

Tampa Bay Estuary Program Models: Loading, Empirical, and Optimization

User's Guide to Programs



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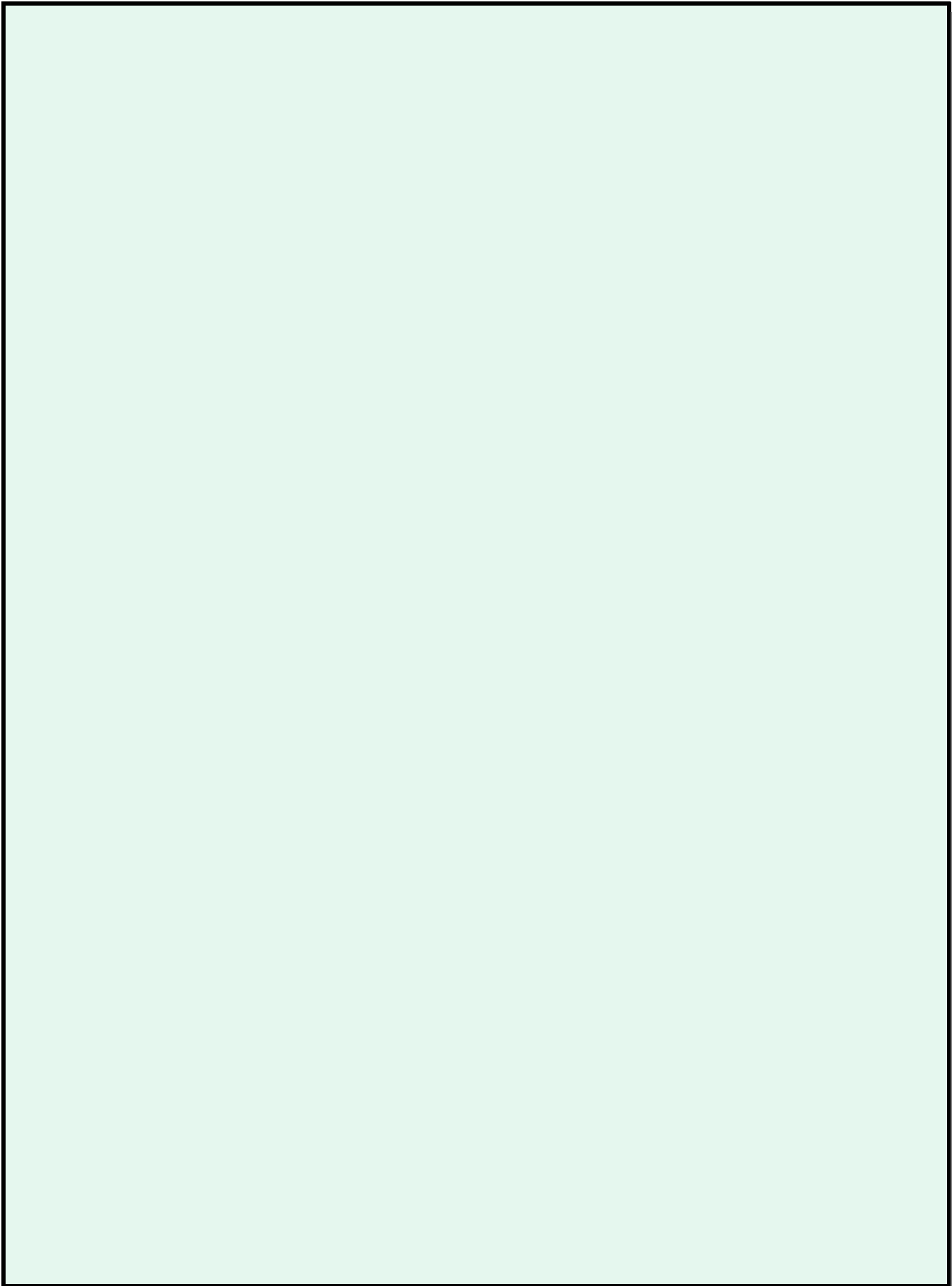
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TABLE OF CONTENTS

1.0	INTRODUCTION	1-1
2.0	WATERSHED LOADING MODELS	2-1
2.1	Introduction to Using the Tampa Bay Watershed Loading Model SAS Programs	2-1
2.1.1	Internal Documentation	2-2
2.1.2	Simplified and Portable Job Control Language	2-2
2.1.3	Dataset Formats	2-2
2.2	Atmospheric Deposition Loads	2-2
2.2.1	Calculating Atmospheric Deposition Hydrologic Loads - AD_RAIN.SAS	2-3
2.2.2	Calculating Atmospheric Deposition Nutrient Loads - AD_LOAD.SAS	2-4
2.3	Non-point Source Loads	2-6
2.3.1	Detailed Hydrologic Load Data (Measured and Estimated)	2-7
2.3.2	Best Estimate Loads	2-12
2.3.3	Model-based Estimate Loads	2-17
2.3.4	Land Use-specific Loads	2-18
2.4	Industrial Point Source Loads	2-20
2.4.1	Detailed Industrial Point Source Loads	2-20
2.4.2	Summarized Industrial Point Source Loads	2-23
2.5	Domestic Point Source Loads	2-25
2.5.1	DPS_LOAD Input Datasets	2-25
2.5.2	DPS_LOAD Operating Algorithm	2-26
2.5.3	DPS_LOAD Output Datasets	2-27
2.6	Spring Loads	2-28
2.6.1	Monthly Spring Discharges - SPRMOD1.SAS	2-28
2.6.2	Detailed Spring Loads - SPRMOD2.SAS	2-29
2.6.3	Summarized Spring Loads - SPRMOD3.SAS	2-30
2.7	Groundwater Loads	2-32
2.7.1	GWMOD Input Datasets	2-32
2.7.2	GWMOD Operating Algorithm	2-32
2.7.3	GWMOD Output Datasets	2-33
2.8	Material Losses Loads	2-35

2.8.1	MLMOD Input Datasets	2-35
2.8.2	MLMOD Operating Algorithm	2-36
2.8.3	MLMOD Output Datasets	2-36
3.0	TBNEP EMPIRICAL MODEL	3-1
3.1	Using the Spreadsheet Workbooks	3-1
3.2	Nitrogen Loads	3-2
3.3	Chlorophyll	3-4
3.4	Light Attenuation	3-4
3.5	Seagrass	3-5
3.6	Back Calculation	3-5
3.7	Literature Cited	3-6
4.0	TBNEP OPTIMIZATION MODEL	4-1
4.1	Summary Reference of Data Used to Operate the Model	4-1
4.1.1	Soil Characteristics Data	4-2
4.1.2	Subbasin Characteristics Data	4-3
4.1.3	Pollutant Loading Data	4-3
4.1.4	BMP Cost, Efficiency, and Constraint Data	4-4
4.1.5	Regionally Specific Real-property Values	4-5
4.2	Summary Reference of the Model	4-6
4.2.1	Module 1: Compile List of Potential BMPs Based on Site Constraints	4-6
4.2.2	Module 2: Evaluate Unit Cost and Benefit for Each Potential BMP	4-9
4.2.3	Module 3: Compile Set of Optimal Management Solutions	4-11
4.2.4	Module 4: Evaluate Management Solutions with Regard to Budgets and Load Reduction Targets	4-12
4.3	Case Study	4-12
4.3.1	The Setting of the Case Study	4-13
4.3.2	Step 1: Applying Module 1 to BMP Screening and Options List Generation	4-16
4.3.3	Step 2: Applying Module 2 to the Costs and Benefits Compilation ...	4-23
4.3.4	Step 3: Applying Module 3 to Identify the Best Types of BMPs for the Watershed	4-31
4.3.5	Step 4: Applying Module 4 to Evaluate Management Priorities, Budgets, and Load Reduction Targets	4-37
4.3.6	Further Application of the Optimization Model	4-41
4.4	Literature Cited	4-43

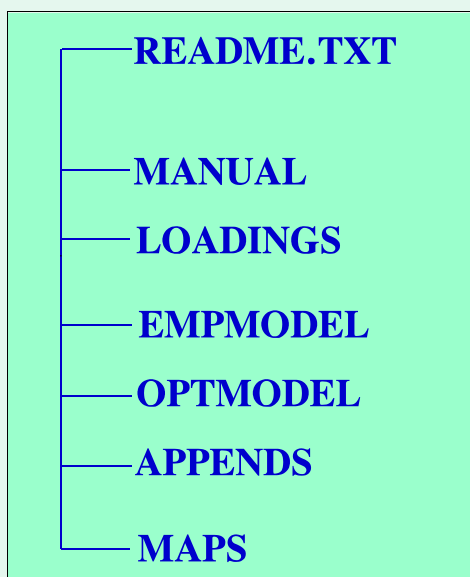


1.0 INTRODUCTION

The purpose of this document is to provide the background, programs, and data sources to enable the reader the ability to exercise the following models developed for the Tampa Bay National Estuary Program (TBNEP):

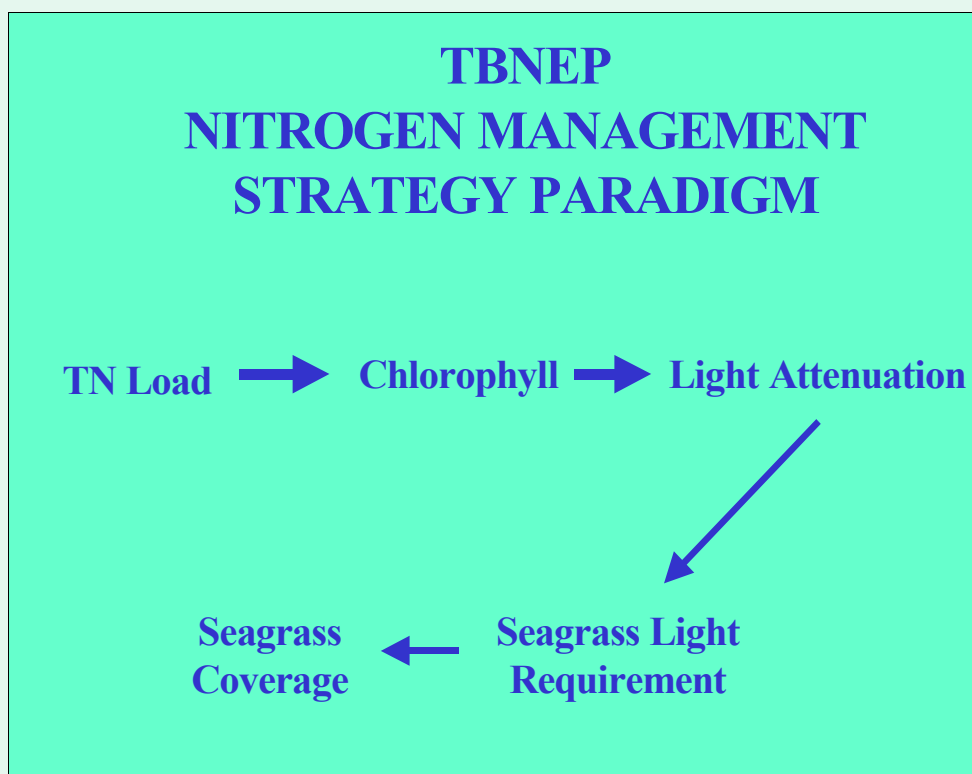
- watershed loading model - this model provides estimates of hydrologic and pollutant (total nitrogen, total phosphorus, and total suspended solids) loadings on a monthly time step for a variety of spatial scales;
- TBNEP empirical model - this model relates nutrient loads to chlorophyll concentrations, chlorophyll concentrations to light attenuation, and light attenuation to bay bottom area with adequate light to support seagrass;
- TBNEP optimization model - this model provides a method for evaluating the most cost effective and optimal methods of controlling nutrient and sediment runoff from specific areas of the watershed.

The following figure presents the directory structure on this CD:



The following were the major contributors to the development and application of these models:

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These contributors recognize the major contributions made by the members of the TBNEP Technical Advisory Committee, and particularly the critical input from the Modeling Subcommittee members. Mr. Dick Eckenrod and Ms. Holly Greening also provided guidance and focus along the way.

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2.0 WATERSHED LOADING MODELS

2.1 Introduction to the Tampa Bay Watershed Loading Model SAS Programs

This chapter provides a comprehensive user's guide to the Tampa Bay National Estuary Program (TBNEP) watershed loading model computer programs. The computer programs are provided in electronic format in the form of SAS software (SAS Institute, Cary, North Carolina) and associated data files. The set of SAS programs and data files may be used to compute and summarize estimated nutrient and hydrologic loads to the Tampa Bay Estuary following the methods developed by the TBNEP.

The watershed loading model programs are flexible.

- The programs allow loading estimates to be calculated using varying combinations of estimated and measured loading data.
- The programs allow flexibility in the geographic and temporal reporting units. Time series data are produced for monthly, annual, and average annual resolutions.
- The programs and data files are constructed to allow additional data to be included as they become available.

This User's Guide documents this set of SAS software in order to enable local and state agency staff to update the nutrient loading estimates. All information and electronic files needed to compute the loadings are provided and described within this manual.

The SAS software are categorized into the following types of loadings:

- Atmospheric Deposition Loads,
- Nonpoint Source Loads,
- Industrial Point Source Loads,
- Domestic Point Source Loads,
- Spring Loads,
- Groundwater Loads, and
- Material Losses Loads.

A section of this chapter of the user's guide is devoted to each category, and includes a description of several SAS programs that are required to estimate values for each particular category of loads. The SAS programs are described with respect to the input datasets, the function of the SAS code, and the output datasets. The SAS programs are also documented extensively within the body of the code with the intention that local and state agency personnel will be able to modify specific details

of the code where desired. Appendices 1 - 7 provide the SAS programs, input datasets, and a description of model output. Appendix 8 contains excerpts from Zarbock et al. (1994) on the estimation methods.

2.1.1 Internal Documentation

The SAS programs have been simplified in order to make them easier to use, and they have been internally documented throughout to provide a complete description of the calculations. Parameters that a user may wish to change to expand the time series or datasets have been identified and commented. Units conversion equations have been commented for ease of use, and variable labels have been included on output datasets. Internal keys for various coded data values have been included as text tables within the individual SAS programs and ASCII text datasets.

2.1.2 Simplified and Portable Job Control Language

The job control language (i.e., JCL) is operationally defined as the set of computer program statements in a SAS program that are specifically designed for a particular computer, and are not portable from one machine to another (e.g., from a PC SAS platform to a UNIX SAS platform).

The job control language for the TBNEP watershed loading model programs has been simplified in order to make the set of programs more portable and adaptable for various computer systems. The job control language currently consists of SAS “libname” and “infile” statements set for the current PC SAS version 6.x. The PC disk drive and subdirectories have been set to the current subdirectory on the “C:” drive. Thus, the SAS programs and datasets may be placed in a single subdirectory of the user’s choice, and the programs may be executed from the subdirectory using standard PC SAS commands (e.g., “SAS program_name”).

2.1.3 Dataset Formats

The datasets are currently formatted for use with PC SAS 6.x. The two types of datasets included are ASCII text tables, and PC SAS datasets (i.e., *.SD2 files). The data files were simplified for readability. The ASCII files include tabular organization, internal documentation comments, and internal key tables for coded variables. The SAS datasets are simplified, non-indexed SD2 files with standard SAS labels for each variable.

2.2 Atmospheric Deposition Loads

The atmospheric deposition (AD) loads represent the hydrologic loads and pollutant loads that are delivered directly to the water surface of the bay by precipitation events. These loads are estimated on a monthly basis for each of the seven TBNEP bay segments.

The two SAS programs that compute these estimates were documented internally in order to assist the user. In addition to the internal documentation, each program is described further within the following sections. Appendix 1 provides the SAS programs, input datasets, and a description of model output. Appendix 8 contains excerpts from Zarbock et al. (1994) on the estimation methods.

2.2.1 Calculating Atmospheric Deposition Hydrologic Loads - AD_RAIN.SAS

This program computes a monthly time series of direct deposition hydrologic loads to each of the seven TBNEP bay segments. Hydrologic loads contributed to the bay by precipitation runoff from upland and wetland drainage areas are estimated separately as described in Section 2.3 of this document.

The AD_RAIN.SAS program uses a computationally intensive surface fitting approach to this estimation, and analyses a very long time series of precipitation data. Hence, this program is one of the most computationally intensive programs in the TBNEP watershed loading model, and additional computing time should be budgeted for its application.

2.2.1.1 AD_RAIN Input Datasets

This program reads a single SAS dataset that represents a monthly time series of precipitation at National Weather Service (NWS) recording stations throughout the Tampa Bay region. The dataset is named NWSTPCP.SD2, and contains the following variables:

- NWSSITE = NWS recording station identifier (e.g., NWS Site Number 228 = Arcadia),
- YEAR = Year in a four character format (e.g., 1995),
- MONTH = Month in a numeric format (e.g., 11 = November), and
- TPCP = Precipitation for the month recorded in total inches.

There is a record in this dataset for each recording station and month in the time series.

2.2.1.2 AD_RAIN Operating Algorithms

This program reads the NWS dataset described above, and subsets the monthly time series for the years specified in the first data step. The starting and ending year may be changed within the code at the locations labeled:

```
"assign starting year of rainfall of calculate"
"assign ending year of rainfall to calculate"
```

The program then combines the NWS data with an internal dataset of the Universal Transverse Mercator (UTM) x and y locations (meters) of the NWS stations.

The program then combines the NWS rainfall data and station coordinate data with a grid of evenly spaced UTM coordinates mapped for the water surface of each of the seven TBNEP bay segments. The estimated total monthly precipitation is then calculated for each of the evenly spaced grid locations using a standard inverse-distance-squared weighted-average surface fitting equation. Thus, NWS stations that are closer to a particular grid location are assigned more weight with respect to the estimated average rainfall for that grid location.

The average total precipitation for each of the seven bay segments is then computed as the average of the grid cell estimates within each particular bay segment.

2.2.1.3 AD_RAIN Output Datasets

This SAS program outputs a single SAS dataset that contains a monthly time series of the direct deposition hydrologic load for each of the seven TBNEP bay segments. The dataset is named AD_RAIN.SD2, and contains the following variables:

- SEGMENT = TBNEP Bay Segment number, where
 - 1 = Old Tampa Bay,
 - 2 = Hillsborough Bay,
 - 3 = Middle Tampa Bay,
 - 4 = Lower Tampa Bay,
 - 5 = Boca Ciega Bay,
 - 6 = Terra Ceia Bay,
 - 7 = Manatee River,
- YEAR = Year in a four character format (e.g., 1995),
- MONTH = Month in a numeric format (e.g., 11 = November),
- TPCP = Precipitation for the month recorded in total inches.

There is a record in this dataset for each TBNEP bay segment and month in the time series.

2.2.2 Calculating Atmospheric Deposition Nutrient Loads - AD_LOAD.SAS

This program computes a monthly time series of direct deposition nutrient and hydrologic loads to each of the seven TBNEP bay segments. Nutrient loads contributed to the bay by non-point source

runoff from upland and wetland drainage areas are estimated separately as described in Section 2.3 of this document.

2.2.2.1 AD_LOAD Input Datasets

This program reads two input datasets, AD_RAIN.SD2 and PPTQUAL.DAT.

The AD_RAIN.SD2 dataset contains estimates of monthly rainfall for each of the seven bay segments. The format of this dataset is presented above in Section 2.2.2.3.

The PPTQUAL.DAT dataset contains National Atmospheric Deposition Program (NADP) estimates of nutrient concentrations in precipitation in the Tampa Bay region. The format of this file is a space-delimited text file with five columns:

Column 1 = CODE – a station identifier

Column 2 = MONTH – a calendar month value, where 1=January

Column 3 = YEAR – a four digit year value

Column 4 = NH4 – measured ammonia concentrations (mg/L)

Column 5 = NO3 – measured nitrate concentrations (mg/L)

Text comments may be entered in this data file to the right of the five columns if preceded by an asterisk character and followed by a semicolon. Updates of these monthly mean precipitation weighted concentrations are available on <http://nadp.sws.uiuc.edu/>.

2.2.2.2 AD_LOAD Operating Algorithms

This program reads the two datasets described above, and computes monthly AD loads of nutrients to each of the seven bay segments. The starting and ending year may be changed within the code at the locations labeled:

"assign starting year of time series"

"assign ending year of time series"

The program then reads an internal dataset containing the water surface area (hectares) of each of the seven bay segments. These areas represent all of the open water areas of the bay that are not included as water areas in the drainage basin definitions.

The program then converts the hydrologic load data read from AD_RAIN.SD2 into the units of

m³/month by calculating the product of rainfall depth and surface area.

The program then calculates the estimated AD nitrogen loads as the nitrogen concentrations from NH₄ and NO₃ multiplied by the hydrologic load volumes. The load is increased by a factor of 3.04 to account for the additional load provided by the process of dry deposition. The user may modify this constant.

The AD phosphorous load is calculated as the product of the AD hydrologic load and an assumed constant total phosphorus concentration of 0.195 mg/L. The user may also modify this constant. The dry deposition factor was assumed to be 3.04. The TBNEP Technical Advisory Committee (TAC) selected the constant values included by default in these programs to be best representative of the Tampa Bay region.

2.2.2.3 AD_LOAD Output Datasets

This SAS program outputs a single SAS dataset that contains a monthly time series of the direct deposition hydrologic loads and pollutant loads for each of the seven TBNEP bay segments. The dataset is named AD_LOAD.SD2, and it contains the following variables:

- SEGMENT = TBNEP Bay Segment number, where
 - a value of “1” = Old Tampa Bay,
 - a value of “2” = Hillsborough Bay,
 - a value of “3” = Middle Tampa Bay,
 - a value of “4” = Lower Tampa Bay,
 - a value of “5” = Boca Ciega Bay,
 - a value of “6” = Terra Ceia Bay,
 - a value of “7” = Manatee River,
- YEAR = Year in a four character format (e.g., 1995),
- MONTH = Month in a numeric format (e.g., 11 = November),
- TNLOAD = Total nitrogen load for the month (kg/month).
- TPLOAD = Total phosphorous load for the month (kg/month).

There is a record in this dataset for each TBNEP bay segment and month in the time series.

2.3 Non-point Source Loads

The non-point source (NPS) loads represent hydrologic and pollutant loads that are discharged from surface water runoff from the watershed land surfaces to the bay. The NPS loads are calculated using a flexible combination of estimated and measured flow data and estimated and measured water quality data. The SAS programs have been simplified and organized to allow the user to select a particular combination of measured and estimated data. The three primary combinations of measured and estimated flow and water quality data used for the TBNEP Comprehensive Conservation and Management Plan are summarized below in Sections 2.3.2, 2.3.3, and 2.3.4. The input data, operating algorithms, and output data for these processes are described within the following sections. Appendix 2 provides the SAS programs, input datasets, and a description of model output. Appendix 8 contains excerpts from Zarbock et al. (1994) on the estimation methods.

2.3.1 Detailed Hydrologic Load Data (Measured and Estimated)

Regardless of the particular combination of measured or estimated flow and water quality data to be used to calculate NPS loads, the first step for all of the calculations is to build a large dataset of detailed measured and estimated flow data by individual subbasin, land use, and soil category. Each record of the data calculated in this step contains a measured (if within a gaged area) and estimated NPS hydrologic load for a particular area of a single land use and soil within a single TBNEP subbasin.

Due to the large datasets involved in this step, the calculations are very computer intensive in terms of both computing time and disk space. This is the reason why this step was separated from the other NPS calculation steps. Typically this step will only need to be executed one time, and the results can be applied to a wide variety of NPS load scenarios.

2.3.1.1 Input Datasets

Four basic input datasets are provided for computing the detailed hydrologic load data. These datasets represent the drainage structure of the watershed (i.e., the subbasins, basins, major basins, and bay segments), the rainfall data, the measured flow data, and the land use/soils data. Each of the datasets is provided in the form of a SAS data file, and they may be expanded or modified by the user as needed.

Drainage Structure Data

The drainage structure data represent the varying levels of watershed drainage areas within the Tampa Bay Watershed as defined for the TBNEP program. The SAS data file is named DBASING.SD2, and it contains the following variables.

VARIABLE NAME	VARIABLE LABEL
COAST_NO	TBNEP Subbasin Number
COAST_CO	TBNEP Subbasin Code
DRNBASIN	SWFWMD Drainage Basin
DRNFEAT	SWFWMD Drainage Feature
NEWGAGE	TBNEP Basin
GAGETYPE	Basin Type (“gaged” or “ungaged”)
HUC	USGS Hydrologic Unit Code
HUC1	Extended HUC Code Level 1
HUC2	Extended HUC Code Level 2
HUC3	Extended HUC Code Level 3
HUC4	Extended HUC Code Level 4
HECTARE	Subbasin Surface Area (ha)
X	Subbasin Centroid Easting (UTM, Zone 17, Meters, NAD 1927)
Y	Subbasin Centroid Northing (UTM, Zone 17, Meters, NAD 1927)

Each record in this data file represents a single TBNEP subbasin.

Rainfall Data

The rainfall SAS data file is named TBNSTR.SD2, and contains a monthly time series of measured rainfall data for the watershed smoothed using a surface fitting method. The file contains the following variables:

VARIABLE NAME	VARIABLE LABEL
YEAR	Year
MONTH	Month
BASIN	TBNEP Basin
RAIN	Monthly precipitation from same month (inches/month)
LAG1RAIN	Monthly precipitation from previous month (inches/month)
LAG2RAIN	Monthly precipitation from two months ago (inches/month)

Each record in the rainfall data file represents the rainfall for a single month for a single TBNEP basin.

Measured Flow Data

The measured flow SAS data file is named TBNEPFL6.SD2, and it contains a time series of the reported measured stream gage flow data for each gaged TBNEP basin in the watershed. The file contains the following variables:

VARIABLE NAME	VARIABLE LABEL
YEAR	Year
MONTH	Month
BASIN	TBNEP Basin
FLOW	Average Monthly Flow (cfs)

Each record in the average measured flow data file represents the flow for a single month for a single TBNEP basin.

Land Use/Soils Data

The land use/soils SAS data file is named TBNSTL.SD2, and it contains the surface area of contributing and non-contributing portions of each TBNEP basin by TBNEP land use category and

Hydrologic Unit group (i.e., soil group). The file contains the following variables:

VARIABLE NAME	VARIABLE LABEL
BASIN	TBNEP Basin
C_C##*	Contributing area for TBNEP land use ## and HSG code * (ha)
NC_C##*	Non-Contributing area for TBNEP land use ## and HSG code * (ha)
TOT_AREA	Total area of basin (ha)

Each record in this data file represents a single TBNEP basin.

2.3.1.2 Operating Algorithm

A series of three SAS programs is run in sequential order to produce the set of detailed hydrologic loadings. The final output from this process will include two variables representing the observed hydrologic loads and the estimated hydrologic loads.

The first of the two SAS programs, NPSMOD01.SAS, reads the input datasets for rainfall, measured flows, and land use/hydrologic soil group as described above in Section 2.3.1.1. This program combines all of these data files into a single intermediate SAS datafile named NPSMOD01.SD2. A single line of code within this program subsets the time series to 1985 – 1994 inclusive, and may be modified as desired by the user in order to make the program execute faster. Also, the intermediate data file NPSMOD01.SD2 is very large, and may be subset for a specific drainage area if desired for specialized analyses. The structure of this detailed intermediate data file is presented below in Section 2.3.1.3.

The second of the two SAS programs, NPSMOD02.SAS, reads the NPSMOD01.SD2 data file and combines it with the drainage structures data file (DBASING.SD2). The program then computes the estimated hydrologic loads by land use and basin. This program eliminates non-contributing drainage areas, open saltwater embayment areas, and tidal flat areas from the total area of each basin. The estimated flows are computed using the TBNEP hydrologic model based on rainfall, antecedent rainfall, land use, hydrologic soil group, surface area, and regression parameters. The regression parameters are listed within a table in the SAS code. The output data are given for each basin as the measured flow from the basin's gage (where available) and the estimated flow.

2.3.1.3 Output Datasets

As discussed above, an intermediate data file is provided with an integrated set of explanatory data for the hydrologic model. The SAS data file NPSMOD01.SD2 contains the following variables:

VARIABLE NAME	VARIABLE LABEL
BASIN	TBNEP Basin
YEAR	Year
MONTH	Month
RAIN	Monthly precipitation from same month (inches/month)
LAG1RAIN	Monthly precipitation from previous month (inches/month)
LAG2RAIN	Monthly precipitation from two months ago (inches/month)
FLOW	Average Monthly Flow (cfs)
C_C##*	Contributing area for TBNEP land use ## and HSG code * (ha)
NC_C##*	Non-Contributing area for TBNEP land use ## and HSG code * (ha)
TOT_AREA	Total area of basin (ha)

Each record in this data file represents a single month of rainfall, flow, land use, and soil group for a single basin.

The final SAS data file of hydrologic loads, NPSMOD02.SD2, contains the following variables:

VARIABLE NAME	VARIABLE LABEL
BASIN	TBNEP Basin
YEAR	Year
MONTH	Month
RAIN	Monthly precipitation from same month (inches/month)
LAG1RAIN	Monthly precipitation from previous month (inches/month)
LAG2RAIN	Monthly precipitation from two months ago (inches/month)
FLOW	Average Observed Monthly Flow (m/month)
FLOWHAT	Average Estimated Monthly Flow (m/month)
LU##	Contributing area for TBNEP land use ## (% of BAS_AREA)
BAS_AREA	Total contributing area of basin (ha)

Each record in this data file represents a monthly flow average for a single basin.

2.3.2 Best Estimate Loads

The best estimate NPS loads are computed using observed data for hydrologic and pollutant loads wherever possible, and using estimated data where the observed data are missing. This method was selected to compute the NPS loadings for current conditions for the TBNEP CCMP. Users who wish to compute current NPS loads to be compared with a proposed future loading scenario (e.g., by substituting a future land use dataset into the previously described program) may wish to use only estimated NPS loads for current conditions. Using this approach, they may investigate changes expected due to land use changes alone (i.e., Section 2.3.3)

2.3.2.1 Input Datasets

Six input datasets are used to compute the best estimate loads. These datasets represent the detailed hydrologic loads (observed and estimated), literature values for pollutant concentrations in NPS runoff, detailed land use/soils data, measured NPS load data for the Lake Manatee basin, measured NPS load data for the basins monitored by the Environmental Protection Commission of Hillsborough County (EPCHC), and measured precipitation water quality data.

Detailed Hydrologic Load Data (Measured and Observed)

The detailed hydrologic load data (measured and observed) were previously described in Section 2.3.1 above. The data file is named NPSMOD02.SD2, and each record in this file represents the average measured and observed (where available) flow for a single month for a single basin.

Literature Values for Pollutant Concentrations in NPS Runoff

The TBNEP-compiled literature values for pollutant concentrations in NPS runoff within the Tampa Bay region are contained in a single SAS data file named NPSPOL.SD2. The file contains the following variables:

VARIABLE NAME	VARIABLE LABEL
C1LUCSID	TBNEP Land Use Category
MEAN_TN	Mean TN Concentration in Runoff (mg/L)
MEAN_TP	Mean TP Concentration in Runoff (mg/L)
MEAN_TSS	Mean TSS Concentration in Runoff (mg/L)

Each record in this file represents a single TBNEP land use category.

Detailed Land Use/Soils

The detailed current conditions land use and soils data for the Tampa Bay Watershed are contained in a SAS data file named NPSAG_3.SD2. The file contains the following variables:

VARIABLE NAME	VARIABLE LABEL
COAST_NO	TBNEP Subbasin Number
BASIN	TBNEP Basin in which the subbasin is located
DRNFEAT	The SWFWMD drainage feature label (e.g., Unditched Creek)
CLUCSID	The TBNEP land use category
HSG	The USGS Hydrologic Soil Group
AREA	The area of the land use/soil group in the subbasin (ha)

This file differs from the previously described land use/soil file TBNESTL.SD2 (Section 2.3.1.1) because the previous file contained a record for each basin, and this file contains a record for each combination of subbasin, land use, and soil group.

Measured Lake Manatee Basin NPS Data

The measured NPS loads for the Lake Manatee basin are compiled in a SAS data file named LAKEMAN2.SD2. These measured loads were computed by combining observed flow from a flow gage at the outfall with measured water quality data from the same location. The variables contained in this file are:

VARIABLE NAME	VARIABLE LABEL
YEAR	Year
MONTH	Month
BASIN	TBNEP Basin
H2OLOAD	Hydrologic Load (m ³ /month)
TNLOAD	TN Load (kg/month)
TPLOAD	TP Load (kg/month)
TSSLOAD	TSS Load (kg/month)

Each record in this data file represents the measured NPS loads for a single month in the time series

for the Lake Manatee basin.

Measured EPCHC NPS Data

The measured NPS loads for the EPCHC monitored basins are compiled in a SAS data file named EPCLOAD.SD2. These measured loads were computed by combining observed flow from a flow gage at the outfall of each basin with measured water quality data from the same location. The variables contained in this file are:

VARIABLE NAME	VARIABLE LABEL
YEAR	Year
MONTH	Month
BASIN	TBNEP Basin
BAS_AREA	Basin contributing area (ha)
H2OLOAD	Hydrologic Load (m ³ /month)
TNLOAD	TN Load (kg/month)
TPLOAD	TP Load (kg/month)
TSSLOAD	TSS Load (kg/month)

Each record in this data file represents the measured NPS loads for a single month in the time series for a single gaged basin.

Precipitation Water Quality Data

The precipitation water quality data are contained in an ASCII data file named PPTQUAL.DAT. These average data are used for optional computations of NPS loads from freshwater wetlands, and are not to be confused with the direct-to-bay atmospheric deposition loads described in the AD load section of this document.

This data file contains five columns of data as follows:

- Column 1 = Year
- Column 2 = Month
- Column 3 = Data Source
- Column 4 = NH₄ concentration (mg/L)
- Column 5 = NO₃ concentration (mg/L)

Each record in this dataset represents the average ammonia and nitrate concentration for a single month in the time series. The data are transformed from molecular ammonia and nitrate

concentrations to TN concentration in the algorithm described below. TP concentrations in precipitation and dry deposition factors are also included in the algorithm described below.

2.3.2.2 Operating Algorithm

Each of the NPS estimation methods described in the remainder of Section 2.3 (i.e., Sections 2.3.2, 2.3.3, 2.3.4) have a single first step in common. This first step, NPSMOD03.SAS, is to compile an intermediate dataset (NPSMOD03.SD2) for hydrologic load that includes measured flow data wherever they exist, and estimated flow data where measured flow data do not exist. This first step ensures that there are no missing gaps in the flow records for individual months. The SAS program is internally documented, and includes the following steps:

- A table inside the SAS program lists literature values for runoff coefficients by land use, hydrologic soil group, and wet/dry season.
- A table inside the SAS program lists the months that comprise the wet and dry season.
- If the observed flow for a basin is missing, then the estimated flow is substituted.
- Hydrologic loads (either measured or estimated) are attributed to individual parcels of land use/soil within each subbasin.
- Pollutant loads are computed as the product of the hydrologic loads and the literature-specific pollutant concentration data in the NPSPOL.SD2 data file.
- Hydrologic loads are summed by subbasin and land use for each month in the time series.

The intermediate dataset, NPSMOD03.SD2, is then created. This dataset contains subbasin and land use-specific hydrologic and pollutant loads using observed data where they exist, and estimated data where observed data do not exist.

The next step in computing the best estimate NPS loads is to compile a dataset of the pollutant loads using measured water quality data where possible, and literature values where the measured water quality data do not exist. The SAS program NPSMOD04.SAS completes this task by reading the LAKEMAN2.SD2, EPCLOAD.SD2, PPTQUAL.DAT, and NPSMOD03.SD2 SAS data files, and producing a single SAS data file NPSMOD04.SD2. The program operates using the following steps:

- Optional variables are set up to compute NPS loadings from freshwater wetlands as the hydrologic load from the wetlands multiplied by the ambient TN concentration in precipitation for the month being calculated. The SAS program is internally documented, and lists constants for TP concentration and dry deposition factors for TN and TP.
- By default, the NPS pollutant loads from freshwater wetlands are set to zero.

- The estimated NPS loads are summed by basin, and combined with the observed NPS load data. The observed NPS loads are used where they exist, and the estimated loads are used where the observed loads do not exist.

- Basins are assigned to major basins and bay segments using a table in the SAS program.

A final dataset is produced that contains a monthly time series of the best estimate NPS loads by basin.

2.3.2.3 Output Datasets

An intermediate SAS data file is produced that contains best estimate NPS hydrologic and pollutant loads as described above. The data file is named NPSMOD03.SD2, and contains the following variables:

VARIABLE NAME	VARIABLE LABEL
YEAR	Year
MONTH	Month
COASTAL_NO	TBNEP Subbasin
AREA	Contributing area of the land use in the subbasin (ha)
BASIN	Basin that the subbasin is located within
BAS_AREA	Area of the basin (ha)
METHOD	Method used to compute the hydrologic loads "FLOW"=measured flow for the basin "FLOWHAT"=estimated flow for the basin
H2OLOAD	Hydrologic Load (m ³ /month)
TNLOAD	TN Load (kg/month)
TPLOAD	TP Load (kg/month)
TSSLOAD	TSS Load (kg/month)

Each record within this data file contains NPS load estimates for a single subbasin and month.

A final SAS data file of best estimate NPS loads is produced as described above. The data file is named NPSMOD04.SD2, and contains the following variables:

VARIABLE NAME	VARIABLE LABEL
YEAR	Year
MONTH	Month
BASIN	Basin that the subbasin is located within
BAS_AREA	Area of the basin (ha)
MAJBASIN	TBNEP major basin that the basin is located within
SEGMENT	TBNEP bay segment that the basin is located within
H2OLOAD	Hydrologic Load (m ³ /month)
TNLOAD	TN Load (kg/month)
TPLOAD	TP Load (kg/month)
TSSLOAD	TSS Load (kg/month)

Each record within this data file represents the best estimate NPS loads for a single month for a single basin.

2.3.3 Model-based Estimate Loads

The model-based estimate NPS loads represent loads computed using only estimated hydrologic loads and literature values for pollutant concentrations. These model-based NPS loads may be useful for comparing NPS loads under current land use conditions to NPS loads under proposed future land use conditions. Thus, the only difference between the current and future loads can be attributed to changes in land use, and not to variation in the measured NPS load data.

2.3.3.1 Input Datasets

This computation begins by reading in the intermediate SAS data file NPSMOD03.SD2 described in Section 2.3.2 above. The only other input data file required is the ambient atmospheric deposition TN concentration data described in Section 2.3.2. These atmospheric deposition concentration data are only used to compute optional freshwater wetland loads using the atmospheric deposition concentrations. The default freshwater wetland NPS pollutant loads are set to zero in the SAS program. The optional methods are documented and labeled within the SAS program NPSMOD4A.SAS.

2.3.3.2 Operating Algorithm

The algorithm for computing the model-based NPS loads is identical to the best estimate method

with a single exception. The exception is that only estimated literature values for pollutant concentrations are used in calculating the TN, TP, and TSS loads. The SAS program is named NPSMOD4A.SAS, and is very similar in structure to the previously described NPSMOD04.SAS.

2.3.3.3 Output Datasets

A final SAS data file of model-based NPS loads is produced as described above. The data file is named NPSMOD4A.SD2, and contains the following variables:

VARIABLE NAME	VARIABLE LABEL
YEAR	Year
MONTH	Month
BASIN	Basin that the subbasin is located within
BAS_AREA	Area of the basin (ha)
MAJBASIN	TBNEP major basin that the basin is located within
SEGMENT	TBNEP bay segment that the basin is located within
H2OLOAD	Hydrologic Load (m ³ /month)
TNLOAD	TN Load (kg/month)
TPLOAD	TP Load (kg/month)
TSSLOAD	TSS Load (kg/month)

Each record within this data file represents the model-based NPS loads for a single month for a single basin.

2.3.4 Land Use-specific Loads

The model-based land use-specific NPS loads represent loads computed using only estimated hydrologic loads and literature values for pollutant concentrations. These model-based NPS loads may be useful for comparing NPS loads under current land use conditions to NPS loads under proposed future land use conditions. The only difference between the model-based NPS loads and the land use-specific NPS loads is that the latter is summarized by land use category as opposed to basin totals.

2.3.4.1 Input Datasets

This computation begins by reading in the intermediate SAS data file NPSMOD03.SD2 described

in Section 2.3.2 above. The only other input data file required is the ambient atmospheric deposition TN concentration data described in Section 2.3.2. These atmospheric deposition concentration data are only used to compute optional freshwater wetland loads using the atmospheric deposition concentrations. The default freshwater wetland NPS pollutant loads are set to zero in the SAS program. The optional methods are documented and labeled within the SAS program NPSMOD6A.SAS.

2.3.4.2 Operating Algorithm

The algorithm for computing the land use-specific NPS loads is identical to the model-based method described in Section 2.3.3 with a single exception. The exception is that the NPS loads are summed by subbasin and land use category. Thus, the output data file is much larger, and the program requires a larger amount of computing time and memory. The SAS program is named NPSMOD6A.SAS, and is very similar in structure to the previously described NPSMOD4A.SAS.

2.3.4.3 Output Datasets

A final SAS data file of land use-specific model-based NPS loads is produced as described above. The data file is named NPSMOD6A.SD2, and contains the following variables:

VARIABLE NAME	VARIABLE LABEL
YEAR	Year
MONTH	Month
COAST_NO	TBNEP Subbasin
CLUCSID	TBNEP land use category
AREA	Area of the land use within the subbasin (ha)
BASIN	TBNEP basin in which the subbasin is located
BAS_AREA	Contributing area of the basin in which the subbasin is located
MAJBASIN	TBNEP major basin that the basin is located within
SEGMENT	TBNEP bay segment that the basin is located within
H2OLOAD	Hydrologic Load (m ³ /month)
TNLOAD	TN Load (kg/month)
TPLOAD	TP Load (kg/month)
TSSLOAD	TSS Load (kg/month)

Each record within this data file represents the land use-specific model-based NPS loads for a single month for a single subbasin and land use.

2.4 Industrial Point Source Loads

The industrial point source (IPS) loads represent loads discharged from individual industrial facilities within the watershed. The IPS loads are calculated using the SAS program IPS_LOAD.SAS, and the loads are then summarized using the SAS program IPSLOAD2.SAS. The input data, operating algorithm, and output data for this process are described within the following sections. Appendix 3 provides the SAS programs, input datasets, and a description of model output. Appendix 8 contains excerpts from Zarbock et al. (1994) on the estimation methods.

2.4.1 Detailed Industrial Point Source Loads – IPS_LOAD.SAS

The first program of this series calculates a monthly time series of detailed IPS load estimates for each discharging facility in the watershed. A second program then summarizes these data as discussed in Section 2.4.2

2.4.1.1 IPS_LOAD Input Datasets

A single input file named IPSDATA.DAT is read into this program. The input file is an ASCII text file that contains 8 columns of data. The parameters in column order are:

Column 1 = Industrial facility identifier code,

Column 2 = Year,

Column 3 = Month,

Column 4 = Discharge applied to land (million gallons per day),

Column 5 = Surface discharge (million gallons per day),

Column 6 = Total nitrogen concentration (mg/L),

Column 7 = Total phosphorous concentration (mg/L), and

Column 8 = TSS concentration (mg/L).

Each row of the file represents one month of data for one facility. Each row of this file must have all 8 parameters filled in, and a standard SAS missing value (“.”) should be entered where a

parameter value is missing.

The data file is internally documented with a key to the facility identifier codes. This key lists the full name of each industrial facility. Because of this internal documentation, the data rows begin on line 41 of the data file. Should a user wish to add additional information to the documented key at the top of this data file, then the SAS program should be modified to reflect the new starting row of the actual 8 column data records. To modify the program, the user would enter a new starting record number to replace the number “41” in the SAS line that reads:

```
infile “ipsdata.dat” firstobs=41;
```

Please note that this line of SAS code must end with a semicolon character.

2.4.1.2 IPS_LOAD Operating Algorithm

Using the input data file, IPSDATA.DAT, the SAS program IPS_LOAD.SAS calculates monthly hydrologic loads (m3/month), TN (kg/month), TP (kg/month), and TSS (kg/month) loads for each facility. The surface discharge loads and the land application discharge loads are computed as the product of the hydrologic loads and the pollutant concentration values.

One facility, Florida Snoman, Inc., is removed from the output dataset due to the fact that this facility was closed during the time period. The facility identifier code for Florida Snoman, Inc., is 4029P20081. Additional facilities may be removed from the output dataset by adding their facility identifier code to this location in the SAS program.

Internal datasets within the IPS_LOAD.SAS program provide additional geographic location information for each facility. The data tables are listed by facility identifier code, and contain the following information with respect to watershed grouping:

- TBNEP subbasin identifier code (the smallest and most detailed TBNEP basin boundaries, based on the Florida Department of Environmental Protection Foose polygons);
- TBNEP basin identifier code (basin boundaries defining groups of subbasins, based on the U.S. Geological Survey Hydrologic Unit Codes);
- TBNEP major basin code (basin boundaries defining groups of basins, based on the major river systems and coastal plains in the watershed:
 - Hillsborough River major basin,
 - Alafia River major basin,
 - Little Manatee River major basin,
 - Manatee River major basin,

- Hillsborough Bay coastal plain,
 - Old Tampa Bay coastal plain,
 - Middle Tampa Bay coastal plain, and
 - Lower Tampa Bay coastal plain);
- the seven TBNEP bay segments:
 - a value of “1” = Old Tampa Bay,
 - a value of “2” = Hillsborough Bay,
 - a value of “3” = Middle Tampa Bay,
 - a value of “4” = Lower Tampa Bay,
 - a value of “5” = Boca Ciega Bay,
 - a value of “6” = Terra Ceia Bay,
 - a value of “7” = Manatee River,

Maps and Geographic Information System (GIS) datasets of the boundaries of these watershed groupings are available from the TBNEP.

2.4.1.3 IPS_LOAD Output Datasets

The IPS_LOAD.SAS program produces a single detailed SAS dataset of IPS loads. The SAS dataset IPSLOAD.SD2 contains the facility-specific monthly discharge rates and nutrient concentrations as listed in the input data file as well as the hydrologic, TN, TP, and TSS loads calculated by the SAS program. Also included in this file are the subbasin, basin, major basin, and bay segment associated with each facility. The variables included in this dataset and their labels are listed below.

Variables included in IPS_LOAD.SD2:

VARIABLE NAME	VARIABLE LABEL
MAJBASIN	TBNEP major basin
BASIN	TBNEP basin
BAY_SEG	TBNEP bay segment
COAST_CO	TBNEP subbasin code
FAC_ID	Facility ID
YEAR	Year
MONTH	Month
Q_LA	Discharge applied to land (mgd)

VARIABLE NAME	VARIABLE LABEL
Q_SW	Surface discharge (mgd)
TN	TN concentration (mg/L)
TP	TP concentration (mg/L)
TSS	TSS concentration (mg/L)
H2OLOAD	Hydrologic Load (m ³ /month)
TNLOAD	TN Load (kg/month)
TPLOAD	TP Load (kg/month)
TSSLOAD	TSS Load (kg/month)

2.4.2 Summarized Industrial Point Source Loads – IPSLOAD2.SAS

The second SAS program in the IPS load series reports the IPS load data summarized by average annual total IPS loads for two geographic scales, so that a user may choose a geographic scale simply by choosing one of two output files. The geographic scales are major basin and bay segment.

2.4.2.1 IPSLOAD2 Input Datasets

The single input dataset for IPSLOAD2.SAS program is the SAS dataset IPSLOAD.SD2 described in Section 2.4.1.3 above. This dataset contains a monthly time series of hydrologic and nutrient loads from industrial point sources for each facility.

2.4.2.2 IPSLOAD2 Operating Algorithm

This program summarizes the detailed IPS load data for two levels of geographic resolution. These two levels of geographic resolution are TBNEP major basin and TBNEP bay segment. For each of these levels of resolution, the program sums the loads across facilities and months for each year and geographic area represented in the input data. The program then computes a mean annual load for each geographic area.

2.4.2.3 IPSLOAD2 Output Datasets

A separate output SAS dataset is created for each of the two levels of geographic resolution summarized by IPSLOAD2.SAS. The average annual loads by major basin and bay segment are stored in the SAS datasets IPS_MBAS.SD2 and IPS_BSEG.SD2, respectively.

The SAS dataset IPS_MBAS.SD2 contains the average annual hydrologic and nutrient loads by major basin. The variables and their labels are as follows:

VARIABLE NAME	VARIABLE LABEL
MAJBASIN	TBNEP major basin
H2OLOAD	Hydrologic Load (m ³ /year)
TNLOAD	TN Load (kg/year)
TPLOAD	TP Load (kg/year)
TSSLOAD	TSS Load (kg/year)

The SAS dataset IPS_BSEG.SD2 contains the average annual hydrologic and nutrient loads by bay segment. The variables and their labels are as follows:

VARIABLE NAME	VARIABLE LABEL
BAY_SEG	TBNEP bay segment
H2OLOAD	Hydrologic Load (m ³ /year)
TNLOAD	TN Load (kg/year)
TPLOAD	TP Load (kg/year)
TSSLOAD	TSS Load (kg/year)

2.5 Domestic Point Source Loads

The domestic point source (DPS) loads represent loads discharged from individual domestic facilities within the watershed (e.g., Wastewater Treatment Plants). The DPS discharge and concentration data are compiled into a SAS dataset, and the loads are then computed and summarized using the SAS program `DPS_LOAD.SAS`. The input data, operating algorithm, and output data for this process are described within the following sections. Appendix 4 provides the SAS programs, input datasets, and a description of model output. Appendix 8 contains excerpts from Zarbock et al. (1994) on the estimation methods.

2.5.1 `DPS_LOAD` Input Datasets

Detailed domestic point source discharge and concentration data are read into a SAS data file using the first part of the program `DPS_LOAD.SAS`. These data represent reported time series of monthly data for individual domestic facilities. This combination of text data and SAS data allows the data to be easily modified or expanded in an original ASCII text file format, and allows filtering and manipulation of the input data to be completed using a well documented SAS program. Thus, the benefits of both approaches may be realized. However, individual users may wish to skip the initial ASCII step, and use the SAS interactive data browser/editor software to maintain a working DPS database exclusively in a SAS data file.

The first part of the `DPS_LOAD.SAS` program reads a single, space-delimited, ASCII data file containing the domestic point source discharge and concentration data. The name of this ASCII data file is `WWTPNEW.DAT`. Each row in this file represents one month for an individual facility, and the data start on the first row of the text file.

The columns of the data file are as follows:

Column 1 = year,

Column 2 = month,

Column 3 = TBNEP facility identifier code,

Column 4 = discharge applied to land (million gallons/day),

Column 5 = surface discharge (million gallons/day),

Column 6 = TSS concentration (mg/L),

Column 7 = TN concentration (mg/L),

Column 8 = TP concentration (mg/L).

Two of the facilities, 149a and 149b, have original discharge data reported in the units of million gallons per month, and the units are converted as described in Section 2.5.2 below.

SAS missing value characters (“.”) may be inserted into the ASCII text data file if needed to indicate missing values for specific parameters and months.

A SAS data file, BASINSET.SD2, is also provided as an input file in order to identify groups of TBNEP subbasins in the watershed by TBNEP basin and TBNEP major basin. As previously described, the subbasins were based on the Florida Department of Environmental Protection Foose polygons, the basins were based on the U.S. Geological Survey Hydrologic Units, and the major basins were based on the four major river systems and the coastal plains of the TBNEP bay segments. GIS maps and electronic files of these boundaries are available from the TBNEP.

2.5.2 DPS_LOAD Operating Algorithm

The first part of the DPS_LOAD.SAS program compiles the detailed DPS discharge and concentration data, and converts all units for discharge to a standard million gallons per day. Two of the facilities, 149a and 149b, have original data entered as million gallons per month. A lookup table of the number of days in each month is provided as an internal data table in the DPS_LOAD.SAS program.

The next step of the DPS_LOAD.SAS program uses an internal lookup table which identifies the TBNEP subbasin for each of the DPS facilities to assign geographic locations and drainage basins. The county is also assigned as the third and fourth characters of the facility identifier. For example, the facility “D_MC_4” would be assigned a county code of “MC” for Manatee County. The county codes are represented as follows:

HC = Hillsborough County,

MC = Manatee County,

PC = Pinellas County, and

PK = Polk County.

No domestic point sources from Pasco County were represented in the reported input data.

The next step of the program computes the pollutant loads as the product of the hydrologic load and pollutant concentration. The units for hydrologic load are converted to m³/month and the units for pollutant loads are converted to kg/month.

The next step of the program corrects the estimated loads for land application losses of water due to retention in the watershed. High and low values for retention are entered as fractions in internal data tables in the SAS program DPS_LOAD.SAS.

The four City of St. Petersburg domestic facilities combine effluents and reroute them across subbasin boundaries to land application areas. The SAS program computes estimates of the rerouting by summing the loads from the St. Petersburg facilities and using an internal table of the proportion of the total load to which discharge occurs within each subbasin.

Finally, the program summarizes the DPS load data by summing the loads by year, month, and basin, and summing the loads by year, month, and major basin. When summing by major basin, several of the basin values are not included in the sums. This is due to the fact that the TBNEP basins are nested with some smaller upstream basins also included in larger basins with discharges located farther downstream.

2.5.3 DPS_LOAD Output Datasets

The DPS_LOAD.SAS program produces two output data files. The first, DPSLOAD.SD2, represents a monthly time series of DPS loads by TBNEP basin, and the second, DPSTOT.SD2, represents a monthly time series of DPS loads by TBNEP major basin. Both of these files have the following variables estimated using the high and low values for retention of land application water discussed above:

VARIABLE NAME	VARIABLE LABEL
YEAR	Year
MONTH	Month
MAJBASIN	TBNEP major basin
BASIN	TBNEP basin
HLALOAD	High H ₂ O load (m ³ /month)
LLALOAD	Low H ₂ O load (m ³ /month)
HLANLOAD	High land TN load (kg/month)
LLANLOAD	Low land TN load (kg/month)
HLAPLOAD	High land TP load (kg/month)
LLAPLOAD	Low land TP load (kg/month)
HLASLOAD	High land TSS load (kg/month)

VARIABLE NAME	VARIABLE LABEL
LLASLOAD	Low land TSS load (kg/month)

2.6 Springs Loads

The spring (SPR) loads represent loads discharged from the major springs in the watershed. The major springs in the watershed are Crystal Springs (02302000), Buckhorn Springs (02301695), Lithia Springs (022301600), and Sulphur Springs (02306000). The SPR discharges are interpolated to a monthly time series using the SAS programs SPRMOD1.SAS. Detailed spring-specific loads are calculated in SPRMOD2.SAS. The loads are then summarized by major basin and bay segment using the SAS programs SPRMOD3.SAS and SPRMOD4.SAS, respectively. The input data, operating algorithm, and the output data for this process are described within the following sections. Appendix 5 provides the SAS programs, input datasets, and a description of model output. Appendix 8 contains excerpts from Zarbock et al. (1994) on the estimation methods.

2.6.1 Monthly Spring Discharges - SPRMOD1.SAS

The first program of this series linearly interpolates discharge data that are measured several times a year at each of the springs into a monthly time series of discharge data.

2.6.1.1 SPRMOD1 Input Datasets

A single input file named TBSPRNGS.DAT is read into this program. The input file is an ASCII text file that contains 4 columns of data. The parameters in column order are:

Column 1 = USGS Gage Identifier,

Column 2 = Year,

Column 3 = Month, and

Column 4 = Discharge (cfs).

Each row of the file represents one month of data for one facility. Each row must have all 4 parameters filled in, and a standard SAS missing value (“.”) should be entered where a parameter value is missing. Also, dummy data records are added to the end of the data for each of the springs when data are not available to the end of the year. For example, if the last record for a spring contains data for the month of October, an additional record is added to the file for the same year but for the month of December and the same discharge as October is recorded on this dummy record. The program then interpolates the October data as a constant for November and December of that final year. A note must be added to the file to show that these are dummy records in the file.

2.6.1.2 SPRMOD1 Operating Algorithm

Using the input data file, TBSPRNGS.DAT, the SAS program SPRMOD1.SAS calculates monthly spring discharges based on several measurements per year. This program uses linear interpolation to estimate monthly discharges.

2.6.1.3 SPRMOD1 Output Datasets

The SPRMOD1.SAS program creates a single SAS dataset of spring discharges for the major springs in the watershed. The SAS dataset SPRMOD1.SD2 contains the spring-specific mean monthly discharge rates as well as the actual measured flow rates. Variables included in SPRMOD1.SD2:

VARIABLE NAME	VARIABLE LABEL
SPRING	Spring name
YEAR	Year
MONTH	Month
SITE	USGS Monitoring Site
FLOW	Estimated Mean Monthly Flow (cfs)
ACT_FL	Observed Mean Monthly Flow (cfs)

2.6.2 Detailed Spring Loads - SPRMOD2.SAS

The second program of the series, SPRMOD2.SAS, calculates a monthly time series of detailed SPR load estimates for major springs in the watershed.

2.6.2.1 SPRMOD2.SAS Input Datasets

The single input dataset for SPRMOD2.SAS program is the SAS dataset SPRMOD1.SD2 described in Section 2.6.1.3 above. This dataset contains a monthly time series of mean monthly flows and actual measured flow for the major springs in the watershed.

2.6.1.2 SPRMOD2 Operating Algorithms

Using the input dataset SPRMOD1.SD2, the SAS program SPRMOD2.SAS calculates monthly

hydrologic loads (m³/month), TN (kg/month), TP (kg/month), and TSS (kg/month) loads for each of the major springs. The loads are computed as the product of the hydrologic loads and the pollutant concentration values. The concentrations for the pollutants for specific time periods are listed as tables in the SAS code.

2.6.1.3 SPRMOD2 Output Datasets

The SPRMOD2.SAS program creates a single SAS dataset of SPR loads. The SAS dataset SPRMOD2.SD2 contains spring-specific monthly mean discharge rates and actual measured flow rates as listed in the input dataset as well as the hydrologic, TN, TP, and TSS loads calculated by the SAS program. The variables included in this dataset and their labels are listed below.

Variables included in SPRMOD2.SD2 :

VARIABLE NAME	VARIABLE LABEL
SPRING	Spring name
YEAR	Year
MONTH	Month
SITE	USGS Monitoring Site
FLOW	Estimated Mean Monthly Flow (cfs)
ACT_FL	Observed Mean Monthly Flow (cfs)
TN	Total Nitrogen Concentration (mg/L)
TP	Total Phosphorus Concentration (mg/L)
TSS	Total Suspended Solids Concentration (mg/L)
H20LOAD	Hydrologic Load (m ³ /month)
TNLOAD	TN Load (kg/month)
TPLOAD	TP Load (kg/month)
TSSLOAD	TSS Load (kg/month)
SOURCE	Source

2.6.3 Summarized Spring Loads - SPRMOD3.SAS

The third SAS program in the SPR load series reports the SPR load data summarized by major basin .

2.6.3.1 SPRMOD3 Input Dataset

The single input dataset for SPRMOD3.SAS is the dataset SPRMOD2.SD2 described in Section 2.6.2.3 above.

2.6.3.2 SPRMOD3 Operating Algorithm

This program sums the spring loads by major basin and bay segment.

2.6.3.3 SPRMOD3 Output Datasets

A separate output SAS dataset is created for each of the two levels of geographic resolution summarized by SPRMOD3.SAS. The monthly time series of loads by major basin and bay segment are stored in the SAS datasets SPRMOD3.SD2 and SPRMOD4.SD2, respectively.

The SAS dataset SPRMOD3.SD2 contains the hydrologic and nutrient loads by major basin. The variables and their labels are as follows:

VARIABLE NAME	VARIABLE LABEL
YEAR	Year
MONTH	Month
MAJ_BASIN	TBNEP Major Basin
BAY_SEG	TBNEP Bay Segment
H20LOAD	Hydrologic Load (m ³ /month)
TNLOAD	TN Load (kg/month)
TPLOAD	TP Load (kg/month)
TSSLOAD	TSS Load (kg/month)
SOURCE	Source

The SAS dataset SPRMOD4.SD2 contains the the hydrologic and nutrient loads by bay segment.

VARIABLE NAME	VARIABLE LABEL
YEAR	Year
MONTH	Month

BAY_SEG	TBNEP Bay Segment
H2OLOAD	Hydrologic Load (m ³ /month)
TNLOAD	TN Load (kg/month)
TPLOAD	TP Load (kg/month)
TSSLOAD	TSS Load (kg/month)

2.7 Groundwater Loads

The groundwater (GW) loads represent loads discharged from the groundwater in the watershed. The GW loads are calculated using the SAS program GWMOD.SAS. The input data, operating algorithm, and output data for this process are described within the following sections. Appendix 6 provides the SAS programs, input datasets, and a description of model output. Appendix 8 contains excerpts from Zarbock et al. (1994) on the estimation methods.

2.7.1 GWMOD Input Dataset

A single input file named GWMOD.DAT is read into this program. The input file is an ASCII text file that contains 8 columns of data. The parameters in column order are:

Column 1 = Segment,

Column 2 = Aquifer,

Column 3 = Year,

Column 4 = Month,

Column 5 = Aquifer Transmissivity (sq ft/day),

Column 6 = Hydraulic Gradient (ft/mile),

Column 7 = Average TN concentration (mg/L), and

Column 8 = Average TP concentration (mg/L).

The data file contains records for all seven segments for the wet and dry season in the Floridan aquifer. The wet season is July-October and the dry season is November-June. The surficial aquifer is characterized by segment. Each row of data in the file represents one segment for one season by aquifer. Each row must have all 8 parameters filled in, and a standard SAS missing value (“.”) should be entered where a parameter value is missing. The data file contains 7 records that

characterize the Floridan aquifer for the wet season, 7 records that characterize the Floridan aquifer for the dry season, and 7 records that characterize the surficial aquifer for both seasons. All 21 records in the file are assumed to characterize the same time period.

2.7.2 GWMOD Operating Algorithm

Using the input data file, GWMOD.DAT, the SAS program GWMOD.SAS calculates monthly, seasonal, and annual groundwater loads by aquifer and segment. The SAS program contains a table that assigns the flow zone length to the seven bay segments. The program then calculates average monthly flow for the wet and dry seasons using Darcy's Equation. The product of the flow and the concentrations are the nutrient loadings. The average monthly values are multiplied by 4 months in the wet season and by 8 months in the dry season to calculate the seasonal loads. The seasonal loads are summed to get the annual loads.

2.7.3 GWMOD Output Datasets

The GWMOD.SAS program creates four SAS datasets of groundwater loads. The four datasets created by GWMOD.SAS are GWMOD.SD2, GW_ANN.SD2, GW_SEAS.SD2, and GW_SEG.SD2.

The variables and their labels for the datasets listed above are as follows.

GWMOD.SD2

VARIABLE NAME	VARIABLE LABEL
AQUIFER	Aquifer
SEGMENT	TBNEP Bay Segment
YEAR	Year
MONTH	Month
SEASON	Season
T	Aquifer Transmissivity (sq ft/day)
I	Hydraulic Gradient (ft/mile)
L	Flow Zone Length (mile)
Q	Flow (MG/month)
TN	Average TN Concentration (mg/L)
TP	Average TP Concentration (mg/L)

TNLOAD	TN Load (lb/month)
TPLOAD	TP Load (lb/month)
TNLD_SEA	TN Load (lb/season)
TPLD_SEA	TP Load (lb/season)
Q_SEA	Flow (MG/season)

GW_ANN.SD2

VARIABLE NAME	VARIABLE LABEL
AQUIFER	Aquifer
SEGMENT	TBNEP Bay Segment
YEAR	Year
TNLD_ANN	TN Load (lb/year)
TPLD_ANN	TP Load (lb/year)
Q_ANN	Flow (MG/year)

GW_SEAS.SD2

VARIABLE NAME	VARIABLE LABEL
AQUIFER	Aquifer
SEGMENT	TBNEP Bay Segment
SEASON	Season
Q	Flow (MG/month)
TNLOAD	TN Load (lb/month)
TPLOAD	TP Load (lb/month)
TNLD_SEA	TN Load (lb/season)
TPLD_SEA	TP Load (lb/season)
Q_SEA	Flow (MG/season)

GW_SEG.SD2

VARIABLE NAME	VARIABLE LABEL
SEGMENT	TBNEP Bay Segment
YEAR	Year

TNLD_ANN	TN Load (lb/year)
TPLD_ANN	TP Load (lb/year)
TNLDANNK	TN Load (kg/season)
TPLDANNK	TP Load (kg/season)
Q_ANN	Flow (MG/year)

2.8 Material Losses Loads

The material losses (ML) loads represent losses of fertilizer product from loading docks at port facilities. The ML loads are calculated using the SAS program MLMOD.SAS. The input data, operating algorithm, and output data for this process are described within the following sections. Appendix 7 provides the SAS programs, input datasets, and a description of model output. Appendix 8 contains excerpts from Zarbock et al. (1994) on the estimation methods.

2.8.1 MLMOD Input Dataset

A single input file named MATLOSS.DAT is read into this program. The input file is an ASCII text file that contains 6 columns of data. The parameters in column order are:

Column 1 = Facility,

Column 2 = Year,

Column 3 = Chemical Handled (tons/year),

Column 4 = Phosphate Rock Handled (tons/year),.

Column 5 = Chemical Loss Rate, and

Column 6 = Phosphate Rock Loss Rate.

Each row of data in the file represents one year of data for one facility. Each row must have all 6 parameters filled in, and a standard SAS missing value (“.”) should be entered where a parameter value is missing. The data file also contains notes that appear to the right of column 6.

The data file is internally documented with a key to the facility identifier codes. This key lists the full name of each facility. Because of this internal documentation, the data rows begin on line 13 of this data file. Should a user wish to add additional information to the documented key at the top of this data file, then the SAS program should be modified to reflect the new starting row of the

actual 6 column data records. To modify the program, the user would enter a new starting record number to replace the number “13” in the SAS line that reads:

```
infile “matloss.dat” firstobs=13;
```

Please note that this line of SAS code must end with a semicolon character.

2.8.2 MLMOD Operating Algorithm

Using the single input file MATLOSS.DAT described above in Section 2.8.1, MLMOD.SAS calculates the losses and nutrient loads. The chemical losses are the product of the chemicals handled and the chemical loss rate. The rock losses are the product of the rock handled and the rock loss rate. Total nitrogen is assumed to be 18% of the fertilizer product, therefore TN is 18% of chemical losses. Total phosphorus is assumed to be 20.1% of the fertilizer product and 14.4% of the phosphate rock, so that TP is the sum of 20.1% of chemical losses and 14.4% of the phosphate rock.

The SAS code also assigns facility name to facility number used in the MATLOSS.DAT input file.

Special cases are also handled in the SAS code. The facility Packhoed-Tampa doesn’t handle phosphorus and therefore the calculation for total phosphorus is set to 0. Similarly, IMC-Agrico Big Bend doesn’t handle nitrogen and the calculation for total nitrogen is set to 0.

2.8.3 MLMOD Output Datasets

The MLMOD.SAS program produces a single detailed SAS dataset of ML loads. The SAS dataset MLMOD.SD2 contains the data from the input file as well as the losses and the nutrient loads.

The parameters and their labels are as follows:

VARIABLE NAME	VARIABLE LABEL
FACILITY	Facility Number
FACNAME	Facility
YEAR	Year
CHEMTONS	Chemicals Handled (tons/year)
ROCKTONS	Rock Handled (tons/year)

CHEMRATE	Chemical Loss Rate (%)
ROCKRATE	Rock Loss Rate (%)
CHEMLOSS	Chemical Loss (tons/year)
ROCKLOSS	Rock Loss (tons/year)
TNLOAD	TN Load (tons/year)
TPLOAD	TP Load (tons/year)

3.0 TBNEP EMPIRICAL MODEL

The Tampa Bay National Estuary Program (TBNEP) has supported the development of these spreadsheet workbooks, EMPMOD.XLS and MIXING.XLS, to allow users to interactively use a series of models developed to set nitrogen load targets for Tampa Bay. The models represent an empirically-based approach to setting external nitrogen load targets to Tampa Bay. Regression models were developed using the available data to investigate the relationships among loadings, water quality, and the subsurface light environments in the bay. The regression parameters included as default values with this spreadsheet workbook were based on the 1985 to 1994 time period. This time period corresponded to the period for which comprehensive loading estimates were developed by the TBNEP. The TBNEP has also published a companion report to this spreadsheet workbook that describes in detail the data sources and methods of estimating the parameters for Tampa Bay (Janicki and Wade, 1996). The methodology and load targets developed by this work are being implemented in a Comprehensive Conservation and Management Plan (CCMP).

The pollutant loading models, an intersegment transport/mixing model, and the nitrogen load target models were originally developed as a series of SAS programs (SAS Institute, Cary, N.C.). The pollutant loading models and the intersegment transport/mixing model are available from the TBNEP as documented SAS software. In order to make the intersegment transport/mixing model and the nitrogen load management target model more readily accessible to the Tampa Bay management community, each was translated into a spreadsheet format (MIXING.XLS and EMPMOD.XLS, respectively).

3.1 Using the Spreadsheet Workbooks

The nitrogen load target spreadsheet workbook (EMPMOD.XLS) was developed to model the consequences of alternative loading scenarios. Nitrogen loading scenarios can be generated by the TBNEP Comprehensive Loading SAS Model (Zarbock et al., 1994) and converted from external

loads to internal loads using the TBNEP Intersegment Transport/Mixing Model (Janicki and Wade, 1996), or generated by the MIXING.XLS spreadsheet model. Instructions for incorporating new loading scenarios into the spreadsheet workbook are included in the section titled Nitrogen Loads (Section 3.2).

User notes are posted within each section of the nitrogen load target model spreadsheet, EMPMOD.XLS, to provide additional information, and red triangles posted on column headings indicate explanatory notes. To view an explanatory note, move the cursor onto the red triangle and it will be displayed.

The following sections are included as individual spreadsheets of the empirical model (EMPMOD.XLS), and may be opened by clicking on the named tab below:

- Tampa Bay Parameters - a set of user modifiable empirically estimated parameters,
- Nitrogen Loads - two nitrogen loading scenarios from Janicki and Wade (1996),
- Chlorophyll - estimated chlorophyll response to the nitrogen loads,
- Light Attenuation - estimated light attenuation response to the chlorophyll concentrations,
- Seagrass - estimated seagrass response to the light attenuation factors,
- Back Calculation - a page to allow back calculation of nitrogen loads consistent with targets, and
- Literature Cited.

Data are shared across the individual spreadsheets in the order indicated by the tabs below from left to right, and equations may be viewed by clicking on a cell of interest. The equations are presented in an easy to use format with the exception of an interpolation engine that is included on the far right of the Seagrass page. These linear interpolation equations were not intended to be modified by users without a more detailed technical knowledge of Excel.

3.2 Nitrogen Loads

Nitrogen Load Scenarios

Nitrogen load scenarios are presented on this worksheet page of EMPMOD.XLS. The scenarios may be changed by the user. The current TBNEP model that estimates chlorophyll-a concentrations as a response to nitrogen loads was parameterized using the total nitrogen loads to each bay segment. The total nitrogen loads include external sources, inter-segment transport, and loads resulting from non-conservative processes.

The TBNEP has developed a series of pollutant loading models to generate these loading scenarios. These models were developed as SAS (SAS Institute, Cary N.C.) programs and associated datasets,

and are available from the TBNEP office. The TBNEP SAS model N-SERIES.SAS will allow a user to develop a detailed time series of total nitrogen loads to be used within this spreadsheet. A spreadsheet model has also been developed to serve the same purpose (MIXING.XLS). This empirical mixing model accounts for the net movement of water and nitrogen into the bay from external sources, between the segments of the bay, and the net results of non-conservative processes such as sediment uptake and release of nitrogen. Detailed descriptions of the N-SERIES.SAS model and the data sources used to parameterize it are presented in Section 5.5 of Janicki and Wade (1996).

Instructions for Changing the Nitrogen Load Scenarios Produced by the N-SERIES.SAS Model

Nitrogen load scenarios generated by the N-SERIES.SAS model may be easily imported into this worksheet. The following steps are suggested:

- 1) Select the "File" icon at the upper left of the Excel desktop, and select "Open".
- 2) Select the .LST output file from the SAS model N-SERIES.SAS, and select "Open".
- 3) Choose the default input options, and Excel will create a new worksheet with the rows and columns of data.
- 4) Within Excel, select the 12 rows and 12 columns that represent a year of interest from the output. This is done by pointing to the upper left of the area of interest, pressing the left mouse button, and moving the mouse to the lower right corner of the area of interest. The 12 selected rows and 12 columns will then be highlighted.
- 5) Press the copy icon on the Excel desktop, minimize the N-SERIES.SAS spreadsheet you created, and maximize the EMPMOD.XLS NITROGEN LOADS worksheet. Move the cursor to the upper left of the load scenario you wish to replace and click the paste icon on the Excel desktop.

Instructions for Changing the Nitrogen Load Scenarios Produced by the MIXING.XLS Model Spreadsheet

Nitrogen load scenarios generated by the MIXING.XLS model may be easily imported into this worksheet. The following steps are suggested:

- 1) Select the "File" icon at the upper left of the Excel desktop, and select "Open".
- 2) Select the Excel mixing model spreadsheet MIXING.XLS and select "Open".
- 3) Select the EXTERNAL LOAD SCENARIO page of the spreadsheet at the bottom of the screen.
- 4) Modify one or both of the following:
 Table A - Change Factor Table, for the segment(s) and year(s) of interest,
 Table B - Constants Added to Scenario, for the segment(s) of interest.
 The resulting monthly external loads for the 15-year time period are calculated in Table C.

- 5) Select the ESTIMATED INTERNAL LOADS page of the spreadsheet at the bottom of the screen.
- 6) For the year for which calculations are desired, select the estimated internal loads (kg/mo) for the five segments. For example, to determine the results of the modified loadings for year 15, move the cursor to cell D-208 and select through cell H-219. Then click the copy icon on the Excel desktop.
- 7) Using the same method as described above, open the EMPMOD.XLS spreadsheet and select the NITROGEN LOADS page of the spreadsheet at the bottom of the screen.
- 8) Move the cursor to cell H-61 and select through cell L-72. Click the Edit tool at the top of the screen, then click Paste Special and select Values. This will replace the default internal nitrogen loads with the newly calculated internal nitrogen loads.

User's Notes: Loads are entered in kg/month and are also calculated as tons/month below.
Nitrogen Load Scenario Labels and Abstracts entered here are carried forward to the Chlorophyll, Seagrass, and Back-calculation pages.

3.3 Chlorophyll

Relationship of Nitrogen Load to Chlorophyll

The chlorophyll-a values are calculated on this page using the TBNEP monthly model. Input data are read from the Nitrogen Loads page and the Tampa Bay Parameters Page of this workbook.

The following model is used:

$$C_{t,s} = A_{t,s} + B_s L_{t,s}$$

where:

$C_{t,s}$ = average chlorophyll-a concentration at month t and segment s;

$L_{t,s}$ = total nitrogen load (L) (i.e., from internal and external sources and non-conservative processes) at month t and segment s;

$A_{t,s}$ and B_s = parameters estimated by regression analysis.

User's Note: Chlorophyll values calculated from data entered on Tampa Bay Parameters and Nitrogen Loads pages.

3.4 Light Attenuation

Relationship of Water Quality to Light Attenuation

The light penetration values are calculated on this page using the TBNEP monthly model. Input data are read from the Chlorophyll page and the Tampa Bay Parameters Page of this workbook.

The following model is used with inverse predictions to compute $Z_{t,s}$ from $C_{t,s}$:

$$\ln(C_{t,s}) = A_{t,s} + B_s \ln(Z_{t,s})$$

where:

$C_{t,s}$ = average chlorophyll-a concentration at month t and segment s;

$Z_{t,s}$ = the depth to which 20.5% of surface irradiance penetrates at month t and bay segment s;

$A_{t,s}$ and B_s = parameters estimated by regression analysis.

User's Note: Depth values calculated from data entered on Tampa Bay Parameters and Chlorophyll pages. Calculated chlorophyll values on previous page may be substituted with constant values for what-if analyses. However, a copy of this workbook should be made prior to overwriting the calculated values to avoid loss of the equations.

3.5 Seagrass

Seagrass Restoration Target Response

The seagrass restoration areas predicted to be illuminated by an annual average of 20.5% of surface light are calculated using the depth of 20.5% surface light penetration from the Light Attenuation page of this workbook and the seagrass restoration area distributions from the Tampa Bay Parameters page.

3.6 Back Calculation

The series of models developed to calculate the seagrass target consequences of various nitrogen load scenarios were operationally defined by the TBNEP Technical Advisory Committee according to a specific paradigm. That paradigm started with nitrogen loads, calculated chlorophyll concentrations, calculated light penetration depths, and finally calculated the area of the bay estimated to be illuminated by the light penetration depths.

During the development of the nitrogen load targets, it was often desired to determine the nitrogen load that would be consistent with illuminating a desired extent of seagrass protection and restoration areas. These nitrogen loads were estimated by linear interpolation from a series of model runs executed following the operationally defined paradigm. This spreadsheet workbook provides

the ideal environment for interactively developing such "what-if" scenarios. To increase the ease of back-calculating with this spreadsheet workbook, the workbook was designed to include two nitrogen loading scenarios, and an interpolation engine and example data are provided within this section. By interactively deciding upon two reasonable scenarios, the user may choose a suitable range over which the response is expected to approximate linearity. However, the ease of interactively iterating the input values may suggest that most users will not require back calculations.

The 15 and 30 year 2% reduction schedule scenarios chosen as the default values for the spreadsheet workbook are likely to be too broad for very precise linear interpolations. These two scenarios were chosen to match the scenarios presented in the companion report (Janicki and Wade, 1996) in order to provide a completely documented example.

The examples use the duration of the nitrogen load reduction schedule (years). However, one may also input the total external loads from the two scenarios to back calculate a target load.

3.7 Literature Cited

Janicki, A. and D. Wade. 1996. Estimating Critical External Nitrogen Loads for the Tampa Bay Estuary: an Empirically Approach to Setting Management Targets. Tampa Bay National Estuary Program Technical Publication # 06-96 Prepared for Tampa Bay National Estuary Program, 111 7th. Avenue South, St. Petersburg, Florida 33701.

Zarbock, H., A. Janicki, D. Wade, D. Heimbuch, and H. Wilson. 1994. Estimates of Total Nitrogen, Total Phosphorus and Total Suspended Solids Loadings to Tampa Bay, Florida. Tampa Bay National Estuary Program Technical Publication # 04-94. Prepared for Tampa Bay National Estuary Program, 111 7th. Avenue South, St. Petersburg, Florida 33701.

4.0 TBNEP OPTIMIZATION MODEL

This chapter is a summary reference guide for the Tampa Bay National Estuary Program (TBNEP) Watershed Management Model for the Optimal Allocation of Best Management Practices. A more detailed description of the software is provided in a separate TBNEP report (Wade et al., 1997).

The goal of the Tampa Bay National Estuary Program (TBNEP) for this project is to assist the local Tampa Bay governments with the process of selecting optimal pollution management strategies. The watershed management model was developed in accordance with the TBNEP's role as a facilitator for the selection process. Specifically, the watershed management model will provide a method for evaluating the most cost effective and optimal methods of controlling nutrient and sediment runoff from specific areas of the watershed.

There are multiple objectives to be addressed by the watershed management model. These objectives include the reduction of total nitrogen (TN) loads, total suspended solids (TSS) loads, and total phosphorus (TP) loads, and the minimization of costs of BMP implementation.

The watershed management model was developed to provide a method for evaluating the most cost effective and optimal methods of controlling nutrient and sediment runoff from specific areas of the watershed. Several Tampa Bay region-specific datasets were compiled for BMP costs and efficiencies. However, the model is intended to be flexible and to be used in conjunction with specific pollutant load and subbasin characteristic datasets developed by individual users for specific areas of interest.

An example case study is presented in the final chapter of this user's manual, and the example data files for this case study are included on the CD containing the computer software.

4.1 Summary Reference of Data Used to Operate the Model

The model was designed so that each data set can be input as a separate data file to be created by the user for his or her particular application. All of the datasets are flexible, and can be expanded, modified, or replaced according to the user's needs. Because the format of the data files was developed to be very flexible, it can be used to model a variety of management scenarios ranging from broad-based investigations of nonpoint source control BMPs to complex combinations of specific point sources, regional stormwater BMP alternatives, and nonpoint source control BMPs.

Alternative input values to allow variations on the example input dataset are listed in Appendix 9. Tampa Bay region-specific datasets for BMP cost, efficiency, and constraints are included. A brief quantitative components of these alternatives presented in Appendix 9 and a more detailed description may be found in Wade et al. (1997).

4.1.1 Soil Characteristics Data

The watershed management model has been developed to consider:

- soil permeability rates,
- slopes, and
- depths to the underlying water table

Because each of these soil characteristics is variable and continuous for any particular soil type, the distribution of each of the soil parameters is useful information for estimating the proportion of land expected to be suitable for implementation of a BMP on a regional basis. The watershed management model has been developed to use a variety of measures of these parameters including:

- minimum values,
- maximum values,
- ranges, or
- triangular distributions defined by a central tendency parameter and two parameters for the tails of the distribution.

This use of flexible parameters allows the user to specify a level of soil characteristic detail desired for his or her particular application.

Potential Data Sources

The U.S. Department of Agriculture, Soil Conservation Service, has developed detailed soil characteristics data for the Tampa Bay area. Published maps and tables of these data are available from the Department of Agriculture for each of the counties within the Tampa Bay region, with the maps developed at a scale of 1:24,000, defining approximately 50 soil categories for each county.

The Southwest Florida Water Management District (SWFWMD) GIS and Mapping Section maintains 1:24,000 scale Geographic Information System (GIS) datasets for the soil series data mapped by the USDA. Digital data files of the soil series may be obtained from the GIS and Mapping Section. The TBNEP data library includes copies of the digital USDA soil series data as originally obtained from the SWFWMD. A set of soil attribute data files, which correspond to selected parameters of the soil series data, and USDA county soil atlases was also developed by the TBNEP.

For more detailed applications of the watershed management model for specific site plans, a custom data set may be readily developed by delineating soil regions within each of the subbasins of the site, and measuring the permeability, slope, and depth to water table within each of these regions. The model's existing USDA soil characteristics data can then be easily replaced with the more detailed measured data.

4.1.2 Subbasin Characteristics Data

The geographic and hydrologic operational unit of the watershed management model is the subbasin. Subbasins may range in size from large regional drainage areas to small sections of a specific development site. The model was developed to use subbasin characteristic data in the form of individual parcels of land or combinations of parcels having unique soil and land use combinations. The variables of interest are:

- subbasin identifier,
- soil code,
- land use/cover code, and
- the area of the parcel or group of parcels.

The subbasin characteristics data are used by the model to determine the amount of land suitable for construction of each BMP in each subbasin.

Potential Data Sources

Subbasin characteristics data may be developed using GIS software to overlay subbasin boundaries, land use/cover data, and soil series data. The area of each combination of subbasin, land use, and soil can then be tabulated in a simple data file for use by the model.

GIS land use datasets are generally available for all areas of the Tampa Bay region. The SWFWMD GIS and Mapping Section has developed a complete dataset for 1990 at 1:24,000 scale using the Florida Department of Transportation (FDOT) Florida Land Use and Cover Classification System (FLUCCS), and these data were updated in 1995. In addition, many of the local governments (e.g., Pinellas County, Hillsborough County) have developed independent land use/cover datasets for their jurisdictions. The TBNEP and Tampa Bay Regional Planning Council have each developed expected future land use GIS data layers for 2010, and these may be useful for planning future implementation of BMPs.

Although useful, GIS data analyses are not required to apply the watershed management model. The model is not linked to any specific GIS software package or data format. Analyses ranging from broad-based regional studies to detailed site evaluations can be conducted by delineating subbasins and parcels on maps and site drainage plans, and estimating the proportion of land use/cover within each area.

4.1.3 Pollutant Loading Data

The model has been developed to use detailed data on the sources, geographic distribution, and quantities of pollutant loads. There are seven categories of major sources of total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) loads. These categories are:

- Atmospheric deposition directly to the receiving water bodies,
- Domestic point sources,
- Industrial point sources,
- Nonpoint sources,
- Groundwater sources (loaded to surface waters),
- Significant natural springs, and
- Fugitive emissions (e.g., transportation and processing losses of fertilizer products).

Although the focus of this project is on nonpoint sources of pollutants, the model has been developed to be flexible and to allow the incorporation of each of the seven sources of pollutant loads.

Potential Data Sources

Nonpoint source pollutant loadings can be modeled using a variety of levels of detail ranging from land use-specific unit-area-load spreadsheet models, to empirical loading models, to mechanistic models based on calibrated physical models of surface water and contaminants. The watershed management model is not dependent on any single pollutant load model. Rather, the model was developed to use tabular loading data specific to particular land uses or point sources.

The TBNEP has developed estimates of pollutant loads for the entire watershed on a regional basis (Zarbock et al., 1996). These results indicate that the most significant sources of pollutant loads include atmospheric deposition and nonpoint sources. Atmospheric deposition loads have been estimated on a bay segment basis, and nonpoint source loads have been estimated on a subbasin and land use-specific basis.

4.1.4 BMP Cost, Efficiency, and Constraint Data

The watershed management model to compute the total costs and benefits of each BMP allocation strategy evaluated uses BMP-specific cost, efficiency, and constraint data. The total costs are estimated in terms of dollars per acre treated per year, and the total benefits are estimated in terms of individual pollutant load reductions for TN, TSS, and TP.

BMP cost data comprise one of the four dimensions of the multiple objective approach, and the watershed management model has been developed to consider:

- BMP life span (years),
- construction costs (dollars/acre treated),
- operation and maintenance costs (dollars/acre treated/year), and
- land required for implementation (acres used by BMP/acre treated).

Each of these cost components is used to compute the total unit cost of each type of BMP.

BMP efficiency data are combined with pollutant load data to estimate the benefits of particular management strategies, and the model has been developed to include:

- percent TN removal efficiency,
- percent TSS removal efficiency, and
- percent TP removal efficiency.

BMP constraint data are used to determine all of the possible places where particular BMPs could be located in the area of interest, and the model has been developed to include:

- suitable land use,
- minimum and maximum drainage areas,
- minimum and maximum soil infiltration rates,
- minimum and maximum depths to the water table, and
- minimum and maximum slopes.

Potential Data Sources

Tampa Bay region-specific datasets for BMP cost, efficiency, and constraints are presented in detail in Appendix 9. The BMP cost, efficiency, and constraint data may all be replaced, augmented, or modified with specific information compiled by an individual user of the model.

4.1.5 Regionally Specific Real-property Values

The real-property value information is comprised of the following variables:

- geographic region within the Tampa Bay watershed,
- land use code,
- minimum value (dollars/acre),
- mean value (dollars/acre), and
- maximum value (dollars/acre).

Potential Data Sources

The TBNEP developed a set of property value estimates for the Tampa Bay watershed (Appendix 9). The minimum, mean, and maximum values were estimated on a regional and land use basis from samples of assessed values recorded by county tax assessors. These estimates were developed for ten major drainage basins and seven land use categories. The ten major drainage basins included the four major rivers (i.e., Hillsborough River, Manatee River, Little Manatee River, and Alafia

River) and the coastal areas of the six major segments of the bay (i.e., Old Tampa Bay, Hillsborough Bay, Middle Tampa Bay, Lower Tampa Bay, Boca Ciega Bay, and Terra Ceia Bay).

Users may also develop their own property value databases. For broad-based regional applications of the watershed management model, property values obtained from assessed taxable values will allow evaluation of BMP alternatives. The multiple objective programming approach only requires relative values for BMP costs, because cost is one of the dimensions of the multiple objective space. However, when property values must be combined with significant construction and/or maintenance costs, the user may wish to adjust the assessed property values to market values.

For detailed site-specific applications of the watershed model, market property values may be estimated for all parcels of land considered. The purchase of environmental easements on private lands may also be modeled on a parcel by parcel basis. For sites where all of the land is already owned by the managing government, property values of a constant such as 1.0 may be assigned to eliminate their consideration.

4.2 Summary Reference of the Model

The model uses a single command to run the program without menus, breaks up each process of the approach into five distinct program modules, and allows complete control of all functions through flexible input datasets.

All of the input and output data files are simply formatted ASCII data files that can be copied and modified with any convenient word processing program. Each input and output data file contains a free form header area at the top that allows the user to make notes describing the particular scenario or data source.

As a general approach, each module is executed by typing the name of the module and the name of a control file at the DOS prompt. The control file simply contains a list of the names of each of the input and output data files desired to be used by that module. Upon execution of a module, the computer program will evaluate the input data sets, and produce a single output data set and an output log file. The output data set contains an ASCII data file of the specific results of that module, and the output log file records the data sites that were used and any important messages to the user.

The specific functions of each of the five modules are discussed within the following sections.

4.2.1 Module 1: Compile List of Potential BMPs Based on Site Constraints

Module 1 reads a list of potential BMP options and evaluates which options are feasible based on soil and land use characteristics. It then outputs a list of all of the feasible BMPs by subbasin. Because the datasets are flexible and expandable, a wide variety of management scenarios can be

easily evaluated.

Module 1 Input Data

Soil Characteristics Data

This data set has one line of data for each unique type of soil, and is structured as follows:

- soil type code,
- minimum slope (%),
- mean slope (%),
- maximum slope (%),
- minimum depth to water table (ft),
- mean depth to water table (ft),
- maximum depth to water table (ft),
- minimum permeability rate (in/hr),
- mean permeability rate (in/hr), and
- maximum permeability rate (in/hr).

A missing value may be indicated for any of these parameters by the value "-999", and it will not be used for eliminating BMPs.

Subbasin Characteristics Data

The subbasin characteristics data set has a line of data for each subbasin, BMP category, and land use as follows:

- subbasin identifier,
- BMP category,
- soil type code,
- land use type code, and
- area available for BMP construction (acres).

Each line of this dataset specifies the total acreage of a particular land use on which BMPs of a particular category may be constructed within that subbasin.

This dataset may be generated by many techniques ranging from simply typing in land use estimates, to output basic information from a GIS overlay, to using a complex GIS-based landscape design model. In the simplest case, a user could input a line of data for each land use in a subbasin, and label the subbasin category "1" for each of these lines of data. Thus, the model would consider placing BMPs anywhere within the subbasin where land use and soil characteristics were suitable.

In order to add complexity to this simple case, the user could add additional records having another subbasin category (e.g., "2") to the database. These additional records could describe special locations within the subbasin where a particular type of BMP could be constructed (e.g., a large regional stormwater retention pond might be possible at the confluence of two tributaries). There is no limit to the number of additional BMP categories that can be entered to the model, and the lands described by the BMP categories can be located in separate places in the subbasin or they can overlap. Point source BMPs can also be modeled using this approach by assigning a separate BMP category and an arbitrary land use code and acreage.

BMP Constraint Data

The BMP constraints database has a line of data for each BMP type as follows:

- BMP identifier code,
- BMP category,
- land use type code,
- minimum area treated by BMP (acres),
- maximum area treated by BMP (acres),
- minimum suitable soil permeability (in/hr),
- maximum suitable soil permeability (in/hr),
- minimum suitable depth to water table (ft),
- maximum suitable depth to water table (ft),
- minimum suitable slope (%), and
- maximum suitable slope (%).

The user may also expand the BMP dataset. In addition to adding more BMPs, the user may evaluate alternative sizes or designs of a single BMP by copying lines of this database and changing the BMP identifier code and parameters of interest. The BMP cost and efficiency datasets would also be modified to reflect these new options. Upstream and downstream combinations of BMPs can also be evaluated using this approach.

Module 1 Process

Module 1 reads the list of potential BMP options from the constraint data file, and evaluates which options are feasible based on the soil and land use characteristics. It then outputs a list of all of the feasible BMPs by subbasin and land use type.

For each area of land described in the subbasin characteristics data file, the computer program for Module 1 determines the amount of this land in acres that is likely to be suitable for construction of the BMP.

A variety of types of distributions of soil characteristics may be approximated by the use of triangular distributions. These include single point means, ranges, uniform distributions, normal distributions, skewed distributions, and peaked or flattened distributions.

Module 1 Output Data

The output data file from this module is a list of all of the types of BMPs listed in the BMP constraint database for which the conditions are suitable for construction, and the land area that is expected to be suitable for construction. This list of potential BMP types is listed by either subbasin and land use type, or by subbasin and specific land use parcel depending on the input subbasin characteristics database. The following variables are included:

- BMP identifier code,
- BMP category,
- BMP minimum drainage area,
- BMP maximum drainage area,
- subbasin identifier,
- land use type code, and
- suitable area for BMP construction (acres).

4.2.2 Module 2: Evaluate Unit Cost and Benefit for Each Potential BMP

Module 2 evaluates the total cost and total benefits (i.e., TN, TP, TSS load reduction) for a single unit of each of the potential BMPs short listed by Module 1. For example, the total cost in dollars per acre treated per year may be estimated for a single 10-acre wet retention pond, or for a single square foot of porous pavement. Combinations of multiple units of BMPs are evaluated later in Modules 3, 4, and 5.

Module 2 Input Data

The BMP shortlist file generated by Module 1 is the first input file for this module. The user may examine this file before running Module 2, and may decide to further eliminate BMP options based on any additional management considerations not included in the Module 1.

Pollutant Load Data

The pollutant load dataset has a line of data for each subbasin, BMP category, and land use to be treated in the watershed, with data as follows:

- subbasin identifier code,
- BMP category,

- land use type code,
- treatment area (acres),
- TN load (tons/yr),
- TP load (tons/yr), and
- TSS load (tons/yr).

The lands to be treated are linked to the potential BMPs and lands on which BMPs are to be constructed by the BMP category variable. Complex modeling scenarios may be easily developed using the BMP category variable, and the lands to be treated may or may not overlap with the lands on which BMPs may be constructed. For example, a user may wish to have a category of BMPs where the lands to be treated are the same as the lands on which BMPs are to be constructed, such as for onsite vegetated swales or concrete paving blocks. In this case, the pollutant load land use data are repeated in the subbasin characteristics dataset. A user may also wish to have a category of BMPs for which the lands to be treated are separated from the lands to be considered for BMP construction. For example, the lands to be considered for BMP construction may represent a specific site identified for a potential regional stormwater pond, and the lands to be treated may represent the drainage area for this regional pond within the subbasin.

BMP Cost Data

The BMP cost dataset has a line of data for each BMP, BMP category, and land use code as follows:

- BMP identifier code,
- BMP category,
- land use type code,
- BMP life span (years),
- BMP construction cost (\$/acre treated),
- BMP operation/maintenance cost (\$/acre treated/yr), and
- BMP land required (acres).

BMP Efficiency Data

The BMP efficiency dataset has a line of data for each BMP and BMP category as follows:

- BMP identifier code,
- BMP category,
- minimum TN efficiency (%),
- mean TN efficiency (%),
- maximum TN efficiency (%),
- minimum TP efficiency (%),

- mean TP efficiency (%),
- maximum TP efficiency (%),
- minimum TSS efficiency (%),
- mean TSS efficiency (%), and
- maximum TSS efficiency (%).

Module 2 Process

Module 2 evaluates the total cost and total benefits (i.e., TN, TP, TSS load reduction) for a single unit of each of the potential BMPs short listed by Module 1. Costs and benefits are computed for each combination of BMP, BMP category, and land use.

Module 2 Output Data

The output data file from this module is a list of each type of BMP, BMP category, and subbasin listed in the BMP shortlist. Each line of this list is accompanied by a total unit cost value, and a total unit benefit value for TN, TP, and TSS.

4.2.3 Module 3: Compile Set of Optimal Management Solutions

Module 3 compiles a set of optimal management solutions by considering all of the possible quantities of the BMPs listed by Module 2 that could be implemented.

Module 3 Input Data

The input data for Module 3 is the unit cost and benefit dataset produced by Module 2.

Module 3 Process

Module 3 applies a multiple objective programming approach to identify a subset of optimal management strategies for each subbasin in the four-dimensional objective space of TN load reduction, TP load reduction, TSS load reduction, and cost. All quantities of BMPs allowed by the available land to be treated and land to be used for BMP construction are considered.

Module 3 Output Data

The output data file from this module is comprised of two datasets that describe the set of optimal strategies from the "efficient frontier" for the watershed as a whole.

The first dataset describes each of the management strategies in detail by listing all of the individual BMPs recommended.

The second dataset has a single record for each management strategy, including a name that can be matched to the data in the first dataset, a total cost, and the total benefits in terms of load reductions.

4.2.4 Module 4: Evaluate Management Solutions with Regard to Budgets and Load Reduction Targets

The final module of the watershed management model can assist the manager in making subjective decisions according to the following steps.

- Step 1: The user specifies a real number weight value ranging from 0 to 1 for each of the three load reduction targets. If the user wishes to consider only a single objective such as TN, then the TN weight would be assigned a value of 1.0 and TP and TSS weights would be assigned values of 0.0. If the user does not wish to compare between the benefit objectives, then the user would simply print the list of solutions provided by Module 3.
- Step 2: The Module 4 output data base listing each management strategy name, total cost, and total benefits is read in, and a weighted average benefit is computed using the weights assigned in Step 1.
- Step 3: The benefit/cost ratio of each of the solutions from Step 2 is then calculated, and the data are sorted by this ratio.
- Step 4: The user may now enact one or both of two options:
 - Option A: The user specifies a nutrient load reduction target in tons/year, and the model lists the management options with the best benefit/cost ratio until the load reduction target is met. The list of management options and the total cost are then reported.
 - Option B: The user specifies a budget in dollars/year, and the model lists the options with the best benefit/cost ratio until the budget is met. The list of management options and the total nutrient load reduction are then reported.

4.3 Case Study

In order to allow users to begin using the model quickly, a narrative case study is presented in this chapter. The case study illustrates how the computer programs could be used to support the development of an actual watershed management plan. Upon reviewing the case study, the reader

will understand;

- how to define a watershed management problem in terms of the model framework,
- how to construct the input datasets needed by the model,
- how to run the model, and
- how to interpret the results.

This case study was designed to demonstrate the variety of functions provided by the model, and to demonstrate its flexibility.

4.3.1 The Setting of the Case Study

The principal character of this case study is a stormwater management engineer, Casey Jones. Mr. Jones works for a fictitious coastal county on the shores of Tampa Bay, and was assigned the task of developing a watershed management plan for one of the drainage basins in the county. This narrative walks through how Mr. Jones used the optimization model to assist in his assigned task.

The county had been participating in a regional pollutant load reduction effort developed through the Tampa Bay National Estuary Program, and had decided to reduce the county's total annual pollutant loads to Tampa Bay by a target amount. The Chief Engineer for the county has assigned each of the County's stormwater management engineers a drainage basin, and instructed them to reduce annual pollutant loads from their particular drainage basin by a given portion of the target amount. Casey Jones was assigned the Round Bay drainage basin, and instructed to reduce annual total nitrogen loads by 0.2 tons/year and minimize TSS loads. A capital budget for the countywide project was not finalized, and the Chief Engineer instructed Casey Jones to first develop a management plan that will meet the pollutant load reduction targets and then report back to him how much it will cost to implement the plan.

The Round Bay drainage basin contains three subbasins, as described below.

Crooked Creek Subbasin:

<i>Hydrography</i>	<i>An ungaged creek which discharges to Round Bay.</i>
<i>Land Cover</i>	<i>Low density residential land use interspersed with patches of forested uplands and freshwater wetlands.</i>
<i>Loadings</i>	<i>Land use-specific TSS, TN, and TP loadings were estimated by an earlier special study of the subbasin.</i>
<i>Special Considerations</i>	<i>None.</i>

Long Lake Subbasin:

<i>Hydrography</i>	<i>A man-made canal which discharges to Round Bay via lower Crooked Creek. There is a stream gaging station at the outfall where both water quantity and quality are measured.</i>
<i>Land Cover</i>	<i>Medium and high-density residential land use surrounding a man-made lake.</i>
<i>Loadings</i>	<i>Land use-specific TSS, TN, and TP nonpoint source loadings were estimated from water quality and quantity data measured at the gage. Point source loads from the Long Lake Wastewater Treatment Plant (WWTP) were recorded monthly.</i>
<i>Special Considerations</i>	<i>- The basin is gaged. - The Long Lake WWTP discharges into the canal.</i>

Bent Branch Subbasin:

<i>Hydrography</i>	<i>An ungaged creek which discharges to Round Bay via lower Crooked Creek.</i>
<i>Land Cover</i>	<i>Low density residential land use interspersed with patches of forested uplands and freshwater wetlands.</i>
<i>Loadings</i>	<i>Land use-specific TSS, TN, and TP loadings not available from other sources, so Casey estimated these loads by applying a unit area load calculation to the GIS land use data.</i>
<i>Special Considerations</i>	<i>None.</i>

After reviewing the available information for the three subbasins, Casey realized that there were two management objectives that would be important to the development of the plan, nitrogen load reduction and TSS load reduction. He also realized that an important implicit objective for the plan would be to minimize costs. Thus, he defined the final formal objectives of the plan as:

Management Objectives of the Round Bay Plan:

Reduce annual TN loads from the basin by 10 tons/year,

Reduce annual TSS loads from the basin, and

Minimize costs associated with the acceptable management actions.

In looking over this list of objectives, it became apparent that the overall problem was a multiple objective problem as discussed in the introductory chapters of this report. Although there was a definite numeric minimum target for TN load reduction, there was not a numeric target for TSS load reduction, and there was no information as to how much any one of the objectives was more important than the others. For example, he did not know whether 1 ton of TN load reduction was equal in value to 1 ton of TSS load reduction. In addition, there was not an actual budget to work with yet, but only the general objective that costs should be minimized.

He defined a “**management plan**” as a set of individual management actions (e.g., BMPs) which could be purchased or constructed in the watershed. Thus, an example management plan might be:

- construct a 2 acre wet detention pond in the Crooked Creek Basin,
- install 10 acres of porous pavement in the Long Lake Basin,
- install equipment at the Long Lake WWTP to reduce TN loads by 2 tons per year.

The expected benefits and costs of any specific management plan could then be calculated in terms of the three objectives: the total TN load reduction, the total TSS load reduction, and the total cost of the set of management actions.

Because of the multiple-objective nature of the problem, he realized that an absolutely best “management plan” could not be objectively defined based on the available data alone. However, the TBNEP optimization model could be used to define a set of “management plans” which are clearly better than all other groups of actions with respect to the three objectives, and then he could work with the other watershed managers to use subjective information (e.g., community acceptance, aesthetic appeal, professional judgement) to choose the best plan.

Casey realized that even in this fairly simple case of three subbasins, there would be thousands of possible combinations of management actions to be compared to identify the group of better options

(i.e., the Pareto optimal set). He decided to solve the problem using the TBNEP optimization software in a series of steps, and noted these in his project log:

Project Logbook - Round Bay Management Plan

Analysis Approach for Round Bay Management Plan Development

- | | |
|----------------|---|
| <i>Step 1:</i> | <i>Put together a list of all BMPs which should be considered, and use site-specific constraints and the Optimization Module 1 to generate a shortlist of BMPs which would be feasible for the Round Bay Basin.</i> |
| <i>Step 2:</i> | <i>Use Optimization Module 2 to identify the costs and benefits of each BMP in the shortlist.</i> |
| <i>Step 3:</i> | <i>Use Optimization Module 3 to identify the best types of BMPs in terms of costs and benefits.</i> |
| <i>Step 4:</i> | <i>Once a Pareto optimal set of management plans has been identified, use Module 4 to evaluate management priorities, budgets, and load reduction targets, and then use this information to select a final management plan.</i> |

4.3.2 Step 1: Applying Module 1 to BMP Screening and Options List Generation

Casey's first task was to compile a list of all BMPs that should be considered for the Round Bay Basin Management Plan. He decided to use the TBNEP Optimization Model to assist in compiling the list of feasible options based on site-specific constraints in the watershed and a set of BMP characteristics. The results of Module 1 would be output in the form of a table of feasible BMP's by subbasin and land use together with an estimate of the suitable area in the watershed for implementing each BMP.

As an alternative to running Module 1, Casey realized that he could have visited the watershed and recorded specific suitable areas and sizes of feasible BMP's. This information could then have been typed into a table in the same format as the output table from Module 1. Thus, he could have started running the Optimization programs with Module 2. However, in this case he only had GIS databases of land use and soil information for the three subbasins of the Round Bay Watershed.

Casey remembered that each module of the TBNEP Optimization Model computer program has four types of files:

- **a program control file** - which contains a set of simple instructions to a particular module,
- **a program log file** - which repeats and verifies the instructions given in the program control file and lists any notes or error messages that may have occurred during the run,
- **input data files** - which contain all of the data needed to run a particular module, and
- **output data files** - which contain tables of the results of the run.

Each of these files is a simple ASCII text file that could be edited with a word processing program or text editor program.

For example, he was using Wordperfect software at the time, and to edit a data file he had to take the following steps:

- Step 1) open the file using the [FILE] [OPEN] buttons,
- Step 2) select the [line printer] font to make the file easier to read,
- Step 3) make the necessary edits to the file, and
- Step 4) save the file using the [FILE] [SAVE AS] [ASCII (DOS) TEXT] buttons.

Creating the Program Control File for Module 1:

Casey copied an existing program control file for Module 1 and edited the contents using his word processing program. The completed file appeared as follows:

```

r1-1.co1    TBNEP BMP Optimization Model, Module 1 Control File

Round Bay Management Plan
  Initial screening run of BMP options using default TBNEP BMP constraint data

Initial Run,      Aug 1, 1996   Casey Jones
Q.C. Reviewed,    Aug 3, 1996   B.G. Fireman

r1-1.o1          - output data file                      line 11
r1-const.bmp     - BMP constraints data file              line 12
r-sub.bmp        - Subbasin description file              line 13
soil.dat         - Soil characteristics data              line 14

```

The first 10 lines of the program control file are free space in which Casey could type whatever notes he wanted to record with respect to this model run. He typed in the name of the control file, a title and description of the run, and a brief history of who worked on the analysis.

The remaining lines of the control file identified the input and output data files for this model run. The program log file was named “r1-1.01”, a list of BMPs and associated constraints was named “r1-const.bmp”, a subbasin description file was named “r-sub.bmp”, and a soil characteristics table was named “soil.dat.”

The program output file would be automatically named the same name as the program control file with an extension of “p1.” Thus, the output file would be created by Module 1 as “r1-1.p1.”

Creating the Input Data Files for Module 1:

Casey needed three input data files. These were a BMP list with constraint data, a subbasin description list, and a soil characteristics list. He copied existing input data files supplied with the TBNEP programs and edited the contents using a word processing program.

He then developed a list of the feasible BMPs by copying the default BMP list “const.bmp” as “r-const.bmp.” After reviewing the BMPs in this file, he decided that he was comfortable building three designs: a constructed wetland, a small wet retention pond, and a large wet retention pond. Therefore, he deleted all of the other lines in the default file other than these three. He then reviewed the default constraints for these three and decided they were acceptable.

In addition, the County had just completed a feasibility study for a new type of porous pavement that could be installed on parking lots owned by the County. As part of this study, the County had compiled detailed inventories of the suitable parking lot areas independently from the GIS land use databases. This was a special case that could be handled by assigning a second “BMP category” to the porous pavement option. Casey then added a line to the BMP list file to represent the constraints for porous pavement installation and labeled it as BMP category 2. The inventory of suitable parking lot areas by subbasin was added to the subbasin description file.

A sample of the contents of this file follows (the actual file listed more land uses and BMPs):

rl-const.bmp Best Management Practice Constraint Data
Values for Round Lake Management Plan

BMP	BMP Category	BMP Land Use	BMP Trtmt Area	BMP Area	BMP Soil Infiltration		BMP Depth to Water Table		BMP Slope		
			acres	acres	min in/hr	max in/hr	min ft	max ft	min %	max %	
CW	1	1	50	2	0.02	8.27	0	-999	-999	-999	
CW	1	2	50	2	0.02	8.27	0	-999	-999	-999	
CW	1	3	50	2	0.02	8.27	0	-999	-999	-999	
PP	2	6	50	20	0.52	30.00	2	-999	3	18	Porous Pavement
WP1	1	1	100	2	0.02	8.27	2	-999	3	18	
WP1	1	2	100	2	0.02	8.27	2	-999	3	18	
WP1	1	3	100	2	0.02	8.27	2	-999	3	18	

As with all of the input files for the Optimization programs, the first 10 lines are free space for documenting runs. A code of -999 indicated missing data, the BMP codes were “CW” for constructed wetland, “PP” for porous pavement, “WP1” for the small pond, and “WP2” for the large pond. Casey included a line in this file for each land use and each BMP that should be considered.

He then developed a data file (“r-sub.bmp”) of the land use and soil by subbasin in the watershed:

r-sub.bmp Subbasin and BMP category specific land use and soil data
 Describes areas suitable for BMP implementation
 (sorted by subbasin/BMP cat/land use)
 Round Bay Basin Management Plan

BMP Soil (MUID)	Subbasin	BMP Category	BMP Land Use	BMP Area Available (acres)
103005	1	1	1	130.391
103018	1	1	1	142.336
103041	1	1	1	38.804
103027	1	1	1	5.986
103041	1	1	3	225.667
103018	1	1	3	141.052
103027	1	1	3	322.842
103002	1	1	5	151.796
103005	2	1	1	230.391
103018	2	1	1	42.336
103041	2	1	1	138.804
103027	2	1	1	5.986
103041	2	1	3	125.667
103018	2	1	3	41.052
103027	2	1	3	122.842
103002	2	1	5	51.796
103005	3	1	1	230.391
103018	3	1	1	142.336
103041	3	1	1	38.804
103027	3	1	1	105.986
103041	3	1	3	225.667
103018	3	1	3	41.052
103027	3	1	3	22.842
103002	3	1	3	51.796
103041	3	1	5	225.667
103018	3	1	5	41.052
103027	3	1	5	22.842
103002	3	1	5	51.796
103041	3	2	6	325.667
103018	3	2	6	141.052
103027	3	2	6	122.842
103002	3	2	6	151.796

These data were obtained by printing a table from his department's GIS database. The soil codes were taken from the U.S. Soil Conservation Service soil atlas for his County, and the land use codes were defined to match the TBNEP land use codes used in the previous BMP constraint list. He realized, however, that he could have readily substituted any other soil or land use codes that he would be comfortable using.

As discussed previously, the inventory of suitable parking lot areas for installation of porous pavement was added to the subbasin description file based on an existing detailed study. These areas were independent of the GIS-based land use data. Thus, they were assigned a BMP category of "2".

Lastly, he then typed in a soil characteristics data file based on information contained in the U.S. Soil Conservation Service Soil Atlas for his county. This file appeared as follows:

soil.dat Soil characteristics data									
TBNEP Optimization Model - Default Soil Data from USDA Soil Atlases Version 1.0 May 1996									
Soil	Slope		Depth to WT			Permeability			
MUID	min	mean	max	min	mean	max	min	mean	max
	%	%	%	ft	ft	ft	in/hr	in/hr	in/hr
103002	-999	-999	-999	0.0	-999	0.8	20.0	-999	30.0
103003	0	-999	5	6.7	-999	10.0	20.0	-999	30.0
103004	5	-999	12	6.7	-999	10.0	20.0	-999	30.0
103005	-999	-999	-999	3.3	-999	5.0	20.0	-999	30.0
103006	-999	-999	-999	0.0	-999	0.8	6.3	-999	20.0
103007	-999	-999	-999	0.0	-999	0.8	6.3	-999	20.0
103008	-999	-999	-999	0.0	-999	1.3	20.0	-999	30.0
103009	-999	-999	-999	0.0	-999	0.001	20.0	-999	30.0
103010	-999	-999	-999	0.0	-999	0.8	0.6	-999	20.0
103011	-999	-999	-999	0.0	-999	0.8	0.6	-999	20.0
103012	-999	-999	-999	0.0	-999	0.8	0.6	-999	20.0
103013	5	-999	8	0.0	-999	0.8	0.1	-999	2.0
103014	-999	-999	-999	0.0	-999	0.8	0.6	-999	20.0
103015	-999	-999	-999	-999	-999	-999	-999	-999	-999
103016	-999	-999	-999	-999	-999	-999	-999	-999	-999
103022	-999	-999	-999	3.3	-999	5.0	20.0	-999	30.0
103023	-999	-999	-999	0.0	-999	0.8	0.6	-999	2.0
103024	0	-999	5	6.7	-999	10.0	20.0	-999	30.0
103025	-999	-999	-999	0.0	-999	0.8	0.6	-999	20.0
103026	-999	-999	-999	0.0	-999	0.8	6.3	-999	20.0
103027	-999	-999	-999	0.8	-999	3.3	2.0	-999	20.0
103028	-999	-999	-999	0.0	-999	0.8	6.3	-999	20.0
103029	-999	-999	-999	0.0	-999	0.8	6.3	-999	20.0
103030	-999	-999	-999	-999	-999	-999	-999	-999	-999
103031	0	-999	5	6.7	-999	10.0	20.0	-999	30.0
103032	5	-999	12	5.0	-999	10.0	20.0	-999	30.0
103033	-999	-999	-999	0.8	-999	3.3	20.0	-999	30.0
103034	-999	-999	-999	0.0	-999	0.8	6.3	-999	20.0
103035	-999	-999	-999	0.0	-999	0.8	0.6	-999	20.0
103036	-999	-999	-999	0.0	-999	0.8	0.6	-999	20.0
103037	-999	-999	-999	-999	-999	-999	-999	-999	-999
103038	0	-999	8	6.7	-999	10.0	20.0	-999	30.0
103039	-999	-999	-999	0.0	-999	0.8	0.6	-999	20.0
103040	-999	-999	-999	0.0	-999	0.8	0.6	-999	20.0
103041	-999	-999	-999	0.8	-999	3.3	2.0	-999	20.0
103042	-999	-999	-999	0.0	-999	0.8	0.6	-999	20.0
103043	-999	-999	-999	0.0	-999	0.8	0.6	-999	20.0
103044	0	-999	5	0.0	-999	0.8	0.6	-999	6.3
103045	-999	-999	-999	-999	-999	-999	-999	-999	-999
103099	-999	-999	-999	-999	-999	-999	-999	-999	-999
103WAT	-999	-999	-999	-999	-999	-999	-999	-999	-999

Running the Computer Program for Module 1:

Once he had completed making the program control file and the three data input files, Casey ran the computer program for Module 1 as follows:

At the DOS prompt of his personal computer, he ran Module 1 using program control file "r1-1.col" by typing

opt-1 r1-1.col

To which the computer responded:

Optimization analysis has commenced
Output printed to r1-1.o1
Intermediate BMP file r1-1.p1 created

The program had completed its run very quickly, and had produced two data files. These files were the program log file "r1-1.o1" and the table of the results "r1-1.p1." He opened both of these files with his word processing program to inspect the results.

The program log file ("r1-1.o1") appeared as follows:

```
Tampa Bay National Estuary Program
BMP Allocation Strategy Optimization Model

                                Output from execution of r1-1.col control file

Control file header:
r1-1.col          TBNEP BMP Optimization Model,  Module 1 Control File

Round Bay Management Plan
  Initial screening run of BMP options using default TBNEP BMP constraint data

Initial Run,          Aug 1, 1996   Casey Jones
Q.C. Reviewed,       Aug 3, 1996   B.G. Fireman

*** Model run using the following data files
Program control file = r1-1.col
Program output file  = r1-1.o1
BMP constraints data = r1-const.bmp
Subbasin data       = r-sub.bmp
Soil data           = soil.dat

*** Program Run Completed
```

He noted that the top of the log file repeated the 10 lines of comments he had entered in the control file so that it would be easy to document the results. The program confirmed and restated the data input files that it had been instructed to use. Lastly, it indicated that the run had been completed without any error messages.

Interpreting the Results from Module 1:

The results of Module 1 were to list all of the feasible BMPs for the watershed. The output data file ("r1-1.p1") containing the results of the Module 1 run appeared as follows:

```

rl-1.pl          Intermediate BMP file rl-1.pl
Created by control file rl-1.col

```

BMP	BMP	BMP	BMP	Subbasin	Land	Suitable
code	Category	Treatment	Area		Use	Area
	(code)	Area	(acres)	(code)	(code)	(acres)
----	-----	-----	-----	-----	-----	-----
CW	1	50.000	2.000	1	1	55.366
CW	1	50.000	2.000	2	1	48.372
CW	1	50.000	2.000	3	1	79.634
CW	1	50.000	2.000	1	3	177.204
CW	1	50.000	2.000	2	3	73.140
CW	1	50.000	2.000	3	3	73.140
CW	1	50.000	2.000	3	5	73.140
PP	2	50.000	20.000	3	6	241.836
WP1	1	100.000	2.000	1	1	5.861
WP1	1	100.000	2.000	2	1	18.946
WP1	1	100.000	2.000	3	1	18.946
WP1	1	100.000	2.000	1	3	71.772
WP1	1	100.000	2.000	2	3	32.517
WP1	1	100.000	2.000	3	3	32.517
WP1	1	100.000	2.000	3	5	32.517
WP2	1	640.000	13.000	1	1	5.861
WP2	1	640.000	13.000	2	1	18.946
WP2	1	640.000	13.000	3	1	18.946
WP2	1	640.000	13.000	1	3	71.772
WP2	1	640.000	13.000	2	3	32.517
WP2	1	640.000	13.000	3	3	32.517
WP2	1	640.000	13.000	3	5	32.517

This results table indicated which BMPs would be feasible given the soils, land use, and available area of each subbasin. For example, the first data line of this file indicates that:

- constructed wetlands (“CW”) could be implemented given the land use/soil,
- that each constructed wetland would treat 50 acres of drainage area,
- that each constructed wetland would occupy 2 acres, and
- that in subbasin 1 and land use 1 there would be an estimated 55,366 acres of suitable area for building constructed wetlands given the land use, soil infiltration rates, depths to the water table, and slopes of the soils present.

4.3.3 Step 2: Applying Module 2 to the Costs and Benefits Compilation

Casey’s second task was to identify the costs and benefits in terms of pollutant load reduction for each of the BMPs in the list of feasible BMPs produced by Module 1. He would require nonpoint source pollutant loading data, BMP cost data, and BMP load reduction efficiency data. He decided to use the TBNEP Optimization model Module 2 to analyze this information. The results of Module 2 would be output as a table of BMPs with specific costs and pollutant load reduction benefits.

As an alternative to running Module 2, Casey realized that he could have developed detailed and specific BMP designs with costs and modeled load reduction efficiencies. This information could then have been typed into a table in the same format as the output table from Module 2. Thus, he could have started running the Optimization programs with Module 3.

Creating the Program Control File for Module 2:

The program control file for Module 2 was very similar to that used in Module 1. Casey copied an existing program control file for Module 2 and edited the contents using a word processing program. The completed file appeared as follows:

```

r1-1.co2      TBNEP Optimization Model,  Module 2 Control File
Round Lake Management Plan

The first 10 lines of this control file provide a free form space which users
may use to document the specifics of each run.


r1-1.co2      - output data file                      line 11
r1-1.pl       - BMP shortlist file                     line 12
r-load.bmp    - BMP load data file                     line 13
r-cost.bmp    - BMP cost data file                     line 14
r-eff.bmp     - BMP efficiency file                    line 15

```

As was the case for Module 1, the first 10 lines of the program control file are free space in which Casey could type whatever notes he wanted to record with respect to this model run. He typed in the name of the control file and a title and description of the run

The remaining lines of the control file identified the input and output data files for this model run. The program log file was named “r1-1.o2”, the list of feasible BMP’s from Module 1 was named “r1-1.pl”, a list of subbasin-specific nonpoint source pollutant loads was named “r-load.bmp”, a list of BMP cost data was named “r-cost.bmp”, and a list of BMP efficiency data was named “r-eff.bmp.”

As was the case for Module 1, the program output file would be automatically named the same name as the program control file with an extension of “p2.” Thus, the output file would be created by Module 2 as “r1-1.p2.”

Creating the Input Data Files for Module 2:

Casey needed four input data files. These were:

- a list of feasible BMP’s either typed in or from the Module 1 output,

- a subbasin-specific nonpoint source pollutant load data file,
- a BMP-specific cost data file, and
- a BMP-specific pollutant load reduction data file.

Again, he copied existing input data files supplied with the TBNEP programs and edited the contents using a word processing program.

Casey Jones called a meeting with his department and went over the list of feasible BMPs with the County's Chief Engineer. The Chief Engineer had just been informed that the local Water Management District had completed a study of combining several BMPs in series. They had combined wet retention ponds and downstream constructed wetlands to achieve higher pollutant load reduction efficiencies. Casey and the Chief Engineer revised the data file containing the feasible BMP options ("r1-1.pl") to reflect this new information. They added "treatment train" BMP options by assuming that they could be implemented anywhere a small wet pond could be implemented. Thus, they copied the data records for the small wet pond option ("WP1"), labeled the new records as treatment train BMPs ("TT"), and updated the pollutant load reduction efficiency and cost data based on the results of the Water Management District study.

The revised data file was named "r1-2.pl", and the contents of this file are presented on the following page. Note the new lines indicating treatment train options.

```

rl-2.pl          Intermediate BMP file
Created by control file rl-1.col
Added treatment train option based on Fireman, Aug 1995 Study    C. Jones

```

BMP code	BMP Category (code)	BMP Treatment Area (acres)	BMP Area (acres)	Subbasin (code)	Land Use (code)	Suitable Area (acres)
CW	1	50.000	2.000	1	3	177.204
CW	1	50.000	2.000	1	1	55.366
CW	1	50.000	2.000	2	3	73.140
CW	1	50.000	2.000	2	1	48.372
CW	1	50.000	2.000	3	3	73.140
CW	1	50.000	2.000	3	5	73.140
CW	1	50.000	2.000	3	1	79.634
PP	2	50.000	20.000	3	6	241.836
TT	1	140.000	4.000	1	1	5.861
TT	1	140.000	4.000	1	3	71.772
TT	1	140.000	4.000	2	3	32.517
TT	1	140.000	4.000	2	1	18.946
TT	1	140.000	4.000	3	5	32.517
TT	1	140.000	4.000	3	1	18.946
TT	1	140.000	4.000	3	3	32.517
WP1	1	100.000	2.000	1	1	5.861
WP1	1	100.000	2.000	1	3	71.772
WP1	1	100.000	2.000	2	3	32.517
WP1	1	100.000	2.000	2	1	18.946
WP1	1	100.000	2.000	3	5	32.517
WP1	1	100.000	2.000	3	1	18.946
WP1	1	100.000	2.000	3	3	32.517
WP2	1	640.000	13.000	1	1	5.861
WP2	1	640.000	13.000	1	3	71.772
WP2	1	640.000	13.000	2	3	32.517
WP2	1	640.000	13.000	2	1	18.946
WP2	1	640.000	13.000	3	5	32.517
WP2	1	640.000	13.000	3	1	18.946
WP2	1	640.000	13.000	3	3	32.517

Casey modified the program control file to read this new data file. As with all of the input files for the Optimization programs, the first 10 lines are free space for documenting runs. Thus Casey, typed a note in this space indicating that treatment train options had been added based on the Water Management District 1995 Study.

As discussed in the introduction to this case study, Casey had previously computed nonpoint source pollutant loads for these three subbasins on an average annual basis. The estimates from ungaged subbasins were estimated using unit area loading calculations based on the land use, soil, and rainfall data. The estimates from gaged subbasins were computed by multiplying measured pollutant concentrations by the total flows recorded at the gages. He used a spreadsheet software package to compile these loading estimates into a simple data file in the format required by the TBNEP Optimization programs.

The pollutant loading file appeared as follows:

r-load.bmp Subbasin and land use-specific pollutant loads
Round Lake Management Plan

Subbasin	Treatment BMP Category	Treatment Area acres	TN tons/yr	TP tons/yr	TSS tons/yr
1	1	1584.5	1.874	1.217	144.022
2	1	1951.9	5.117	1.631	280.460
3	1	1553.8	1.929	1.211	93.687
3	2	500.0	0.524	0.443	73.932

Casey had to develop a separate set of nonpoint source pollutant load estimates for the parking lot areas considered for installation of porous pavement. These loads were entered into the data file as BMP category 2, together with the drainage areas that would drain to these particular parking lots.

He then compiled a BMP-specific cost data file using the format required by the TBNEP computer programs. He started by copying the default cost data file “cost.bmp”, and modifying it slightly to include the treatment train options and the specific cost data he possessed for porous pavement. The cost data file is presented on the following page. Note that the land cost for the porous pavement option had been entered as zero since the County already owned these parking lots.

r-cost.bmp Best Management Practice Cost Data
Round Lake Management Plan
Sorted by BMP/BMP cat/land use

BMP	BMP Category	BMP Land Use	BMP Life Span (Yr)	BMP Construction Cost (\$/Acre Treated)	BMP O&M Cost (\$/acre treated /Year)	Land Cost (\$/acre)
CW	1	1	20	2800	75.00	365462.00
CW	1	2	20	2800	75.00	365462.00
CW	1	3	20	2800	75.00	398573.00
CW	1	4	20	2800	75.00	38950.00
CW	1	5	20	2800	75.00	376497.00
CW	1	6	20	2800	75.00	34723.00
CW	1	6	20	2800	75.00	34723.00
CW	1	7	20	2800	75.00	38950.00
CW	1	8	20	2800	75.00	34723.00
CW	1	9	20	2800	75.00	34723.00
CW	1	10	20	2800	75.00	34723.00
CW	1	11	20	2800	75.00	61929.00
CW	1	12	20	2800	75.00	61929.00
CW	1	13	20	2800	75.00	61929.00
CW	1	14	20	2800	75.00	61929.00
PP	2	6	10	6000	2000.00	0.00
TT	1	1	20	4600	85.00	365462.00
TT	1	2	20	4600	85.00	365462.00
TT	1	3	20	4600	85.00	398573.00
TT	1	4	20	4600	85.00	38950.00
TT	1	5	20	4600	85.00	376497.00
TT	1	6	20	4600	85.00	34723.00
TT	1	6	20	4600	85.00	34723.00
TT	1	7	20	4600	85.00	38950.00
TT	1	8	20	4600	85.00	34723.00
TT	1	9	20	4600	85.00	34723.00
TT	1	10	20	4600	85.00	34723.00
TT	1	11	20	4600	85.00	61929.00
TT	1	12	20	4600	85.00	61929.00
TT	1	13	20	4600	85.00	61929.00
TT	1	14	20	4600	85.00	61929.00
WP1	1	1	20	2600	65.00	365462.00
WP1	1	2	20	2600	65.00	365462.00
WP1	1	3	20	2600	65.00	398573.00
WP1	1	4	20	2600	65.00	38950.00
WP1	1	5	20	2600	65.00	376497.00
WP1	1	6	20	2600	65.00	34723.00
WP1	1	6	20	2600	65.00	34723.00
WP1	1	7	20	2600	65.00	38950.00
WP1	1	8	20	2600	65.00	34723.00
WP1	1	9	20	2600	65.00	34723.00
WP1	1	10	20	2600	65.00	34723.00
WP1	1	11	20	2600	65.00	61929.00
WP1	1	12	20	2600	65.00	61929.00
WP1	1	13	20	2600	65.00	61929.00
WP1	1	14	20	2600	65.00	61929.00
WP2	1	1	20	2600	65.00	365462.00
WP2	1	2	20	2600	65.00	365462.00
WP2	1	3	20	2600	65.00	398573.00
WP2	1	4	20	2600	65.00	38950.00
WP2	1	5	20	2600	65.00	376497.00
WP2	1	6	20	2600	65.00	34723.00
WP2	1	6	20	2600	65.00	34723.00
WP2	1	7	20	2600	65.00	38950.00
WP2	1	8	20	2600	65.00	34723.00
WP2	1	9	20	2600	65.00	34723.00
WP2	1	10	20	2600	65.00	34723.00
WP2	1	11	20	2600	65.00	61929.00
WP2	1	12	20	2600	65.00	61929.00
WP2	1	13	20	2600	65.00	61929.00
WP2	1	14	20	2600	65.00	61929.00

Lastly, Casey compiled a table of the pollutant load reduction efficiencies for each BMP. He started with the default table provided with the TBNEP programs, modified it slightly to reflect the County's preferences, and added efficiency data for treatment trains and for porous pavement.

The pollutant load reduction efficiency data file appeared as follows:

r-eff.bmp Best Management Practice Efficiency Data										
Round Lake Management Plan										
BMP	BMP Category	min %	TN mean %	max %	min %	TP mean %	max %	min %	TSS mean %	max %
ED	1	10	30	60	30	60	90	5	48	90
WP1	1	10	30	60	30	60	90	30	60	90
WP2	1	10	30	60	30	60	90	30	60	90
CW	1	0	25	40	10	35	65	-999	75	-999
VS	1	0	10	25	-999	15	30	-999	35	70
VF	1	0	35	70	0	45	90	20	50	80
IB1	1	45	58	70	50	63	75	75	87	99
IB2	1	45	58	70	50	63	75	75	87	99
IT	1	40	57	80	40	57	80	60	83	100
TT	1	10	65	70	50	75	95	35	65	95
PP	2	0	35	70	0	45	90	20	50	80

Note that certain minimum and maximum efficiency values were not available in the literature, and a -999 code was entered for these values. Also note that porous pavement has again been assigned a separate BMP category.

Running the Computer Program for Module 2:

Once he had completed making the program control file and the four data input files, Casey ran the computer program for Module 2 as follows:

At the DOS prompt of his personal computer, he ran Module 2 using program control file "r1-1.co2" by typing:

```
opt-2 r1-1.co2
```

To which the computer responded:

```
Optimization analysis has commenced
Output printed to r1-1.o2
Intermediate BMP file r1-1.p2 created
```

The program had completed its run very quickly, and had produced two data files. These files were the program log file “r1-1.o2” and the table of the results “r1-1.p2.” He opened both of these files with his word processing program to inspect the results.

The program log file (“r1-1.o2”) appeared as follows:

```
Tampa Bay National Estuary Program
BMP Allocation Strategy Optimization Model

                                Output from execution of r1-1.co2 control file

Control file header:
r1-1.co2          TBNEP Optimization Model,  Module 2 Control File
                  Round Lake Management Plan

The first 10 lines of this control file provide a free form space which users
may use to document the specifics of each run.


*** Model run using the following data files
    Program control file = r1-1.co2
    Program output file  = r1-1.o2
    BMP short list file  = r1-2.pl
    BMP efficiency file  = r-eff.bmp
    Pollutant load file  = r-load.bmp

*** Program Run Completed
```

He noted that the top of the log file had again repeated the 10 lines of comments he had entered in the control file and had confirmed the data input files that it had been instructed to use. Lastly, it indicated that the run had been completed without any error messages.

Interpreting the Results from Module 2:

The results of Module 2 were lists of the costs and benefits of each of the feasible BMPs for the watershed. The output data file (“r1-1.p2”) containing the results of the Module 2 run appeared as follows:

r1-1.p2 Intermediate BMP file r1-1.p2
Created by control file r1-1.co2

BMP code	BMP Category (code)	BMP Tritmt Area (acres)	BMP Area (acres)	Sub- basin (code)	Avail. BMP Area (acres)	Avail. Tritmt. Area (acres)	BMP Cost (\$/yr)	TN Reduct. (ton/yr)	TP Reduct. (ton/yr)	TSS Reduct. (ton/yr)
CW	1	50.0	2.0	1	232.6	1584.5	49819.05	0.01	0.01	3.41
CW	1	50.0	2.0	2	121.5	1951.9	49289.20	0.03	0.01	5.39
CW	1	50.0	2.0	3	225.9	1553.8	48725.43	0.02	0.01	2.26
PP	2	50.0	20.0	3	241.8	500.0	130000.00	0.02	0.02	3.70
TT	1	140.0	4.0	1	77.6	1584.5	123314.65	0.11	0.08	8.27
TT	1	140.0	4.0	2	51.5	1951.9	121376.65	0.24	0.09	13.08
TT	1	140.0	4.0	3	84.0	1553.8	120611.06	0.11	0.08	5.49
WP1	1	100.0	2.0	1	77.6	1584.5	59107.32	0.04	0.05	5.45
WP1	1	100.0	2.0	2	51.5	1951.9	58138.33	0.08	0.05	8.62
WP1	1	100.0	2.0	3	84.0	1553.8	57755.53	0.04	0.05	3.62
WP2	1	640.0	13.0	1	77.6	1584.5	382247.61	0.23	0.29	34.90
WP2	1	640.0	13.0	2	51.5	1951.9	375949.11	0.50	0.32	55.18

This results table listed costs and benefits by BMPs. For example, the first data line of this file indicates that:

- a single constructed wetland (“CW”) if implemented would treat up to 50 acres, and would occupy 2 acres,
- subbasin 1 has 232.6 acres where the wetlands could likely be built,
- subbasin 1 has 1584.5 acres of drainage area that could likely be treated,
- the estimated cost of a typical constructed wetland in subbasin 1 would be \$49,819.05 per year, and
- the BMP would reduce TN loads by 0.01 tons per year, TP loads by 0.01 tons per year, and TSS loads by 3.41 tons per year.

4.3.4 Step 3: Applying Module 3 to Identify the Best Types of BMPs for the Watershed

Casey’s third task was to identify the best types of BMPs to build in terms of costs and pollutant load reduction. The only data he would require would be the table of BMPs with specific costs and pollutant load reduction benefits output from Module 2. Module 3 of the TBNEP programs would permute through all of the hundreds of thousands of possible combinations of BMPs that could be implemented in the Round Bay Watershed, and present the set of options that would be better than all of the other options. Using the Pareto optimal techniques described in detail in the introductory sections of this chapter, a small manageable subset of optimal solutions would be produced.

Creating the Program Control File for Module 3:

The program control file for Module 3 was very similar to those used in Modules 1 and 2. Casey copied an existing program control file for Module 3 and edited the contents using a word processing program. The completed file appeared as follows:

```
r1-1.co3    TBNEP Optimization Model, Module 3 Control FILE
Round Bay Management Plan

The first 10 lines of this control file provide a free form space which users
may use to document the specifics of each run.


r1-1.o3      - output data file                      line 11
r1-1.p2      - BMP strategy shortlist                 line 12
r1-1.p3a     - BMP strategy with permutation indices  line 13
r1-1.p3b     - BMP strategies with costs/benefits     line 14
r-load.bmp   - Load data file (need subbasins only)  line 15

Choose the Criteria to Consider in Optimization
(Enter "y" or "n" in first column)
-----
y = Cost
y = Total Nitrogen Load Reduction
n = Total Phosphorous Reduction
y = TSS Load Reduction
```

As was the case for Modules 1 and 2, the first 10 lines of the program control file are free space in which Casey could type whatever notes he wanted to record with respect to this model run. He typed in the name of the control file and a title and description of the run.

The remaining lines of the control file identified the input and output data files for this model run. The program log file was named "r1-1.o3", the detailed list of Pareto optimal BMPs from Module 3 was named "r1-1.p3a", and a summary list was named "r1-1.p3b." The pollutant load data file from Module 2 was entered here again only because Module 3 would need to use the subbasin records for its computations.

At the bottom of the control file, there were lines to specify which of the cost/benefit dimensions the user wished to build the Pareto optimal "efficient frontier" in. As described previously, Casey knew that Round Bay was not phosphorous limited, and that he was interested in minimizing costs, maximizing TN load reduction, and maximizing TSS load reduction. Therefore, he would have a three-dimensional efficient frontier. He also realized that, by only selecting the dimensions of interest for building the frontier, he could minimize the size of the optimal set of strategies. To select the dimensions he wanted, he enter "y" in the first column of the line pertaining to each of the desired dimensions.

Creating the Input Data Files for Module 3:

Casey Jones called another meeting with his department and went over the list of feasible BMPs and associated costs and benefits with the County's Chief Engineer. The Chief Engineer had just been informed that the Public Works Department of the County had completed a feasibility study of improving the Wastewater Treatment Plant in the Long Lake subbasin (subbasin 3). This looked like a promising alternative to nonpoint source control of nitrogen inputs to Round Bay, and they wanted to include it in the optimization analysis. Casey and the Chief Engineer revised the data file containing the BMP options ("r1-1.p2") to reflect this new information. They added two different Long Lake Wastewater Plant improvement options, a less expensive option that involved upgrading an existing treatment unit and a more expensive option that involved adding a new treatment unit. Thus, they added two data records for the plant improvement options, labeled the new records as "WW-A", and updated the pollutant load reduction efficiency and cost data based on the results of the Public Works Department feasibility study.

The revised data file was named "r1-2.p2", and it appeared as follows:

r1-2.p2 Intermediate BMP file r1-1.p2										
Created by control file r1-1.co2										
Added 4 Long Lake WWTP Improvement Options based on Ray Elroad 1994 Report C. Jones										
BMP	BMP	BMP	BMP	Sub-	Avail.	Avail.	BMP	TN	TP	TSS
Category	Trtmt	Area	Area	basin	BMP	Trtmt.	Cost	Reduct.	Reduct.	Reduct.
code	(code)	(acres)	(acres)	(code)	(acres)	(acres)	(\$/yr)	(ton/yr)	(ton/yr)	(ton/yr)
CW	1	50.0	2.0	1	232.6	1584.5	49819.05	0.01	0.01	3.41
CW	1	50.0	2.0	2	121.5	1951.9	49289.20	0.03	0.01	5.39
CW	1	50.0	2.0	3	225.9	1553.8	48725.43	0.02	0.01	2.26
PP	2	50.0	20.0	3	241.8	500.0	130000.00	0.02	0.02	3.70
TT	1	140.0	4.0	1	77.6	1584.5	123314.65	0.11	0.08	8.27
TT	1	140.0	4.0	2	51.5	1951.9	121376.65	0.24	0.09	13.08
TT	1	140.0	4.0	3	84.0	1553.8	120611.06	0.11	0.08	5.49
WP1	1	100.0	2.0	1	77.6	1584.5	59107.32	0.04	0.05	5.45
WP1	1	100.0	2.0	2	51.5	1951.9	58138.33	0.08	0.05	8.62
WP1	1	100.0	2.0	3	84.0	1553.8	57755.53	0.04	0.05	3.62
WP2	1	640.0	13.0	1	77.6	1584.5	382247.61	0.23	0.29	34.90
WP2	1	640.0	13.0	2	51.5	1951.9	375949.11	0.50	0.32	55.18
WP2	1	640.0	13.0	3	84.0	1553.8	373460.95	0.24	0.30	23.15
WW-A	3	1	1	3	1	1	50000.00	0.02	0.01	1.00
WW-A	3	1	1	3	1	1	125000.00	0.05	0.04	4.00

Note that the wastewater plant improvement options were identified as BMP category 3. There would only be the one plant to improve, so the treatment area, BMP area, available BMP area, and available treatment area were all set to 1 to result in only one choice for implementation representing the one wastewater treatment plant.

Casey then modified the program control file to read this new data file, and typed a note in the header space indicating that the new options had been added based on the Public Works Study.

Running the Computer Program for Module 3:

Once he had completed making the program control file and the four data input files, Casey ran the computer program for Module 3 as follows:

At the DOS prompt of his personal computer, he ran Module 3 using program control file "r1-1.co3" by typing:

```
opt-3 r1-1.co3
```

To which the computer responded:

```
Optimization analysis has commenced  
Output printed to r1-1.o3
```

```
Please enter a limiting budget value:
```

The limiting budget value is a way of speeding up the execution of this module by excluding BMP strategies which would be unreasonably expensive. Thus, instead of comparing hundreds of millions of combinations of BMPs, the program will compare hundreds of thousands of combinations.

Casey knew that anything more than \$200,000 dollars per year for the management of Round Bay would be clearly unreasonable, so he entered \$200,000 as the limiting budget. He typed:

```
200000
```

to which the computer responded:

```
Comparing 512000 combinations of 12 BMP's
```

The program had completed its run after four to five minutes, and had produced three data files. These files were the program log file "r1-1.o3" and two tables of the results "r1-1.p3a" and r1-1.p3b." He opened each of these files with his word processing program to inspect the results.

The program log file ("r1-1.o3") appeared as follows:

```

BMP Allocation Strategy Optimization Model

Output from execution of r1-1.co3 control file

Control file header:
r1-1.co3    TBNEP Optimization Model, Module 3 Control File

Round Bay Management Plan

The first 10 lines of this control file provide a free form space which users
may use to document the specifics of each run.


*** Model run using the following data files
Program control file = r1-1.co3
Program output file = r1-1.o3
BMP short list file = r1-2.p2
BMP strategy key    = r1-1.p3a
Optimal strategy set = r1-1.p3b
Subbasin input data = r-load.bmp

Criteria used for optimization
-----
Cost          y
TN Load Reduction y
TP Load Reduction n
TSS Load Reduction y

Comparing 512000 combinations of 12 BMPs.
Using a maximum budget of      200000.00
Finding optimal set from 512000 combinations of 12 BMPs.
Optimal set completed with 20 members.

*** Program Run Completed

```

He noted that the top of the log file had:

- repeated the 10 lines of comments he had entered in the control file,
- confirmed the data input files that it had been instructed to use,
- confirmed the cost/benefit dimensions requested,
- reported that 12 BMPs met the \$200,000 budget,
- the 12 BMPs could be combined in 512,000 different combinations,
- that 20 strategies were better in all dimensions (cost, TN, TSS) than all of the other 511,080 strategies, and
- lastly, it indicated that the run had been completed without any error messages.

Interpreting the Results from Module 3:

The results of Module 3 were to list the best combinations of BMPs possible given the costs and benefits of each of the feasible BMPs for the watershed. The Pareto optimal method was used to identify these 20 BMP strategies without the need to specify whether cost, TN load reduction, or TSS load reduction was more important (see detailed discussion in introductory sections of this chapter). The output data file ("r1-1.p3b") contained a summary of the results of the Module 3 run, appearing as follows:

Created by control file r1-1.co3
BMP permutation key filer1-1.p3b

Strategy Number	Total Cost (\$)	TN Reduct. (ton/yr)	TP Reduct. (ton/yr)	TSS Reduct. (ton/yr)
1	0.00	0.000	0.000	0.000
5	57755.53	0.040	0.050	3.620
17	58138.33	0.080	0.050	8.620
21	115893.86	0.120	0.100	12.240
33	116276.66	0.160	0.100	17.240
37	174032.19	0.200	0.150	20.860
49	174414.99	0.240	0.150	25.860
513	121376.65	0.240	0.090	13.080
517	179132.18	0.280	0.140	16.700
529	179514.98	0.320	0.140	21.700
4097	48725.43	0.020	0.010	2.260
4113	106863.76	0.100	0.060	10.880
4129	165002.09	0.180	0.110	19.500
4609	170102.08	0.260	0.100	15.340
20481	49289.20	0.030	0.010	5.390
20497	107427.53	0.110	0.060	14.010
20513	165565.86	0.190	0.110	22.630
20993	170665.85	0.270	0.100	18.470
40961	98578.40	0.060	0.020	10.780
40977	156716.73	0.140	0.070	19.400

This results table listed costs and benefits by BMPs. For example, the second data line of this file indicates that:

- strategy number 5 if implemented would cost \$57,755.53,
- would remove 0.04 tons of TN per year,
- would remove 0.05 tons of TP per year, and
- would remove 3.62 tons of TSS per year.

The first data record in the file is a "do nothing strategy" with zero costs and zero benefits. Following the definition of a Pareto optimal set, all of these 20 strategies are better than all of the other 511,080 strategies in cost, TN reduction, and TSS reduction. However, none of the 20 is clearly better than any other of the 20 in all three dimensions. Thus, from a strictly **objective** point of view these strategies cannot be further ranked. Casey is now faced with applying his professional judgement and other **subjective** information to decide on a final strategy. He decides to run Module 4 to assist in the final subjective selection of a strategy.

In addition to running Module 4, Casey also knew that he wanted to use his professional judgement to examine the details of each of the BMP strategies identified by the model. In order to look at these 20 strategies, Casey opened the more detailed output file “r1-1.p3a” with his word processing software. This file lists the individual BMPs that make up each of the 20 strategies in the Pareto optimal set. For example, the entry for strategy number 4609 appears as follows:

Pareto-Optimal BMP Strategy Details				
Strategy Number	Total Cost (\$)	TN Reduct. (ton/yr)	TP Reduct. (ton/yr)	TSS Reduct. (ton/yr)
4609	170102.08	0.260	0.100	15.340
BMP Name	BMP Category	Subbasin	Quantity to Implement	
CW	1	3	1	
TT	1	2	1	

where:

- the total cost is \$170,102.08 per year and total load reductions are given,
- the strategy calls for two BMPs to be built,
- 1 constructed wetland (“CW”) in subbasin 3, and
- 1 treatment train BMP (“TT”) in subbasin 2.

4.3.5 Step 4: Applying Module 4 to Evaluate Management Priorities, Budgets, and Load Reduction Targets

Once a Pareto optimal set of 20 management strategies had been identified, Casey decided to use Module 4 to evaluate management priorities, budgets, and load reduction targets, and then use this information to select a final management strategy. He would require a data set of the Pareto optimal strategies, costs, and benefits (“r1-1.p3b”). The results of Module 4 would be output in the form of an ordered list of strategies sorted by a weighted benefit/cost ratio.

In this case, Casey knew that nitrogen load reduction was the most important objective of the Round Bay Watershed Management Plan. Thus this criteria would be given more weight in the final analysis.

Creating the Program Control File for Module 4:

The program control file for Module 4 was very similar to that used in the other modules. Casey

copied an existing program control file for Module 4 and edited the contents using a word processing program. The completed file appeared as follows:

```

r1-1.co4    TBNEP Optimization Model, Module 4 Control File
Round Bay Management Plan

The first 10 lines of this control file provide a free form space which users
may use to document the specifics of each run.


r1-1.o4          - output data file                      line 11
r1-1.p3b         - BMP strategies with costs/benefits    line 12
r1-1.p4          - BMP strategies sorted by benefit/cost line 13

Choose the Weights to Use in Weighted Cost/Benefit Average
(a real number between 0 and 1, where 1 is given the most weight)
-----
1.0              Total Nitrogen Load Reduction
0.0              Total Phosphorous Reduction
0.0              TSS Load Reduction

```

The control file identified the input and output data files for this model run. The program log file was named "r1-1.o4", and the list of optimal strategies from Module 3 was named "r1-1.p3b."

As was the case for Module 1, the program output file would be automatically named the same name as the program control file with an extension of "p4." Thus, the output file would be created by Module 4 as "r1-1.p4." Weights for benefits were entered at the bottom of the file.

Creating the Input Data Files for Module 4:

No new data input files needed to be created.

Running the Computer Program for Module 4:

Once he had completed making the program control file, Casey ran the computer program for Module 4.

At the DOS prompt of his personal computer, he ran Module 4 using program control file "r1-1.co4" by typing:

```
opt-4 r1-1.co4
```

The program had completed its run very quickly, and had produced two data files. These files were the program log file "r1-1.o4" and the table of the results "r1-1.p4." He opened both of these files

with his word processing program to inspect the results.

```
Tampa Bay National Estuary Program
BMP Allocation Strategy Optimization Model

                                Output from execution of r1-1.co4 control file

Control file header:
r1-1.co4          TBNEP Optimization Model,  Module 4 Control FILE

Round Bay Management Plan

The first 10 lines of this control file provide a free form space which users
may use to document the specifics of each run.

*** Model run using the following data files
    Program control file = r1-1.co4
    Program output file  = r1-1.p4
    Optimal strategy set = r1-1.p3b

    Weights used for Cost/Benefit
    -----
    TN Load Reduction   1.0000000000E+00
    TP Load Reduction    0.0000000000E+00
    TSS Load Reduction   0.0000000000E+00

*** Program Run Completed
```

He noted that the log file had confirmed the data input files and benefit weights, and that the run had been completed without any error messages.

Interpreting the Results from Module 4:

The results of Module 4 were to rank the Pareto optimal BMP strategies by a weighted benefit/cost ratio. In this case the benefit/cost ratio requested was merely TN reduction per dollar of cost. The output data file ("r1-1.p4") containing the results of the Module 4 run appeared as follows:

Created by control file rl-1.co4

Strategy Number	Total Cost (\$)	TN Reduct. (ton/yr)	TP Reduct. (ton/yr)	TSS Reduct. (ton/yr)	Weighted Benefit/Cost Ratio
513	121376.65	0.240	0.090	13.080	1.9773160653E-06
529	179514.98	0.320	0.140	21.700	1.7825810414E-06
20993	170665.85	0.270	0.100	18.470	1.5820388203E-06
517	179132.18	0.280	0.140	16.700	1.5630915674E-06
4609	170102.08	0.260	0.100	15.340	1.5284939490E-06
49	174414.99	0.240	0.150	25.860	1.3760285168E-06
17	58138.33	0.080	0.050	8.620	1.3760285168E-06
33	116276.66	0.160	0.100	17.240	1.3760285168E-06
37	174032.19	0.200	0.150	20.860	1.1492126830E-06
20513	165565.86	0.190	0.110	22.630	1.1475795795E-06
4129	165002.09	0.180	0.110	19.500	1.0908952729E-06
21	115893.86	0.120	0.100	12.240	1.0354301772E-06
20497	107427.53	0.110	0.060	14.010	1.0239460965E-06
4113	106863.76	0.100	0.060	10.880	9.3577092926E-07
40977	156716.73	0.140	0.070	19.400	8.9333155433E-07
5	57755.53	0.040	0.050	3.620	6.9257437340E-07

This results table indicates that strategy 513 is the best strategy in terms of TN load reduction per cost. Because it is in the Pareto optimal set, we also know that no other strategy of the 511,999 compared was better simultaneously in terms of cost, TN load reduction, and TSS load reduction.

Casey wanted to review strategy 513, and he remembered that one of the program output files from the Module 3 program contained detailed descriptions of each strategy. He opened the more detailed output file “rl-1.p3a” with his word processing software.

The entry for strategy number 513 appeared as follows:

Strategy Number	Total Cost (\$)	TN Reduct. (ton/yr)	TP Reduct. (ton/yr)	TSS Reduct. (ton/yr)
513	121376.65	0.240	0.090	13.080
BMP Name	BMP Category	Subbasin	Quantity to Implement	
TT	1	2	1	

where:

- the total cost is \$121,376.65 per year,
- the total nitrogen load reduction is 0.24 tons per year,
- the total phosphorus load reduction is 0.90 tons per year,
- the total suspended solids load reduction is 13.08 tons per year, and
- the strategy calls for one treatment train BMP to be built in subbasin 2.

Casey was then instructed by the Chief Engineer to see what the Round Bay Watershed Management Plan could provide in order to meet the TN load reduction goal of 0.20 tons per year and to stay under a capital budget of \$150,000 per year. He produced a figure of the strategy (Figure 4-1). The final strategy was number 513, and it entailed constructing single treatment train facility in the Bent Branch subbasin (subbasin 2) at a cost of \$121,376.00 per year. This facility would exceed the TN load reduction goal and provide Pareto optimal load reductions in TSS as well.

4.3.6 Further Application of the Optimization Model

The flexible nature of the Optimization Model will allow analyses at many different levels of detail. After choosing the strategy of building a treatment train BMP in the Bent Branch subbasin, Casey and the Chief engineer realized that the TBNEP Optimization Model could also be applied to the more specific design tasks needed for implementation of the plan. They would compile detailed information regarding the Bent Branch subbasin, such as identifying specific parcels of land that could be purchased, and surveying local topography, drainage, and wetland features. They would then use a hydrodynamic model and a water quality model to investigate a suite of alternative designs for the treatment train BMP. Using the more detailed data, Casey would again run Module 3 of the TBNEP programs. However, this time the model would be comparing the cost and benefits of specific design alternatives in terms of the project objectives.

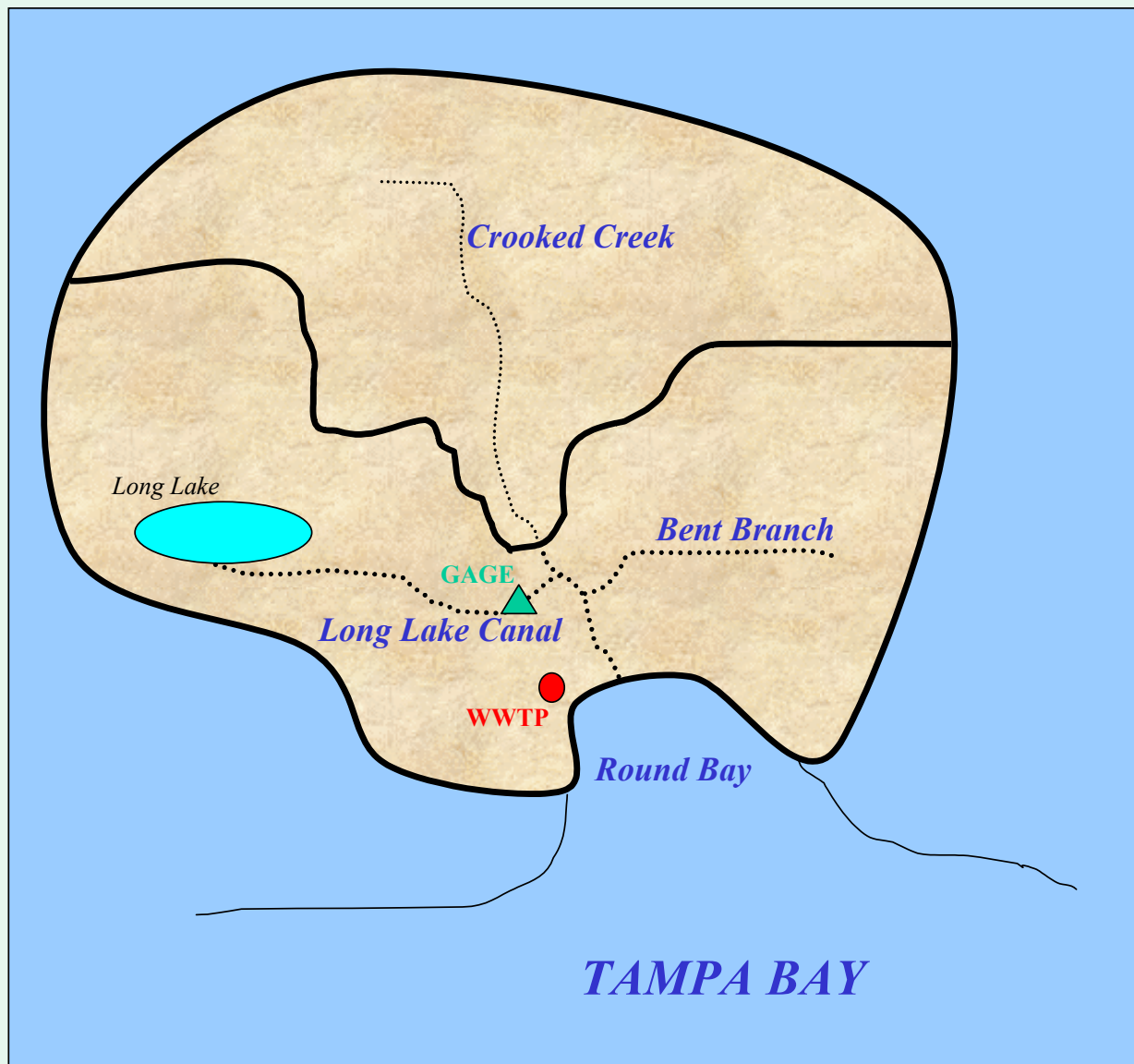


Figure 4-1. Map of Crooked Creek Basin.

4.4 LITERATURE CITED

Janicki, A.J. and D.L. Wade. 1996. Estimating Critical External Nitrogen Loads for the Tampa Bay Estuary: An Empirically-based Approach to Setting Management Targets. Prepared for Tampa Bay National Estuary Program. St. Petersburg, Florida.

Wade, D.L., A. Janicki, and R. Pribble. 1997. Watershed Management Model for Optimal Allocation of Best Management Practices: User's Guide and Case Study. Prepared for Tampa Bay National Estuary Program. St. Petersburg, Florida.

Wanielista, Martin P. and Yousef A. Yousef. 1992. Stormwater Management John H. Wiley & Sons, Inc. New York. New York.

Zarbock, H., A. Janicki, and D. Wade. 1996. Model Based Estimates of Total Nitrogen Loading to Tampa Bay. Draft Report. Prepared for Tampa Bay National Estuary Program. St. Petersburg, Florida.