Evaluation of Alternative Stormwater Regulations for Southwest Florida

Final Report

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Prepared by:

ERD

Environmental Research & Design, Inc.

3419 Trentwood Blvd., Suite 101
Orlando, FL 32812

Harvey H. Harper, Ph.D., P.E.
David M. Baker, P.E.

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SECTION 1

INTRODUCTION

This document provides a summary of work efforts performed by Environmental Research & Design, Inc. (ERD) for the Water Enhancement and Restoration Coalition, Inc. (WERC) to evaluate and develop alternative stormwater treatment criteria for Southwest Florida. The alternative stormwater design criteria discussed in this report are designed to reduce post-development loadings of stormwater pollutants to values which are equal to or less than pollutant loadings generated from a development site under pre-development conditions. Alternative stormwater treatment criteria are developed for four common stormwater constituents, including total nitrogen, total phosphorus, biochemical oxygen demand (BOD), and total suspended solids (TSS).

The methodology used in this evaluation is based upon land use characterization and performance evaluation studies for stormwater treatment systems located in Central and South Florida, and to the extent possible, studies performed specifically in Southwest Florida. The data utilized in this report were obtained from studies and scientific literature prepared by the South Florida Water Management District (SFWMD), the Southwest Florida Water Management District (SWFWMD), the St. Johns River Water Management District (SJRWMD), the Florida Department of Environmental Protection (FDEP), the U.S. Geological Survey (USGS), the National Climatic Data Center (NCDC), Collier County, Lee County, Environmental Research & Design, and private consulting firms. The results and recommendations provided in this report are designed to be practical and scientifically defensible, while achieving the goal of no net increase in pollution for selected stormwater constituents under post-development conditions.

Estimation of rainfall characteristics, areas, and calculations of runoff volumes are performed using English units of measurement, such as inches, acres, and acre-feet (ac-ft). Calculations of mass are performed using metric units of kg due to the lack of a scientifically defensible English unit of mass.

SECTION 2

ESTIMATION OF PRE- AND POST-DEVELOPMENT LOADINGS

For purposes of this evaluation, both pre- and post-development loadings are calculated using the concentration-based method. This method is more accurate than the areal loading method since the concentration-based method considers site-specific hydrologic characteristics in estimation of pollutant loadings. Pre- and post-development loadings are calculated by generating estimates of runoff volumes and runoff characteristics for pre- and post-development conditions.

2.1 <u>Calculation of Runoff Volumes</u>

A methodology was developed to evaluate the annual runoff volume generated from a given parcel under both pre- and post-development conditions. This analysis is based upon an evaluation of runoff volumes generated by common rain events which occur in the vicinity of the project site during an average year. After reviewing the available meteorological records, Ft. Myers is the only major city in Southwest Florida which has sufficient long-term meteorological data for estimation of rainfall trends. Hourly meteorological data was obtained from the National Climatic Data Center (NCDC) for the Ft. Myers Meteorological Station from 1960-1993.

The continuous hourly rainfall record from Ft. Myers was scanned to determine the total rainfall depth for individual rain events occurring at the monitoring site. A rain event is defined as a period of continuous rainfall. For purposes of this analysis, rain events separated by less than three hours of dry conditions are considered to be one continuous event. Rain events separated by three hours or more of dry conditions are assumed to be separate events.

Rainfall events were divided into 19 rainfall event ranges which include 0.00-0.10 inches, 0.11-0.20 inches, 0.21-0.30 inches, 0.31-0.40 inches, 0.41-0.50 inches, 0.51-1.00 inch, 1.01-1.50 inches, 1.51-2.00 inches, 2.01-2.50 inches, 2.51-3.00 inches, 3.01-3.50 inches, 3.51-4.00 inches, 4.01-4.50 inches, 4.51-5.00 inches, 5.01-6.00 inches, 6.01-7.00 inches, 7.01-8.00 inches, 8.01-9.00 inches, and greater than 9 inches. For each rainfall event range, the mean depth of rain events within the interval was calculated. A probability distribution was performed on all rainfall events within each rainfall event range to determine the average number of rain events and the mean rainfall duration for each rainfall event range.

A summary of rain event characteristics used in the analysis is provided in Table 1. Of the 115 average annual rain events at the monitoring station, 84 events have rainfall amounts of 0.5 inches or less, 101 events have rainfall amounts of 1.00 inches or less, and 112 events have rainfall amounts of 2.00 inches or less. In addition to evaluating the historic rainfall data as previously described, simple statistics were performed on the rainfall data, as presented in Table 2. From 1960-1993, annual rainfall ranged from a minimum value of 32.83 inches to a maximum value of 71.94 inches with a mean value of 53.13 inches. Event duration ranged from a minimum value of 0.5 hours to a maximum value of 40.5 hours, with a mean value of 2.32 hours.

A statistical summary of seasonal rainfall characteristics measured in the Ft. Myers area from 1960-1993 is given in Table 3. For purposes of this analysis, the wet season is assumed to include the months of June through September, with the dry season extending from October to May. During an average year, a total of 35.23 inches of rainfall occurs during wet season conditions, with 17.90 inches of rainfall occurring during dry season conditions. The mean event rainfall depth during wet season conditions is approximately 0.50 inches, with a mean event rainfall depth of 0.40 inches during the dry season. Event durations are relatively similar between the two seasonal conditions, with a mean event duration of 2.19 hours under wet season conditions and 2.54 hours under dry season conditions. However, a substantial difference appears to exist in antecedent dry period conditions between the two seasons. During wet season conditions, mean antecedent dry period between rainfall events is approximately 1.66

TABLE 1

SUMMARY OF RAINFALL EVENT CHARACTERISTICS AT PAGE FIELD, FT. MYERS FROM 1/1/60 TO 12/31/93[1]

RAINFALL EVENT RANGE (inches)	RAINFALL INTERVAL POINT (inches)	MEAN RAINFALL DURATION (hours)	FRACTION OF ANNUAL RAIN EVENTS	NUMBER OF ANNUAL EVENTS IN RANGE
0.00-0.10	0.059	1.003	0.390	45.2
0.11-0.20	0.163	1.855	0.140	16.2
0.21-0.30	0.267	2.391	0.100	11.6
0.31-0.40	0.374	2.694	0.052	6.1
0.41-0.50	0.473	2.975	0.046	5.3
0.51-1.00	0.739	3.439	0.141	16.4
1.01-1.50	1.253	3.877	0.063	7.3
1.51-2.00	1.758	5.335	0.030	3.4
2.01-2.50	2.243	6.029	0.013	1.5
2.51-3.00	2.738	4.250	0.008	0.87
3.01-3.50	3.208	8.115	0.005	0.57
3.51-4.00	3.708	3.900	0.002	0.22
4.01-4.50	4.083	11.750	0.002	0.17
4.51-5.00	4.647	13.333	0.002	0.26
5.01-6.00	5.555	13.250	0.002	0.17
6.01-7.00	6.180	37.500	0.000	0.04
7.01-8.00	---	---	0.000	0.00
8.01-9.00	8.280	24.000	0.001	0.09
>9.00	10.150	34.500	0.000	0.04
			TOTAL	**115.4**

AVERAGE ANNUAL RAINFALL: **53.15 inches**

1. Not including years 1980-1984 and 1986-1992

TABLE 2

STATISTICAL SUMMARY OF RAINFALL EVENT CHARACTERISTICS AT PAGE FIELD, FT. MYERS FROM 1/1/60 TO 12/31/93[1]

PARAMETER	UNITS	MINIMUM VALUE	MAXIMUM VALUE	MEAN VALUE	ONE STANDARD DEVIATION
Annual Rainfall	Inches	32.83	71.94	53.13	8.68
Event Duration	Hours	0.5	40.5	2.32	2.86
Ant. Dry Period	Days	0.17	52.4	3.06	4.86

1. Not including years 1980-1984 and 1986-1992

TABLE 3

STATISTICAL SUMMARY OF SEASONAL RAINFALL CHARACTERISTICS AT PAGE FIELD, FT. MYERS FROM 1/1/60 TO 12/31/93[1]

PARAMETER	UNITS	MINIMUM VALUE	MAXIMUM VALUE	MEAN VALUE	ONE STANDARD DEVIATION
A. Dry Season					
Season Rainfall	Inches	6.25	33.52	17.90	6.48
Event Rainfall	Inches	0.01	5.68	0.40	0.64
Event Duration	Hours	0.50	21.50	2.54	2.95
Ant. Dry Period	Days	0.17	52.42	5.31	6.91
B. Wet Season					
Season Rainfall	Inches	20.57	46.58	35.23	6.77
Event Rainfall	Inches	0.01	10.15	0.50	0.76
Event Duration	Hours	0.50	40.50	2.19	2.80
Ant. Dry Period	Days	0.17	23.00	1.66	1.87

1. Not including years 1980-1984 and 1986-1992

days (40 hours). However, during dry season conditions, the mean antecedent dry period between rain events is approximately 5.31 days (127 hours).

Estimates of annual runoff coefficients (C value) were generated for a wide variety of combinations of directly connected impervious area (DCIA) and non-DCIA curve numbers. An impervious area is considered connected if runoff from it flows directly into the drainage system. It is also considered directly connected if runoff from it occurs as concentrated shallow flow that runs over a pervious area, such as a roadside swale, and then into a drainage system. Non-DCIA areas include all pervious areas and portions of impervious areas not considered to be directly connected.

Runoff calculations were performed for combinations of DCIA values ranging from 0-100%, in 5% increments, and for non-DCIA curve numbers ranging from 25-95, in 5 unit increments. Non-DCIA curve numbers of 96, 97, and 98 were also included in the analysis. For each combination of DCIA and non-DCIA curve number, the estimated annual runoff coefficient was calculated by estimating the annual runoff volume generated by the typical annual storm events summarized in Table 1.

The runoff volume for each rainfall interval is calculated by adding the rainfall excess from the non-DCIA portion for each DCIA and curve number combination to the rainfall excess created from the DCIA portion of the same combination. Rainfall excess from the non-DCIA areas is calculated using the following set of equations:

$$nDCIA\ \ CN = \frac{CN * (100 - Imp) + 98\ (Imp - DCIA)}{(100 - DCIA)}$$

$$Soil\ \ Storage,\ S = \left(\frac{1000}{nDCIA\ \ CN} - 10 \right)$$

$$Q_{nDCIA_i} = \frac{(P_i - 0.2S)^2}{(P_i + 0.8S)}$$

where:

CN	=	curve number for pervious area
Imp	=	percent impervious area
$DCIA$	=	percent directly connected impervious area
$nDCIA\ CN$	=	curve number for non-DCIA area
P_i	=	median rainfall for rainfall event interval (i)
Q_{nDCIAi}	=	rainfall excess for non-DCIA for rainfall event interval (i)

For rainfall events where P_i is less than 0.10, the rainfall excess (Q_{nDCIAi}) is assumed to be zero. For the DCIA portion, rainfall excess is calculated using the following equation:

$$Q_{DCIA_i} = (P_i - 0.1)$$

When P_i is less than 0.1, Q_{DCIAi} is equal to zero.

The total volume for a rainfall event interval is calculated using the following equation:

$$RO_i = \left[[Q_{nDCIAi} \ x \ A \ x \ (100 - DCIA)] + [Q_{DCIAi} \ x \ A \ x \ DCIA] \right] x \ \frac{1}{12} \ x \ \frac{1}{100} \ x \ N$$

where:

A	=	area for specific land use-HSG (ac)
RO_i	=	runoff volume for rainfall interval (i)
N	=	number of annual runoff events in interval (i)

The sum of all the runoff volumes (RO_i) for each rainfall event interval is the total annual rainfall volume for a given DCIA and curve number combination. The weighted basin "C" value is calculated using the following equation:

$$C\ \ Value\ =\ \frac{Generated\ \ Runoff\ \ Volume\ (ac\text{ - }ft/yr)}{Area\ \ x\ Total\ \ Annual\ \ Rainfall\ (inches)}\ \ x\ \ \frac{12\ \ inches}{1\ \ ft}$$

The average total annual rainfall for Ft. Myers from 1960-1993 is 53.15 inches. The process summarized above is repeated for each of the 378 combinations of DCIA and curve number.

A summary of calculated runoff coefficients, as a function of curve number and DCIA, for Southwest Florida conditions is given in Table 4 based upon the methodology outlined previously. The estimated annual runoff volume for a given parcel under either pre- or post-development conditions is calculated by multiplying the mean annual rainfall depth for the given area times the appropriate runoff coefficient based upon DCIA and curve number characteristics for the parcel under the evaluated development option, as follows:

$$Annual\ Runoff\ Volume\ \ (ac\text{-}ft) =$$

$$Area\ \ (acres)\ \ x\ \ Mean\ \ Annual\ \ Rainfall\ \ (inches)\ \ x\ \ C\ Value\ \ x\ \ \frac{1\ \ ft}{12\ \ in}$$

Linear interpolation can be used to estimate curve numbers for specific combinations of DCIA and curve number not provided in Table 4.

2.2 Evaluation of Runoff Characteristics

A survey was performed to develop typical runoff characteristics for common pre- and post-development land use categories in the Southwest Florida area. Pre-development land use categories include agricultural areas (pasture, citrus, and row crops), open space/ undeveloped/rangeland/ forests, mining areas, wetlands, and open water/lake. Post-development runoff characteristics were developed for low-density residential, single-family residential, multi-family residential, low-intensity commercial, high-intensity commercial, industrial, and highway land uses.

Table 4

Calculated Annual Runoff Coefficients as a Function of Curve Number and DCIA for Southwest Florida Conditions

DCIA	Non DCIA Curve Number																	
	25	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**96**	**97**	**98**
0	0.001	0.002	0.004	0.007	0.011	0.018	0.026	0.039	0.056	0.080	0.113	0.160	0.229	0.332	0.506	0.557	0.618	0.692
5	0.040	0.041	0.043	0.045	0.050	0.056	0.064	0.076	0.092	0.115	0.146	0.191	0.256	0.355	0.520	0.569	0.626	0.697
10	0.079	0.080	0.082	0.084	0.088	0.094	0.102	0.113	0.129	0.150	0.180	0.222	0.284	0.377	0.534	0.580	0.634	0.701
15	0.118	0.119	0.120	0.123	0.127	0.132	0.140	0.150	0.165	0.186	0.213	0.253	0.312	0.400	0.548	0.591	0.642	0.706
20	0.157	0.158	0.159	0.162	0.165	0.170	0.178	0.188	0.201	0.221	0.247	0.284	0.339	0.422	0.561	0.602	0.651	0.710
25	0.196	0.197	0.198	0.201	0.204	0.209	0.215	0.225	0.238	0.256	0.280	0.316	0.367	0.445	0.575	0.614	0.659	0.715
30	0.235	0.236	0.237	0.239	0.242	0.247	0.253	0.262	0.274	0.291	0.314	0.347	0.395	0.467	0.589	0.625	0.667	0.719
35	0.274	0.275	0.276	0.278	0.281	0.285	0.291	0.299	0.310	0.326	0.347	0.378	0.422	0.490	0.603	0.636	0.675	0.724
40	0.313	0.314	0.315	0.317	0.320	0.323	0.329	0.336	0.346	0.361	0.380	0.409	0.450	0.512	0.617	0.647	0.683	0.728
45	0.352	0.353	0.354	0.356	0.358	0.362	0.366	0.373	0.383	0.396	0.414	0.440	0.478	0.535	0.630	0.658	0.692	0.733
50	0.391	0.392	0.393	0.394	0.397	0.400	0.404	0.410	0.419	0.431	0.447	0.471	0.505	0.557	0.644	0.670	0.700	0.737
55	0.430	0.431	0.432	0.433	0.435	0.438	0.442	0.448	0.455	0.466	0.481	0.502	0.533	0.580	0.658	0.681	0.708	0.742
60	0.469	0.470	0.471	0.472	0.474	0.476	0.480	0.485	0.492	0.501	0.514	0.533	0.561	0.602	0.672	0.692	0.716	0.746
65	0.509	0.509	0.510	0.511	0.512	0.514	0.518	0.522	0.528	0.536	0.548	0.564	0.588	0.625	0.685	0.703	0.725	0.751
70	0.548	0.548	0.549	0.549	0.551	0.553	0.555	0.559	0.564	0.571	0.581	0.595	0.616	0.647	0.699	0.715	0.733	0.755
75	0.587	0.587	0.587	0.588	0.589	0.591	0.593	0.596	0.601	0.607	0.615	0.627	0.644	0.670	0.713	0.726	0.741	0.760
80	0.626	0.626	0.626	0.627	0.628	0.629	0.631	0.633	0.637	0.642	0.648	0.658	0.671	0.692	0.727	0.737	0.749	0.764
85	0.665	0.665	0.665	0.666	0.666	0.667	0.669	0.671	0.673	0.677	0.682	0.689	0.699	0.715	0.741	0.748	0.757	0.769
90	0.704	0.704	0.704	0.704	0.705	0.706	0.706	0.708	0.709	0.712	0.715	0.720	0.727	0.737	0.754	0.760	0.766	0.773
95	0.743	0.743	0.743	0.743	0.743	0.744	0.744	0.745	0.746	0.747	0.749	0.751	0.754	0.760	0.768	0.771	0.774	0.778
100	0.782	0.782	0.782	0.782	0.782	0.782	0.782	0.782	0.782	0.782	0.782	0.782	0.782	0.782	0.782	0.782	0.782	0.782

Basic information for many of the evaluated land uses was obtained from the document by Harper (1994) titled "Stormwater Loading Rate Parameters for Central and South Florida". This report presents the results of an extensive literature search and analysis of runoff characteristics for selected parameters and land use types within Central and South Florida. The runoff characteristics provided in this document include publications and studies conducted specifically within Central and South Florida by a variety of state, federal, and local governments, along with private consultants. Each study was reviewed for adequacy of the database, with special attention to factors such as length of study, number of runoff events monitored, monitoring methodology, as well as completeness and accuracy of the work.

The Harper (1994) report includes all stormwater characterization studies performed in Central and South Florida prior to the early 1990s. However, a limited number of additional runoff characterization studies have been performed since the last publication date for this report. Therefore, a supplemental literature search was performed by ERD to identify additional resources for characterization data. Additional land use characterization studies were obtained for single-family residential areas, low-intensity commercial, highway/transportation land use, agriculture-citrus, agriculture-row crop, and open space/undeveloped/rangeland/forest areas. Additional land use characterization data for residential, low-intensity commercial, and open space/undeveloped/rangeland/forest areas was obtained from ongoing work efforts by ERD within Sarasota and Charlotte Counties. A complete listing of literature-based hydrologic and stormwater characteristics for low-density residential, single-family residential, multi-family residential, low-intensity commercial, high-intensity commercial, industrial, highway, agriculture-pasture, agriculture-citrus, and agriculture-row crops is given in Appendix A.

Information on the ambient characteristics of wetland systems was obtained from monitoring data collected specifically in Lee and Collier Counties by Lee County and SFWMD from 1995-2003. During this time, continuous monitoring was performed by the two agencies at 19 separate wetland monitoring stations, with multiple measurements collected at each site during each year of the monitoring program. The monitoring data includes a variety of palustrine wetlands with various degrees of impact. Palustrine wetlands include all non-tidal wetlands dominated by trees, shrubs, persistent emergent species, mosses, or lichens. Mean values for each of the 19 wetland monitoring sites is given in Table 5. In general, measured concentrations for the evaluated parameters appear to be relatively consistent between the measured wetland systems. If available, site-specific water quality data for wetlands within a particular project area should be used. However, in the absence of site-specific data, the overall mean values presented at the bottom of Table 5 should be used as estimates of pre-development wetland characteristics for loading evaluation purposes.

Estimates of the chemical characteristics of open water/lakes in Lee and Collier Counties were obtained from the same database which was utilized for estimation of wetland characteristics. Data for open water monitoring stations collected by FDEP, Collier County, and LAKEWATCH from 1995-2003 were summarized, with mean values calculated for each site which was part of the monitoring program. A summary of the results of this data search is given in Table 6. The data include a wide range of water quality characteristics, ranging from mesotrophic to hypereutrophic. If available, site-specific water quality data for waterbodies in a particular project area should be used. However, in the absence of site-specific data, the mean values summarized at the bottom of Table 6 can be used as estimates of ambient characteristics of open water/lakes to be used in generation of pollutant loadings for this particular land use category.

A summary of overall literature-based runoff concentrations for selected land use categories in Southwest Florida is given in Table 7. The values presented in this table reflect the summary values provided in Appendix A and Tables 5 and 6. These values are recommended as estimates of pre- and post-development runoff characteristics for the identified land use categories in Southwest Florida whenever site-specific land use characterization data is unavailable for a given land use category.

Table 5

Summary of Wetland Monitoring Data for Lee and Collier Counties
From 1995 - 2003 (Source: USEPA Storet Data)

Station Name	Wetland Type	Cadmium (µg/l)	Copper (µg/l)	Lead (µg/)	Zinc (µg/l)	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)	BOD (mg/l)	TSS (mg/l)
DEEP LAGOON- Gladiolus, W. of A&W Bulb Rd.	Palustrine, emergent		1.22	0.64	11.70	1.30	0.24	3.04	10.81
DEEP LAGOON- Summerlin W. of Bass RD.	Palustrine, emergent		1.51	0.77	10.29	1.45	0.25	4.15	28.17
SIX MILE CYPRESS- Daniels Rd.	Palustrine, emergent		0.79	0.75	7.79	0.79	0.11	2.12	7.10
SIX MILE CYPRESS- Daniels Pkwy near "Sunharvest"	Palustrine, emergent		1.43	0.60	7.47	0.84	0.10	2.98	6.52
SIX MILE CYPRESS- Buckingham Rd.	Palustrine, forested		0.76	1.61	29.37	1.17	0.15	3.71	14.63
SIX MILE CYPRESS- I-75	Palustrine, moss-lichen		1.50	0.81	11.23	1.08	0.14	3.22	17.59
SIX MILE CYPRESS- Six Mile Slough	Palustrine, moss-lichen		0.79	0.88	7.56	0.76	0.10	2.16	12.62
ESTERO RIVER- Three Oaks Blvd.	Palustrine, shrub-scrub		0.80	0.62	7.03	0.61	0.09	1.66	5.08
GATOR SLOUGH- I-75	Palustrine, shrub-scrub		1.65	0.63	6.94	0.89	0.13	1.84	6.05
IMPERIAL RIVER- Corkscrew Rd.	Palustrine, shrub-scrub		1.64	0.68	0.01	0.88	0.16	1.40	3.45
KISSIMMEE BILLY STRAND	Palustrine, emergent		1.85		0.00	0.83	0.02		
MULLET SLOUGH	Palustrine, emergent	0.05	0.20		0.92	0.82	0.01		
DEEP LAKE	Palustrine, emergent		1.18			0.52	0.01		
QUAKENHASSEE	Palustrine, emergent				1.96	0.86	0.01		
WEST MUD LAKE	Palustrine, emergent		1.01		2.54	0.84	0.01		
LITTLE MARSK	Palustrine, emergent		1.46	0.19	0.90	2.05	0.04		
COWBELL STRAND	Palustrine, emergent		1.79	0.17	11.66	1.63	0.05		
EAST HINSON MARSH	Palustrine, emergent		0.55		0.84	1.26	0.03		
MONUMENT ROAD	Palustrine, emergent	0.04	2.11		0.66	0.59	0.01		
	Mean	**0.04**	**1.23**	**0.70**	**6.60**	**1.01**	**0.09**	**2.63**	**11.20**

TABLE 6

SUMMARY OF LAKE / OPEN WATER MONITORING DATA FOR LEE AND COLLIER COUNTIES FROM 1995 – 2003

STATION ID	PARAMETER				REFERENCE
	TOTAL N	TOTAL P	BOD	TSS	
28030069FTM	1.10	0.048	--	--	Fla. Dept. of Environmental Protection, South District
Lake Trafford	2.70	0.18	5.80	16.07	Collier County Pollution Control
Lucky Lake	1.10	0.023	--	7.5	Collier County Pollution Control
Millexpo	0.64	0.212	--	27.3	Collier County Pollution Control
Longshore	0.71	0.025	--	--	Lakewatch
East Rocks	2.33	0.049	--	--	Lakewatch
East Rocks West	1.90	0.053	--	--	Lakewatch
Gulf Pines	1.74	0.095	--	--	Lakewatch
Gulf Shores	1.85	0.063	--	--	Lakewatch
Gumbo Limbo	1.19	0.069	--	--	Lakewatch
Lady Finger	2.63	0.038	--	--	Lakewatch
Little Murex	2.06	0.025	--	--	Lakewatch
Little Portion	0.99	0.029	--	--	Lakewatch
Ruseate	1.79	0.052	--	--	Lakewatch
Sea Oats	1.81	0.039	--	--	Lakewatch
St. Kilda	1.23	0.043	--	--	Lakewatch
Venus	2.32	0.055	--	--	Lakewatch
West Rocks	1.59	0.050	--	--	Lakewatch
Gladiolus East	0.71	0.115	2.40	8.7	Lee County

MEAN	**1.60**	**0.067**	**4.10**	**14.87**

TABLE 7

SUMMARY OF LITERATURE-BASED RUNOFF CONCENTRATIONS FOR SELECTED LAND USE CATEGORIES IN SOUTHWEST FLORIDA

LAND USE CATEGORY	TYPICAL RUNOFF CONCENTRATION (mg/l)							PERCENT IMPERVIOUS (%)
	TOTAL N	TOTAL P	BOD	TSS	COPPER	LEAD	ZINC	
1. Low-Density Residential[1]	1.64	0.191	4.3	16.9	0.012	0.022	0.040	14.7
2. Single-Family	2.18	0.335	7.4	26.0	0.023	0.039	0.073	28.1
3. Multi-Family	2.42	0.49	11.0	71.7	0.031	0.087	0.055	67.0
4. Low-Intensity Commercial	1.12	0.18	7.4	72.8	0.023	0.136	0.111	91.0
5. High-Intensity Commercial	2.83	0.43	17.2	94.3	--	0.214	0.170	97.5
6. Industrial	1.79	0.31	9.6	93.9	--	0.202	0.122	86.8
7. Highway	2.23	0.27	6.7	49.1	0.040	0.211	0.167	76.6
8. Agricultural								
a. Pasture	2.48	0.476	5.1	94.3	--	--	--	0.00
b. Citrus	2.24	0.183	2.55	15.5	0.003	0.001	0.012	0.00
c. Row Crops	2.88	0.638	--	20.4	0.054	0.009	0.041	0.00
d. General Agriculture	2.32	0.344	3.8	55.3	--	--	--	0.00
9. Undeveloped Rangeland/Forest	1.09	0.046	1.23	7.8	--	0.005[2]	0.006[2]	1.50
10. Mining	1.18	0.15	9.6[4]	93.9[4]	--	0.202[4]	0.122[4]	23.0
11. Wetland	1.01	0.09	2.63	11.2	0.001	0.001	0.006	0.00
12. Open Water/Lake	1.60	0.067	1.6	3.1		0.025[2]	0.028	100

1. Average of single-family and recreational/open space loading rates
2. Runoff concentrations assumed equal to wetland values for these parameters
3. Orthophosphorus concentrations assumed to equal 50% of average total phosphorus
4. Runoff concentrations assumed equal to industrial values for these parameters

2.3 Estimation of Pre- and Post-Development Loadings

Both pre- and post-development loadings are calculated using the concentration-based methodology. The annual runoff volume for each pre- and post-development land use is estimated using the methodology outlined in Section 2.1. The runoff volume is then multiplied times the estimated chemical characteristics of the selected runoff constituent in each land use category. The computational formula for these calculations is summarized below:

$$Load\ (kg/yr) =$$

$$\frac{\overset{i=1}{\Sigma}}{n} \left[(A_i)\ x\ \frac{43{,}560\ ft^2}{acre}\ x\ R\ x\ CV_i\ x\ \frac{1\ ft}{12\ inches}\ x\ \frac{7.48\ gal}{ft^3}\ x\ \frac{3.785\ liter}{gal}\ x\ C_i\ x\ \frac{1\ kg}{10^6\ mg} \right]$$

where:

A_i	=	area of land use category, i (acres)
n	=	number of different land use categories
C_i	=	concentration of selected runoff constituent in land use category, i (mg/l)
R	=	annual rainfall at site (inches/yr)
CV_i	=	runoff "C" value for land use category i (dimensionless)

The concentration-based methodology is utilized since it incorporates site-specific hydrologic characteristics for each evaluated site. This technique is thought to be substantially more accurate than the areal loading methodology which assumes that the hydrologic characteristics are identical throughout a given land use category.

After estimation of pre- and post-development loadings, the required removal efficiency to achieve no net increase in pollutant loading for a given runoff constituent following development is calculated utilizing the following equation:

$$\text{Required Removal Efficiency (\%)} = \left[\frac{\text{Post-Dev. Load} - \text{Pre-Dev. Load}}{\text{Post-Dev. Load}} \right] x\ 100$$

The removal efficiency calculated utilizing this procedure is then used to select the required stormwater treatment options which will achieve the desired goal of no net increase in pollutant loadings for the evaluated constituent.

SECTION 3

STORMWATER TREATMENT OPTIONS

3.1 Evaluation of Potential Treatment Options

A general literature review was conducted of previous research performed within the State of Florida which quantifies pollutant removal efficiencies associated with various stormwater management systems. Much of this research had previously been summarized by Harper (1995) in the publication titled "Pollutant Removal Efficiencies for Typical Stormwater Management Systems in Florida". The ASCE National Database was also surveyed to include additional studies not available at the time of the Harper (1995) publication. Comparative removal efficiency data was obtained for dry retention, wet retention, off-line retention/detention systems, wet detention, wet detention with filtration, dry detention, and dry detention with filtration. Estimated pollutant removal efficiencies were generally available for total nitrogen, total phosphorus, TSS, BOD, copper, lead, and zinc.

To achieve the goal of no net increase in loadings under post-development conditions, pollutant removal efficiencies from 60% to more than 95% may be required for a selected runoff constituent. Based upon the literature review, only two common stormwater management systems appear to be capable of consistently achieving pollutant removal efficiencies within this range. These stormwater management systems include dry retention, which disposes of stormwater runoff by evaporation and infiltration into the ground in such a manner to prevent direct discharge of stormwater runoff into receiving waters, and wet detention, which acts similar to a natural lake system. As a result, the treatment options discussed in following sections are limited to dry retention and wet detention systems only.

3.2 Performance Efficiencies of Selected Treatment Options

The performance efficiencies of dry retention and wet detention systems were evaluated under a wide range of operational conditions. The purpose of these evaluations was to develop a generalized methodology for evaluating the removal efficiencies achieved by these systems for typical stormwater constituents as a function of runoff volume treated or residence time. The results of these analyses are outlined in the following sections.

Estimated performance efficiencies were calculated for both dry retention and wet detention stormwater management systems under a variety of design options. Each of the performance evaluations for the two stormwater management systems is based upon common assumptions used during the evaluation process. A summary of these assumptions is given below:

1. Watershed areas contributing to each stormwater management facility do not exhibit first-flush effects with respect to runoff concentrations. Although small, highly impervious watershed areas, typically less than 5-10 acres in size, may exhibit first- flush effects under certain conditions, there is no scientific evidence to indicate that larger sub-basin areas exhibit a first-flush effect on a continuous basis. Therefore, the analyses presented in this report may be somewhat conservative for small basins which exhibit a first-flush effect.

2. The stated treatment volume is fully recovered prior to the next storm event.

3. Pollutant loads from various runoff depths are constant throughout the year.

4. Pollutant removal efficiencies for runoff constituents are constant throughout the year.

A summary of estimated performance efficiencies for dry retention and wet detention stormwater management systems under a variety of design conditions is given in the following sections.

3.2.1 Dry Retention Systems

Dry retention systems consist primarily of infiltration basins which are used to retain stormwater runoff on-site, thus reducing discharge to downstream waterbodies. Disposal of stormwater runoff occurs by infiltration into the groundwater and evaporation from the water surface. Because these systems rely primarily on infiltration of stormwater into the ground to regain the available pond storage, construction of these systems is limited to areas with low groundwater tables and high permeability soils. The soil and water table conditions must be such that the system can provide for a new volume of storage through percolation or evaporation within a maximum of 72 hours following the stormwater event. Certification by a registered geotechnical engineer or hydrogeologist is typically required to verify that the pond design will meet the minimum drawdown requirements.

A schematic diagram of a typical dry retention system is given in Figure 1. This system is constructed as a dry pond with the pond bottom constructed a minimum of 1-3 ft above the seasonal high groundwater table elevation. The pond is typically designed to hold a volume of stormwater, called the "treatment volume", which is equivalent to a certain depth of runoff over the contributing watershed area. Dry retention ponds may be constructed as either on-line or off-line systems. Off-line systems typically provide storage for the treatment volume only. In on-line systems, an additional volume may be provided above the initial treatment volume for peak attenuation of on-site discharges during major (10-year, 25-year, or 100-year) storm events.

Although retention ponds are most commonly constructed as basins similar to Figure 1, retention systems may also be constructed which combine other uses in addition to stormwater control. Retention ponds can be constructed as depressional areas along road right-of-way, within the median strips in parking lots, within recreational sites such as playgrounds or athletic fields, within natural depressional areas, in open land or as part of the landscaping for a commercial site, or as a shallow swale. Dual use of facilities provides a method for conserving valuable land resources while incorporating stormwater management systems into the on-site landscape.

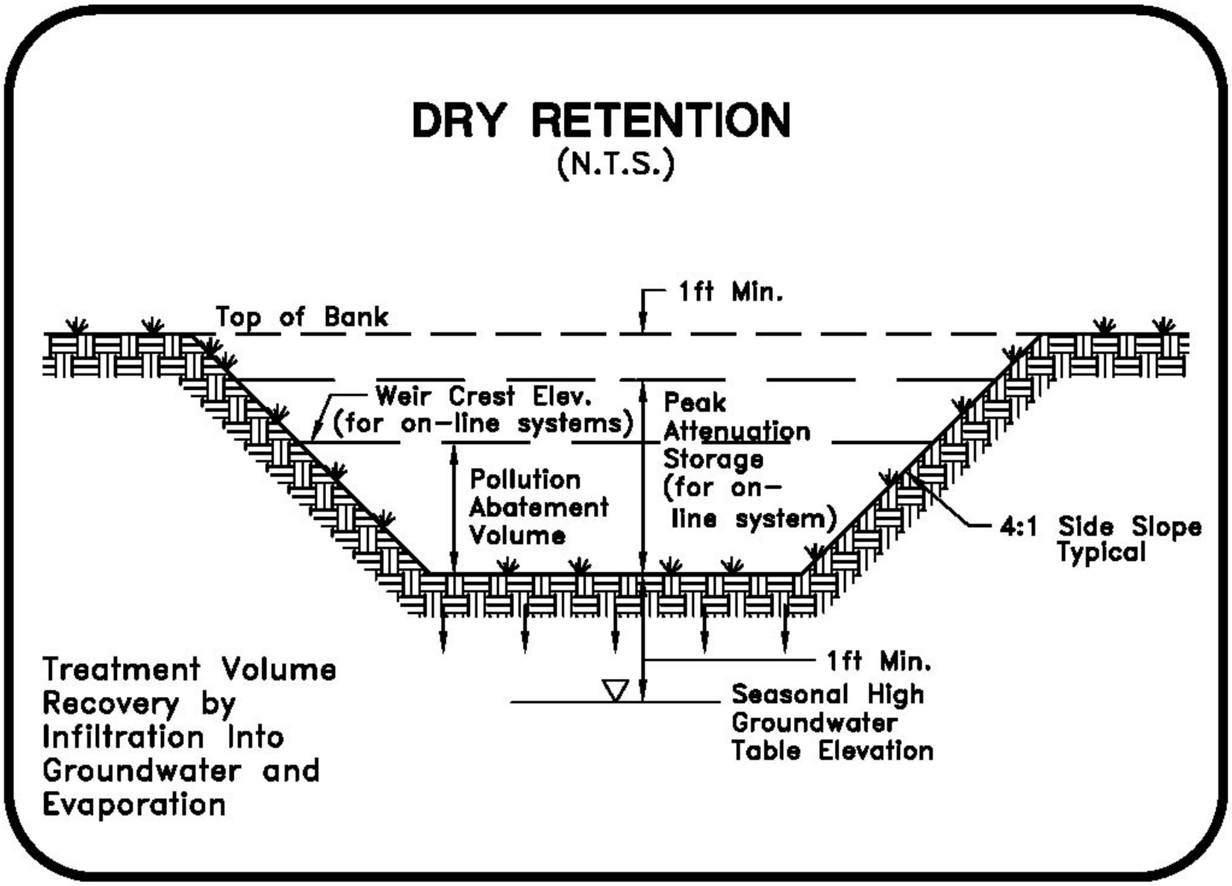


Figure 1. Schematic of a Dry Retention Facility.

As the stormwater runoff percolates through the soil, a variety of physical, chemical, and biological processes occur which retain a majority of the stormwater pollutants in the upper layers of the soil within the retention basin (Harper, 1985; Harper, 1988). Previous research conducted by Harper (1985, 1988) has indicated that stormwater pollutants are trapped in relatively stable associations in the upper 4 inches of soil within retention basins. Concentrations of nutrients and heavy metals in groundwater beneath dry retention basins are typically lower in value than measured in stormwater runoff entering the retention system.

Even though dry retention systems prevent direct discharge of stormwater runoff to receiving waterbodies, care must be taken in the design of retention facilities to ensure that significant underground migration of pollutants does not occur to adjacent surface waters. A substantial quantity of pollutant loadings may still reach adjacent receiving waters when retention systems are constructed immediately adjacent to the shoreline. Lateral distances between retention ponds and surface water should be maintained as large as possible, at least 100 ft or more, depending on the site conditions (FDEP, 1988).

The side slopes and bottoms of dry retention basins should be fully vegetated with sod cover. Vegetation plays a crucial role in the removal of contaminants from stormwater, in stabilization of the soil, and in maintaining soil permeability. Bahia grass is typically used for sod cover since it is drought resistant and can withstand periodic inundation.

Since runoff concentrations are assumed to be constant from rain event to rain event, the calculated performance efficiency of a dry retention stormwater management system is based entirely upon the percentage of water retained during each storm event. For a dry retention system, it is assumed that a pollutant removal efficiency of 100% is achieved for the entire treatment volume retained within the system. As a result, removal efficiencies of 100% are achieved for all rainfall events which generate runoff volumes less than or equal to the design treatment volume for the pond. Removal efficiencies for rainfall events which generate runoff in excess of the treatment volume are assumed to be 100% for all generated runoff up to the treatment volume, with a removal efficiency of 0% for runoff inputs which enter the pond in excess of the treatment volume. This analysis may be slightly conservative for rain events which generate runoff in excess of the required treatment volume, since settling of discrete particles would occur as the runoff inputs are detained within the pond prior to ultimate discharge.

Pollutant removal efficiencies were calculated for selected dry retention treatment volumes for each of the combinations of DCIA and non-DCIA curve number given in Table 4 based upon the assumptions outlined in the previous paragraphs. Removal efficiencies were calculated for retention treatment volumes ranging from 0.25-inch to 4.0-inch of runoff in

0.25-inch increments. The results of these analyses are summarized in Appendix B. In general, the removal efficiency increases as the retention treatment volume increases. Also, treatment efficiency decreases as the DCIA and non-DCIA curve number increases. Removal efficiencies summarized in these tables are valid for all stormwater constituents since the efficiencies are based upon total retention of a specific runoff volume within the pond. As a result, the stated removal efficiencies are assumed to be valid for all stormwater constituents, including total nitrogen, total phosphorus, TSS, and BOD.

To determine the required retention volume for a given project, the specific combination of DCIA and non-DCIA curve number is evaluated for the project under post-development conditions. The tables in Appendix B are then scanned to determine which retention depth is required to achieve the desired pollutant removal efficiency for the specific combination of DCIA and curve number for the given project. This methodology can be used if retention is selected as the sole method of stormwater treatment or if retention is selected as part of a treatment train.

To achieve the desired goal of no net increase in pollutant loadings under post-development conditions, a retention pond must be capable of providing adequate levels of stormwater treatment under a wide range of operating conditions. The most significant factor regulating the performance efficiency of a dry retention basin is the stored treatment volume and the ability of the pond to recover the treatment volume between storm events. As seen in Table 3, the mean antecedent dry period between rain events under dry season conditions is approximately 5.31 days, However, under wet season conditions, the mean antecedent dry period between rain events decreases to approximately 1.66 days (40 hours). In order for a dry retention pond to achieve the target removal efficiencies, the stored treatment volume must be evacuated within a minimum of 40 hours, reflecting the mean antecedent dry period under wet season conditions.

A summary of recommended design criteria for dry retention ponds is given in Table 8. Recovery of the required treatment volume must be achieved within 40 hours or less. Ability of the pond to achieve this recovery rate must be certified by a registered geotechnical engineer. All side slopes and bottom areas of the pond must be sodded with water-tolerant grass species. Inlets and outlets must be located as far apart as possible to prevent short-circuiting. Oil and grease skimmers must be provided at all outfall structures. Other requirements related to side slopes, fencing, maintenance berms, and access will adhere to applicable local or regulatory agency criteria.

TABLE 8

RECOMMENDED DESIGN CRITERIA FOR DRY RETENTION PONDS

PARAMETER	DESIGN CRITERIA
Recovery of Treatment Volume	<40 hours (certified by registered geotechnical engineer)
Side Slopes and Bottom	Sodded with water-tolerant grass species
Inlet and Outlet	Located as far apart as possible to prevent short-circuiting
Oil and Grease Skimmers	Provided at outlet structure
Requirements related to side slopes, fencing, maintenance berms, and access	According to applicable local or regulatory agency criteria

3.2.2 Wet Detention Systems

Wet detention systems are currently a very popular stormwater management technique throughout the State of Florida, particularly in areas with high groundwater tables. A wet detention pond is simply a modified detention facility which is designed to include a permanent pool of water with a depth of approximately 6-30 ft. These permanently wet ponds are designed to slowly release collected runoff through an outlet structure. A schematic diagram of a wet detention system is given in Figure 2.

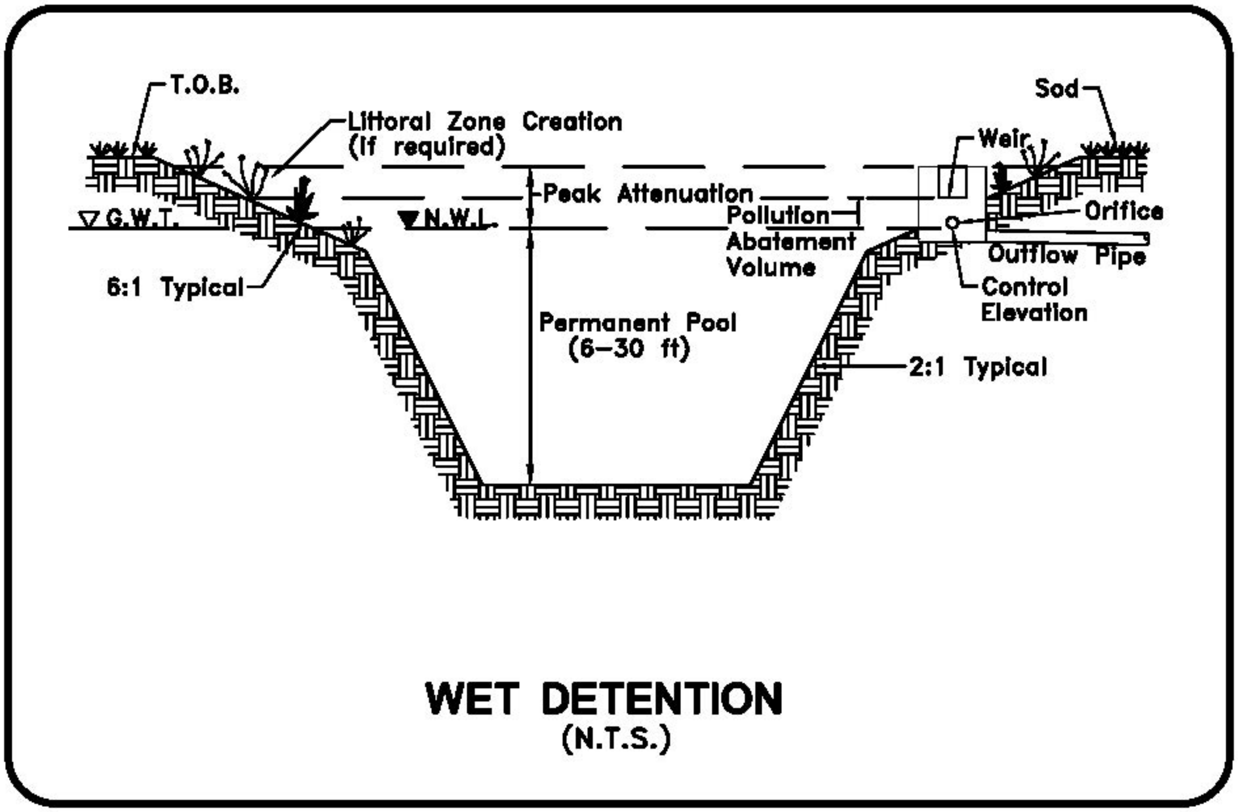


Figure 2. Schematic of a Wet Detention System.

Pollutant removal processes in wet detention systems occur through a variety of mechanisms, including physical processes such as sedimentation, chemical processes such as precipitation and adsorption, and biological uptake from algae, bacteria and rooted vegetation. In essence, these systems operate similar to a natural lake system.

The water level in a wet detention system is controlled by an orifice located in the outfall structure from the pond. Each facility is designed with a specified treatment volume based upon a specified depth of runoff over the contributing drainage basin area. Inputs of stormwater runoff equal to or less than the treatment volume exit the facility through an orifice in the outfall structure or through percolation into the surrounding groundwater table. Stormwater inputs into the facility in excess of the treatment volume can exit from the facility directly over a weir included in the pond outfall structure. The weir is designed to provide attenuation for peak storm events so that the post-development rate of discharge from the facility does not exceed the pre-development rate of discharge for specified design storm events. A littoral zone is typically planted around the perimeter of a wet detention facility to provide additional biological uptake and enhanced biological communities.

Upon entering a wet detention facility, stormwater inputs mix rapidly with existing water contained in the permanent pool. Physical, chemical, and biological processes begin to rapidly remove pollutant inputs from the water column. Water which leaves through the orifice in the outfall structure is a combination of the mixture of partially treated stormwater and the water contained within the permanent pool. In general, the concentration of constituents in the permanent pool are typically much less than input concentrations in stormwater runoff, resulting in discharges from the facility which are substantially lower in concentration than found in raw stormwater. As a result, good removal efficiencies are achieved within a wet detention facility for most stormwater constituents. Although the littoral zone provides a small amount of enhanced biological uptake, previous research has indicated that a vast majority of removal processes in wet detention facilities occur within the permanent pool volume rather than in the littoral zone vegetation (Harper, 1985; Harper 1988; Harper and Herr, 1993).

Wet detention systems offer several advantages over many other stormwater management systems. First, wet detention systems provide relatively good removal of stormwater constituents since physical, chemical, and biological mechanisms are all available for pollutant attenuation. Other stormwater management facilities provide only one or two of these basic removal methods for stormwater. A second advantage of wet detention systems is that the systems are not complex and can be relatively easily maintained. Wet detention systems do not have underdrain systems which can become clogged and need periodic maintenance. Wet detention systems can also be used as waterfront amenities in development projects.

Current research on wet detention systems clearly indicates that the performance efficiency for this type of stormwater management technique is primarily a function of residence time within the system. Residence time within the system is determined by the relationship between the permanent pool volume and the annual runoff inputs, as follows:

$$Detention\ \ Time,\ t_d\ (days)\ =\ \frac{PPV}{RO}\ x\ \frac{365\ \ days}{year}$$

where:

PPV = permanent pool volume (ac-aft)

RO = annual runoff inputs (ac-ft/yr)

For purposes of this calculation, the permanent pool volume is considered to include the total volume of water within the pond below the control elevation. The permanent pool volume is unrelated to the concept of treatment volume which is a common wet detention design criterion used to regulate drawdown of the runoff inputs.

A literature review was conducted of previous studies which evaluated the performance efficiency of wet detention ponds for total nitrogen, total phosphorus, and TSS. Information regarding percent removal and residence time was extracted from each available study which evaluated wet detention systems within the State of Florida. Plots of removal efficiency as a function of residence time were then prepared for total nitrogen, total phosphorus, and TSS. A summary of these plots is given in Figures 3 through 5. For each of the evaluated constituents, best-fit equations are also provided for calculation of removal efficiency as a function of residence time

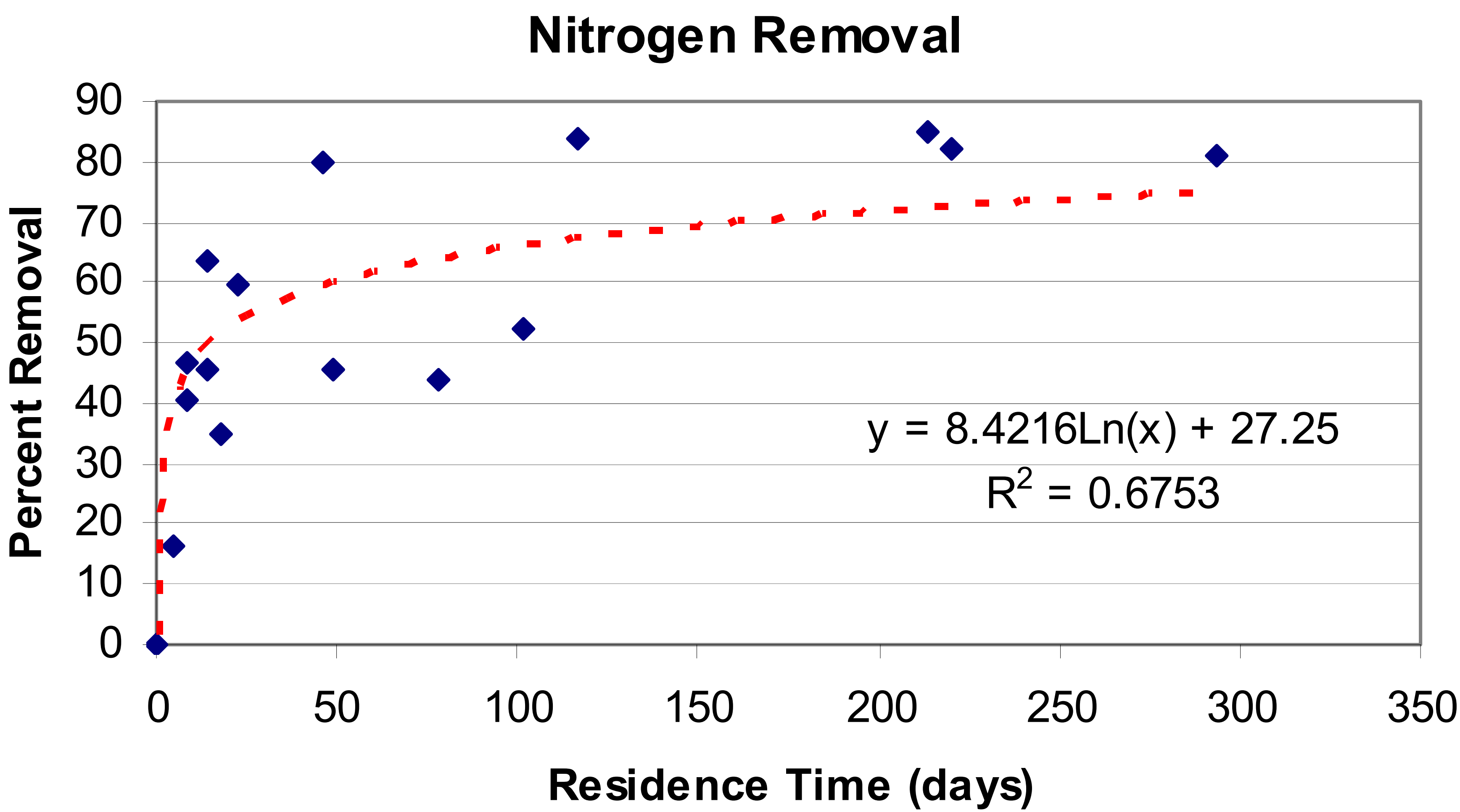


Figure 3. Removal of Total N as a Function of Residence Time in a Wet Detention Pond.

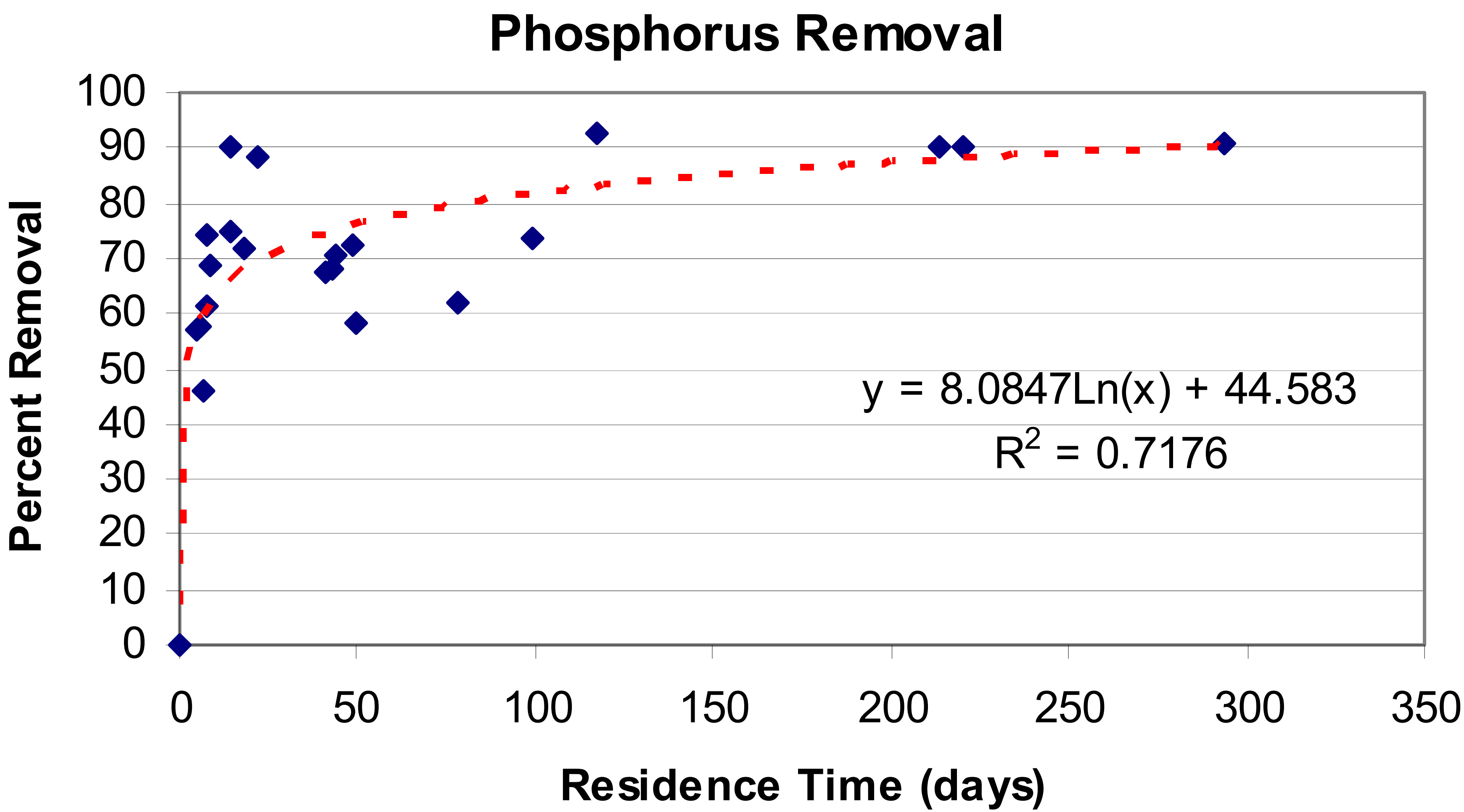


Figure 4. Removal of Total P as a Function of Residence Time in a Wet Detention Pond.

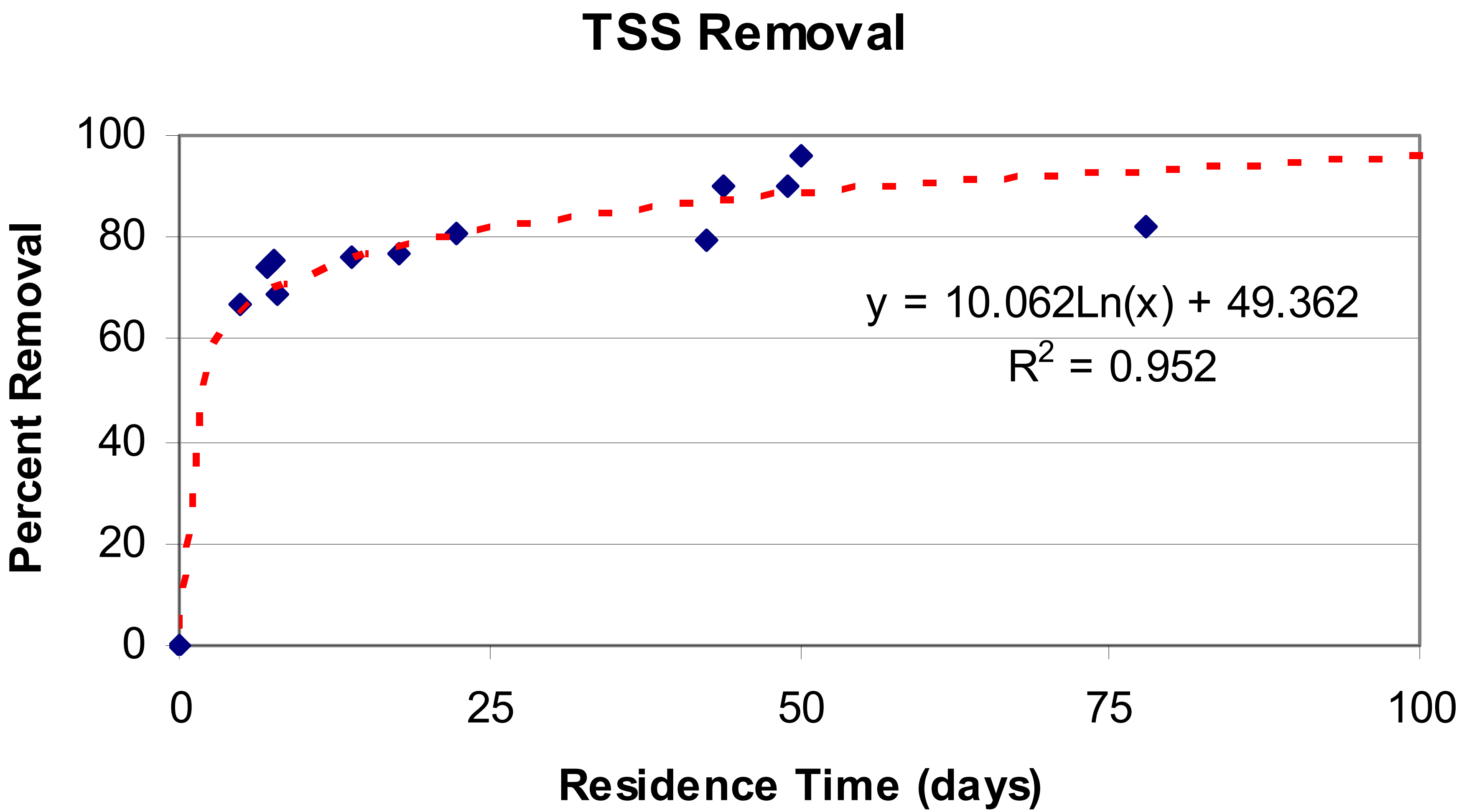


Figure 5. Removal of TSS as a Function of Residence Time in a Wet Detention Pond.

within a given pond system. If the percent removal for a given constituent is known, the required residence time can be calculated using the best-fit equations provided on the respective figures. The removal efficiencies summarized in Figures 3 through 5 represent a combination of wet detention ponds both with and without vegetated littoral zones.

During the literature search, it became apparent that insufficient data is available to evaluate removal of BOD for wet detention systems based upon previous research. As a result, removal efficiencies for BOD were estimated based upon the theoretical degradation relationship for BOD as a function of time, according to the following equation:

$$BOD_t = BOD_o \quad x \quad \exp(-K \ x \ t)$$

where:

BOD_t	=	BOD at time, t (mg/l)
BOD_o	=	initial BOD (mg/l)
t	=	time (days)
K	=	decomposition constant

BOD decomposition rates range from a low of 0.1/day for surface waters to a high of 0.4/day for strong municipal wastewater. For purposes of this evaluation, a BOD decomposition constant of 0.1/day is assumed, which may impart a slight conservative bias to the evaluation.

A graphical representation of the removal of BOD as a function of time is given in Figure 6. This relationship can be used to estimate the time required to achieve a certain BOD removal efficiency within a wet detention pond. The analysis assumes that the pond is well mixed and maintains a minimum dissolved oxygen level of 2 mg/l throughout the water column at all times.

Although the theoretical relationship expressed in Figure 6 documents BOD removal efficiencies approaching 100%, the practical limit for BOD within a wet detention pond is approximately 1-2 mg/l which reflects background conditions. Wet detention ponds are subjected

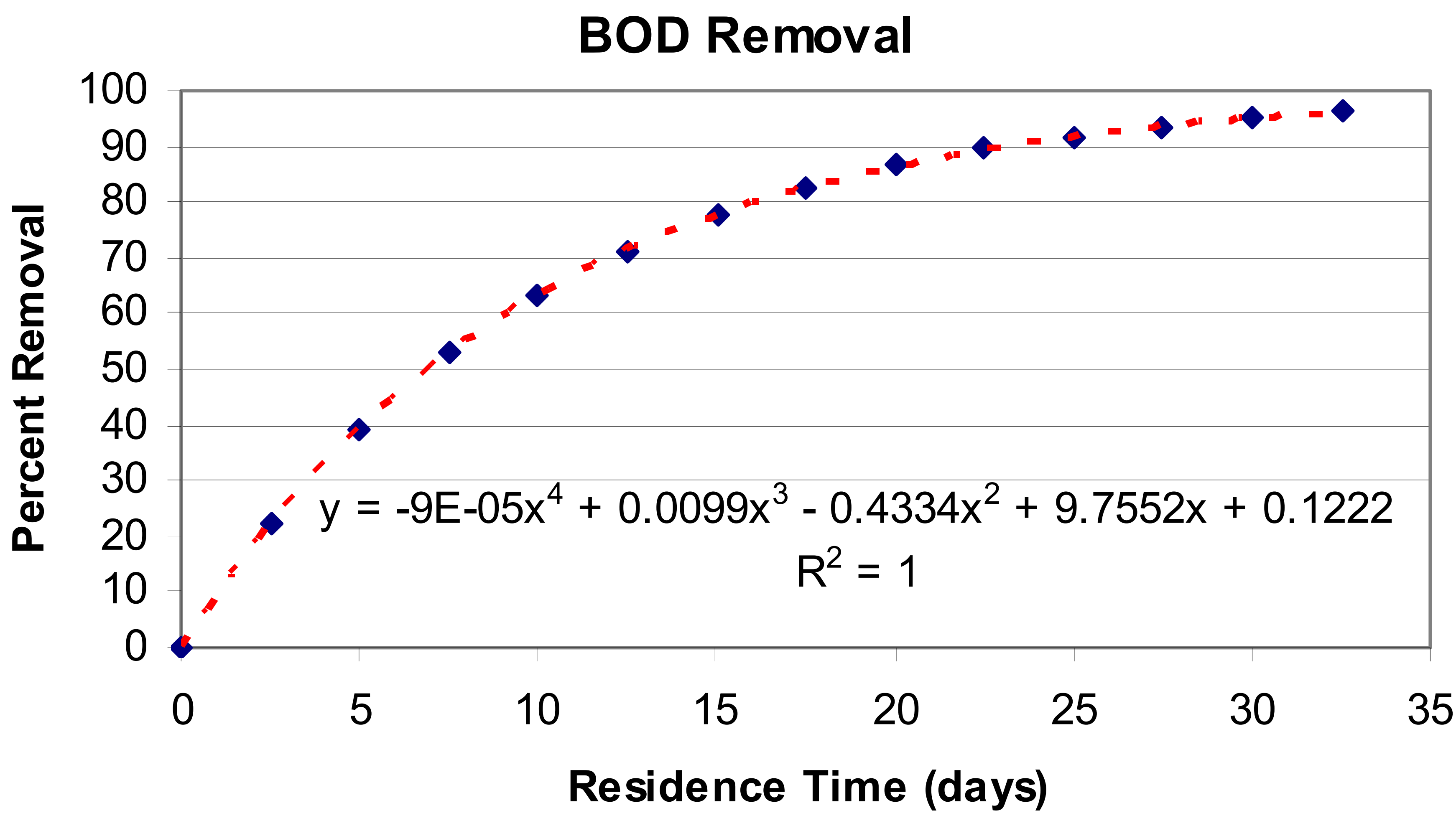


Figure 6. Removal of BOD as a Function of Residence Time in a Wet Detention Pond.

to BOD loadings from algal respiration, waterfowl, and other sources, independent of runoff loadings, which create a continuous oxygen demand of approximately 1-2 mg/l at all times. Therefore, it is generally not possible to achieve BOD concentrations in a wet detention pond less than approximately 1-2 mg/l.

A summary of recommended design criteria for wet detention ponds is given in Table 9. Based upon the information presented previously, the most important factor in regulating the performance efficiency of a wet detention pond is the residence time for runoff inputs within the system. Since residence time is determined primarily by the permanent pool volume, this volume becomes the single most important design parameter for wet detention ponds. The required volume of the permanent pool can be calculated based upon the removal relationships presented previously in Figures 3 through 6. Design criteria are also listed for the treatment volume, which represents the water volume stored on top of the permanent pool during an individual rain event. Pond requirements for treatment volume and recovery time for the treatment volume are based upon current SFWMD criteria.

Design criteria for pond depth are also based upon current SFWMD criteria which requires that 25-50% of the pond area be deeper than 12 ft. These deeper areas provide storage for accumulation of solids within the pond and minimize the frequency of maintenance activities. No restrictions are placed on the configuration of the pond, provided that the inlet and outlet from the system are located as far apart as possible. In addition, it is recommended that at least 20% of the pond surface be planted with a littoral zone consisting of a combination of submergent and emergent aquatic vegetation. Creation of a littoral zone will create a more stable environment and will probably enhance the overall performance efficiency of the wet detention system.

TABLE 9

RECOMMENDED DESIGN CRITERIA FOR WET DETENTION PONDS

PARAMETER	DESIGN CRITERIA
Treatment Volume	1-inch runoff or 2.5 inch x impervious percent (current SFWMD criteria)
Recovery Time	Bleed-down 0.5-inch of detention volume in 24 hours (current SFWMD criteria)
Permanent Pool	Volume based on required removal efficiency
Pond Depth/ Configuration/ Side Slopes	Depth: 25-50% of the pond area to be deeper than 12 ft Configuration: no restriction provided that the inlet and outlet are located as far apart as possible Side Slopes: 4:1 minimum
Littoral Zone	At least 20% of the pond surface

3.3 Selection of Treatment Options

After calculating the required removal efficiency to achieve no net increase in loading under post-development conditions, the required stormwater treatment system can be evaluated using the methodology outlined in the previous sections. The treatment system can consist of either dry retention or wet detention systems alone, or a combination of the two systems as part of a treatment train. The stormwater treatment system requirements do not include any additional volumes which may be necessary to achieve attenuation of flow rates for flood control purposes.

When treatment systems are used in series as part of a treatment train, the efficiency of the overall treatment train can be calculated using the following equation:

$$\textit{Overall Treatment Train Efficiency (\%)} = Eff_1 + (1 - Eff_1) \times Eff_2$$

where:

Eff_1 = efficiency of initial treatment system

Eff_2 = efficiency of second treatment system

After treatment in the initial treatment system, a load reduction has occurred which is a function of the type of treatment provided initially. After migrating through the initial treatment system, the remaining load consists of mass which was not removed in the initial system. This mass is then acted upon by the second treatment system with an efficiency associated with the particular type of system used. The overall efficiency can then be calculated according to the above equation.

3.4 Evaluation of Pond Stratification Potential

Typical zonation in a pond or lake is illustrated on Figure 7. The upper portions of the water column in a waterbody are typically well mixed, with a relatively uniform temperature. This upper layer, often called the epilimnion, is the area in which the majority of algal production within the lake occurs. In this zone, photosynthesis exceeds respiration, and adequate levels of dissolved oxygen are typically maintained. Lower layers of a lake are often isolated from the upper layers as a result of thermal stratification within the waterbody. Penetration of sunlight into these lower layers is typically extremely poor, and as a result, little or no algal productivity occurs in these areas. In this lower zone, commonly referred to as the hypolimnion, respiration exceeds photosynthesis, and the water column is void of dissolved oxygen throughout much of the year.

Development of stratification in waterbodies occurs primarily as a result of differential absorption of solar energy within the water column resulting in relatively large temperature differences between the upper warm epilimnion water and the lower cooler hypolimnion water. In Florida, temperature differences as high as 8-10EC can occur during the summer months between the epilimnion and the hypolimnion in a deep waterbody. Temperature differences within the water

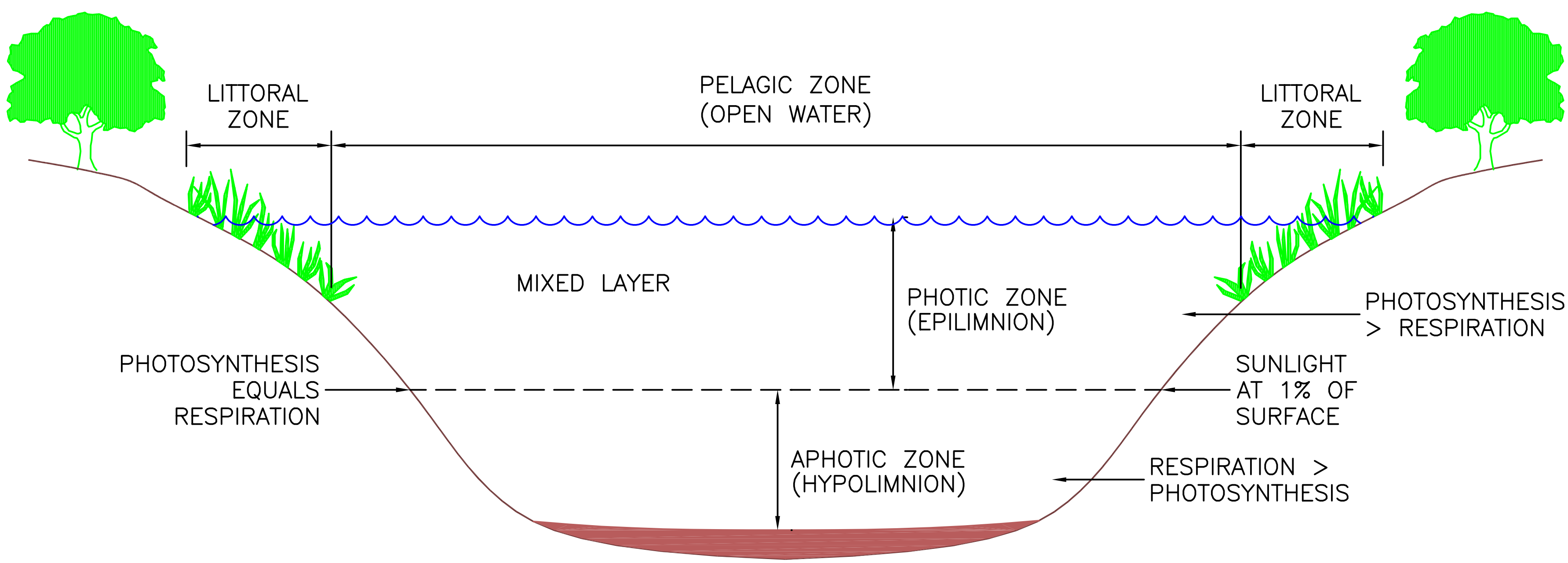


Figure 7. Typical Zonation in a Lake or Pond.

column result in density gradients which inhibit circulation between surface and deeper portions of the water column, resulting in stable stratified conditions.

Under stratified conditions, the hypolimnion becomes isolated from oxygen input mechanisms such as reaeration from the surface and algal production, and anaerobic conditions may develop in deeper waters. Anaerobic conditions are considered to occur when dissolved oxygen concentrations in portions of a waterbody decrease to less than 1 mg/l. These anaerobic conditions may increase the release of ions such as ammonia and orthophosphorus, along with gases such as H_2S and CO_2, from the bottom sediments into the hypolimnion water where significant accumulation of these ions and gases can occur. The accumulated constituents in the hypolimnion can then be circulated into the epilimnion as a result of a destratifying event, such as a prolonged windy period or strong storm event, resulting in episodes of reduced water quality. Circulation may also occur naturally within a waterbody with seasonal changes in temperature.

Stratified conditions commonly develop as a result of absorption of solar energy by particles in the water column, either as a result of turbidity or by excess algal production near the surface. Both inorganic particles and organic matter can strongly absorb solar radiation and create a significant degree of stratification and a sharp decrease in temperature in the water column at depths below 4-6 feet if large quantities of suspended matter are present in the water column. However, if significant suspended matter is not present in the water column, waterbodies as deep as 20 feet or more with low algal production may not experience stratification or anaerobic conditions at deeper water depths.

One method of evaluating the potential for stratification in a waterbody is to perform estimates of anticipated algal production and corresponding chlorophyll-a values within the proposed system. If algal production is predicted to be low, generally characterized by chlorophyll-a concentrations less than 5 mg/m^3, then the potential for stratification in a waterbody is low, and if it develops, it will occur in relatively deep portions of the water column. The stratification potential increases substantially as chlorophyll-a concentrations increase above these values. If total phosphorus concentrations in a waterbody are known or can be estimated, the corresponding chlorophyll-a concentration can be calculated based on the empirical relationship between chlorophyll-a and total phosphorus as proposed by Dillon and Rigler (1974):

$$\log(Chyl\text{-}a) = 1.449 \ \log TP - 1.136$$

where:

TP = Mean total phosphorus concentration (µg/l)

Once the anticipated algal production and chlorophyll-a values in the aquatic system have been determined, corresponding Secchi disk depths can be estimated based upon the empirical relationship presented by Dillon and Rigler (1974) which results in an estimated Secchi disk depth in meters, based upon a chlorophyll-a input in units of mg/m^3 according to the following equation:

$$SD = 8.7 \left(\frac{1}{1 + 0.47 \ Chyl - a} \right)$$

where:

SD = Secchi disk depth (m)

Chyl-a = Chlorophyll-a concentration (mg/m^3)

The Secchi disk is a simple device used to estimate water clarity in a lake or pond. It consists of a weighted circular plate, 20 cm in diameter, with the surface painted with alternating black and white quarters. The depth to which this disk can be seen in the water column is defined as the Secchi disk depth. The Secchi disk depth in a body of water is generally assumed to correspond to a water depth where the available light is approximately 10-15% of the incident light at the water surface.

Development of stratification and anoxic conditions in a non-colored waterbody is directly related to the amount of algal production and the corresponding Secchi disk depth within the water column. Since algal production is limited by inputs of total phosphorus, phosphorus is also an important variable in evaluating the depth of anoxia.

A linear regression was developed to predict the depth of anoxia in a waterbody as a function of ambient concentrations of chlorophyll-a and total phosphorus, along with the Secchi disk depth. The depth of anoxia was obtained from field measured dissolved oxygen profiles collected in the waterbody at the time of sample collection for laboratory analyses. A data set was established containing over 150 sets of measurements of Secchi disk depth, chlorophyll-a, total phosphorus, and depth of anoxia, defined as dissolved oxygen concentrations less than 1 mg/l, for waterbodies in Central and South Florida. Both linear and log transformations were performed on the variables to obtain the "best-fit" model which maximizes R^2 while minimizing the mean square error (MSE). This modeling exercise is designed to maximize the predictability of the model rather than to examine functional forms. The resulting linear regression relationship for the variables is:

$$\textit{Anoxic Depth} = 2.3893 \times \textit{Secchi} + 0.5749 \times \ln(\textit{chyl-a}) - 0.0113 \times \textit{Total P}$$

where:

Anoxic Depth	=	depth of anoxia (m)
Secchi	=	Secchi disk depth (m)
chyl-a	=	chlorophyll-a concentration (mg/m^3)
Total P	=	total phosphorus concentration (µg/l)

The above equation is valid for:

$$0.47\ m < \textit{anoxic depth} < 7.11\ m$$

$$0.24\ m < \textit{Secchi} < 3.23\ m$$

$$0.6\ mg/m^3 < \textit{chyl-a} < 330\ mg/m^3$$

$$1\ \mu g/l < \textit{Total P} < 795\ \mu g/l$$

The R^2 value for this relationship is 0.9837 which indicates that the predictive variables explain 98.4% of the variability in estimated anoxic depth. This relationship can be used to estimate the depth of anoxia in a waterbody based on measured or calculated values of chlorophyll-a, total phosphorus, and Secchi disk depth.

3.5 Estimation of Loadings from Wetland Systems

Estimation of pre- or post-development loadings discharging from wetland systems is dictated to a large degree by the hydrologic characteristics of the individual wetland system. For purposes of this analysis, wetlands may exist as isolated or flow-through systems. Isolated wetlands consist primarily of depressional wetland areas which receive little or no direct runoff from adjacent upland areas. Hydraulic discharges from isolated wetlands occur primarily during wet season conditions, with little or no runoff discharging during dry season conditions.

Flow-through wetlands are often larger wetland systems which receive significant runoff inputs from upland areas. The chemical characteristics of runoff inputs from the upland areas are modified during migration through the wetland, with reductions in chemical characteristics occurring for many stormwater constituents. Flow-through wetlands typically discharge on a more frequent basis than isolated wetlands and may even exhibit dry weather baseflow conditions as a result of influx of groundwater from adjacent upland areas. Recommended methodologies for estimation of loadings from isolated and flow-through wetlands are given in the following sections.

3.5.1 Isolated Wetlands

Mass loadings from isolated wetlands under pre- or post-development conditions are calculated using the concentration-based methodology outlined in Section 2.3. For purposes of this analysis, isolated wetland areas are considered to have a runoff coefficient (C Value) of 0.225. Estimated wetland discharge characteristics are assumed to be similar to the wetland monitoring data for Lee and Collier Counties, summarized in Table 5. Based upon the information provided in

Table 5, wetland systems are assumed to have ambient total nitrogen concentrations of approximately 1.01 mg/l and a total phosphorus concentration of 0.09 mg/l.

3.5.2 Flow-Through Wetlands

Pollutant discharges from flow-through wetlands under either pre- or post-development conditions include loadings generated within the wetland areas as well as loadings from upland areas which had been altered during migration through the wetland. The volume of water discharging from flow-through wetlands is a combination of runoff generated within the wetland itself, as well as runoff generated from upland areas which has migrated through the wetland area. The total volume of water discharging from a flow-through wetland is the sum of these two inputs. A mathematical expression for estimation of the annual runoff volume discharging from a flow-through wetland is given below:

Annual Runoff Volume Discharging from Flow-Through Wetland =

$$\left[\text{Wetland Area (ac)} \ x \ \frac{\text{53.15 inches of rainfall}}{\text{yr}} \ x \ \frac{\text{1 ft}}{\text{12 inches}} \ x \ 0.225 \right]$$

$$+ \left[\text{Upland Area (ac)} \ x \ \frac{\text{53.15 inches of rainfall}}{\text{yr}} \ x \ \frac{\text{1 ft}}{\text{12 inches}} \ x \ \text{C Value (Table 4)} \ x \ 0.5 \right]$$

For purposes of this calculation, it is assumed that approximately 50% of the annual runoff volume discharging into the wetland from upland areas will be retained within the wetland, with the remaining 50% discharging from the wetland as excess flow.

Estimates of the annual mass of total nitrogen and total phosphorus discharging from the wetland are estimated based upon the following relationship:

Annual Load Discharging from Wetland =

$$Annual\ \ Runoff\ \ Volume\ \ (ac - ft)\ \ x\ \ \frac{43{,}560\ \ ft^2}{acre}\ \ x\ \ \frac{7.48\ \ gal}{ft^3}\ \ x\ \ \frac{3.785\ \ liter}{gal}\ \ x\ \ C\ \ x\ \ \frac{1\ \ kg}{10^6\ \ mg}$$

where:

C_{TN} = 1.01 mg/l

C_{TP} = 0.09 mg/l

For purposes of this analysis, discharges from wetland areas are assumed to have a mean total nitrogen concentration of 1.01 mg/l and a mean total phosphorus concentration of 0.09 mg/l.

The loading estimates generated using the above methodology include inputs from both the wetland and upland areas discharging into the wetland. This analysis assumes that transformations will occur within the wetland such that discharge concentrations from the wetland will have the assumed concentrations for total nitrogen and total phosphorus regardless of the input concentrations from the upland areas. Upland areas which do not discharge into the wetland area are calculated using the methodologies outlined in Section 2.3.

SECTION 4

DESIGN EXAMPLES

4.1 Design Example #1

Determine the water quality treatment requirements for a 100-acre proposed single-family residential site. Pre-development land use is rangeland/forest. Assume that both nitrogen and phosphorus are constituents of concern.

Pre-Development

1. Land Use: 90 acres - mixture of rangeland/forest (fair condition)
   10 acres – isolated wetlands

2. Ground Cover/Soil Types: Rangeland/Forest – Hydrologic Soil Group D
   Wetland – hydric soils

3. Impervious Areas – 0% impervious, 0% DCIA

4. Estimate curve number/runoff coefficient

   A. Rangeland/Forest: From TR-55 (USDA, 1986), the curve number for rangeland in fair condition in HSG D is 84. The curve number for forests in fair condition in HSG D is 79. Assume an average curve number of 84 + 79 = 81.5

   From Table 4, the runoff coefficient for 0% DCIA and non-DCIA curve number of 81.5 is 0.181 by linear interpolation between non-DCIA curve numbers of 80 and 85.

   B. Wetland: Due to the large evapotranspiration losses in wetlands, an average runoff coefficient of 0.225 is assumed.

5. Calculate annual runoff volumes: Assume an annual rainfall depth of 53.15 inches

   A. Rangeland/Forest

$$Annual\ Runoff\ Volume\ (ac - ft) = 90\ ac\ x\ \frac{53.15\ inches}{year}\ x\ \frac{1\ ft}{12\ inches}\ x\ 0.181 = \underline{72.15\ ac - ft/yr}$$

B. Wetland

$$\text{Annual Runoff Volume (ac - ft)} = 10 \text{ ac} \times \frac{53.15 \text{ inches}}{\text{year}} \times \frac{1 \text{ ft}}{12 \text{ inches}} \times 0.225 = \underline{9.97 \text{ ac - ft/yr}}$$

6. Estimate runoff characteristics for land uses

A. Rangeland/Forest: From Table 7, mean runoff concentrations of total nitrogen and total phosphorus in rangeland/forest are:

TN = 1.09 mg/l TP = 0.046 mg/l

B. Wetland: From Table 7, mean concentrations of total nitrogen and total phosphorus in wetlands are:

TN = 1.01 mg/l TP = 0.09 mg/l

7. Calculate pre-development loadings

A. Rangeland/Forest

1. Total N

$$\frac{72.15 \text{ ac - ft}}{\text{year}} \times \frac{43{,}560 \text{ ft}^2}{\text{ac}} \times \frac{7.48 \text{ gal}}{\text{ft}^3} \times \frac{3.785 \text{ liter}}{\text{gal}} \times \frac{1.09 \text{ mg}}{\text{liter}} \times \frac{1 \text{ kg}}{10^6 \text{ mg}} = \underline{97.0 \text{ kg TN / yr}}$$

2. Total P

$$\frac{72.15 \text{ ac - ft}}{\text{year}} \times \frac{43{,}560 \text{ ft}^2}{\text{ac}} \times \frac{7.48 \text{ gal}}{\text{ft}^3} \times \frac{3.785 \text{ liter}}{\text{gal}} \times \frac{0.046 \text{ mg}}{\text{liter}} \times \frac{1 \text{ kg}}{10^6 \text{ mg}} = \underline{4.09 \text{ kg TP/yr}}$$

B. Wetland

1. Total N

$$\frac{9.97 \text{ ac - ft}}{\text{year}} \times \frac{43{,}560 \text{ ft}^2}{\text{ac}} \times \frac{7.48 \text{ gal}}{\text{ft}^3} \times \frac{3.785 \text{ liter}}{\text{gal}} \times \frac{1.01 \text{ mg}}{\text{liter}} \times \frac{1 \text{ kg}}{10^6 \text{ mg}} = \underline{12.42 \text{ kg TN / yr}}$$

2. Total P

$$\frac{9.97\ ac\text{-}ft}{year} \times \frac{43{,}560\ ft^2}{ac} \times \frac{7.48\ gal}{ft^3} \times \frac{3.785\ liter}{gal} \times \frac{0.09\ mg}{liter} \times \frac{1\ kg}{10^6\ mg} = \underline{1.11\ kg\ TP/yr}$$

A. Total Pre-Development Loads

1. Total N: 97.0 kg/yr + 12.42 kg/yr = 109.4 kg TN/yr

2. Total P: 4.09 kg/yr + 1.11 kg/yr = 5.20 kg TP/yr

Post-development loads must not exceed these values

Post Development

1. Land Use: 95 acres of single-family residential
5 acres of stormwater management

NOTE: Stormwater management systems are not included in estimates of post-development loadings since incidental mass inputs of pollutants to these systems are included in the estimation of removal effectiveness

2. Ground Cover/Soil Types

A. Residential areas will be covered with lawns in good condition

B. Soil types will remain HSG D

3. Impervious/DCIA Areas

A. Residential areas will be 25% impervious, 75% of which will be DCIA

Impervious = 25% = 95 ac x 0.25 = 23.75 acres

DCIA = 23.75 acres x 0.75 = 17.81 acres

(17.81 ac/95.0 ac) x 100 = 18.7%

4. Estimate curve number/runoff coefficient

A. Calculate composite non-DCIA curve number from TR-55:

Curve number for lawns in good condition in HSG D = 80

Areas of lawns = 95 acres - 23.75 ac = 71.25 acres

Impervious area which is not DCIA = 23.75 ac - 17.81 ac = 5.94 ac

Assume a curve number of 98 for impervious areas

Non-DCIA curve number =

$$\frac{71.25\ ac\ (80)\ +\ 5.94\ ac\ (98)}{71.25\ ac\ +\ 5.94\ ac} = \underline{81.4}$$

B. From Table 4, the runoff coefficient for an area which is 18.75% DCIA and a non-DCIA curve number of 81.4 is 0.292 by linear interpolation

5. Calculate annual runoff volume

$$Runoff\ \ from\ single-family\ area = 95\ ac\ x\ \frac{53.15\ inches}{yr}\ x\ \frac{1\ ft}{12\ inches}\ x\ 0.292 = \underline{122.9\ ac-ft/yr}$$

6. Estimate runoff characteristics

A. Single-Family: From Table 7, mean total nitrogen and total phosphorus concentrations for single-family residential runoff are:

TN = 2.18 mg/l TP = 0.335 mg/l

7. Calculate post-development loading

Post-development load =

A. Total N

$$\frac{122.9\ ac-ft}{year}\ x\ \frac{43,560\ \ ft^2}{ac}\ x\ \frac{7.48\ gal}{ft^3}\ x\ \frac{3.785\ liter}{gal}\ x\ \frac{2.18\ mg}{liter}\ x\ \frac{1\ kg}{10^6\ \ mg} = \underline{330\ kg\ TN\ /\ yr}$$

B. Total P

$$\frac{122.9\ ac\text{-}ft}{year} \times \frac{43{,}560\ ft^2}{ac} \times \frac{7.48\ gal}{ft^3} \times \frac{3.785\ liter}{gal} \times \frac{0.335\ mg}{liter} \times \frac{1\ kg}{10^6\ mg} = \underline{50.8\ kg\ TP/yr}$$

Stormwater Treatment Requirements

1. Estimate required percentage reduction in mass load to achieve no net increase in post-development load

A. Total N

$$Removal = \frac{330\ kg/yr\ (post) - 109.4\ kg/yr\ (pre)}{330\ kg/yr\ (post)} \times 100 = \underline{67.0\%\ reduction\ in\ Total\ N}$$

B. Total P

$$Removal = \frac{50.8\ kg/yr\ (post) - 5.2\ kg/yr\ (pre)}{50.8\ kg/yr\ (post)} \times 100 = \underline{89.8\%\ reduction\ in\ Total\ P}$$

2. Evaluate alternatives to achieve required reduction

A. Dry Retention Option

The removal efficiency achieved using dry retention is a function of the water volume infiltrated and is independent of the chemical species. Since the greatest required removal is 89.9% (for total P), this dictates the design.

Review Tables B.1-B.16 to identify the required dry retention volume for DCIA = 18.75% and non-DCIA curve number of 81.4 to achieve a mass removal of 89.8%

As seen in Table B.8, a dry retention depth of 2.00-inch will achieve a removal of about 90% for the site-specific hydrologic characteristics

Therefore, select a retention depth of 2.00 inches

The required dry retention volume is:

$$95 \ acres \ \ x \ \ 2.00 \ inch \ \ x \ \ \frac{1 \ ft}{12 \ inches} \ = \ \underline{15.83 \ \ ac - ft}$$

Note that the calculated dry retention volume does not include volume requirements for peak flow attenuation.

B. Wet Detention Option

1. Total N

A relationship between removal of total nitrogen and residence time in a wet detention pond is given in Figure 3. This relationship can be expressed mathematically as follows:

$$Removal \ (y) = 8.4216 \ ln \ (residence \ time, \ days) \ + \ 27.25$$

For a removal of 67.0%, the required residence time is:

$$Residence \ \ Time \ = \ \exp\left(\frac{Removal \ \ Eff. \ - \ 27.25}{8.4216}\right)$$

$$Residence \ \ Time \ = \ \exp\left(\frac{67.0 \ - \ 27.25}{8.4216}\right) \ = \ \underline{112 \ \ days}$$

2. Total P

A relationship between removal of total phosphorus and residence time in a wet detention pond is given in Figure 3. This relationship can be expressed mathematically as follows:

$$Removal \ (y) = 8.0847 \ ln \ (residence \ time, \ days) \ + \ 44.583$$

For a removal of 89.8%, the required residence time is:

$$Residence\ Time = \exp\left(\frac{Removal\ Eff.\ -\ 44.583}{8.0847}\right)$$

$$Residence\ Time = \exp\left(\frac{89.8\ -\ 44.583}{8.0847}\right) = \underline{269\ days}$$

Since the detention time required to remove total P is greater than the residence time for total N removal, the residence time for total P governs the design.

Required permanent pool volume = annual runoff volume x residence time =

$$\frac{122.9\ ac-ft}{year}\ x\ 269\ days\ x\ \frac{1\ year}{365\ days} = \underline{90.6\ ac-ft}$$

According to applicable SFWMD design criteria, a wet detention pond would then be designed with a permanent pool volume of at least 90.6 ac-ft. This treatment volume could be achieved with a 6-acre pond at an average depth of 15.1 ft. The pond could also be used for flood attenuation purposes through proper design of the outfall structure and weirs.

<u>Evaluate estimated depth of anoxia in pond</u>

The potential for pond stratification and development of anoxic conditions is regulated primarily by the amount of algal growth within the detention pond, which is regulated by the concentrations of total phosphorus in the water column.

(1) <u>Calculate mean water column concentration of TP</u>

Annual P load leaving pond = pre-development load = <u>5.2 kg/yr</u>

Annual water volume leaving pond = runoff volume (assuming that inputs from precipitation and losses from evaporation are approximately equal over an annual period).

Mean outfall concentration = input mass/runoff volume =

$$\frac{5.2\ kg\ P}{yr}\ x\ \frac{1\ yr}{122.9\ ac-ft}\ x\ \frac{1\ ac}{43{,}560\ ft^2}\ x\ \frac{1\ ft^3}{7.48\ gal}\ x\ \frac{1\ gal}{3.785\ liter}\ x\ \frac{10^6\ mg}{kg} = \underline{0.034\ mg/l}$$

This value can also be obtained by multiplying the weighted runoff concentration times the required mass removal efficiency, as follows:

$$\frac{0.335\ mg\ TP}{liter}\ \text{(input runoff concentration)}\ x\ (1 - 0.898) = \underline{0.034\ mg\ TP / liter} = \underline{34\ \mu g\ TP / liter}$$

(2) Calculate equilibrium mean chlorophyll-a concentration

$$\log (chyl\text{-}a) = 1.449 \log (TP) - 1.136$$

where:

TP = mean total P (µg/l)

chyl-a = equilibrium chlorophyll-a (mg/m^3)

$$\log (chyl\text{-}a) = 1.449 \log (34) - 1.136 = 1.083$$

$$chyl\text{-}a = 10^{1.083} = \underline{12.1\ mg/m^3}$$

(3) Calculate mean Secchi disk depth

$$SD = 8.7 \left(\frac{1}{1 + 0.47\ chyl\text{-}a} \right)$$

where:

SD = Secchi disk depth (m)

chyl-a = chlorophyll-a (mg/m^3)

$$SD = 8.7 \left(\frac{1}{1 + 0.47\ (12.1)} \right) = \underline{1.3\ m} = \underline{4.3\ ft}$$

(4) Calculate depth of anoxic conditions in pond: Using the relationship in Section 3.4, the depth of anoxic conditions within the pond can be estimated as follows:

$$\textit{Depth of DO} < 1 = 2.3893 \times \textit{Secchi} + 0.5749 \times \ln(\textit{chyl-a}) - 0.0113 \times \textit{Total P}$$

$$= 2.3893\ (1.3) + 0.5749 \times \ln(12.1) - 0.0113\ (34) = \underline{4.16\ m} = \underline{13.6\ ft}$$

Since the proposed pond depth of 18.1 ft (mean depth) exceeds the estimated photic zone depth of 13.6 ft, aeration or other mixing will be required in areas of the pond deeper than 13.6 ft to maintain a well mixed water column. The aeration or mixing must be sufficient to mix the water column to the maximum pond depth. The specific design of the required system should be selected by a qualified aeration specialist.

As an alternative to providing aeration or mixing within the pond, which may be closely scrutinized by the District or local agencies, the required permanent pool volume could be considered as only the volume above the anoxic zone and not the entire volume of the pond. Areas below the anoxic depth would be considered as dead storage, although these areas would provide a significant storage volume for collected solids. However, this would require that the actual pond volume be larger than the required permanent pool volume.

After the pond is modified, the calculations given under the heading of "Evaluate estimated depth of anoxia in pond" would need to be redone to estimate new values for total phosphorus, Secchi disk depth, chlorophyll-a, and depth of anoxia to demonstrate that the new design meets the required permanent pool volume above the zone of anoxia.

C. Combined System Option

Suppose that the drainage system for the residential area consists of grassed swales with raised inlets which can provide 0.25 inch of dry retention as pre-treatment followed by a wet detention pond. How large would the wet detention pond need to be?

(1) Calculate mass removal in swale treatment system: From Table B.1, the removal efficiency for 0.25 inch of retention, based on DCIA = 18.75% and non-DCIA curve number of 81.4, is 43.5% by linear interpolation

a. Mass load of total nitrogen removed = 330 kg/yr x 0.435 = 144 kg/yr

Mass nitrogen load remaining = 330 kg/yr – 144 kg/yr = 186 kg/yr

b. Mass load of total phosphorus removed = 50.8 kg/yr x 0.435 = <u>22.1 kg/yr</u>

Mass phosphorus load remaining = 50.8 kg/yr - 22.1 kg/yr = <u>28.7 kg/yr</u>

(2) <u>Calculate additional mass removal required in wet detention pond</u>

a. Total N

$$\frac{186\ kg/yr\ (input)\ -\ 109.4\ kg/yr\ (pre\text{-})}{186\ kg/yr}\ x\ 100\ =\ 41.2\%$$

b. Total P

$$\frac{28.7\ kg/yr\ (input)\ -\ 5.2\ kg/yr\ (pre\text{-})}{28.7\ kg/yr}\ x\ 100\ =\ \underline{81.9\%}$$

(3) <u>Calculate required wet detention residence time</u>

a. Total N

$$Residence\ Time\ =\ \exp\left(\frac{removal\ eff\ -\ 27.25}{8.4216}\right)\ =\ \exp\left(\frac{41.2\ -\ 27.25}{8.4216}\right)\ =\ \underline{5.2\ days}$$

b. Total P

$$Residence\ Time\ =\ \exp\left(\frac{removal\ eff\ -\ 44.583}{8.0847}\right)\ =\ \exp\left(\frac{81.9\ -\ 44.583}{8.0847}\right)\ =\ \underline{101\ days}$$

The pond design is determined by the most restrictive (largest) residence time of 101 days.

$$Permanent\ Pool\ Volume\ =\ \frac{122.9\ ac\text{-}ft}{year}\ x\ 101\ days\ x\ \frac{1\ year}{365\ days}\ =\ \underline{34.0\ ac\text{-}ft}$$

This could be accomplished using a 3-acre wet detention pond with a mean depth of 11.3 ft, plus any additional volume or surface area which may be necessary for flood attenuation.

Evaluate potential for pond stratification

(1) Calculate mean water column concentration of TP

Annual P load leaving pond = 5.2 kg/yr

Annual water volume leaving pond = generated runoff volume - runoff volume lost in retention system

The amount of runoff volume lost in the retention system is the same as the mass removal obtained for 0.25-inch of retention, based on DCIA = 18.75% and a non-DCIA curve number of 81.4 which is 43.5%

Annual volume leaving pond =

$$\frac{122.9 \ ac\text{-}ft}{yr} \ x \ (1 - 0.435) = \underline{69.4 \ ac\text{-}ft / yr}$$

Mean outfall concentration =

$$\frac{5.2 \ kg \ P}{yr} \ x \ \frac{1 \ yr}{69.4 \ ac\text{-}ft} \ x \ \frac{1 \ ac}{43{,}560 \ ft^2} \ x \ \frac{1 \ ft^3}{7.48 \ gal}$$

$$x \ \frac{1 \ gal}{3.785 \ liter} \ x \ \frac{10^6 \ mg}{kg} = \underline{0.061 \ mg \ TP / liter} = \underline{61 \ \mu g \ TP / liter}$$

(2) Calculate equilibrium mean chlorophyll-a concentration

$$log\ (chyl\text{-}a) = 1.449\ log\ (TP) - 1.136$$

$$log\ (chyl\text{-}a) = 1.449\ log\ (61) - 1.136$$

$$chyl\text{-}a = 10^{1.451} = \underline{28.2\ mg/m^3}$$

(3) Calculate mean Secchi disk depth

$$SD = 8.7 \left(\frac{1}{1 + 0.47\ chyl - a} \right) = 8.7 \left(\frac{1}{1 + 0.47\ (28.2)} \right) = \underline{0.6\ m} = \underline{2.0\ ft}$$

(4) Calculate depth of anoxic conditions in pond: Using the relationship in Section 3.4, the depth of anoxic conditions within the pond can be estimated as follows:

$$Depth\ of\ DO < 1 = 2.3893\ x\ Secchi + 0.5749\ x\ ln\ (chyl\text{-}a) - 0.0113\ x\ Total\ P$$

$$= 2.3893\ (0.6) + 0.5749\ x\ ln\ (28.2) - 0.0113\ (61) = \underline{2.7\ m} = \underline{8.7\ ft}$$

Since the proposed pond depth of 11.3 ft (mean depth) exceeds the estimated photic zone depth of 8.7 ft, aeration or other mixing will be required for areas deeper than 8.7 ft to maintain a well mixed water column. As an alternative, only the volume above a depth of 8.7 ft could be assumed to be included as the permanent pool volume.

4.2 Design Example #2

A residential community is planned for a 200-acre parcel consisting of rangeland/forests and flow-through wetlands. The post-development conditions will include three sub-basins with wet detention treatment ponds. Determine if the proposed design meets the post $\leq$ pre loading requirements for total N and total P.

Pre-Development Characteristics

1. Land Use:

LAND USE CATEGORY	AREA (acres)	COMMENTS
Rangeland/Forest	90	Fair condition
Wetland	50	Flow-through wetlands
Rangeland/Forest	60	Upland area which discharges to the flow-through wetland
TOTAL:	**200**	

2. Ground Cover/Soil Types: Rangeland/Forest – Hydrologic Soil Group C
   Wetland – hydric soils

3. Impervious Areas – 0% impervious, 0% DCIA

4. Estimate curve number/runoff coefficient

   A. Rangeland/Forest: From TR-55 (USDA, 1986), the curve number for rangeland in fair condition in HSG C is 79. The curve number for forests in fair condition in HSG C is 73. Assume an average curve number of 79 + 73 = 76.0

   From Table 4, the runoff coefficient for 0% DCIA and non-DCIA curve number of 76.0.is 0.122 by linear interpolation between non-DCIA curve numbers of 75 and 80.

   B. Wetland: Due to the large evapotranspiration losses in wetlands, an average runoff coefficient of 0.225 is assumed, based on the literature review summarized in Table 7.

5. Calculate annual runoff volumes: Assume an annual rainfall depth of 53.15 inches

A. Rangeland/Forest

(1) Areas which do not flow to the wetland:

$$Annual\ Runoff\ Volume\ (ac-ft) = 90\ ac\ x\ \frac{53.15\ inches}{year}\ x\ \frac{1\ ft}{12\ inches}\ x\ 0.122 = \underline{48.63\ ac-ft/yr}$$

(2) Areas which flow into the wetland:

$$Annual\ Runoff\ Volume\ (ac-ft) = 60\ ac\ x\ \frac{53.15\ inches}{year}\ x\ \frac{1\ ft}{12\ inches}\ x\ 0.122 = \underline{32.42\ ac-ft/yr}$$

B. Wetland

$$Annual\ Runoff\ Volume\ (ac-ft) = 50\ ac\ x\ \frac{53.15\ inches}{year}\ x\ \frac{1\ ft}{12\ inches}\ x\ 0.225 = \underline{49.83\ ac-ft/yr}$$

6. Estimate runoff characteristics for land uses

A. Rangeland/Forest: From Table 7

Total N = 1.09 mg/l   Total P = 0.046 mg/l

B. Wetland: From Table 7

Total N = 1.01 mg/l   Total P = 0.09 mg/l

7. Calculate pre-development loadings

A. Rangeland/Forest – Areas not discharging to wetland

(1) Total N

$$\frac{48.63\ ac-ft}{year}\ x\ \frac{43{,}560\ ft^2}{ac}\ x\ \frac{7.48\ gal}{ft^3}\ x\ \frac{3.785\ liter}{gal}\ x\ \frac{1.09\ mg}{liter}\ x\ \frac{1\ kg}{10^6\ mg} = \underline{65.37\ kg\ TN/yr}$$

(2) Total P

$$\frac{48.63\ ac\text{-}ft}{year} \times \frac{43{,}560\ ft^2}{ac} \times \frac{7.48\ gal}{ft^3} \times \frac{3.785\ liter}{gal} \times \frac{0.046\ mg}{liter} \times \frac{1\ kg}{10^6\ mg} = \underline{2.76\ kg\ TP/yr}$$

B. <u>Wetland – includes wetland plus upland areas draining to wetland</u>

Wetland Discharge = 49.83 ac-ft/yr (wetland runoff) + 32.43 ac-ft/yr x 0.5

(50% of runoff from upland areas) = <u>66.05 ac-ft/yr</u>

(1) Total N – assumes that all water discharged from the wetland has a TN = 1.01 mg/l

$$\frac{66.05\ ac\text{-}ft}{year} \times \frac{43{,}560\ ft^2}{ac} \times \frac{7.48\ gal}{ft^3} \times \frac{3.785\ liter}{gal} \times \frac{1.01\ mg}{liter} \times \frac{1\ kg}{10^6\ mg} = \underline{82.3\ kg\ TN/yr}$$

(2) Total P – assumes that all water discharged from the wetland has a TP = 0.09 mg/l

$$\frac{66.05\ ac\text{-}ft}{year} \times \frac{43{,}560\ ft^2}{ac} \times \frac{7.48\ gal}{ft^3} \times \frac{3.785\ liter}{gal} \times \frac{0.09\ mg}{liter} \times \frac{1\ kg}{10^6\ mg} = \underline{7.33\ kg\ TP/yr}$$

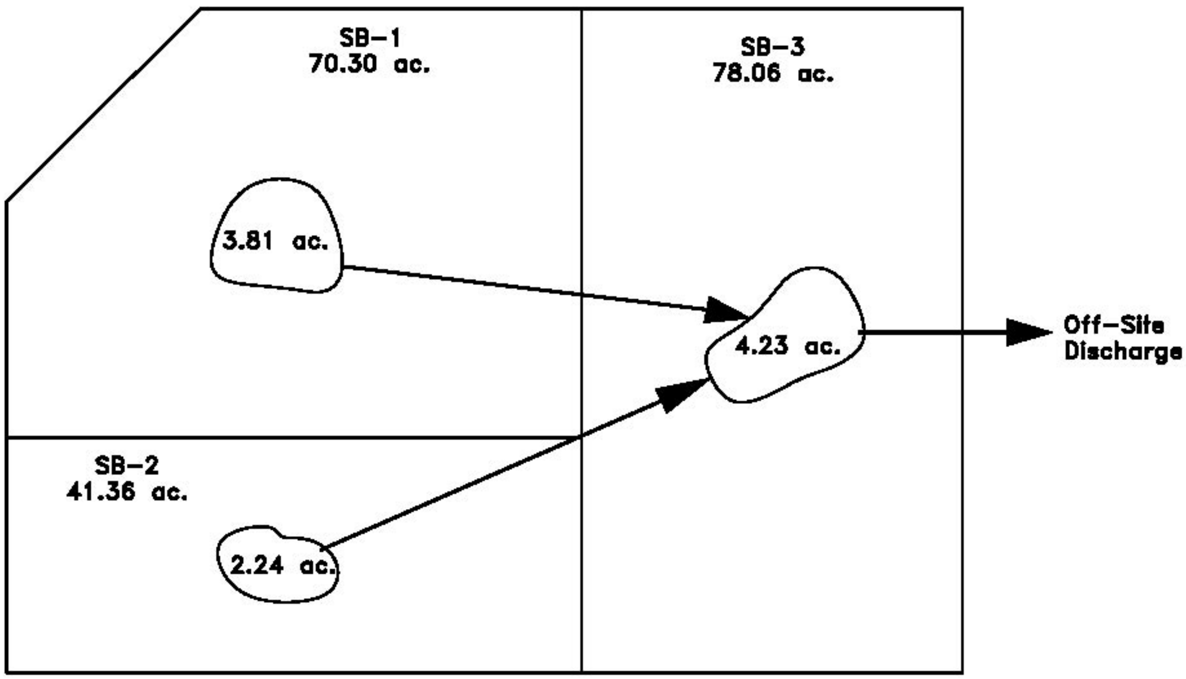
Total pre-development Total N load = 65.37 kg/yr + 82.3 kg/yr = <u>147.7 kg TN/yr</u>

Total pre-development Total P load = 2.76 kg/yr + 7.33 kg/yr = <u>10.09 kg TP/yr</u>

Post-development load must not exceed these values

Post-Development Characteristics

Under post-development conditions, the site will be divided into 3 sub-basin areas as follows:



1. Land Use

BASIN	AREA (acres)			TOTAL (acres)
	SINGLE-FAMILY	WETLANDS	TREATMENT POND	
SB-1	57.80	12.50	3.81	74.11
SB-2	32.61	8.75	2.24	43.60
SB-3	63.43	14.63	4.23	82.29
TOTALS:	153.84	35.88	10.28	200.0

2. Ground Cover / Soil Types

A. Residential areas will be covered with lawns in good condition

B. Soil types for upland areas will remain in HSG C. Disturbed wetland area will be filled with on-site soils and will be assumed to have hydrologic characteristics similar to HSG C. Undisturbed wetland soils will have the original hydric soils.

3. Impervious/DCIA Areas

Residential areas will be 35% impervious, 75% of which will be DCIA.

For Basin SB-1:

Impervious = 35% = 57.80 ac x 0.35 = 20.23 ac

DCIA = 20.23 ac x 0.75 = 15.17 ac = (15.17 ac/57.8 ac) x 100 = 26.25%

For Basin SB-2:

Impervious = 35% = 32.61 ac x 0.35 = 11.41 ac

DCIA = 11.41 ac x 0.75 = 8.56 ac = (8.56 ac/32.61 ac) x 100 = 26.25%

For Basin SB-3:

Impervious = 35% = 63.43 ac x 0.35 = 22.20 ac

DCIA = 22.20 ac x 0.75 = 16.65 ac = (16.65 ac/63.43 ac) x 100 = 26.25%

4. Estimate curve number/runoff coefficient

A. Calculate composite non-DCIA curve number

Curve number for lawns in good condition in HSG C = 74

1. Basin SB-1

Areas of lawns = 57.80 ac - 20.23 ac = 37.57 ac

Impervious area which is not DCIA = 20.23 ac - 15.17 ac = 5.06 ac

Assume a curve number of 98 for impervious areas

Non-DCIA curve number =

$$\frac{37.57\ ac\ (74)\ +\ 5.06\ ac\ (98)}{37.57\ ac\ +\ 5.06\ ac} = \underline{76.85}$$

2. Basin SB-2

Areas of lawns = 32.61 ac - 11.41 ac = 21.20 ac

Impervious area which is not DCIA = 11.41 ac - 8.56 ac = 2.85 ac

Assume a curve number of 98 for impervious areas

Non-DCIA curve number =

$$\frac{21.20 \ ac \ (74) \ + \ 2.85 \ ac \ (98)}{21.20 \ ac \ + \ 2.85 \ ac} = \underline{76.85}$$

3. Basin SB-3

Areas of lawns = 63.43 ac - 22.20 ac = 41.23 ac

Impervious area which is not DCIA = 22.20 ac - 16.65 ac = 5.55 ac

Assume a curve number of 98 for impervious areas

Non-DCIA curve number =

$$\frac{41.23 \ ac \ (74) \ + \ 5.55 \ ac \ (98)}{41.23 \ ac \ + \ 5.55 \ ac} = \underline{76.85}$$

B. From Table 4, the runoff coefficient for an area which is 26.2% DCIA and a non-DCIA curve number of 76.85 is 0.301 by linear interpolation

This curve number is valid for all residential areas in the 3 basins since they all have the same %DCIA and non-DCIA curve number.

5. Calculate annual runoff volumes

Annual runoff volumes for each land use are calculated using the equations on page 2-7. A summary of this procedure is given on the following page.

BASIN	ANNUAL RAINFALL (inches)	SINGLE-FAMILY RESIDENTIAL			WETLAND AREAS		
		AREA (ac)	C VALUE	RUNOFF (ac-ft/yr)	AREA (ac)	C VALUE	RUNOFF (ac-ft/yr)
SB-1	53.15	57.80	0.301	77.06	12.50	0.225	12.46
SB-2	53.15	32.61	0.301	43.48	8.75	0.225	8.72
SB-3	53.15	63.43	0.301	84.56	14.63	0.225	14.58

6. Estimate runoff characteristics

A. Single-Family: From Table 7, mean single-family runoff characteristics are:

TN = 2.18 mg/l TP = 0.335 mg/l

B. Wetlands: From Table 7, mean wetland characteristics are:

TN = 1.01 mg/l TP = 0.09 mg/l

7. Calculate post-development loadings of TN and TP for each basin

Under post-development conditions, all developed single-family areas and wetlands will be routed into the on-site wet detention ponds. Therefore, the calculated loads represent the loadings reaching the treatment pond in each basin. Loadings are calculated using the method summarized below:

For residential loadings of TN in Basin SB-1:

$$\frac{77.06\ ac-ft}{yr} \times \frac{43{,}560\ ft^2}{ac} \times \frac{7.48\ gal}{ft^3} \times \frac{3.785\ liter}{gal} \times \frac{2.18\ mg}{liter} \times \frac{1\ kg}{10^6\ mg} = \underline{207.2\ kg\ TN / yr}$$

Loadings from other sub-basin areas are summarized below:

BASIN	SINGLE-FAMILY RESIDENTIAL					WETLAND AREAS					BASIN TOTALS		
	Runoff (ac-ft/yr)	Runoff (mg/l)		Load (kg/yr)		Runoff (ac-ft/yr)	Runoff (mg/l)		Load (kg/yr)		Runoff (ac-ft/yr)	TN Load (kg/yr)	TP Load (kg/yr)
		TN	TP	TN	TP		TN	TP	TN	TP			
SB-1	77.06	2.18	0.335	207.2	31.8	12.46	1.01	0.09	15.52	1.38	89.52	222.7	33.2
SB-2	43.48	2.18	0.335	116.9	18.0	8.72	1.01	0.09	10.86	0.97	52.20	127.8	19.0
SB-3	84.56	2.18	0.335	227.3	34.9	14.58	1.01	0.09	18.16	1.62	99.14	245.5	36.5

Stormwater Treatment

1. Characteristics of Wet Detention Treatment Lakes

POND	SURFACE AREA (ac)	MEAN DEPTH (ft)	VOLUME (ac-ft)	MAXIMUM DEPTH (ft)
SB-1	3.81	12	45.72	21
SB-2	2.24	12	26.88	20
SB-3	4.23	12	50.76	24
TOTAL:	10.28 (5.1% of site)			

2. Evaluate treatment provided by Pond SB-1

$$Pond\ Detention\ Time = \frac{Pond\ Volume}{Annual\ Runoff\ Inputs} = 45.72\ ac - ft\ x\ \frac{1}{89.52\ ac\text{-}ft / yr}\ x\ \frac{365\ days}{yr} = \underline{186\ days}$$

From Figure 3, estimated TN removal

$$Removal = 8.4216\ ln\ (x) + 27.25$$

$$= 8.4216\ ln\ (186) + 278.25 = \underline{71.3\%}$$

From Figure 4, estimated TP removal

$$Removal = 8.0847\ ln\ (x) + 44.583$$

$$= 8.0847\ ln\ (186) + 44.583 = \underline{86.8\%}$$

Fate of hydraulic and mass loadings to Pond SB-1:

PARAMETER	INPUTS TO POND SB-1	REMOVAL BY POND	DISCHARGE FROM POND SB-1 TO POND SB-3
Total N	222.7 kg/yr	71.3%	63.9 kg/yr
Total P	33.2 kg/yr	86.8%	4.38 kg/yr
Volume	89.52 ac-ft/yr	0%[1]	89.52 ac-ft/yr

1. Assumes that precipitation and evaporation are approximately equal over an annual cycle

3. <u>Evaluate treatment provided by Pond SB-2</u>

$$Pond\ Detention\ Time = \frac{Pond\ Volume}{Annual\ Runoff\ Inputs} = \frac{26.88\ \ ac-ft}{52.20\ \ ac-ft/yr}\ x\ \frac{365\ \ days}{yr} = \underline{188\ \ days}$$

From Figure 3, estimated TN removal

$$Removal = 8.4216\ ln\ (188) + 27.25 = \underline{71.3\%}$$

From Figure 4, estimated TP removal

$$Removal = 8.0847\ ln\ (188) + 44.583 = \underline{86.8\%}$$

Fate of hydraulic and mass loadings to Pond SB-2:

PARAMETER	INPUTS TO POND SB-2	REMOVAL BY POND	DISCHARGE FROM POND SB-2 TO POND SB-3
Total N	127.8 kg/yr	71.3%	36.7 kg/yr
Total P	19.0 kg/yr	86.9%	2.49 kg/yr
Volume	52.20 ac-ft/yr	0%[1]	52.20 ac-ft/yr

1. Assumes that precipitation and evaporation are approximately equal over an annual cycle

4. Evaluate treatment provided by Pond SB-3

Summary of inputs to Pond SB-3:

PARAMETER	INPUTS FROM INTERCONNECTED PONDS		INPUTS FROM BASIN SB-3	TOTAL INPUTS
	POND SB-1	POND SB-2		
Total N	63.9 kg/yr	36.7 kg/yr	245.5 kg/yr	346.1 kg/yr
Total P	4.38 kg/yr	2.49 kg/yr	36.5 kg/yr	43.4 kg/yr
Volume	89.52 ac-ft/yr	52.20 ac-ft/yr	99.14 ac-ft/yr	240.86 ac-ft/yr

Pond Detention Time = Pond Volume/Annual Inputs =

$$\frac{50.76 \ \ ac\text{ - }ft}{240.86 \ \ ac\text{ - }ft\ /\ yr} \ \ x \ \ \frac{365 \ \ days}{yr} \ \ = \ \ \underline{76.9 \ \ days}$$

From Figure 3, estimated TN removal =

$$8.4216 \ln (x) + 27.25$$

$$Removal = 8.4216 \ln (76.9) + 27.25 = \underline{63.8\%}$$

From Figure 4, estimated TP removal =

$$8.0847 \ln (x) + 44.583$$

$$\text{Removal} = 8.0847 \ \text{ln} \ (76.9) + 44.583 = \underline{79.7\%}$$

5. Estimate post-development loadings discharged off-site

PARAMETER	INPUTS TO POND SB-3	REMOVAL BY POND	OFF-SITE DISCHARGE
Total N	346.1 kg/yr	63.8%	125.3 kg/yr
Total P	43.4 kg/yr	79.7%	8.81 kg/yr
Volume	240.86 ac-ft/yr	0%	240.86 ac-ft/yr

6. Compare pre- and post-development loadings

PARAMETER	PRE-DEVELOPMENT LOADINGS	POST-DEVELOPMENT LOADINGS
Total N	147.7 kg TN/yr	125.3 kg/yr
Total P	10.09 kg TP/yr	8.81 kg/yr

Since the post-development loadings < pre-development loadings, the design is acceptable with respect to off-site loadings of total nitrogen and total phosphorus. The ponds must now be checked for depth of anoxia to verify that the permanent pool volume will remain aerated.

7. Evaluate depth of pond anoxia

Calculates for estimated concentrations of total phosphorus, chlorophyll-a, Secchi disk depth, and depth of anoxia are performed as in Example #1. A summary of these calculations is given in the table below:

POND	ANNUAL TP DISCHARGED (kg/yr)	ANNUAL VOLUME DISCHARGED (ac-ft/yr)	MEAN TP CONC. IN DISCHARGE (mg/l)	MEAN CHYL-A CONC. (mg/m^3)	MEAN SECCHI DISK DEPTH (m)	DEPTH OF ANOXIA	
						m	ft
SB-1	4.38	89.52	0.040	15.3	1.06	3.65	12.0
SB-2	2.49	52.20	0.039	14.8	1.09	3.71	12.2
SB-3	8.81	240.86	0.030	10.1	1.51	4.60	15.1

Since the proposed pond depths exceed the calculated zone of anoxia, further revisions to the pond design or permanent pool volumes are necessary.

SECTION 5

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APPENDICES

APPENDIX A

LITERATURE-BASED HYDROLOGIC AND STORMWATER CHARACTERISTICS FOR EVALUATION OF LAND USE CATEGORIES

TABLE A.1

SUMMARY OF HYDROLOGIC CHARACTERISTICS FROM SINGLE-FAMILY RESIDENTIAL STORMWATER RUNOFF STUDIES IN CENTRAL/SOUTH FLORIDA

PARAMETER	POMPANO BEACH	TAMPA-CHARTER STREET	TAMPA-KIRBY STREET	TAMPA-ST. LOUIS STREET DITCH	HIDDEN LAKE, SANFORD	ORLANDO DUPLEX	SPRINGHILL SUBDIVISION, PALM BEACH	TAMPA-102nd AVE.	SARASOTA COUNTY	OVERALL MEAN VALUE
Watershed Area	40.8 ac	42.0 ac	897 ac	326 ac	54.3 ac	25.13 ac	32.4 ac	70.0 ac	30.0 ac	--
Percent Impervious (%)	43.9	14.0	19.0	27.0	24.5	34.0	37.0	N/A	25.0	28.1
Land Use	Single-Family Residential (5.3 units/ac)	Low-Density Residential (2 units/ac)	68% Single-Family (2.5 units/ac)	69% Single-Family (2 units/ac)	Low-Density Residential (3 units/ac)	Duplex (4 units/ac)	Single-Family (3 units/ac)	Single-Family Residential	Single-Family Residential	--
Runoff Coefficient	0.169[1]	0.298[1]	0.333[1]	0.389[1]	0.220	0.440	0.461[1]	N/A	N/A	0.330
Drainage System	Grass Swales	12% Curb-Gutter 75% Grass Swales 13% Ditches (100% Sewered)	Curb and Gutter	Curb and Gutter	Grass Swales	Curb and Gutter	Grass Swales	Curb and Gutter	Grass Swales	--
Reference	Mattraw, et al. (1978)	U.S. EPA (1983)	Lopez, et al. (1984)	Lopez, et al. (1984)	Harper, et al. (1985)	Harper (1988)	Greg, et al. (1989)	Holtkamp (1998)	ERD (2003)	--

1. Runoff coefficient not provided in reference. Value shown is a calculated estimate.

TABLE A.2

SUMMARY OF MEAN STORMWATER CHARACTERISTICS FROM SINGLE-FAMILY RESIDENTIAL STORMWATER RUNOFF STUDIES IN CENTRAL/SOUTH FLORIDA

MEAN RUNOFF CONCENTRATION (mg/l)	POMPANO BEACH	TAMPA-CHARTER STREET	ST. PETE-BEAR CREEK	TAMPA-KIRBY STREET	TAMPA-ST. LOUIS STREET DITCH	HIDDEN LAKE, SANFORD	ORLANDO DUPLEX	SPRINGHILL SUBDIVISION, PALM BEACH	TAMPA-102nd AVE.	SARASOTA COUNTY	OVERALL MEAN VALUE
Total N	2.14	2.31	1.50	2.20	3.00	0.605	4.62	1.18	2.62	1.60	2.18
Total P	0.32	0.40	0.200	0.25	0.45	0.073	1.69[1]	0.307	0.510	0.506	0.335
BOD	8.3	13.0	4.7	4.5	6.1	2.9	9.5	--	13.4	4.4	7.4
T.S.S.	28.0	33.0	--	--	--	7.2	63.2	3.5	36.8	10.1	26.0
Copper	0.008	--	0.009	--	0.016	0.026	0.033	--	0.019	--	0.023
Lead	0.166[1]	0.049	0.128[1]	0.050	0.213[1]	0.033	0.058	--	0.005	--	0.039
Zinc	0.086	0.053	0.083	--	0.133	0.006	0.089	--	0.060	--	0.073
Reference	Mattraw, et al. (1978)	U.S. EPA (1983)	Lopez, et al. (1984)	Lopez, et al. (1984)	Lopez, et al. (1984)	Harper, et al. (1985)	Harper (1988)	Greg, et al. (1989)	Holtkamp (1998)	ERD (2003)	--

1. Data not included in mean value.

TABLE A.3

SUMMARY OF HYDROLOGIC CHARACTERISTICS FROM MULTI-FAMILY RESIDENTIAL STORMWATER RUNOFF STUDIES IN CENTRAL/SOUTH FLORIDA

PARAMETER	ORLANDO-SHOALS APARTMENTS	MIAMI-KINGS CREEK APARTMENTS	LOCH LOMOND	ORLANDO DOWNTOWN	TAMPA-YOUNG APARTMENTS	ORLANDO ESSEX POINTE	OVERALL MEAN VALUE
Watershed Area	NA	14.7 ac	26.0 ac	62.5 ac	8.7 ac	7.39 ac	--
Percent Impervious (%)	74.0	70.7	65.0	66.4	61.0	65.0	67.0
Land Use	Apartments	Apartments	High-Density (18 units/ac)	High-Density	High-Density Multi-Family	Cluster Homes	--
Runoff Coefficient	0.723[1]	0.700[1]	0.662[1]	0.674	0.631[1]	0.660[1]	0.675
Drainage System	100% Grates and Sewers	Drainage Along Centerline of Roadway	100% Grates and Sewers	100% Curb and Gutter	100% Curb and Gutter	100% Curb and Gutter	--
Reference	ECFRPC (1978)	Miller (1979)	Weinburg, et al. (1980)	Wanielista, et al. (1982)	U.S. EPA (1983)	Harper (1988)	--

1. Runoff coefficient not provided in reference. Value shown is a calculated estimate.

TABLE A.4

SUMMARY OF MEAN STORMWATER CHARACTERISTICS FROM MULTI-FAMILY RESIDENTIAL STORMWATER RUNOFF STUDIES IN CENTRAL/SOUTH FLORIDA

MEAN RUNOFF CONCENTRATION (mg/l)	ORLANDO-SHOALS APARTMENTS	MIAMI-KINGS CREEK APARTMENTS	LOCH LOMOND	ORLANDO DOWNTOWN	TAMPA-YOUNG APARTMENTS	ORLANDO ESSEX POINTE	OVERALL MEAN VALUE
Total N	1.91	2.57	1.91	4.68	1.61	1.85	2.42
Total P	0.51	0.45	0.73	0.72	0.33	0.20	0.49
BOD	7.8	14.5	--	10.1	16.0	6.5	11.0
T.S.S.	143	36.8	--	95.6	53.0	30.1	71.7
Copper	--	--	--	--	--	0.031	0.031
Lead	0.341[1]	0.054	--	--	0.076	0.132	0.087
Zinc	--	0.059	--	--	0.060	0.045	0.055
Reference	ECFRPC (1978)	Miller (1979)	Weinburg, et al. (1980)	Wanielista, et al. (1982)	U.S. EPA (1983)	Harper (1988)	--

1. Value not included in calculation of mean values.

TABLE A.5

SUMMARY OF HYDROLOGIC CHARACTERISTICS FROM LOW INTENSITY COMMERCIAL STORMWATER RUNOFF STUDIES IN CENTRAL/SOUTH FLORIDA

PARAMETER	ORLANDO AREAWIDE STUDY[1]	FT. LAUDERDALE CORAL RIDGE MALL	TAMPA-NORMA PARK	ORLANDO INTERNATIONAL MARKET PLACE	SARASOTA COUNTY	OVERALL MEAN VALUE
Watershed Area	--	20.4 ac	46.6 ac	2.17 ac	N/A	--
Percent Impervious (%)	75.5	98.0	90.3	100.0	N/A	91.0
Land Use	Parking Lot, Motel Strip Commercial	Shopping Center	Commercial	Parking Lot, Strip Mall	Commercial area along major highway	--
Runoff Coefficient	0.729[2]	0.967[2]	0.832[2]	0.900	N/A	0.857
Drainage System	Curb and Gutter or Inlets with Sewers	100% Inlets and Stormsewers	21.7% Curb/Gutter 72.5% Ditch/Swale 5.8% Grass Swale	100% Inlets and Stormsewers	100% Inlets and Stormsewers	--
Reference	ECFRPC (1978)	Miller (1979)	U.S. EPA (1983)	Harper (1988)	ERD (2003)	--

1. Average of studies performed on a parking lot, motel complex and commercial strip development.
2. Runoff coefficient not provided in reference. Value shown is a calculated estimate.

TABLE A.6

SUMMARY OF MEAN STORMWATER CHARACTERISTICS FROM LOW-INTENSITY COMMERCIAL STORMWATER RUNOFF STUDIES IN CENTRAL/SOUTH FLORIDA

MEAN RUNOFF CONCENTRATION (mg/l)	ORLANDO AREAWIDE STUDY[1]	FT. LAUDERDALE CORAL RIDGE MALL	TAMPA-NORMA PARK	ORLANDO INTERNATIONAL MARKET PLACE	SARASOTA COUNTY	OVERALL MEAN VALUE
Total N	0.89	1.1	1.19	1.53	0.88	1.12
Total P	0.16	0.10	0.15	0.19	0.31	0.18
BOD	3.6	5.4	12.0	11.6	4.3	7.4
T.S.S.	146	45.0	22.0	111	39.9	72.8
Copper	--	0.015	--	0.031	--	0.023
Lead	0.068[2]	0.387[2]	0.046[2]	0.136	--	0.136
Zinc	--	0.128	0.037	0.168	--	0.111
Total Coliform (No./100 ml)	206	43,000	--	--	--	--
Reference	ECFRPC (1978)	Miller (1979)	U.S. EPA (1983)	Harper (1988)	ERD (2003)	--

1. Average of studies performed on a parking lot, motel complex and commercial strip development.
2. Value not included in calculation of mean value.

TABLE A.7

SUMMARY OF HYDROLOGIC CHARACTERISTICS FROM HIGH-INTENSITY COMMERCIAL STORMWATER RUNOFF STUDIES IN CENTRAL/SOUTH FLORIDA

PARAMETER	ORLANDO-DOWNTOWN AREA	DADE COUNTY	BROWARD COUNTY	OVERALL MEAN VALUE
Watershed Area	83.3 ac	NA	NA	--
Percent Impervious (%)	96.4	98.0	98.0	97.5
Land Use	Downtown Commercial/Office Area, Parking Lots	Commercial Area with Heavy Traffic	Heavily Traveled Highway with Adjacent Commercial Area	--
Runoff Coefficient	0.889[1]	0.886[1]	0.886[1]	0.887
Drainage System	100% Curb and Gutter	Overland Flow to Roadside Swale	Overland Flow to Roadside Swale	--
Reference	Wanielista (1982)	Waller (1984)	Howie, et al. (1986)	--

1. Runoff coefficient not provided in reference. Value shown is a calculated estimate.

TABLE A.8

SUMMARY OF MEAN STORMWATER CHARACTERISTICS FROM HIGH-INTENSITY COMMERCIAL STORMWATER RUNOFF STUDIES IN CENTRAL/SOUTH FLORIDA

MEAN RUNOFF CONCENTRATION (mg/l)	ORLANDO-DOWNTOWN AREA	DADE COUNTY	BROWARD COUNTY	OVERALL MEAN VALUE
Total N	2.81	3.53	2.15	2.83
Total P	0.31	0.82	0.15	0.43
BOD	17.2	--	--	17.2
T.S.S.	94.3	--	--	94.3
Lead	0.560[1]	0.187	0.241	0.214
Zinc	0.165	0.183	0.162	0.170
Reference	Wanielista (1982)	Waller (1984)	Howie, et al. (1986)	--

1. Value not included in calculation of mean.

TABLE A.9

SUMMARY OF HYDROLOGIC CHARACTERISTICS FROM HIGHWAY/TRANSPORTATION STORMWATER RUNOFF STUDIES IN CENTRAL/SOUTH FLORIDA

PARAMETER	BROWARD COUNTY	I-95 MIAMI	I-4 MAITLAND INTERCHANGE	EPCOT INTERCHANGE	ORLANDO I-4	ORLANDO I-4	OVERALL MEAN VALUE
Watershed Area	58.3 ac	1.43 ac	48.9 ac	--	1.17 ac	1.30 ac	--
Percent Impervious (%)	36.4	100	--	--	100	70	76.6
Land Use	6-Lane Divided Highway plus Roadside Areas	Asphalt Interstate Highway, 70,000 vpd	Asphalt Interstate Highway, 15,000 vpd	Asphalt Interstate Highway	Concrete Interstate Highway, 65,000 vpd	Concrete Interstate Highway, 69,000 vpd	--
Annual Runoff Coefficient	0.190	0.818[1]	0.850[1]	0.80[1]	0.85	0.63	0.690
Drainage System	Curb and Gutter	Curb and Gutter/ Inlets with Sewers	Curb and Gutter/ Inlets with Sewers	Curb and Gutter/ Roadside Swale	Curb and Gutter/ Inlets with Sewers	Concrete Swales/ Stormsewers	--
Reference	Mattraw, et al. (1978)	McKenzie, et al. (1983)	Yousef, et al. (1986)	Yousef, et al. (1986)	Harper (1988)	Harper (1988)	--

1. Runoff coefficient not provided in reference. Value shown is a calculated estimate.

TABLE A.10

SUMMARY OF MEAN STORMWATER CHARACTERISTICS FROM HIGHWAY / TRANSPORTATION STORMWATER RUNOFF STUDIES IN CENTRAL/SOUTH FLORIDA

MEAN RUNOFF CONCENTRATION (mg/l)	BROWARD COUNTY (6-lane)	I-95 MIAMI	I-4 MAITLAND INTERCHANGE	I-4 EPCOT INTERCHANGE	ORLANDO I-4	ORLANDO I-4	OVERALL MEAN VALUE
Total N	0.96	4.12	1.40	3.16	1.60	2.15	2.23
Total P	0.08	0.17	0.17	0.42	0.23	0.159	0.27
BOD	9.0	--	--	--	6.9	4.2	6.7
T.S.S.	15.0	81.0	--	--	34.0	66.5	49.1
Copper	0.006	0.054	0.039	0.024	0.050	0.067	0.040
Lead	0.282	0.680[1]	0.181	0.026	0.224	0.343	0.211
Zinc	0.090	0.370	0.074	0.024	0.170	0.272	0.167
Reference	Mattraw, et al. (1978)	McKenzie, et al. (1983)	Yousef, et al. (1986)	Yousef, et al. (1986)	Harper (1988)	Harper (1988)	--

1. Value not included in calculation of mean value.

TABLE A.11

SUMMARY OF HYDROLOGIC CHARACTERISTICS FROM PASTURE LAND USE RUNOFF STUDIES IN CENTRAL / SOUTH FLORIDA

PARAMETER	ORLANDO AREAWIDE STUDY	ST. JOHNS RIVER BASIN (PASTURE)	ASH SLOUGH	MEAN VALUES
Watershed Area	NA	155,741 ac	220 ac	--
Soil Types	Poorly Drained Soils	Muck, Fine Sand, Peat	Felda, Myakka, Pompano Sands	--
Land Use	Pasture, Cattle	Pasture	Pasture	--
Runoff Coefficient	0.251	0.413	0.400	0.355
Reference	ECFRPC (1978)	Fall (1987)	Hendrickson (1987)	--

TABLE A.12

SUMMARY OF MEAN STORMWATER CHARACTERISTICS FROM PASTURE LAND USE RUNOFF STUDIES IN CENTRAL / SOUTH FLORIDA

MEAN RUNOFF CONCENTRATION (mg/l)	ORLANDO AREAWIDE STUDY	ST. JOHNS RIVER BASIN (PASTURE)	ASH SLOUGH	MEAN VALUES
Total N	2.58	2.48	2.37	2.48
Total P	0.46	0.27	0.697	0.476
BOD	7.0	3.2	--	5.1
T.S.S.	180	8.6	--	94.3
Reference	ECFRPC (1978)	Fall (1987)	Hendrickson (1987)	--

TABLE A.13

SUMMARY OF HYDROLOGIC CHARACTERISTICS FROM CITRUS LAND USE RUNOFF STUDIES IN CENTRAL/SOUTH FLORIDA

PARAMETER	UPPER ST. JOHNS RIVER BASIN	ST. JOHNS WATER CONTROL DISTRICT	ARMSTRONG SLOUGH	UPPER ST. JOHNS RIVER BASIN	GATOR SLOUGH (Hendry/ Collier Counties)	CHARLOTTE/ DeSOTO COUNTIES (4 sites)	UPPER ST. JOHNS RIVER BASIN	MEAN VALUES
Watershed Area	56,867 ac	27,721 ac	10,000 ac	27,721 ac	1,492 ac	184-602 ac	--	--
Soil Types	Muck, Peat	Organic Muck, Poorly Drained	Placid, Basinger Sands; Samsula Muck	Poorly Drained Sand	Sand/Muck, Poorly Drained	Poorly Drained Sand	Poorly Drained Sand	--
Land Use	Citrus/Some Row Crops	Citrus/ Some Pasture	Citrus/ Some Pasture	Citrus/ Some Pasture	Citrus	Citrus	Citrus	--
Runoff Coefficient	0.251	0.302	0.294	--	0.757	--	--	0.401
Reference	Fall (1987)	Fall, et al. (1987)	Hendrickson (1987)	Fall (1990)	Sawka and Black (1993)	Bahk, et al. (1997)	Fall (1995)	--

TABLE A.14

SUMMARY OF HYDROLOGIC CHARACTERISTICS FROM ROW CROP RUNOFF STUDIES IN CENTRAL/SOUTH FLORIDA

PARAMETER	WILLOWBROOK FARMS	UPPER ST. JOHNS RIVER BASIN	UPPER ST. JOHNS RIVER BASIN	UPPER ST. JOHNS RIVER BASIN	MANATEE COUNTY (5 sites)	COCKROACH BAY (Ruskin, FL)	UPPER ST. JOHNS RIVER BASIN (3 sites)	MEAN VALUES
Watershed Area	5,680 ac	N/A	N/A	N/A	5 areas ranging from 12-20 acres	210 ac	N/A	--
Soil Types	Felda, Wabasso Sands; Canova Peat	Sand/Muck	Sand/Muck	Sand/Muck	Sand/Muck	Sand/Muck	Sand/Muck	--
Land Use	Row Crop	Row Crops/ Some Citrus	Row Crops/ Some Pasture	Row Crops/ Some Dairy	Row Crops/ Tomatoes	Row Crops	Row Crops	--
Runoff Coefficient	0.204	--	--	--	--	--	--	0.204
Reference	Hendrickson (1987)	Fall (1987)	Fall (1990)	Fall (1995)	Bahk, et al. (1997)	Bahk (1997)	Hendrickson (unpublished data)	--

TABLE A.15

SUMMARY OF MEAN STORMWATER CHARACTERISTICS FROM CITRUS LAND USE RUNOFF STUDIES IN CENTRAL/SOUTH FLORIDA

MEAN RUNOFF CONCENTRATION (mg/l)	ST. JOHNS RIVER BASIN (Citrus/Row)	ST. JOHNS WATER CONTROL DISTRICT (Citrus/ Pasture)	ARMSTRONG SLOUGH (Citrus/Pasture)	UPPER ST. JOHNS RIVER BASIN	GATOR SLOUGH (Hendry/ Collier Counties)	UPPER ST. JOHNS RIVER BASIN	CHARLOTTE/ DeSOTO COUNTIES (4 sites)	MEAN VALUES
Total N	3.26	1.33	1.57	2.72	3.32	2.31	1.15	2.24
Total P	0.24	0.09	0.09	0.16	0.170	0.45	0.08	0.183
BOD	3.0	2.1	--	--	--	--	--	2.55
T.S.S.	28.0	4.6	--	23.3	--	20.1	1.69	15.5
Cadmium	--	--	--	--	--	--	0.0004	0.0004
Chromium	--	--	--	--	--	--	0.001	0.001
Copper	--	--	--	0.004	0.002	--	--	0.003
Lead	--	--	--	--	--	--	0.001	0.001
Zinc	--	--	--	--	--	--	0.012	0.012
Reference	Fall (1987)	Fall, et al. (1987)	Hendrickson (1987)	Fall (1990)	Sawka and Black (1993)	Fall (1995)	Bahk and Kehoe (1997)	--

TABLE A.16

SUMMARY OF STORMWATER CHARACTERISTICS FROM ROW CROP LAND USE RUNOFF STUDIES IN CENTRAL/SOUTH FLORIDA

MEAN RUNOFF CONCENTRATION (mg/l)	WILLOWBROOK FARMS	UPPER ST. JOHNS RIVER BASIN	UPPER ST. JOHNS RIVER BASIN	UPPER ST. JOHNS RIVER BASIN	MANATEE COUNTY (5 sites)	COCKROACH BAY (Ruskin, FL)	UPPER ST. JOHNS RIVER BASIN (3 sites)	MEAN VALUES
Total N	2.68	3.26	4.73	3.36	1.45	2.39	2.26	2.88
Total P	0.562	0.24	0.43	1.07	0.500	1.50	0.163	0.638
BOD	--	--	--	--	--	--	--	--
T.S.S.	--	--	37.4	32.4	7.0	--	4.9	20.4
Cadmium	--	--	--	--	0.0001	--	--	0.0001
Chromium	--	--	--	--	0.001	--	--	0.001
Copper	--	--	--	--	0.011	0.097	--	0.054
Lead	--	--	--	--	0.0008	0.17	--	0.009
Zinc	--	--	--	--	0.017	0.064	--	0.041
Reference	Hendrickson (1987)	Fall (1987)	Fall (1990)	Fall (1995)	Bahk, et al. (1997)	Bahk (1997)	Hendrickson (unpublished data)	--

TABLE A.17

SUMMARY OF HYDROLOGIC CHARACTERISTICS FROM OPEN SPACE / UNDEVELOPED RANGELAND / FOREST STORMWATER RUNOFF STUDIES IN CENTRAL / SOUTH FLORIDA

PARAMETER	ORLANDO ECFRPC	MIAMI	BOGGY CREEK STUDY	SARASOTA/ CHARLOTTE COUNTIES (3 sites)	OVERALL MEAN VALUE
Watershed Area (ha)	NA	NA	NA	N/A	--
Percent Impervious (%)	0	0	2	0	1.5
Land Use	Range/Park	Range/Park	Range/Park	Range/Forest	--
Runoff Coefficient	0.127	0.152	0.210	N/A	0.163
Reference	ECFRPC (1978)	Waller (1982)	ECFRPC (1988)	ERD (2003)	--

TABLE A.18

SUMMARY OF STORMWATER CHARACTERISTICS FROM RECREATIONAL / OPEN SPACE / UNDEVELOPED RANGELAND / FOREST STORMWATER RUNOFF STUDIES IN CENTRAL / SOUTH FLORIDA

MEAN RUNOFF CONCENTRATION (mg/l)	ORLANDO ECFRPC	MIAMI	BOGGY CREEK STUDY	SARASOTA/ CHARLOTTE COUNTIES	OVERALL MEAN VALUE
Total N	1.38	0.90	1.47	0.596	1.09
Total P	0.07	0.02	0.07	0.025	0.046
BOD	1.45	--	--	1.00	1.23
T.S.S.	17.3	4.8	--	1.2	7.8
Total Zn	--	--	--	--	--
Total Pb	--	--	--	--	--
Reference	ECFRPC (1978)	Waller (1982)	ECFRPC (1988)	ERD (2003)	--

TABLE A.19

SUMMARY OF HYDROLOGIC AND STORMWATER CHARACTERISTICS FROM MINING / EXTRACTIVE STORMWATER RUNOFF STUDIES IN CENTRAL / SOUTH FLORIDA

PARAMETER	BOGGY CREEK STUDY	OVERALL MEAN VALUE
Watershed Area	NA	--
Percent Impervious (%)	23	23
Land Use	Mixed Mining Activities	--
Runoff Coefficient	0.361[1]	0.361
Total N (mg/l)	1.18	1.18
Total P (mg/l)	0.15	0.15
BOD (mg/l)	--	--
T.S.S. (mg/l)	--	--
Total Pb (mg/l)	--	--
Total Zn (mg/l)	--	--
Reference	ECFRPC (1988)	--

1. Runoff coefficient not provided in reference. Value shown is a calculated estimate.

TABLE A.20

SUMMARY OF HYDROLOGIC PARAMETERS FROM WETLAND STORMWATER RUNOFF STUDIES IN CENTRAL / SOUTH FLORIDA

PARAMETER	ORLANDO AREAWIDE STUDY	HIDDEN LAKE-SANFORD	MIAMI AREA	BOGGY CREEK STUDY	OVERALL MEAN VALUE
Watershed Area	NA	2.47 ac	NA	NA	--
Percent Impervious (%)	0.0	0.0	0.0	1.0	0.25
Land Use	Hardwood Wetland	Hardwood Wetland	Mixed	Mixed	--
Soil Type	Peat	Peat	Mixed	Mixed	--
Runoff Coefficient	0.191[1]	0.303	0.200[1]	0.207[1]	0.225
Drainage System	Overland Flow	Overland Flow	Mixed	Mixed	--
Reference	ECFRPC (1978)	Harper, et al. (1985)	USGS (1985)	ECFRPC (1988)	--

1. Runoff coefficient not provided in reference. Value shown is a calculated estimate.

APPENDIX B

CALCULATED POLLUTANT REMOVAL EFFICIENCIES FOR DRY RETENTION PONDS AS A FUNCTION OF TREATMENT VOLUME

Table B.1

Calculated Removal Efficiency for 0.25 inch of Retention as a Function of Curve Number and DCIA for Southwest Florida Conditions

DCIA	Non DCIA Curve Number																	
	25	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**96**	**97**	**98**
5	97.0	94.5	90.7	85.6	79.7	73.4	67.1	60.7	55.1	51.2	46.1	43.8	39.6	37.7	34.2	33.4	32.9	32.5
10	92.4	91.3	89.3	86.4	82.5	77.6	72.4	66.4	61.2	55.1	49.9	46.0	40.7	38.8	34.1	33.3	32.9	32.4
15	86.4	85.7	84.5	82.8	80.3	77.0	72.9	67.8	62.1	56.9	52.6	46.3	41.7	39.7	34.0	33.3	32.9	32.4
20	79.5	79.1	78.3	77.1	75.5	73.2	70.3	66.5	62.3	57.7	51.8	46.5	42.5	40.0	33.9	33.3	32.8	32.3
25	72.8	72.5	72.0	71.1	70.0	68.4	66.3	63.5	60.1	55.8	51.1	46.7	43.2	39.2	33.9	33.3	32.7	32.3
30	67.2	67.0	66.6	66.0	65.2	64.0	62.4	60.4	57.7	54.3	50.5	46.8	43.8	38.5	33.8	33.2	32.6	32.2
35	63.2	63.1	62.8	62.3	61.7	60.8	59.6	58.0	55.9	53.2	50.0	47.0	43.0	37.9	33.7	33.2	32.5	32.2
40	59.7	59.6	59.4	59.0	58.5	57.8	56.9	55.6	54.0	51.8	49.2	45.8	41.7	37.3	33.6	33.0	32.4	32.1
45	54.8	54.7	54.5	54.3	53.9	53.4	52.7	51.7	50.4	48.7	46.6	43.9	40.5	36.8	33.6	32.9	32.3	32.1
50	50.8	50.8	50.6	50.4	50.2	49.8	49.2	48.5	47.5	46.1	44.5	42.2	39.4	36.3	33.3	32.7	32.2	32.0
55	47.6	47.5	47.4	47.3	47.1	46.8	46.3	45.8	45.0	43.9	42.6	40.8	38.5	35.9	33.1	32.6	32.2	32.0
60	44.9	44.9	44.8	44.7	44.5	44.3	43.9	43.5	42.9	42.1	41.0	39.5	37.7	35.5	32.9	32.5	32.1	31.9
65	42.6	42.6	42.5	42.4	42.3	42.1	41.9	41.5	41.1	40.4	39.6	38.4	36.9	34.9	32.7	32.3	32.0	31.9
70	40.5	40.4	40.4	40.3	40.2	40.1	39.9	39.6	39.3	38.8	38.1	37.2	36.0	34.4	32.5	32.2	31.9	31.8
75	38.5	38.5	38.4	38.4	38.3	38.2	38.1	37.9	37.6	37.2	36.7	36.0	35.1	33.8	32.3	32.1	31.9	31.7
80	36.7	36.7	36.7	36.7	36.6	36.5	36.4	36.3	36.1	35.8	35.5	35.0	34.2	33.3	32.2	32.0	31.8	31.6
85	35.2	35.2	35.2	35.2	35.1	35.1	35.0	34.9	34.8	34.6	34.3	34.0	33.5	32.8	32.0	31.8	31.6	31.5
90	33.8	33.8	33.8	33.8	33.8	33.8	33.7	33.7	33.6	33.5	33.3	33.1	32.8	32.4	31.8	31.6	31.5	31.4
95	32.5	32.5	32.5	32.5	32.4	32.4	32.4	32.4	32.4	32.3	32.2	32.1	32.0	31.8	31.5	31.4	31.3	31.3
100	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2

Table B.2

Calculated Removal Efficiency for 0.50 inch of Retention as a Function of Curve Number and DCIA for Southwest Florida Conditions

DCIA	Non DCIA Curve Number																	
	25	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**96**	**97**	**98**
5	98.8	96.7	94.1	90.6	86.4	81.4	76.6	72.3	68.6	64.9	61.9	60.6	57.5	56.3	53.1	53.4	54.0	53.2
10	97.8	96.6	94.8	92.1	89.0	85.3	81.4	77.3	72.8	69.2	65.2	62.2	58.9	56.3	53.4	53.6	54.1	53.1
15	95.6	94.9	93.6	91.7	89.2	86.1	82.8	78.8	75.2	70.9	67.5	63.0	60.0	56.2	53.6	53.8	54.3	52.9
20	92.8	92.3	91.4	90.0	88.1	85.5	82.6	79.3	75.5	72.0	67.9	63.7	61.0	56.2	53.8	53.9	54.4	52.8
25	89.6	89.2	88.5	87.5	86.1	84.1	81.6	78.7	75.6	72.0	67.8	64.2	61.2	56.2	54.0	54.1	54.1	52.7
30	86.6	86.3	85.8	85.1	84.0	82.5	80.5	77.8	74.6	71.1	67.7	64.6	60.5	56.2	54.2	54.3	53.9	52.5
35	82.7	82.5	82.1	81.5	80.7	79.5	77.9	75.8	73.2	70.4	67.6	64.4	59.9	56.2	54.4	54.4	53.6	52.4
40	79.7	79.5	79.2	78.8	78.1	77.2	75.9	74.2	72.2	69.9	67.0	63.2	59.4	56.2	54.5	54.6	53.4	52.3
45	76.7	76.5	76.3	75.9	75.4	74.7	73.7	72.3	70.5	68.2	65.3	62.1	59.0	56.2	54.7	54.4	53.2	52.1
50	72.9	72.8	72.6	72.4	72.0	71.4	70.6	69.5	68.1	66.2	63.8	61.2	58.6	56.2	54.9	54.0	52.9	52.0
55	69.9	69.8	69.6	69.4	69.1	68.7	68.0	67.2	66.0	64.5	62.6	60.4	58.2	56.2	54.7	53.7	52.7	51.9
60	67.3	67.3	67.1	67.0	66.7	66.4	65.9	65.2	64.3	63.0	61.5	59.7	57.9	56.2	54.2	53.3	52.5	51.8
65	65.2	65.1	65.0	64.9	64.7	64.4	64.0	63.5	62.8	61.8	60.5	59.1	57.6	56.2	53.7	53.0	52.3	51.7
70	63.3	63.3	63.2	63.1	63.0	62.7	62.4	62.0	61.5	60.7	59.7	58.5	57.3	56.1	53.3	52.6	52.0	51.5
75	61.7	61.7	61.6	61.6	61.4	61.3	61.1	60.7	60.3	59.7	58.9	58.0	57.1	55.2	52.8	52.3	51.8	51.4
80	59.8	59.8	59.7	59.7	59.6	59.5	59.3	59.1	58.7	58.3	57.7	56.9	55.7	54.3	52.4	52.0	51.6	51.3
85	57.2	57.2	57.1	57.1	57.0	56.9	56.8	56.7	56.5	56.2	55.8	55.2	54.4	53.3	52.0	51.7	51.4	51.2
90	54.8	54.8	54.8	54.8	54.8	54.7	54.6	54.5	54.4	54.2	54.0	53.6	53.1	52.5	51.6	51.4	51.2	51.1
95	52.8	52.7	52.7	52.7	52.7	52.7	52.7	52.6	52.6	52.5	52.4	52.2	52.0	51.6	51.2	51.1	51.1	51.0
100	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9

Table B.3

Calculated Removal Efficiency for 0.75 inch of Retention as a Function of Curve Number and DCIA for Southwest Florida Conditions

DCIA	Non DCIA Curve Number																	
	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	96	97	98
5	99.5	98.1	95.7	93.2	90.0	86.6	82.5	78.9	76.1	73.4	71.1	69.8	68.6	66.7	65.8	65.0	64.5	64.6
10	98.9	97.8	96.5	94.6	92.3	89.3	86.2	83.0	79.7	76.9	73.9	71.4	70.0	67.2	65.7	65.0	64.5	64.6
15	98.1	97.3	96.2	94.5	92.5	90.1	87.4	84.6	81.7	78.4	75.8	72.6	70.6	67.6	65.6	64.9	64.5	64.6
20	96.7	96.1	95.2	93.8	92.1	90.1	87.7	85.2	82.2	79.4	76.3	73.6	70.7	68.0	65.5	64.9	64.5	64.6
25	94.9	94.5	93.9	92.8	91.3	89.5	87.5	85.0	82.4	79.7	76.7	74.3	70.8	68.4	65.5	64.9	64.5	64.6
30	92.9	92.6	92.1	91.3	90.1	88.5	86.6	84.6	82.2	79.5	77.0	74.2	70.9	68.7	65.4	64.8	64.5	64.6
35	91.0	90.7	90.3	89.7	88.7	87.4	85.7	83.7	81.5	79.3	77.1	73.8	70.9	69.0	65.3	64.8	64.5	64.6
40	88.6	88.4	88.1	87.5	86.8	85.8	84.4	82.8	81.0	79.1	76.2	73.4	71.0	69.1	65.2	64.8	64.5	64.6
45	86.7	86.6	86.3	85.9	85.3	84.5	83.4	81.9	80.0	77.8	75.4	73.1	71.0	68.5	65.2	64.8	64.5	64.6
50	84.0	83.8	83.6	83.3	82.8	82.2	81.3	80.1	78.5	76.7	74.8	72.8	71.1	68.0	65.1	64.7	64.5	64.6
55	81.7	81.6	81.4	81.1	80.8	80.2	79.5	78.5	77.3	75.8	74.2	72.6	70.6	67.5	65.0	64.7	64.5	64.6
60	79.7	79.7	79.5	79.3	79.0	78.6	78.0	77.2	76.2	75.0	73.7	72.1	69.6	67.1	65.0	64.7	64.5	64.6
65	78.1	78.1	78.0	77.8	77.6	77.2	76.8	76.1	75.3	74.1	72.6	70.8	68.8	66.7	64.9	64.7	64.5	64.6
70	75.4	75.3	75.2	75.1	74.9	74.7	74.3	73.8	73.1	72.2	71.0	69.6	68.0	66.3	64.9	64.7	64.5	64.6
75	73.0	72.9	72.9	72.8	72.6	72.4	72.2	71.8	71.3	70.6	69.7	68.6	67.3	66.0	64.8	64.6	64.5	64.6
80	70.9	70.8	70.8	70.7	70.6	70.5	70.3	70.0	69.6	69.1	68.4	67.6	66.7	65.7	64.7	64.6	64.5	64.6
85	69.0	69.0	69.0	68.9	68.8	68.7	68.6	68.4	68.2	67.8	67.3	66.7	66.1	65.4	64.7	64.6	64.5	64.6
90	67.4	67.3	67.3	67.3	67.3	67.2	67.1	67.0	66.8	66.6	66.3	65.9	65.5	65.1	64.6	64.6	64.5	64.6
95	65.9	65.9	65.9	65.9	65.8	65.8	65.8	65.7	65.6	65.5	65.4	65.2	65.0	64.8	64.6	64.6	64.5	64.6
100	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6

Table B.4

Calculated Removal Efficiency for 1.00 inch of Retention as a Function of Curve Number and DCIA for Southwest Florida Conditions

DCIA	Non DCIA Curve Number																	
	25	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**96**	**97**	**98**
5	100.0	99.0	97.0	94.6	92.3	89.4	86.7	83.5	81.0	79.1	77.3	76.1	75.5	74.8	73.6	73.7	74.1	74.0
10	99.5	98.6	97.3	96.0	94.2	92.0	89.4	86.7	84.1	81.9	79.8	77.7	76.2	75.5	73.8	73.9	74.2	74.0
15	98.9	98.2	97.4	96.1	94.6	92.6	90.4	88.0	85.8	83.3	80.9	78.9	76.9	75.9	73.9	74.0	74.3	73.9
20	98.2	97.7	96.9	95.7	94.3	92.6	90.7	88.7	86.4	84.3	81.6	79.8	77.4	75.9	74.0	74.1	74.4	73.9
25	97.2	96.8	96.1	95.0	93.8	92.3	90.7	88.7	86.7	84.4	82.2	79.9	77.8	75.9	74.2	74.2	74.5	73.8
30	95.9	95.6	95.0	94.2	93.2	91.9	90.3	88.6	86.6	84.5	82.6	80.1	78.2	75.8	74.3	74.3	74.4	73.7
35	94.5	94.3	93.8	93.2	92.2	91.1	89.8	88.0	86.2	84.5	82.3	80.2	78.6	75.8	74.4	74.4	74.3	73.7
40	93.0	92.8	92.4	91.9	91.1	90.1	88.8	87.4	86.0	84.1	82.1	80.3	78.4	75.8	74.5	74.6	74.2	73.6
45	91.4	91.3	91.0	90.6	90.0	89.1	88.1	86.8	85.2	83.5	81.9	80.3	78.0	75.7	74.6	74.7	74.1	73.6
50	89.7	89.6	89.4	89.0	88.5	87.8	86.9	85.7	84.4	83.1	81.7	79.9	77.6	75.7	74.7	74.6	74.0	73.5
55	88.1	88.0	87.8	87.5	87.1	86.6	85.8	84.9	83.8	82.7	81.1	79.2	77.3	75.7	74.8	74.4	73.9	73.5
60	86.7	86.7	86.5	86.3	86.0	85.5	84.9	84.1	83.0	81.7	80.2	78.6	77.1	75.7	74.8	74.2	73.7	73.4
65	84.6	84.6	84.5	84.3	84.0	83.7	83.2	82.5	81.6	80.5	79.3	78.1	76.8	75.7	74.5	74.1	73.6	73.3
70	82.8	82.7	82.7	82.5	82.3	82.0	81.6	81.1	80.4	79.6	78.6	77.6	76.6	75.6	74.3	73.9	73.5	73.3
75	81.2	81.1	81.1	81.0	80.8	80.6	80.3	79.9	79.3	78.7	78.0	77.2	76.4	75.6	74.0	73.7	73.4	73.2
80	79.8	79.7	79.7	79.6	79.5	79.3	79.1	78.8	78.4	77.9	77.4	76.8	76.2	75.2	73.8	73.6	73.3	73.2
85	78.5	78.5	78.5	78.4	78.3	78.2	78.1	77.9	77.6	77.2	76.9	76.3	75.5	74.6	73.6	73.4	73.3	73.1
90	76.7	76.7	76.7	76.7	76.6	76.5	76.4	76.3	76.1	75.9	75.5	75.1	74.6	74.0	73.4	73.3	73.2	73.1
95	74.8	74.7	74.7	74.7	74.7	74.7	74.6	74.6	74.5	74.4	74.2	74.0	73.8	73.5	73.2	73.1	73.1	73.0
100	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0

Table B.5

Calculated Removal Efficiency for 1.25 inch of Retention as a Function of Curve Number and DCIA for Southwest Florida Conditions

DCIA	Non DCIA Curve Number																	
	25	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**96**	**97**	**98**
5	100.0	99.5	98.4	95.9	93.7	91.7	89.2	87.1	84.7	83.0	81.8	80.9	80.1	79.8	80.0	79.6	79.4	79.6
10	99.8	99.3	98.1	96.8	95.5	93.7	91.7	89.4	87.2	85.3	83.7	82.4	81.0	80.1	80.0	79.6	79.5	79.6
15	99.4	98.7	97.9	97.0	95.8	94.3	92.5	90.6	88.6	86.7	84.8	83.2	81.7	80.5	80.0	79.6	79.5	79.6
20	98.9	98.4	97.8	96.8	95.7	94.4	92.8	91.0	89.2	87.5	85.5	83.7	82.3	80.7	79.9	79.6	79.5	79.7
25	98.3	97.9	97.3	96.5	95.4	94.2	92.7	91.1	89.6	87.7	86.1	84.0	82.7	81.0	79.9	79.6	79.5	79.7
30	97.5	97.2	96.6	95.9	94.9	93.8	92.5	91.2	89.5	87.9	86.1	84.3	82.7	81.2	79.9	79.7	79.5	79.7
35	96.5	96.2	95.8	95.1	94.3	93.3	92.2	90.8	89.4	87.9	86.1	84.6	82.8	81.4	79.9	79.7	79.6	79.7
40	95.5	95.3	94.9	94.4	93.6	92.7	91.6	90.5	89.1	87.6	86.1	84.6	82.8	81.6	79.9	79.7	79.6	79.7
45	94.3	94.1	93.8	93.4	92.8	92.0	91.1	89.9	88.6	87.3	86.1	84.3	82.8	81.8	79.9	79.7	79.6	79.7
50	93.0	92.9	92.7	92.3	91.8	91.1	90.2	89.2	88.2	87.1	85.6	84.1	82.8	81.7	79.9	79.7	79.6	79.7
55	91.8	91.7	91.5	91.2	90.8	90.2	89.5	88.7	87.7	86.5	85.2	84.0	82.9	81.4	79.9	79.7	79.6	79.7
60	90.5	90.4	90.3	90.0	89.7	89.2	88.6	87.8	86.9	85.9	84.8	83.8	82.9	81.2	79.9	79.7	79.7	79.7
65	89.1	89.0	88.9	88.7	88.4	88.0	87.5	86.9	86.2	85.4	84.5	83.7	82.4	81.0	79.8	79.7	79.7	79.7
70	87.8	87.8	87.7	87.5	87.3	87.0	86.6	86.1	85.5	84.9	84.2	83.2	82.0	80.8	79.8	79.7	79.7	79.7
75	86.8	86.7	86.7	86.5	86.4	86.1	85.8	85.4	84.9	84.2	83.4	82.5	81.5	80.6	79.8	79.7	79.7	79.8
80	85.1	85.0	85.0	84.9	84.8	84.6	84.4	84.0	83.6	83.1	82.5	81.8	81.1	80.4	79.8	79.8	79.7	79.8
85	83.5	83.5	83.5	83.4	83.3	83.2	83.0	82.8	82.5	82.1	81.7	81.3	80.7	80.2	79.8	79.8	79.7	79.8
90	82.1	82.1	82.1	82.1	82.0	81.9	81.8	81.7	81.5	81.3	81.0	80.7	80.4	80.1	79.8	79.8	79.8	79.8
95	80.9	80.9	80.9	80.9	80.8	80.8	80.8	80.7	80.6	80.5	80.4	80.2	80.1	79.9	79.8	79.8	79.8	79.8
100	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8

Table B.6

Calculated Removal Efficiency for 1.50 inch of Retention as a Function of Curve Number and DCIA for Southwest Florida Conditions

DCIA	Non DCIA Curve Number																	
	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	96	97	98
5	100.0	100.0	98.9	97.2	94.9	93.1	91.5	89.3	87.7	86.1	84.9	84.5	84.0	83.6	83.7	83.9	84.2	84.4
10	100.0	99.6	98.8	97.5	96.2	95.0	93.3	91.6	89.7	88.0	86.5	85.5	84.8	84.0	83.8	84.0	84.3	84.4
15	99.7	99.2	98.4	97.6	96.7	95.5	94.1	92.5	90.8	89.1	87.6	86.3	85.2	84.4	83.9	84.1	84.3	84.3
20	99.3	98.8	98.3	97.6	96.7	95.6	94.3	92.8	91.3	89.7	88.4	86.8	85.5	84.7	84.0	84.1	84.4	84.3
25	98.9	98.5	98.0	97.3	96.5	95.5	94.2	92.9	91.5	90.1	88.6	87.3	85.8	85.0	84.1	84.2	84.5	84.3
30	98.4	98.1	97.6	97.0	96.1	95.2	94.1	92.9	91.6	90.4	88.8	87.5	86.0	85.0	84.2	84.3	84.5	84.3
35	97.7	97.4	97.0	96.4	95.7	94.8	93.8	92.7	91.6	90.3	89.0	87.5	86.2	85.0	84.3	84.4	84.5	84.3
40	96.9	96.7	96.3	95.8	95.1	94.3	93.4	92.6	91.4	90.2	89.0	87.5	86.4	85.1	84.4	84.5	84.4	84.2
45	96.0	95.8	95.5	95.1	94.5	93.9	93.1	92.1	91.1	90.1	88.7	87.5	86.5	85.1	84.5	84.6	84.4	84.2
50	95.1	95.0	94.7	94.4	93.9	93.2	92.5	91.7	90.8	89.7	88.5	87.5	86.3	85.1	84.6	84.6	84.4	84.2
55	94.1	94.0	93.8	93.5	93.1	92.6	92.0	91.1	90.2	89.3	88.4	87.5	86.2	85.1	84.7	84.6	84.3	84.2
60	93.1	93.0	92.8	92.6	92.2	91.7	91.2	90.5	89.8	89.0	88.2	87.1	86.1	85.2	84.8	84.5	84.3	84.2
65	92.0	91.9	91.8	91.6	91.3	90.9	90.5	89.9	89.3	88.7	87.7	86.8	85.9	85.2	84.7	84.4	84.3	84.2
70	91.1	91.0	90.9	90.8	90.5	90.2	89.8	89.3	88.7	88.0	87.3	86.5	85.8	85.2	84.6	84.4	84.2	84.1
75	89.8	89.7	89.7	89.5	89.4	89.1	88.8	88.4	87.9	87.4	86.8	86.3	85.7	85.2	84.5	84.3	84.2	84.1
80	88.7	88.6	88.6	88.5	88.4	88.2	87.9	87.6	87.3	86.9	86.5	86.0	85.6	85.2	84.4	84.3	84.2	84.1
85	87.7	87.6	87.6	87.5	87.5	87.3	87.2	87.0	86.7	86.4	86.1	85.8	85.5	84.9	84.3	84.2	84.1	84.1
90	86.8	86.8	86.7	86.7	86.7	86.6	86.5	86.3	86.2	85.9	85.7	85.3	85.0	84.6	84.2	84.1	84.1	84.1
95	85.4	85.4	85.4	85.3	85.3	85.3	85.2	85.2	85.1	84.9	84.8	84.7	84.5	84.3	84.1	84.1	84.1	84.1
100	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0

Table B.7

Calculated Removal Efficiency for 1.75 inch of Retention as a Function of Curve Number and DCIA for Southwest Florida Conditions

DCIA	Non DCIA Curve Number																	
	25	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**96**	**97**	**98**
5	100.0	100.0	99.4	98.4	96.1	94.2	92.7	91.4	89.8	88.5	87.5	86.9	86.8	86.7	87.0	87.0	87.0	87.3
10	100.0	99.8	99.3	98.2	96.9	95.8	94.6	93.0	91.7	90.1	88.8	87.9	87.3	86.9	87.1	87.0	87.1	87.3
15	99.9	99.6	98.9	98.1	97.2	96.3	95.2	93.9	92.4	91.0	89.7	88.7	87.8	87.2	87.1	87.0	87.1	87.3
20	99.7	99.2	98.6	98.0	97.3	96.5	95.4	94.3	92.9	91.5	90.2	89.3	88.2	87.3	87.2	87.1	87.1	87.3
25	99.2	98.9	98.4	97.9	97.2	96.4	95.5	94.3	93.1	91.9	90.6	89.5	88.5	87.5	87.2	87.1	87.2	87.3
30	98.9	98.6	98.2	97.6	97.0	96.3	95.3	94.3	93.1	92.0	90.9	89.7	88.8	87.7	87.2	87.2	87.2	87.4
35	98.4	98.2	97.8	97.3	96.7	95.9	95.1	94.1	93.1	92.1	91.0	89.8	88.8	87.8	87.3	87.2	87.2	87.4
40	97.8	97.6	97.3	96.8	96.2	95.5	94.8	93.9	93.0	92.1	91.0	90.0	88.8	87.9	87.3	87.2	87.2	87.4
45	97.1	97.0	96.7	96.2	95.7	95.1	94.4	93.6	92.9	91.9	90.9	90.0	88.8	88.1	87.3	87.3	87.3	87.4
50	96.4	96.3	96.0	95.7	95.2	94.6	94.1	93.4	92.6	91.7	90.9	89.8	88.8	88.2	87.3	87.3	87.3	87.4
55	95.7	95.6	95.4	95.1	94.7	94.2	93.6	92.9	92.2	91.5	90.6	89.7	88.8	88.2	87.4	87.3	87.3	87.4
60	94.8	94.7	94.6	94.3	94.0	93.6	93.1	92.5	92.0	91.2	90.3	89.6	88.9	88.1	87.4	87.3	87.4	87.4
65	94.0	94.0	93.8	93.6	93.4	93.0	92.6	92.0	91.4	90.8	90.1	89.4	88.9	88.0	87.4	87.4	87.4	87.5
70	93.1	93.0	92.9	92.8	92.5	92.2	91.8	91.4	90.9	90.4	89.9	89.3	88.7	87.9	87.4	87.4	87.4	87.5
75	92.1	92.1	92.0	91.9	91.7	91.5	91.2	90.8	90.5	90.1	89.7	89.1	88.4	87.9	87.5	87.4	87.4	87.5
80	91.3	91.3	91.2	91.1	91.0	90.8	90.6	90.4	90.1	89.6	89.2	88.7	88.2	87.8	87.5	87.5	87.5	87.5
85	90.3	90.3	90.3	90.2	90.1	90.0	89.8	89.6	89.3	89.0	88.7	88.4	88.0	87.7	87.5	87.5	87.5	87.5
90	89.3	89.3	89.3	89.2	89.2	89.1	89.0	88.8	88.7	88.5	88.3	88.1	87.9	87.7	87.5	87.5	87.5	87.5
95	88.4	88.4	88.4	88.3	88.3	88.3	88.2	88.2	88.1	88.0	87.9	87.8	87.7	87.6	87.5	87.5	87.5	87.5
100	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5

Table B.8

Calculated Removal Efficiency for 2.00 inch of Retention as a Function of Curve Number and DCIA for Southwest Florida Conditions

DCIA	Non DCIA Curve Number																	
	25	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**96**	**97**	**98**
5	100.0	100.0	99.9	98.8	97.3	95.2	93.8	92.7	91.5	90.6	89.6	89.0	88.8	88.9	89.1	89.3	89.5	89.8
10	100.0	100.0	99.5	98.9	97.6	96.4	95.4	94.4	93.0	91.9	90.7	89.9	89.5	89.2	89.2	89.3	89.6	89.8
15	100.0	99.7	99.4	98.6	97.7	96.9	96.1	94.9	93.8	92.6	91.4	90.5	90.0	89.4	89.3	89.4	89.6	89.8
20	99.8	99.6	99.0	98.4	97.8	97.1	96.3	95.2	94.2	93.0	91.9	90.9	90.3	89.7	89.4	89.5	89.7	89.8
25	99.5	99.2	98.7	98.3	97.8	97.1	96.2	95.4	94.3	93.3	92.2	91.2	90.4	89.9	89.4	89.5	89.7	89.8
30	99.2	98.9	98.6	98.1	97.6	96.9	96.2	95.3	94.4	93.4	92.4	91.5	90.6	90.0	89.5	89.6	89.8	89.8
35	98.9	98.6	98.3	97.8	97.3	96.8	96.0	95.2	94.3	93.4	92.5	91.7	90.7	90.1	89.6	89.7	89.8	89.8
40	98.4	98.2	97.9	97.5	97.1	96.4	95.8	95.0	94.2	93.4	92.5	91.7	90.8	90.1	89.7	89.7	89.8	89.8
45	98.0	97.8	97.5	97.1	96.6	96.1	95.5	94.8	94.1	93.3	92.6	91.7	90.9	90.1	89.7	89.8	89.8	89.8
50	97.4	97.2	97.0	96.6	96.2	95.7	95.2	94.5	93.9	93.3	92.4	91.7	91.0	90.1	89.8	89.8	89.8	89.8
55	96.7	96.6	96.4	96.1	95.7	95.3	94.8	94.3	93.7	93.0	92.3	91.6	90.9	90.2	89.8	89.9	89.8	89.8
60	96.0	96.0	95.8	95.6	95.2	94.9	94.5	94.0	93.4	92.8	92.2	91.6	90.8	90.2	89.9	89.9	89.8	89.8
65	95.4	95.3	95.2	95.0	94.7	94.4	94.0	93.5	93.1	92.6	92.1	91.4	90.7	90.2	90.0	89.9	89.8	89.8
70	94.6	94.6	94.5	94.3	94.1	93.8	93.5	93.1	92.8	92.3	91.7	91.2	90.6	90.2	90.0	89.9	89.8	89.8
75	94.0	93.9	93.8	93.7	93.5	93.3	93.0	92.7	92.3	91.9	91.4	91.0	90.6	90.2	89.9	89.9	89.8	89.8
80	93.1	93.1	93.0	92.9	92.8	92.6	92.4	92.1	91.8	91.5	91.2	90.8	90.5	90.2	89.9	89.8	89.8	89.8
85	92.3	92.2	92.2	92.1	92.0	91.9	91.8	91.6	91.4	91.1	90.9	90.7	90.4	90.2	89.9	89.8	89.8	89.8
90	91.5	91.5	91.5	91.5	91.4	91.3	91.2	91.1	91.0	90.8	90.7	90.5	90.3	90.1	89.9	89.8	89.8	89.8
95	90.8	90.7	90.7	90.7	90.7	90.6	90.6	90.5	90.5	90.4	90.3	90.2	90.0	89.9	89.8	89.8	89.8	89.8
100	89.8	89.8	89.8	89.8	89.8	89.8	89.8	89.8	89.8	89.8	89.8	89.8	89.8	89.8	89.8	89.8	89.8	89.8

Table B.9

Calculated Removal Efficiency for 2.25 inch of Retention as a Function of Curve Number and DCIA for Southwest Florida Conditions

DCIA	Non DCIA Curve Number																	
	25	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**96**	**97**	**98**
5	100.0	100.0	100.0	99.2	98.3	96.3	94.7	93.7	93.0	91.9	91.4	90.8	90.6	90.8	91.1	91.2	91.3	91.5
10	100.0	100.0	99.8	99.2	98.3	97.0	96.0	95.2	94.2	93.2	92.2	91.5	91.0	91.0	91.2	91.2	91.3	91.5
15	100.0	99.9	99.6	99.0	98.2	97.4	96.6	95.9	94.8	93.9	92.8	92.0	91.4	91.2	91.3	91.3	91.3	91.5
20	99.9	99.7	99.4	98.7	98.1	97.5	96.9	96.1	95.1	94.2	93.2	92.4	91.7	91.3	91.3	91.3	91.3	91.5
25	99.7	99.5	99.0	98.6	98.1	97.6	97.0	96.1	95.4	94.4	93.5	92.6	91.9	91.5	91.4	91.3	91.4	91.5
30	99.4	99.1	98.8	98.5	98.0	97.5	96.8	96.2	95.4	94.5	93.6	92.8	92.2	91.6	91.4	91.4	91.4	91.5
35	99.1	98.9	98.6	98.3	97.9	97.3	96.7	96.1	95.3	94.5	93.7	92.9	92.4	91.7	91.4	91.4	91.4	91.6
40	98.9	98.7	98.4	98.0	97.6	97.1	96.6	95.9	95.2	94.5	93.7	93.0	92.4	91.8	91.4	91.4	91.4	91.6
45	98.5	98.3	98.0	97.7	97.4	96.9	96.3	95.7	95.1	94.4	93.7	93.1	92.4	91.9	91.5	91.4	91.5	91.6
50	98.1	97.9	97.7	97.3	97.0	96.5	96.1	95.5	94.9	94.3	93.7	93.2	92.4	91.9	91.5	91.5	91.5	91.6
55	97.5	97.4	97.2	96.9	96.6	96.2	95.7	95.3	94.7	94.2	93.7	93.0	92.4	92.0	91.5	91.5	91.5	91.6
60	96.9	96.8	96.7	96.4	96.2	95.8	95.4	95.0	94.5	94.1	93.6	93.0	92.4	92.0	91.5	91.5	91.5	91.6
65	96.3	96.3	96.1	95.9	95.7	95.4	95.1	94.7	94.4	93.9	93.4	92.9	92.4	92.0	91.6	91.5	91.6	91.6
70	95.8	95.7	95.6	95.5	95.3	95.0	94.8	94.4	94.0	93.6	93.2	92.8	92.4	91.9	91.6	91.6	91.6	91.6
75	95.2	95.1	95.0	94.9	94.7	94.5	94.3	94.0	93.7	93.4	93.0	92.7	92.3	91.9	91.6	91.6	91.6	91.6
80	94.5	94.5	94.4	94.3	94.2	94.0	93.8	93.6	93.4	93.1	92.9	92.5	92.1	91.8	91.6	91.6	91.6	91.7
85	93.9	93.9	93.8	93.8	93.7	93.6	93.4	93.2	93.0	92.8	92.5	92.3	92.0	91.8	91.6	91.6	91.6	91.7
90	93.1	93.1	93.1	93.0	93.0	92.9	92.8	92.7	92.5	92.4	92.2	92.1	91.9	91.8	91.7	91.7	91.7	91.7
95	92.4	92.4	92.3	92.3	92.3	92.3	92.2	92.2	92.1	92.0	91.9	91.9	91.8	91.7	91.7	91.7	91.7	91.7
100	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7

Table B.10

Calculated Removal Efficiency for 2.50 inch of Retention as a Function of Curve Number and DCIA for Southwest Florida Conditions

DCIA	Non DCIA Curve Number																	
	25	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**96**	**97**	**98**
5	100.0	100.0	100.0	99.7	98.7	97.3	95.6	94.5	93.9	93.3	92.6	92.2	92.0	92.1	92.5	92.6	92.8	93.1
10	100.0	100.0	100.0	99.5	98.9	97.7	96.6	95.8	95.1	94.2	93.5	92.8	92.4	92.3	92.5	92.7	92.8	93.1
15	100.0	100.0	99.7	99.4	98.6	97.8	97.1	96.4	95.7	94.7	94.1	93.2	92.7	92.5	92.6	92.7	92.9	93.1
20	100.0	99.8	99.6	99.1	98.5	97.9	97.3	96.7	95.9	95.1	94.3	93.6	93.0	92.7	92.7	92.8	92.9	93.1
25	99.8	99.7	99.3	98.9	98.4	97.9	97.4	96.8	96.0	95.4	94.5	93.8	93.2	92.8	92.7	92.8	92.9	93.1
30	99.7	99.4	99.1	98.7	98.3	97.9	97.5	96.8	96.1	95.4	94.6	93.9	93.3	93.0	92.8	92.9	93.0	93.1
35	99.3	99.1	98.9	98.6	98.2	97.9	97.3	96.7	96.2	95.4	94.7	94.0	93.4	93.1	92.8	92.9	93.0	93.1
40	99.1	98.9	98.7	98.4	98.1	97.6	97.2	96.7	96.0	95.4	94.7	94.1	93.5	93.2	92.9	92.9	93.0	93.1
45	98.9	98.7	98.5	98.2	97.8	97.4	97.0	96.5	95.9	95.3	94.7	94.1	93.6	93.2	92.9	93.0	93.1	93.1
50	98.5	98.3	98.1	97.9	97.6	97.2	96.8	96.3	95.8	95.2	94.7	94.1	93.7	93.2	93.0	93.0	93.1	93.1
55	98.1	98.0	97.8	97.6	97.2	96.9	96.5	96.1	95.6	95.2	94.6	94.1	93.8	93.2	93.0	93.1	93.1	93.1
60	97.6	97.5	97.4	97.1	96.9	96.6	96.2	95.8	95.4	95.0	94.5	94.1	93.7	93.3	93.1	93.1	93.1	93.1
65	97.1	97.0	96.9	96.7	96.5	96.2	95.9	95.6	95.2	94.8	94.5	94.1	93.6	93.3	93.1	93.1	93.1	93.1
70	96.6	96.6	96.5	96.3	96.1	95.8	95.6	95.3	95.0	94.7	94.4	94.0	93.6	93.3	93.2	93.1	93.1	93.1
75	96.1	96.0	95.9	95.8	95.7	95.5	95.3	95.1	94.8	94.5	94.2	93.9	93.6	93.3	93.1	93.1	93.1	93.1
80	95.6	95.6	95.5	95.4	95.3	95.1	94.9	94.7	94.5	94.2	94.0	93.7	93.5	93.3	93.1	93.1	93.1	93.1
85	95.0	94.9	94.9	94.8	94.7	94.6	94.5	94.3	94.2	94.0	93.8	93.6	93.5	93.3	93.1	93.1	93.1	93.1
90	94.4	94.4	94.3	94.3	94.2	94.2	94.1	94.0	93.9	93.8	93.7	93.5	93.4	93.2	93.1	93.1	93.1	93.1
95	93.8	93.8	93.8	93.8	93.8	93.7	93.7	93.6	93.6	93.5	93.4	93.3	93.3	93.2	93.1	93.1	93.1	93.1
100	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1

Table B.11

Calculated Removal Efficiency for 2.75 inch of Retention as a Function of Curve Number and DCIA for Southwest Florida Conditions

DCIA	Non DCIA Curve Number																	
	25	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**96**	**97**	**98**
5	100.0	100.0	100.0	100.0	99.1	98.3	96.5	95.3	94.6	94.3	93.7	93.5	93.2	93.3	93.7	93.8	93.9	94.1
10	100.0	100.0	100.0	99.7	99.2	98.3	97.2	96.3	95.7	95.2	94.4	94.0	93.6	93.5	93.8	93.9	93.9	94.1
15	100.0	100.0	99.9	99.5	99.1	98.3	97.5	96.9	96.3	95.6	94.9	94.3	93.9	93.6	93.8	93.9	94.0	94.1
20	100.0	100.0	99.7	99.5	98.8	98.2	97.7	97.1	96.6	95.8	95.2	94.5	94.0	93.7	93.9	93.9	94.0	94.1
25	99.9	99.8	99.6	99.2	98.7	98.2	97.8	97.3	96.7	96.0	95.5	94.7	94.2	93.9	94.0	94.0	94.0	94.1
30	99.8	99.6	99.3	98.9	98.6	98.2	97.8	97.4	96.7	96.1	95.5	94.9	94.3	94.0	94.0	94.0	94.0	94.2
35	99.6	99.3	99.1	98.8	98.5	98.2	97.8	97.3	96.7	96.3	95.5	95.0	94.4	94.0	94.0	94.0	94.1	94.2
40	99.3	99.1	98.9	98.7	98.4	98.1	97.6	97.2	96.7	96.2	95.6	95.0	94.5	94.1	94.0	94.0	94.1	94.2
45	99.1	98.9	98.7	98.5	98.2	97.9	97.5	97.1	96.6	96.1	95.6	95.0	94.6	94.2	94.1	94.1	94.1	94.2
50	98.9	98.7	98.5	98.3	98.0	97.7	97.3	97.0	96.5	96.0	95.5	95.1	94.6	94.3	94.1	94.1	94.1	94.2
55	98.5	98.4	98.2	98.0	97.8	97.5	97.1	96.7	96.3	95.9	95.5	95.0	94.6	94.3	94.1	94.1	94.1	94.2
60	98.2	98.1	97.9	97.7	97.5	97.2	96.9	96.5	96.2	95.8	95.4	95.0	94.6	94.4	94.1	94.1	94.2	94.2
65	97.7	97.6	97.5	97.3	97.1	96.9	96.6	96.3	96.0	95.7	95.3	94.9	94.6	94.4	94.2	94.1	94.2	94.2
70	97.3	97.2	97.1	97.0	96.8	96.6	96.3	96.1	95.8	95.5	95.2	94.9	94.7	94.4	94.2	94.2	94.2	94.2
75	96.8	96.8	96.7	96.6	96.4	96.2	96.0	95.8	95.6	95.3	95.1	94.9	94.6	94.4	94.2	94.2	94.2	94.2
80	96.3	96.3	96.2	96.1	96.0	95.9	95.7	95.5	95.4	95.2	95.0	94.8	94.6	94.3	94.2	94.2	94.2	94.2
85	95.9	95.8	95.8	95.7	95.6	95.5	95.4	95.3	95.2	95.0	94.9	94.7	94.5	94.3	94.2	94.2	94.2	94.3
90	95.4	95.4	95.3	95.3	95.2	95.2	95.1	95.0	94.9	94.8	94.6	94.5	94.4	94.3	94.2	94.2	94.3	94.3
95	94.8	94.8	94.8	94.8	94.7	94.7	94.7	94.6	94.6	94.5	94.5	94.4	94.3	94.3	94.3	94.3	94.3	94.3
100	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3

Table B.12

Calculated Removal Efficiency for 3.00 inch of Retention as a Function of Curve Number and DCIA for Southwest Florida Conditions

DCIA	Non DCIA Curve Number																	
	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	96	97	98
5	100.0	100.0	100.0	100.0	99.5	98.6	97.4	96.1	95.3	95.0	94.8	94.3	94.3	94.3	94.5	94.7	94.9	95.1
10	100.0	100.0	100.0	99.9	99.4	98.9	97.8	96.9	96.2	95.8	95.3	94.8	94.5	94.4	94.6	94.7	94.9	95.1
15	100.0	100.0	100.0	99.7	99.4	98.7	97.9	97.3	96.7	96.3	95.6	95.2	94.7	94.5	94.7	94.8	94.9	95.1
20	100.0	100.0	99.8	99.6	99.2	98.6	98.0	97.5	97.0	96.5	95.9	95.5	94.9	94.7	94.7	94.8	94.9	95.1
25	100.0	99.9	99.7	99.5	99.0	98.5	98.1	97.6	97.2	96.6	96.1	95.6	95.1	94.8	94.8	94.9	95.0	95.1
30	99.9	99.8	99.6	99.2	98.8	98.4	98.1	97.7	97.3	96.7	96.2	95.7	95.2	94.9	94.8	94.9	95.0	95.1
35	99.8	99.6	99.3	99.0	98.7	98.4	98.1	97.8	97.2	96.7	96.3	95.7	95.3	95.0	94.9	94.9	95.0	95.1
40	99.5	99.3	99.1	98.9	98.6	98.3	98.1	97.6	97.2	96.8	96.3	95.8	95.3	95.0	94.9	95.0	95.1	95.1
45	99.3	99.1	98.9	98.7	98.5	98.3	97.9	97.5	97.1	96.8	96.2	95.8	95.4	95.1	95.0	95.0	95.1	95.1
50	99.1	98.9	98.8	98.6	98.4	98.1	97.7	97.4	97.1	96.6	96.2	95.8	95.4	95.1	95.0	95.0	95.1	95.2
55	98.9	98.7	98.6	98.4	98.1	97.9	97.6	97.3	96.9	96.5	96.2	95.8	95.4	95.1	95.0	95.1	95.1	95.2
60	98.5	98.4	98.3	98.1	97.9	97.7	97.4	97.1	96.8	96.5	96.1	95.8	95.4	95.1	95.1	95.1	95.1	95.2
65	98.2	98.1	98.0	97.9	97.7	97.4	97.2	96.9	96.6	96.3	96.0	95.7	95.4	95.2	95.1	95.1	95.1	95.2
70	97.8	97.7	97.6	97.5	97.3	97.1	96.9	96.7	96.5	96.2	95.9	95.7	95.4	95.2	95.1	95.2	95.1	95.2
75	97.4	97.4	97.3	97.2	97.0	96.9	96.7	96.5	96.3	96.1	95.8	95.6	95.4	95.2	95.2	95.2	95.2	95.2
80	97.0	96.9	96.9	96.8	96.7	96.5	96.4	96.3	96.1	95.9	95.7	95.5	95.4	95.2	95.2	95.2	95.2	95.2
85	96.5	96.5	96.5	96.4	96.3	96.2	96.1	96.0	95.9	95.7	95.6	95.5	95.4	95.3	95.2	95.2	95.2	95.2
90	96.1	96.1	96.0	96.0	96.0	95.9	95.8	95.7	95.7	95.6	95.5	95.4	95.3	95.3	95.2	95.2	95.2	95.2
95	95.7	95.7	95.7	95.6	95.6	95.6	95.6	95.5	95.5	95.4	95.4	95.3	95.3	95.2	95.2	95.2	95.2	95.2
100	95.2	95.2	95.2	95.2	95.2	95.2	95.2	95.2	95.2	95.2	95.2	95.2	95.2	95.2	95.2	95.2	95.2	95.2

Table B.13

Calculated Removal Efficiency for 3.25 inch of Retention as a Function of Curve Number and DCIA for Southwest Florida Conditions

DCIA	Non DCIA Curve Number																	
	25	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**96**	**97**	**98**
5	100.0	100.0	100.0	100.0	99.9	99.0	98.3	96.8	95.9	95.5	95.4	95.2	95.1	95.1	95.4	95.5	95.6	95.7
10	100.0	100.0	100.0	100.0	99.6	99.1	98.3	97.4	96.7	96.3	96.0	95.5	95.4	95.2	95.4	95.5	95.6	95.7
15	100.0	100.0	100.0	99.9	99.5	99.1	98.3	97.6	97.1	96.7	96.3	95.8	95.6	95.3	95.5	95.5	95.6	95.8
20	100.0	100.0	100.0	99.7	99.5	98.9	98.3	97.8	97.4	97.0	96.5	96.0	95.7	95.5	95.5	95.6	95.6	95.8
25	100.0	100.0	99.8	99.6	99.3	98.8	98.3	97.9	97.5	97.2	96.6	96.2	95.8	95.6	95.6	95.6	95.7	95.8
30	100.0	99.8	99.7	99.4	99.1	98.7	98.3	98.0	97.6	97.2	96.7	96.3	95.9	95.6	95.6	95.6	95.7	95.8
35	99.8	99.7	99.5	99.2	98.9	98.6	98.3	98.0	97.7	97.2	96.8	96.4	96.0	95.7	95.6	95.6	95.7	95.8
40	99.7	99.5	99.3	99.0	98.8	98.6	98.3	98.0	97.6	97.2	96.8	96.4	96.0	95.7	95.6	95.7	95.7	95.8
45	99.4	99.3	99.1	98.9	98.7	98.5	98.2	97.9	97.6	97.2	96.9	96.4	96.1	95.8	95.7	95.7	95.7	95.8
50	99.2	99.1	99.0	98.8	98.6	98.4	98.1	97.8	97.5	97.2	96.8	96.4	96.1	95.8	95.7	95.7	95.7	95.8
55	99.0	98.9	98.8	98.7	98.5	98.2	98.0	97.7	97.4	97.1	96.7	96.4	96.1	95.8	95.7	95.7	95.8	95.8
60	98.8	98.8	98.6	98.4	98.2	98.0	97.8	97.6	97.3	97.0	96.7	96.4	96.1	95.9	95.7	95.8	95.8	95.8
65	98.5	98.4	98.3	98.2	98.0	97.9	97.7	97.4	97.2	96.9	96.6	96.4	96.1	95.9	95.8	95.8	95.8	95.8
70	98.2	98.2	98.1	98.0	97.8	97.6	97.4	97.2	97.0	96.8	96.6	96.3	96.1	95.9	95.8	95.8	95.8	95.9
75	97.9	97.8	97.7	97.6	97.5	97.4	97.2	97.0	96.9	96.7	96.5	96.3	96.1	95.9	95.8	95.8	95.8	95.9
80	97.5	97.5	97.4	97.3	97.2	97.1	97.0	96.8	96.7	96.5	96.4	96.2	96.0	95.9	95.8	95.8	95.8	95.9
85	97.1	97.1	97.0	97.0	96.9	96.8	96.7	96.6	96.5	96.4	96.3	96.1	96.0	95.9	95.8	95.9	95.9	95.9
90	96.7	96.7	96.7	96.6	96.6	96.5	96.5	96.4	96.3	96.2	96.1	96.0	96.0	95.9	95.9	95.9	95.9	95.9
95	96.3	96.3	96.3	96.3	96.2	96.2	96.2	96.1	96.1	96.1	96.0	96.0	95.9	95.9	95.9	95.9	95.9	95.9
100	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9

Table B.14

Calculated Removal Efficiency for 3.50 inch of Retention as a Function of Curve Number and DCIA for Southwest Florida Conditions

DCIA	Non DCIA Curve Number																	
	25	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**96**	**97**	**98**
5	100.0	100.0	100.0	100.0	100.0	99.3	98.6	97.6	96.5	96.0	95.9	96.0	95.7	95.9	96.0	96.1	96.2	96.4
10	100.0	100.0	100.0	100.0	99.8	99.3	98.9	97.9	97.1	96.7	96.4	96.2	96.0	96.0	96.1	96.1	96.2	96.4
15	100.0	100.0	100.0	100.0	99.7	99.3	98.8	98.0	97.5	97.1	96.8	96.4	96.2	96.0	96.1	96.2	96.3	96.4
20	100.0	100.0	100.0	99.8	99.6	99.3	98.7	98.1	97.7	97.3	97.0	96.6	96.3	96.1	96.1	96.2	96.3	96.4
25	100.0	100.0	99.9	99.7	99.5	99.1	98.6	98.2	97.8	97.5	97.2	96.7	96.5	96.2	96.2	96.2	96.3	96.4
30	100.0	99.9	99.8	99.6	99.3	98.9	98.6	98.2	97.9	97.6	97.2	96.8	96.6	96.2	96.2	96.2	96.3	96.4
35	99.9	99.8	99.7	99.4	99.1	98.8	98.5	98.3	98.0	97.7	97.2	96.9	96.6	96.3	96.2	96.3	96.3	96.4
40	99.8	99.7	99.5	99.2	99.0	98.7	98.5	98.3	98.0	97.6	97.3	97.0	96.6	96.3	96.3	96.3	96.3	96.4
45	99.6	99.4	99.3	99.1	98.9	98.7	98.5	98.2	98.0	97.6	97.3	97.0	96.6	96.4	96.3	96.3	96.4	96.4
50	99.4	99.3	99.1	99.0	98.8	98.6	98.4	98.2	97.9	97.6	97.3	97.0	96.6	96.4	96.3	96.3	96.4	96.4
55	99.2	99.1	99.0	98.8	98.7	98.5	98.3	98.0	97.8	97.5	97.3	97.0	96.7	96.5	96.3	96.4	96.4	96.4
60	99.0	98.9	98.8	98.7	98.6	98.4	98.1	97.9	97.7	97.5	97.2	96.9	96.7	96.5	96.4	96.4	96.4	96.4
65	98.8	98.8	98.6	98.5	98.3	98.2	98.0	97.8	97.6	97.4	97.1	96.9	96.7	96.5	96.4	96.4	96.4	96.4
70	98.5	98.5	98.4	98.3	98.1	98.0	97.9	97.7	97.5	97.3	97.1	96.9	96.7	96.5	96.4	96.4	96.4	96.5
75	98.3	98.2	98.2	98.1	98.0	97.8	97.7	97.5	97.3	97.2	97.0	96.8	96.6	96.5	96.4	96.4	96.4	96.5
80	97.9	97.9	97.8	97.8	97.7	97.6	97.4	97.3	97.2	97.0	96.9	96.8	96.6	96.5	96.5	96.4	96.4	96.5
85	97.6	97.6	97.5	97.5	97.4	97.3	97.2	97.1	97.0	96.9	96.8	96.7	96.6	96.5	96.5	96.5	96.5	96.5
90	97.2	97.2	97.2	97.1	97.1	97.0	97.0	96.9	96.8	96.8	96.7	96.6	96.6	96.5	96.5	96.5	96.5	96.5
95	96.9	96.9	96.8	96.8	96.8	96.8	96.7	96.7	96.7	96.6	96.6	96.6	96.5	96.5	96.5	96.5	96.5	96.5
100	96.5	96.5	96.5	96.5	96.5	96.5	96.5	96.5	96.5	96.5	96.5	96.5	96.5	96.5	96.5	96.5	96.5	96.5

Table B.15

Calculated Removal Efficiency for 3.75 inch of Retention as a Function of Curve Number and DCIA for Southwest Florida Conditions

DCIA	Non DCIA Curve Number																	
	25	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**96**	**97**	**98**
5	100.0	100.0	100.0	100.0	100.0	99.7	98.9	98.4	97.2	96.6	96.4	96.4	96.3	96.4	96.6	96.7	96.8	96.9
10	100.0	100.0	100.0	100.0	100.0	99.5	99.1	98.4	97.6	97.1	96.8	96.7	96.5	96.5	96.6	96.7	96.8	96.9
15	100.0	100.0	100.0	100.0	99.8	99.5	99.2	98.4	97.8	97.4	97.1	97.0	96.7	96.7	96.7	96.7	96.8	96.9
20	100.0	100.0	100.0	99.9	99.7	99.5	99.0	98.4	98.0	97.6	97.3	97.1	96.8	96.8	96.7	96.7	96.8	96.9
25	100.0	100.0	100.0	99.8	99.6	99.3	98.9	98.5	98.1	97.8	97.5	97.2	96.9	96.8	96.7	96.8	96.8	96.9
30	100.0	100.0	99.9	99.7	99.5	99.2	98.8	98.5	98.2	97.9	97.6	97.3	97.0	96.8	96.8	96.8	96.8	96.9
35	100.0	99.9	99.8	99.6	99.3	99.0	98.7	98.5	98.2	97.9	97.7	97.3	97.1	96.9	96.8	96.8	96.9	96.9
40	99.9	99.8	99.7	99.4	99.2	98.9	98.7	98.5	98.2	98.0	97.7	97.3	97.1	96.9	96.8	96.8	96.9	96.9
45	99.8	99.6	99.4	99.2	99.0	98.8	98.7	98.4	98.2	98.0	97.6	97.4	97.2	96.9	96.8	96.9	96.9	96.9
50	99.5	99.4	99.3	99.1	98.9	98.8	98.6	98.4	98.2	97.9	97.6	97.4	97.2	96.9	96.9	96.9	96.9	96.9
55	99.3	99.2	99.1	99.0	98.9	98.7	98.5	98.4	98.1	97.9	97.6	97.4	97.2	97.0	96.9	96.9	96.9	96.9
60	99.2	99.1	99.0	98.9	98.7	98.6	98.5	98.2	98.0	97.8	97.6	97.4	97.2	97.0	96.9	96.9	96.9	96.9
65	99.0	98.9	98.9	98.8	98.6	98.5	98.3	98.1	97.9	97.8	97.6	97.4	97.1	97.0	96.9	96.9	96.9	97.0
70	98.8	98.8	98.7	98.6	98.4	98.3	98.1	98.0	97.9	97.7	97.5	97.3	97.1	97.0	96.9	96.9	96.9	97.0
75	98.5	98.5	98.4	98.3	98.2	98.1	98.0	97.9	97.8	97.6	97.4	97.3	97.1	97.0	96.9	96.9	96.9	97.0
80	98.3	98.3	98.2	98.1	98.1	98.0	97.9	97.7	97.6	97.5	97.3	97.2	97.1	97.0	96.9	96.9	96.9	97.0
85	98.0	98.0	97.9	97.9	97.8	97.7	97.6	97.5	97.5	97.4	97.3	97.2	97.1	97.0	97.0	97.0	97.0	97.0
90	97.7	97.6	97.6	97.6	97.5	97.5	97.4	97.4	97.3	97.3	97.2	97.1	97.1	97.0	97.0	97.0	97.0	97.0
95	97.3	97.3	97.3	97.3	97.3	97.2	97.2	97.2	97.2	97.1	97.1	97.1	97.0	97.0	97.0	97.0	97.0	97.0
100	97.0	97.0	97.0	97.0	97.0	97.0	97.0	97.0	97.0	97.0	97.0	97.0	97.0	97.0	97.0	97.0	97.0	97.0

Table B.16

Calculated Removal Efficiency for 4.00 inch of Retention as a Function of Curve Number and DCIA for Southwest Florida Conditions

DCIA	Non DCIA Curve Number																	
	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	96	97	98
5	100.0	100.0	100.0	100.0	100.0	100.0	99.2	98.7	97.8	97.1	96.8	96.8	96.9	96.9	97.1	97.1	97.2	97.3
10	100.0	100.0	100.0	100.0	100.0	99.8	99.3	98.9	98.1	97.5	97.2	97.1	97.1	97.0	97.1	97.2	97.2	97.3
15	100.0	100.0	100.0	100.0	100.0	99.6	99.3	98.8	98.2	97.7	97.4	97.3	97.2	97.0	97.2	97.2	97.2	97.3
20	100.0	100.0	100.0	100.0	99.8	99.6	99.3	98.8	98.3	97.9	97.7	97.5	97.2	97.1	97.2	97.2	97.3	97.3
25	100.0	100.0	100.0	99.9	99.7	99.5	99.2	98.7	98.3	98.0	97.8	97.6	97.3	97.2	97.2	97.2	97.3	97.3
30	100.0	100.0	99.9	99.8	99.6	99.4	99.0	98.7	98.4	98.1	97.9	97.7	97.4	97.3	97.2	97.2	97.3	97.4
35	100.0	99.9	99.8	99.7	99.5	99.2	98.9	98.7	98.4	98.2	98.0	97.7	97.4	97.3	97.2	97.3	97.3	97.4
40	99.9	99.8	99.7	99.6	99.4	99.1	98.9	98.6	98.4	98.2	98.0	97.7	97.5	97.4	97.3	97.3	97.3	97.4
45	99.8	99.8	99.6	99.4	99.2	99.0	98.8	98.6	98.4	98.2	98.0	97.7	97.5	97.4	97.3	97.3	97.3	97.4
50	99.7	99.6	99.4	99.3	99.1	98.9	98.8	98.6	98.4	98.3	98.0	97.7	97.5	97.4	97.3	97.3	97.3	97.4
55	99.5	99.4	99.3	99.1	99.0	98.9	98.7	98.6	98.4	98.2	97.9	97.7	97.6	97.4	97.3	97.3	97.3	97.4
60	99.3	99.2	99.1	99.0	98.9	98.8	98.6	98.5	98.3	98.1	97.9	97.7	97.6	97.4	97.3	97.3	97.4	97.4
65	99.2	99.1	99.0	98.9	98.8	98.7	98.6	98.4	98.2	98.1	97.9	97.7	97.6	97.4	97.3	97.3	97.4	97.4
70	99.0	98.9	98.9	98.8	98.7	98.6	98.4	98.3	98.1	98.0	97.9	97.7	97.6	97.4	97.4	97.4	97.4	97.4
75	98.8	98.8	98.7	98.6	98.5	98.4	98.3	98.2	98.1	97.9	97.8	97.7	97.6	97.4	97.4	97.4	97.4	97.4
80	98.5	98.5	98.5	98.4	98.3	98.2	98.2	98.1	98.0	97.9	97.8	97.6	97.5	97.4	97.4	97.4	97.4	97.4
85	98.3	98.3	98.3	98.2	98.2	98.1	98.0	98.0	97.9	97.8	97.7	97.6	97.5	97.4	97.4	97.4	97.4	97.4
90	98.0	98.0	98.0	98.0	97.9	97.9	97.8	97.8	97.7	97.6	97.6	97.5	97.5	97.4	97.4	97.4	97.4	97.4
95	97.7	97.7	97.7	97.7	97.7	97.6	97.6	97.6	97.6	97.5	97.5	97.5	97.5	97.4	97.4	97.4	97.4	97.4
100	97.4	97.4	97.4	97.4	97.4	97.4	97.4	97.4	97.4	97.4	97.4	97.4	97.4	97.4	97.4	97.4	97.4	97.4