduced event mean concentrations associated with the undeveloped land uses.

Chapter 6: DETERMINATION OF THE TMDL

6.1 Expression and Allocation of the TMDL

The objective of a TMDL is to provide a basis for allocating acceptable loads among all of the known pollutant sources in a watershed so that appropriate control measures can be implemented and water quality standards achieved. A TMDL is expressed as the sum of all point source loads (Waste Load Allocations, or WLAs), nonpoint source loads (Load Allocations, or LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\textbf{TMDL} = \sum \textbf{WLAs} + \sum \textbf{LAs} + \textbf{MOS}$$

As discussed earlier, the WLA is broken out into separate subcategories for wastewater discharges and stormwater discharges regulated under the NPDES Program:

$$\textbf{TMDL} \cong \sum \textbf{WLAs}_{\textbf{wastewater}} + \sum \textbf{WLAs}_{\textbf{NPDES Stormwater}} + \sum \textbf{LAs} + \textbf{MOS}$$

It should be noted that the various components of the revised TMDL equation may not sum up to the value of the TMDL because a) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is also accounted for within the LA, and b) TMDL components can be expressed in different terms (for example, the WLA for stormwater is typically expressed as a percent reduction, and the WLA for wastewater is typically expressed as mass per day).

WLAs for stormwater discharges are typically expressed as “percent reduction” because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish loads from MS4s from other nonpoint sources (given the nature of stormwater transport). The permitting of stormwater discharges also differs from the permitting of most wastewater point sources. Because stormwater discharges cannot be centrally collected, monitored, and treated, they are not subject to the same types of effluent limitations as wastewater facilities, and instead are required to meet a performance standard of providing treatment to the “maximum extent practical” through the implementation of BMPs.

This approach is consistent with federal regulations (40 CFR § 130.2[I]), which state that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or **other appropriate measure**. TMDLs for Crane Strand Drain (WBID 3014) are expressed in terms of pounds per year and percent reduction, and represent the amount of BOD and TN loading that will bring the current DO levels to the standard of 5 mg/L **(Table 6.1).**

Table 6.1 TMDL Components and Current Loadings for Crane Strand Drain (WBID 3014)

Parameter	WLA		LA (lbs/year)	MOS	TMDL (lbs/year)	Current Loading (lbs/year)	Percent Reduction
	Wastewater (lbs/year)	NPDES Stormwater (Percent Reduction)					
BOD	N/A	57%	68,917	Implicit	68,917	158,776	57%
TN	N/A	29%	29,828	Implicit	29,828	42,020	29%

6.2 Wasteload Allocation (WLA)

6.2.1 NPDES Wastewater Discharges

There are currently four wastewater facilities in the Crane Strand Drain watershed, but only two of these are NPDES permitted wastewater discharges (City Industries and CEMEX/Goldenrod Concrete Batch Plant). As neither facility is expected to have reasonable potential to cause or contribute to violations of the DO criteria, the WLA is not applicable to either facility.

6.2.2 NPDES Stormwater Discharges

The WLAs for stormwater discharges with an MS4 permit (Orange and Seminole County and the City of Winter Park) are a 57% reduction in BOD load and a 29% reduction in TN load. It should be noted that any MS4 permittee will only be responsible for reducing the anthropogenic loads associated with stormwater outfalls that it owns or otherwise has responsible control over, and it is not responsible for reducing other nonpoint source loads in its jurisdiction.

6.3 Load Allocation (LA)

The Load Allocation is the nonpoint source component of the load, which, combined with WLA stormwater discharges, is responsible for 100% of the current load as well as the percentage load reduction. The total maximum daily load is 68,917 lbs/yr BOD and 29,828 lbs/yr of Total Nitrogen, all of which is allocated to the categories of LA and WLA stormwater. Based on the SWMM model simulation, this represents a BOD and TN load reduction of 57% and 29%, respectively.

6.4 Margin of Safety (MOS)

Consistent with the recommendations of the Allocation Technical Advisory Committee (Florida Department of Environmental Protection, February 1, 2001), an implicit margin of safety (MOS) was used in the development of this TMDL. An implicit MOS was provided by the conservative decisions associated with a number of modeling assumptions, the development of site-specific alternative water quality targets, and the development of the assimilative capacity. This includes the establishment of the TMDL at a load that is expected to maintain the annual average BOD concentration below the screening threshold of 2 mg/L and TN below the critical concentration of 0.784 mg/L. The average daily BOD and Total Nitrogen concentrations associated with their annual load allocations are 1.78 mg/L and 0.69 mg/L respectively (**Table 4.16**). In establishing these loads, error margins were included by setting the assimilative capacities midway between simulated natural background conditions and the screening load (BOD) or critical load (Total Nitrogen).

Chapter 7: NEXT STEPS: IMPLEMENTATION PLAN DEVELOPMENT AND BEYOND

7.1 Basin Management Action Plan

Following the adoption of this TMDL by rule, the next step in the TMDL process is to develop an implementation plan for the TMDL, which will be a component of the Basin Management Action Plan (BMAP) for the Middle St. Johns River basin. This document will be developed over the next year in cooperation with local stakeholders and will attempt to reach consensus on more detailed allocations and on how load reductions will be accomplished. The BMAP will include the following:

- Appropriate allocations among the affected parties,
- A description of the load reduction activities to be undertaken,
- Timetables for project implementation and completion,
- Funding mechanisms that may be utilized,
- Any applicable signed agreement,
- Local ordinances defining actions to be taken or prohibited,
- Local water quality standards, permits, or load limitation agreements, and
- Monitoring and follow-up measures.

References

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Appendices

Appendix A: Background Information on Federal and State Stormwater Programs

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as authorized in Chapter 403, F.S., was established as a technology-based program that relies on the implementation of BMPs that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Chapter 62-40, F.A.C.

The rule requires the state's water management districts (WMDs) to establish stormwater pollutant load reduction goals (PLRGs) and adopt them as part of a SWIM plan, other watershed plan, or rule. Stormwater PLRGs are a major component of the load allocation part of a TMDL. To date, stormwater PLRGs have been established for Tampa Bay, Lake Thonotosassa, the Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka. No PLRG has been developed for Newnans Lake at the time this study was conducted.

In 1987, the U.S. Congress established Section 402(p) as part of the federal Clean Water Act Reauthorization. This section of the law amended the scope of the federal NPDES stormwater permitting program to designate certain stormwater discharges as "point sources" of pollution. These stormwater discharges include certain discharges that are associated with industrial activities designated by specific Standard Industrial Classification (SIC) codes, construction sites disturbing five or more acres of land, and master drainage systems of local governments with a population above 100,000, which are better known as municipal separate storm sewer systems (MS4s). However, because the master drainage systems of most local governments in Florida are interconnected, the EPA has implemented Phase 1 of the MS4 permitting program on a countywide basis, which brings in all cities (incorporated areas), Chapter 298 urban water control districts, and the Florida Department of Transportation throughout the fifteen counties meeting the population criteria.

An important difference between the federal and state stormwater permitting programs is that the federal program covers both new and existing discharges, while the state program focuses on new discharges. Additionally, Phase 2 of the NPDES Program will expand the need for these permits to construction sites between one and five acres, and to local governments with as few as 10,000 people. These revised rules require that these additional activities obtain permits by 2003. While these urban stormwater discharges are now technically referred to as "point sources" for the purpose of regulation, they are still diffuse sources of pollution that cannot be easily collected and treated by a central treatment facility similar to other point sources of pollution, such as domestic and industrial wastewater discharges. The Department recently accepted delegation from the EPA for the stormwater part of the NPDES Program. It should be noted that most MS4 permits issued in Florida include a re-opener clause that allows permit revisions to implement TMDLs once they are formally adopted by rule.

Appendix B: BOD and Nutrient Sample Concentrations from Crane Strand Drain.

(Note: 2/23/05 Sampling and Analysis was completed after WBID was placed on Verified TMDL list)

STATION	DATE	Temp. (°C)	DO	BOD	TKN	NO3	NO2	NO2-NO3	TP
20010196	3/18/02	25.34	6.1	2.5	0.59			0.17	0.14
20010196	4/30/02	26.44	4.61	2.4	0.58			0.11	0.14
20010196	6/5/02	27.31	3.95		0.48			0.19	0.15
20010196	9/3/02	28.79	3.04		0.75			0.21	0.086
20010196	10/22/02	27.66	7.75		0.55			0.37	0.11
20010196	2/23/05	23.32	7.1	0.51	0.58			0.22	0.11
20010357	1/25/99	20.8	8.2	1.1	0.47			0.2	
20010357	7/12/99	30.1	8.6	1	0.5			0.18	
20010357	3/18/02	27.89	10.57		0.39			0.13	0.14
20010357	4/30/02	30.33	10.95		0.42			0.025	0.13
20010357	6/5/02	28.35	8.8		0.32			0.027	0.16
20010357	9/3/02	29.54	5.34		0.66			0.33	0.12
20010357	10/22/02	23.36	4.15		0.48			0.34	0.14
20010357	2/23/05	23.9	9.1	1.1	0.4			0.15	0.12
20010381	2/23/05	21.37	6.87	0.86	0.46			0.16	0.084
20010393	3/18/02	23.03	6.26	2.4	0.43			0.12	0.11
20010393	4/30/02	26.3	5.8		0.41			0.031	0.093
20010393	6/5/02	27.06	4.45		0.4			0.032	0.12
20010393	9/3/02	27.64	4.94		0.68			0.33	0.08
20010393	10/22/02	27.63	6.25		0.44			0.31	0.066
20010393	2/23/05	21.66	6.99	0.89	0.51			0.12	0.11
20010394	3/18/02	26.05	8.25	2.1	0.39			0.18	0.089
20010394	4/30/02	28.28	7.57		0.45			0.075	0.079
20010394	6/5/02	27.96	7.45		0.36			0.031	0.093
20010394	9/3/02	29.11	3.26		0.89			0.5	0.12
20010394	10/22/02	24.42	5.35		0.45			0.24	0.12
20010394	2/23/05	24.21	9.85	1.4	0.51			0.16	0.12
CRA	8/10/00	27.41	2.87	2	0.97	0.019	0.0022		0.096
CRA	11/2/00	21.77	6.82	3.2	0.58	0.003	0.0022		0.074
CRA	2/1/01	20.05	4.52	2	0.89	0.083	0.0022		0.083
CRA	5/8/01	25.54	7.86	2	0.72	0.003	0.0022		0.13
CRA	8/7/01	26.64	3.45	2.4	0.94	0.031	0.0022		0.13
CRA	11/7/01	20.8	4.11	2	0.74	0.036	0.0022		0.076
CRA	8/5/02	30.22	5.1	3.4	1.7	0.15	0.0022		0.32
CRA	11/14/02	19.68	6.9	4.7	0.77	0.036	0.0022		0.082

Appendix C: SWMM Model Output Used to Calculate Pollutant Loads

Table C.1 Crane Strand Drain Natural Background Condition Daily Simulation Summary

BACKGROUND										
	SWMM Simulation, utilizing Weather Data from Orlando WSO Airport Weather Station Flow in the last Section of Crane Strand Drain									
Date	A SWMM Simulated Flow (CFS)	B BOD Concentration (mg/L)	C Total Nitrogen (mg/L)	D Total Phosphorus (mg/L)	E Flow Based on Banner Dam Gage	F BOD Load (LBS/DAY) A x B x 5.395	G TN load (LBS/DAY) A x C x 5.395	H TP load (LBS/DAY) A x D x 5.395	I BOD load limit A x 1.9 mg/L x 5.395	J TN load limit A x .75 mg/L x 5.396
1/1/2002	8.02	1.54	0.5	0.11	7.55	66.63	21.63	4.76	86.54	33.92
1/2/2002	42.44	1.18	0.87	0.14	28.04	270.18	199.20	32.05	457.93	179.51
1/3/2002	9.27	1.5	0.65	0.1	19.41	75.02	32.51	5.00	100.02	39.21
1/4/2002	7.63	1.61	0.54	0.11	8.63	66.27	22.23	4.53	82.33	32.27
1/5/2002	7.56	1.61	0.53	0.11	7.01	65.67	21.62	4.49	81.57	31.98
1/6/2002	7.49	1.61	0.53	0.11	7.01	65.06	21.42	4.44	80.82	31.68
1/7/2002	7.44	1.61	0.53	0.11	7.01	64.62	21.27	4.42	80.28	31.47
1/8/2002	7.35	1.61	0.53	0.11	7.01	63.84	21.02	4.36	79.31	31.09
1/9/2002	7.29	1.61	0.53	0.11	7.01	63.32	20.84	4.33	78.66	30.83
1/10/2002	7.21	1.61	0.53	0.11	7.01	62.63	20.62	4.28	77.80	30.50
1/11/2002	7.13	1.61	0.53	0.11	7.01	61.93	20.39	4.23	76.93	30.16
1/12/2002	7.08	1.61	0.53	0.11	6.47	61.50	20.24	4.20	76.39	29.95
1/13/2002	7.02	1.62	0.53	0.11	6.47	61.35	20.07	4.17	75.75	29.69
1/14/2002	23.31	1.26	0.81	0.14	9.71	158.45	101.86	17.61	251.51	98.59
1/15/2002	7.79	1.52	0.64	0.1	15.64	63.88	26.90	4.20	84.05	32.95
1/16/2002	6.67	1.62	0.54	0.11	7.55	58.30	19.43	3.96	71.97	28.21
1/17/2002	6.57	1.62	0.53	0.11	7.01	57.42	18.79	3.90	70.89	27.79
1/18/2002	6.46	1.62	0.53	0.11	6.47	56.46	18.47	3.83	69.70	27.32
1/19/2002	6.43	1.62	0.54	0.11	5.93	56.20	18.73	3.82	69.38	27.20
1/20/2002	6.4	1.62	0.54	0.11	5.34	55.94	18.65	3.80	69.06	27.07
1/21/2002	6.4	1.62	0.54	0.11	5.93	55.94	18.65	3.80	69.06	27.07
1/22/2002	6.4	1.62	0.54	0.11	5.93	55.94	18.65	3.80	69.06	27.07
1/23/2002	6.37	1.62	0.54	0.11	5.93	55.67	18.56	3.78	68.73	26.94
1/24/2002	6.35	1.62	0.54	0.11	5.39	55.50	18.50	3.77	68.52	26.86
1/25/2002	6.33	1.62	0.54	0.11	5.39	55.32	18.44	3.76	68.30	26.77
1/26/2002	6.3	1.62	0.54	0.11	5.93	55.06	18.35	3.74	67.98	26.65
1/27/2002	6.28	1.62	0.54	0.11	5.93	54.89	18.30	3.73	67.76	26.56
1/28/2002	6.23	1.62	0.54	0.11	5.93	54.45	18.15	3.70	67.22	26.35
1/29/2002	6.2	1.62	0.54	0.11	5.93	54.19	18.06	3.68	66.90	26.22
1/30/2002	6.16	1.62	0.54	0.11	5.93	53.84	17.95	3.66	66.47	26.05
1/31/2002	6.19	1.62	0.54	0.11	5.93	54.10	18.03	3.67	66.79	26.18
2/1/2002	6.65	1.63	0.54	0.11	5.12	58.48	19.37	3.95	71.75	28.13
2/2/2002	6.61	1.63	0.54	0.11	5.93	58.13	19.26	3.92	71.32	27.96
2/3/2002	6.59	1.63	0.54	0.11	5.93	57.95	19.20	3.91	71.11	27.87
2/4/2002	6.54	1.63	0.54	0.11	5.93	57.51	19.05	3.88	70.57	27.66
2/5/2002	6.48	1.63	0.54	0.11	5.93	56.98	18.88	3.85	69.92	27.41
2/6/2002	6.45	1.63	0.54	0.11	5.93	56.72	18.79	3.83	69.60	27.28
2/7/2002	28.02	1.22	0.85	0.14	9.17	184.42	128.49	21.16	302.34	118.52
2/8/2002	6.99	1.53	0.63	0.1	7.55	57.70	23.76	3.77	75.42	29.57
2/9/2002	6.25	1.62	0.55	0.11	5.93	54.62	18.55	3.71	67.44	26.44
2/10/2002	25.59	1.22	0.84	0.14	7.01	168.43	115.97	19.33	276.12	108.24
2/11/2002	6.69	1.52	0.63	0.1	8.09	54.86	22.74	3.61	72.19	28.30
2/12/2002	5.84	1.62	0.55	0.11	7.01	51.04	17.33	3.47	63.01	24.70
2/13/2002	5.67	1.62	0.54	0.11	8.09	49.56	16.52	3.36	61.18	23.98
2/14/2002	5.47	1.62	0.54	0.11	8.09	47.81	15.94	3.25	59.02	23.14
2/15/2002	5.24	1.62	0.54	0.11	7.55	45.80	15.27	3.11	56.54	22.16
2/16/2002	5.01	1.62	0.54	0.11	7.01	43.79	14.60	2.97	54.06	21.19

Table C.2 Crane Strand Drain Natural Daily BOD Simulation Summary

Date	STREAM FLOW		BOD				
	SWMM Simulated Flow (CFS)	Area:Ratio Relationship Utilizing Banner Dam Gage	Existing Conditions		Natural Background		Load at FLDEP Screening Level (BOD=2.0 mg/L)
			SWMM Simulated Concentration (mg/L)	SWMM Based Load (LBS/DAY)	SWMM Simulated Concentration (mg/L)	SWMM Based Load (LBS/DAY)	SWMM Simulated Screening Level Load (LBS/DAY)
1/1/2002	8.02	7.55	1.54	66.63	1.54	66.63	86.54
1/2/2002	42.44	28.04	6.67	1527.19	1.18	270.18	457.93
1/3/2002	9.27	19.41	3.4	170.04	1.50	75.02	100.02
1/4/2002	7.63	8.63	1.75	72.04	1.61	66.27	82.33
1/5/2002	7.56	7.01	1.62	66.07	1.61	65.67	81.57
1/6/2002	7.49	7.01	1.61	65.06	1.61	65.06	80.82
1/7/2002	7.44	7.01	1.61	64.62	1.61	64.62	80.28
1/8/2002	7.35	7.01	1.61	63.84	1.61	63.84	79.31
1/9/2002	7.29	7.01	1.61	63.32	1.61	63.32	78.66
1/10/2002	7.21	7.01	1.61	62.63	1.61	62.63	77.80
1/11/2002	7.13	7.01	1.61	61.93	1.61	61.93	76.93
1/12/2002	7.08	6.47	1.61	61.50	1.61	61.50	76.39
1/13/2002	7.02	6.47	1.62	61.35	1.62	61.35	75.75
1/14/2002	23.31	9.71	5.76	724.36	1.26	158.45	251.51
1/15/2002	7.79	15.64	3.11	130.70	1.52	63.88	84.05
1/16/2002	6.67	7.55	1.72	61.89	1.62	58.30	71.97
1/17/2002	6.57	7.01	1.62	57.42	1.62	57.42	70.89
1/18/2002	6.46	6.47	1.62	56.46	1.62	56.46	69.70
1/19/2002	6.43	5.93	1.62	56.20	1.62	56.20	69.38
1/20/2002	6.4	5.34	1.62	55.94	1.62	55.94	69.06
1/21/2002	6.4	5.93	1.62	55.94	1.62	55.94	69.06
1/22/2002	6.4	5.93	1.62	55.94	1.62	55.94	69.06
1/23/2002	6.37	5.93	1.62	55.67	1.62	55.67	68.73
1/24/2002	6.35	5.39	1.62	55.50	1.62	55.50	68.52
1/25/2002	6.33	5.39	1.62	55.32	1.62	55.32	68.30
1/26/2002	6.3	5.93	1.62	55.06	1.62	55.06	67.98
1/27/2002	6.28	5.93	1.62	54.89	1.62	54.89	67.76
1/28/2002	6.23	5.93	1.62	54.45	1.62	54.45	67.22
1/29/2002	6.2	5.93	1.62	54.19	1.62	54.19	66.90
1/30/2002	6.16	5.93	1.62	53.84	1.62	53.84	66.47
1/31/2002	6.19	5.93	1.62	54.10	1.62	54.10	66.79
2/1/2002	6.65	5.12	1.63	58.48	1.63	58.48	71.75
2/2/2002	6.61	5.93	1.63	58.13	1.63	58.13	71.32
2/3/2002	6.59	5.93	1.63	57.95	1.63	57.95	71.11
2/4/2002	6.54	5.93	1.63	57.51	1.63	57.51	70.57
2/5/2002	6.48	5.93	1.63	56.98	1.63	56.98	69.92
2/6/2002	6.45	5.93	1.63	56.72	1.63	56.72	69.60
2/7/2002	28.02	9.17	6.29	950.85	1.22	184.42	302.34
2/8/2002	6.99	7.55	2.97	112.00	1.53	57.70	75.42
2/9/2002	6.25	5.93	1.69	56.98	1.62	54.62	67.44
2/10/2002	25.59	7.01	6.17	851.82	1.22	168.43	276.12
2/11/2002	6.69	8.09	3.03	109.36	1.52	54.86	72.19
2/12/2002	5.84	7.01	1.7	53.56	1.62	51.04	63.01
2/13/2002	5.67	8.09	1.63	49.86	1.62	49.56	61.18
2/14/2002	5.47	8.09	1.62	47.81	1.62	47.81	59.02
2/15/2002	5.24	7.55	1.62	45.80	1.62	45.80	56.54
2/16/2002	5.01	7.01	1.62	43.79	1.62	43.79	54.06
2/17/2002	4.73	7.01	1.62	41.34	1.62	41.34	51.04
2/18/2002	4.45	7.01	1.62	38.89	1.62	38.89	48.02
2/19/2002	4.21	7.01	1.61	36.57	1.61	36.57	45.43
2/20/2002	4.11	4.10	1.61	35.70	1.61	35.70	44.35
2/21/2002	4.12	2.37	1.61	35.79	1.61	35.79	44.45
2/22/2002	46.58	22.65	7.29	1831.97	1.13	283.97	502.60
2/23/2002	108.35	42.60	7.66	4477.64	1.10	643.00	1169.10
2/24/2002	8.84	42.07	5.24	249.91	1.35	64.38	95.38
2/25/2002	5.29	25.89	2.12	60.50	1.60	45.66	57.08

Table C.3 Crane Strand Drain Daily Total Nitrogen Simulation Summary

Date	STREAM FLOW		TOTAL NITROGEN				
	SWMM Simulated Flow (CFS)	Area:Ratio Relationship Utilizing Banner Dam Gage	Existing Conditions		Natural Background		Critical TN Concentration Based on Regression Equation (TN=0.784 mg/L)
			SWMM Simulated Concentration (mg/L)	SWMM Based Load (LBS/DAY)	SWMM Simulated Concentration (mg/L)	SWMM Based Load (LBS/DAY)	SWMM Simulated Load (LBS/DAY) at Critical Total Nitrogen Concentration
1/1/2002	8.02	7.55	0.5	21.63	0.50	21.63	33.92
1/2/2002	42.44	28.04	1.57	375.50	0.87	199.20	179.51
1/3/2002	9.27	19.41	0.89	47.01	0.65	32.51	39.21
1/4/2002	7.63	8.63	0.57	23.05	0.54	22.23	32.27
1/5/2002	7.56	7.01	0.53	21.62	0.53	21.62	31.98
1/6/2002	7.49	7.01	0.53	21.42	0.53	21.42	31.68
1/7/2002	7.44	7.01	0.53	21.27	0.53	21.27	31.47
1/8/2002	7.35	7.01	0.53	21.02	0.53	21.02	31.09
1/9/2002	7.29	7.01	0.53	20.84	0.53	20.84	30.83
1/10/2002	7.21	7.01	0.53	20.62	0.53	20.62	30.50
1/11/2002	7.13	7.01	0.53	20.39	0.53	20.39	30.16
1/12/2002	7.08	6.47	0.53	20.24	0.53	20.24	29.95
1/13/2002	7.02	6.47	0.53	20.07	0.53	20.07	29.69
1/14/2002	23.31	9.71	1.38	181.09	0.81	101.86	98.59
1/15/2002	7.79	15.64	0.85	36.56	0.64	26.90	32.95
1/16/2002	6.67	7.55	0.56	20.15	0.54	19.43	28.21
1/17/2002	6.57	7.01	0.53	19.14	0.53	18.79	27.79
1/18/2002	6.46	6.47	0.53	18.47	0.53	18.47	27.32
1/19/2002	6.43	5.93	0.53	18.73	0.54	18.73	27.20
1/20/2002	6.4	5.34	0.53	18.65	0.54	18.65	27.07
1/21/2002	6.4	5.93	0.53	18.65	0.54	18.65	27.07
1/22/2002	6.4	5.93	0.54	18.65	0.54	18.65	27.07
1/23/2002	6.37	5.93	0.54	18.56	0.54	18.56	26.94
1/24/2002	6.35	5.39	0.54	18.50	0.54	18.50	26.86
1/25/2002	6.33	5.39	0.54	18.44	0.54	18.44	26.77
1/26/2002	6.3	5.93	0.54	18.35	0.54	18.35	26.65
1/27/2002	6.28	5.93	0.54	18.30	0.54	18.30	26.56
1/28/2002	6.23	5.93	0.54	18.15	0.54	18.15	26.35
1/29/2002	6.2	5.93	0.54	18.06	0.54	18.06	26.22
1/30/2002	6.16	5.93	0.54	17.95	0.54	17.95	26.05
1/31/2002	6.19	5.93	0.54	18.03	0.54	18.03	26.18
2/1/2002	6.65	5.12	0.54	19.37	0.54	19.37	28.13
2/2/2002	6.61	5.93	0.54	19.26	0.54	19.26	27.96
2/3/2002	6.59	5.93	0.54	19.20	0.54	19.20	27.87
2/4/2002	6.54	5.93	0.54	19.05	0.54	19.05	27.66
2/5/2002	6.48	5.93	0.54	18.88	0.54	18.88	27.41
2/6/2002	6.45	5.93	0.54	18.79	0.54	18.79	27.28
2/7/2002	28.02	9.17	1.49	234.31	0.85	128.49	118.52
2/8/2002	6.99	7.55	0.83	31.68	0.63	23.76	29.57
2/9/2002	6.25	5.93	0.56	18.88	0.55	18.55	26.44
2/10/2002	25.59	7.01	1.48	211.23	0.84	115.97	108.24
2/11/2002	6.69	8.09	0.85	31.04	0.63	22.74	28.30
2/12/2002	5.84	7.01	0.56	17.64	0.55	17.33	24.70
2/13/2002	5.67	8.09	0.54	16.52	0.54	16.52	23.98
2/14/2002	5.47	8.09	0.54	15.94	0.54	15.94	23.14
2/15/2002	5.24	7.55	0.54	15.27	0.54	15.27	22.16
2/16/2002	5.01	7.01	0.54	14.60	0.54	14.60	21.19
2/17/2002	4.73	7.01	0.54	13.78	0.54	13.78	20.01
2/18/2002	4.45	7.01	0.54	12.96	0.54	12.96	18.82
2/19/2002	4.21	7.01	0.54	12.26	0.54	12.26	17.81
2/20/2002	4.11	4.10	0.54	11.97	0.54	11.97	17.38
2/21/2002	4.12	2.37	0.54	12.00	0.54	12.00	17.43
2/22/2002	46.58	22.65	1.71	447.31	0.91	228.68	197.02
2/23/2002	108.35	42.60	1.8	1087.26	0.94	549.48	458.29
2/24/2002	8.84	42.07	1.26	64.38	0.78	37.20	37.39
2/25/2002	5.29	25.89	0.66	18.84	0.58	16.55	22.38
2/26/2002	5.47	19.95	0.55	16.23	0.55	16.23	23.14
2/27/2002	5.73	14.56	0.54	16.69	0.54	16.69	24.24
2/28/2002	6	11.86	0.54	17.48	0.54	17.48	25.38
3/1/2002	6.65	10.25	0.54	19.73	0.55	19.73	28.13
3/2/2002	6.79	9.17	0.54	20.15	0.55	20.15	28.72

Appendix D: General Input Data for the SWMM Crane Strand Drain Simulation

Crane Strand Drain SWMM Simulation

Crane Strand Drain SWMM Simulation
2002 through 2003 Orlando WSO Airport Gage

FLOW UNITS: *CFS*
INFILTRATION *GREEN AMPT*
FLOW ROUTING *IKINWAVE*
START DATE 01/01/2002
START TIME 00:00:00
REPORT START DATE 01/01/2002
REPORT START TIME 00:00:00
END DATE 12/31/2003
END TIME 23:00:00
SWEEP START 01/01
SWEEP END 10/31
DRY DAYS 5
WET STEP 00:10:00
DRY STEP 00:10:00
ROUTING STEP 00:05:00
REPORT STEP 24:00:00
ALLOW PONDING YES
INERTIAL DAMPING PARTIAL
VARIABLE STEP 0.75
LENGTHENING STEP 0
MIN SURFAREA 0
COMPATIBILITY 5
[EVAPORATION]
;;Type Parameters
MONTHLY .0748 .1022 .1325 .1663 .2158 .1525 .1782 .1624 .1420 .1159 .0843 .0640
[TEMPERATURE]
FILE "E: \Nat Documents\Weather Data\Weather Sites\ClimateAvalon6 .DAT"
WINDSPEED FILE
SNOWNELT 34 0.5 0.6 0.0 50.0 0.0
ADC IMPERVIOUS 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
ADC PERVIOUS 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
[RAINGAGES]
Rain Recd. Snow Data Source Station Rain
;;Name Type Freq. Catch Source Name ID Units
Gag1 VOLUME 24:00 1.0 FILE "E:\Nat Duur[[nts\Wath Data\Wath SiLs\OIlaIIdu1.daL

[SUBCATCHMENTS]

Total Pcnt. Pcnt. Curb Snow

;;**Name**	Raingage	Outlet	Area	Imperv	Width	Slope	Curb Length
S-D0l	Gagel	JNorth	237	27.7	150	.28	80434
S-D02	Gagel	J-2	166	31.15	93	0.18	52616
S-D03	Gagel	J-B1	142	35.84	275	0.18	44692
S-D04	Gagel	J-B2	120	31.23	311	0.28	40285
S-D05	Gagel	J-B3	134	42.8	132	0.28	40857
S-D06	Gagel	J-C3	60	31.92	194	0.28	20210
S-D07	Gagel	J-B4	141	38.64	255	0.28	46614
S-D08	Gagel	J-CRA	216	24.22	77	0.28	67414
5-D09	Gagel	J-1	182	11.43	318	0.1	5582
S-D10	Gagel	J-1	191	22.72	318	0.1	12985
S-D11	Gagel	J-B1	199	38.4	275	.18	65788
S-D12	Gagel	J-196	95	34.94	230	0.1	31892
S-D13	Gagel	J-196	239	34.32	230	0.28	73004
S-D14	Gagel	J-4	441	28.81	154	.28	134965
S-D15	Gagel	J-4	126	30.77	154	0.18	41434
S-D16	Gagel	J-394	98	38.44	130	0.36	21488
S-D17	Gagel	J-D1	360	42.26	632	0.36	90542
S-D18	Gagel	J-D2	224	32.56	255	0.36	76003
S-D19	Gagel	J-D1	509	36.39	632	0.36	141945
S-D20	Gagel	J-357	152	28.68	448	0.36	41921
S-D21	Gagel	J-393	178	23.47	244	0.36	31546
S-D22	Gagel	J-El	478	36.06	554	.36	114039.2
S-D23	Gagel	J-6	194	*2937*	344	0.36	337209

[SUBAREAS]

	Mannings		Storage			
;;Subcatchment	N-Imperv	N-Perv	S-Imperv	S-Perv	PctZero	Route To
S-D01	.01	.20	.022	.2	0	OUTLET
S-D02	0.01	0.1	0.05	.2	0	OUTLET
S-D03	0.01	0.1	0.05	.2	0	OUTLET
S-D04	0.01	0.1	0.05	.2	0	OUTLET
S-D05	0.01	0.1	0.05	.2	0	OUTLET
S-D06	0.01	0.1	0.05	.2	0	OUTLET
S-D07	0.01	0.1	0.05	.2	0	OUTLET
S-D08	0.01	0.1	0.05	.2	0	OUTLET
S-D09	0.01	0.1	0.05	.2	0	OUTLET
S-D10	0.01	0.1	0.05	.2	0	OUTLET
S-D11	.01	.20	.022	.2	0	OUTLET
S-D12	0.01	0.1	0.05	.2	0	OUTLET
S-D13	0.01	0.1	0.05	.2	0	OUTLET
S-D14	.01	.20	.022	.2	0	OUTLET
S-D15	0.01	0.1	0.05	.2	0	OUTLET
S-D16	0.01	0.1	0.05	.2	0	OUTLET
S-D17	0.01	0.1	0.05	.2	0	OUTLET
S-D18	0.01	0.1	0.05	.2	0	OUTLET
S-D19	0.01	0.1	0.05	.2	0	OUTLET
S-D20	0.01	0.1	0.05	.2	0	OUTLET
S-D21	0.01	0.1	0.05	.2	0	OUTLET
S-D22	.01	.20	.022	.2	0	OUTLET
S-D23	0.01	0.1	0.05	.2	0	OUTLET

[INFILTRATION]

;;Subcatchment	Suction Head	Saturated HydCon	IMDmax
S-D01	2.64	6.64	.312
S-D02	4.28	0.71	.312
S-D03	2.79	3.42	.312
S-D04	3.09	3.07	.312
S-D05	2.61	4.79	.312
S-D06	1.89	10.39	.312
S-D07	1.77	14.29	.312
S-D08	2.44	6.65	.312
S-D09	4.41	0.63	.312
S-D10	2.74	3.19	.312
S-D11	3.94	1.45	.312
S-D12	2.77	*4.55*	.312
S-D13	3.99	1.20	.312
S-D14	3.95	1.83	.312
S-D15	2.52	4.59	.312
S-D16	2.3	7.32	.312
S-D17	*3.36*	3.87	.312
S-D18	2.31	7.79	.312
S-D19	2.35	6.43	.312
S-D20	2.45	5.31	.312
S-D21	2.78	3.84	.312
S-D22	2.73	5.29	.312
S-D23	2.64	5.16	.312

[JUNCTIONS]
Invert Max. Init. Surcharge Ponded
;;Name Elev. Depth Depth Depth Area
J-1 80 4 0 0 0
J-2 79 10 0 0 0
J-3 78 10 0 0 0
J-4 77.5 10 0 0 0
J-5 77 15 0 0 0
J-6 65 15 0 0 0
J-7 45 4 0 0 0
J-CRA 80.5 4 0 0 0
J-196 77.8 4 0 0 0
J-394 75 4 0 0 0
J-357 70 4 0 0 0
J-393 65 4 0 0 0
J-E1 70 4 0 0 0
J-D1 85 4 0 0 0
J-B3 90 4 0 0 0
J-B2 89 4 0 0 0
J-B1 87 4 0 0 0
J-C2 95 4 0 0 0
JNorth 81.5 ***4*** 0 0 0
J-B4 95 4 0 0 0
J-C3 96 4 0 0 0
J-D2 90 4 0 0 0
OUT FALLS I
Invert Outfall Stage/Table Tide
;;Name Elev. Type Time Series Gate
Outl 44.5 NORMAL NO

[CONDUITS]
Inlet Outlet Manning Inlet Outlet Init.
;;Name Node Node Length N Height Height Flow
C-01 J-CRA J-1 771.72 0.03 0 0 2
C-02 J-1 J-2 3181.71 0.03 0 0 2
C-03 J-2 J-3 931 0.03 0 0 2
C-04 J-3 J-196 2319 0.03 0 0 2
C-OS J-4 J-5 1546 0.03 0 0 2
C-06 J-S J-394 1460 0.03 0 0 2
C-07 J-394 J-357 1300 0.03 0 0 2
C-08 J-357 J-393 4489 0.03 0 0 2
C-b J-6 J-7 3446 0.03 0 0 2
C-7 J-7 Outl 20 0.03 0 0 2
C11 J-196 J-4 2704 0.03 0 0 2

C-09 J-393 J-6 2440 0.03 0 0 2
C-07L J-D1 J-357 6327 0.015 0 0 2
C14 J-B3 J-B2 1320 0.015 0 0 2
C15 J-B2 J-B1 3115 0.015 0 0 2
C16 J-C2 J-B1 4532 0.015 0 0 2
C17 J-B1 J-3 2753 0.015 0 0 2
c-OqL J-E1 J-3q3 5540 0.015 0 0 2
CNorth JNorth J-CRA 1500 0.03 0 0 2
CHigh J-B4 J-B3 1500 0.015 0 0 2
C19 J-C3 J-C2 1942 0.015 0 0 2
C20 J-D2 J-D1 2557 0.015 0 0 2
[XSECT IONS]
;;Link Type Geoml Geom2 Geom3 Geom4 Barrels
C-01 TRAPEZOIDAL 10 10 2 2 1
C-02 TRAPEZOIDAL 10 10 2 2 1
C-03 TRAPEZOIDAL 10 10 2 2 1
C-04 TRAPEZOIDAL 10 10 2 2 1
C-05 TRAPEZOIDAL 10 10 2 2 1
C-06 TPAPEZOTDAT 10 *20 2 2* 1
C-07 TRAPEZOIDAL 10 20 2 2 1
C-08 TRAPEZOIDAL 10 20 2 2 1
C-10 TRAPEZOIDAL 10 20 2 2 1
C-7 TRAPEZOIDAL 10 20 2 2 1
C11 TRAPEZOIDAL 10 10 2 2 1
C-09 TRAPEZOIDAL 10 20 2 2 1
C-07L CIRCULAR 6 0 0 0 1
C14 CIRCULAR 6 0 0 0 1
C15 CIRCULAR 6 0 0 0 1
C16 CIRCULAR 6 0 0 0 1
C17 CIRCULAR 6 0 0 0 1
C-09L CIRCULAR 6 0 0 0 1
CNorth TRAPEZOIDAL 10 10 2 2 1
CHigh CIRCULAR 6 0 0 0 1
C19 CIRCULAR 6 0 0 0 1
C20 CIRCULAR 6 0 0 0 1

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