Appendix

Innovative Stormwater Management in New Development: Planning Case Study[1]

Brian W. Mack, Michael F. Schmidt, and Michelle Solberg

Introduction

Background

In March 1994, the City of Orlando, FL entered into a Joint Planning Agreement with Orange County which facilitated the annexation of approximately 20 square miles (11,500 acres) of primarily undeveloped land southeast of the Orlando International Airport as shown in Figure A-1. Outlined in the Growth Management Plan Southeast Annexation Study is the City's vision for the development of this area which includes providing "opportunities for economic development, protecting natural resources, and developing an integrated and efficient system of infrastructure and social service delivery." Over the next 20 years, the entire Southeast Annexation Area is expected to develop with a mixture of land uses. City planners will regulate the development of the area, with the goal of creating a compact urban growth center. The growth center will support the future development of Orlando International Airport and will contain land uses such as office, service and industrial development, with housing to support the employment generated by the airport expansion.

The stormwater element of this planning effort included the development of a Master Stormwater Management Plan (MSMP) for the annexed area. The goals of the MSMP are to provide regional flood control and water quality protection, protect existing wetlands, and site regional facilities in such a manner that they meet both the City's and private land owners' interests. Orlando will use the MSMP to guide development as it occurs.

In November 1994, the City contracted with WBQ Design and Engineering Inc. to provide engineering services for the Narcoossee Road Improvement Project. In August 1995, the City amended its contract with WBQ to include the development of an MSMP also addresses the environmental goals of the City's Southeast/Orlando International Airport Future Growth Center Plan (May 1995) for the Lake Hart Basin. The MSMP would provide stormwater management for the projected future growth in the basin as well as for the Narcoossee Road Improvement Project.

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1. This is a condensed version of the Southeast Annexation Area Lake Hart Basin Master Stormwater Management Plan, City of Orlando, Florida.

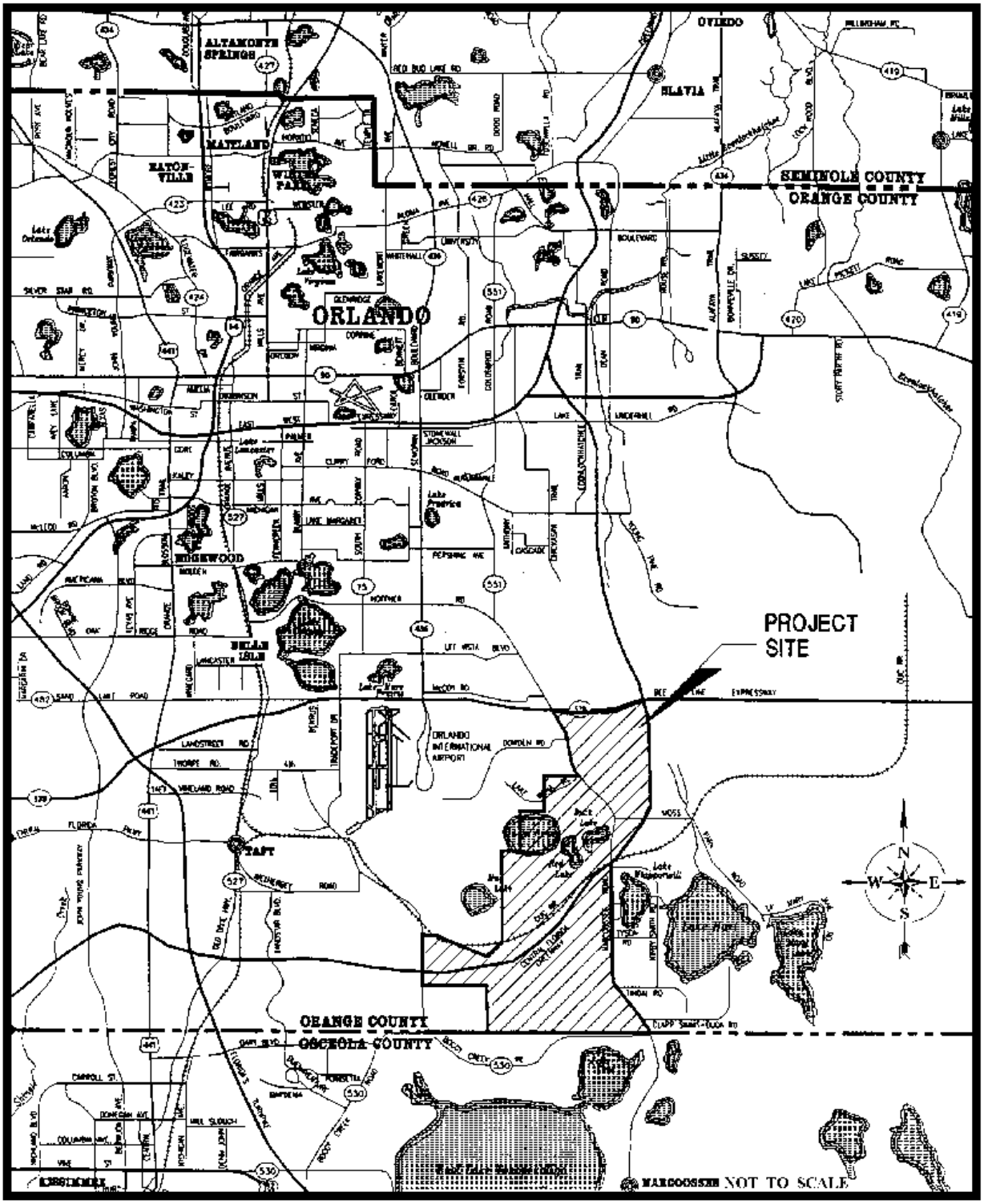


Figure A-1. Southeast annexation area vicinity map. (Reprinted courtesy of the City of Orlando, FL)

In September 1995, WBQ contracted with Camp Dresser & McKee Inc. (CDM) to provide engineering services for the development of the Lake Hart basin MSMP. The focus of this cooperative effort was to develop an MSMP with innovative options to accomplish the general goals of the City of Orlando Urban Stormwater Management Manual (OUSWMM). CDM, working with the City, outlined a “watershed based” or often called a “regional approach” to water quantity and water quality issues for this project. This included an inventory and mapping of stormwater facilities and problems and an evaluation of stormwater-related issues, alternatives, and solutions with emphasis on the management of the Primary Stormwater Management System (PSWMS) within the Lake Hart basin. The PSWMS is the major network of streams, lakes, wetlands, bridges, and culverts that convey the majority of stormwater runoff southeasterly to Lake Hart as shown in Figure A-2. This system must be operational so that the proposed secondary systems (developments) within the basin can function as designed. The MSMP will establish the framework for stormwater management within the Lake Hart.

The Master Planning Process

Stormwater runoff can be controlled by natural or man-made systems of conveyance and storage, guided development (land use controls), and the conservation of natural systems. In urban, built-out conditions, a combination of all three methods of control is necessary along with a proactive maintenance program to reach the stormwater management goals of a community. In less urban, or rural areas, stormwater management can be accomplished through land use controls and natural systems, although some conveyance and storage facilities may be needed. To gauge how well goals are achieved, levels of service (LOS) are established to quantify system performance.

The control of runoff is, therefore, a mixture of storage and conveyance engineering, land use controls, and ecosystems management. The three areas of runoff control are not mutually exclusive nor distinct. For example, land use controls affect storage and conveyance as well as natural systems. The interdependent development of conveyance and storage engineering, maintenance programs, and possibly land use controls can be of benefit to the City for planning of capital improvement programs.

Program Goals

The general goals of the Lake Hart MSMP are the development of an integrated stormwater, wetland, and open space management system that would balance preservation of natural systems with land development. The general goals are to be accomplished by meeting the following three key objectives in a cost-effective manner: flood control, pollution control, and ecosystem management (which includes wetlands protection, aquifer recharge, and water conservation). A summary of each of these

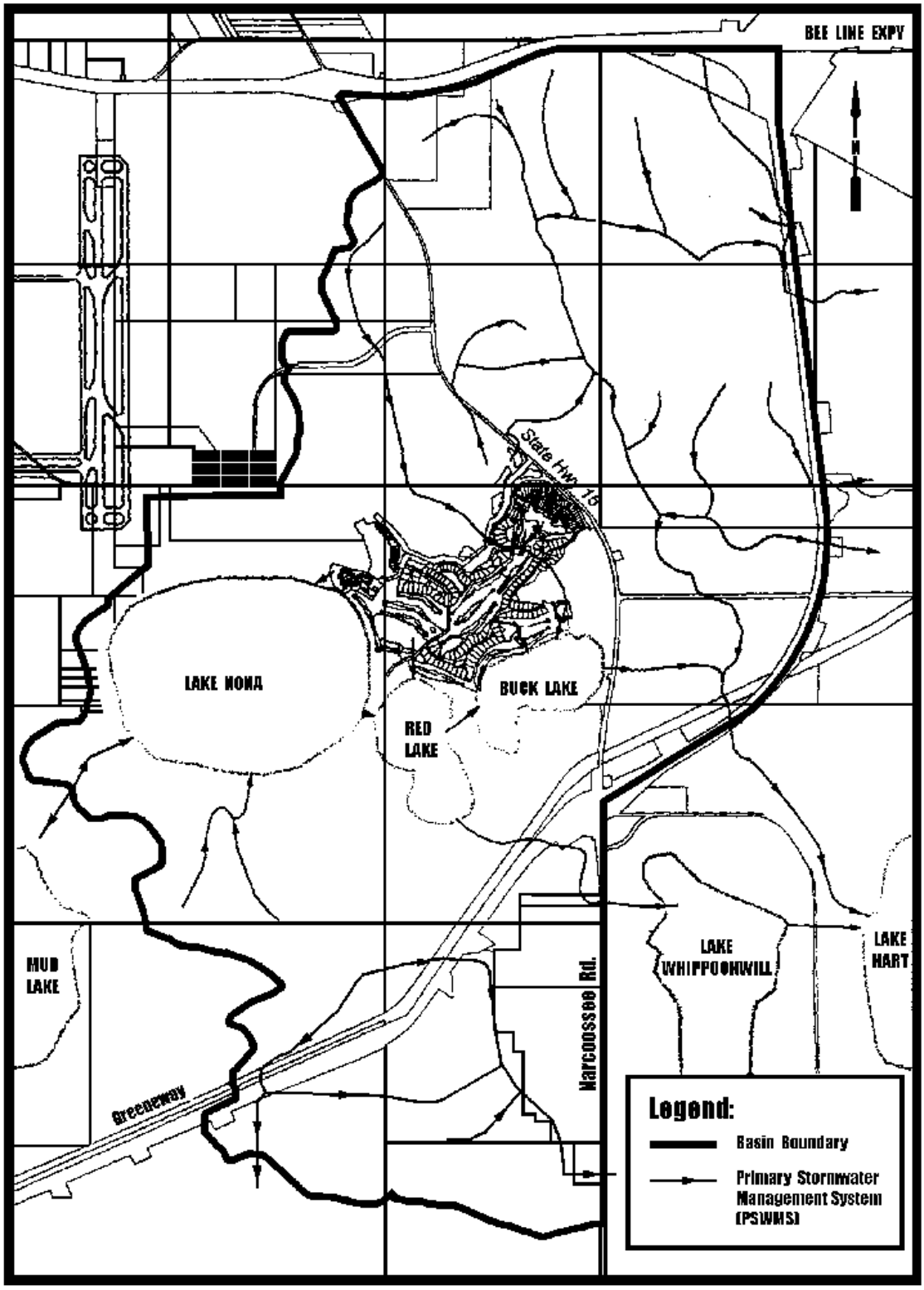


Figure A-2. Study area and primary stormwater management system. (Reprinted courtesy of the City of Orlando, FL)

objectives is presented here and further details on how goals and objectives will be met are contained in subsequent sections.

Flood Control

The flood control objective for the Lake Hart basin is locating regional facilities that will provide proper storage and conveyance of peak flows and volumes as development occurs. The facilities are to be located and conceptually designed to meet both the City's and private landowners' interests to the extent practicable (e.g., aesthetics, cost, ease of operation and maintenance). This requires close coordination with both the public and private sectors.

Water Quality Control

The water quality control objective is to provide a regional system that will treat the "first-flush" of runoff or reduce pollutant loads to the maximum extent practicable. Because of the high groundwater table and the need for fill, a wet detention system combined with pretreatment Best Management Practices (BMPs) for stormwater runoff are considered to be the most cost-effective way to meet this objective.

Ecosystem Management

The objective of ecosystem management is to develop a regional system that will protect healthy/pristine wetlands (abundant throughout the Lake Hart basin) and provide potential landscape irrigation with surface water (pretreatment and reuse).

To implement a plan that will meet these objectives, the City requested that the Lake Hart basin MSMP establish a framework for the design and review of proposed stormwater management systems within the SEAA that could be beneficially used by both City staff and developers. In general, the City wanted to supplement the stormwater management requirements of the OUSWMM with innovative technology that would address stormwater management in areas with extensively interconnected wetlands and lakes and in areas that have a high seasonal groundwater table (low infiltration potential). This framework would eventually be refined into a document similar to the OUSWMM that would eventually become the Southeast Annexation Area Stormwater Management Manual.

The City stressed the importance of training its staff to use the regional stormwater management model developed for the PSWMS in the Lake Hart MSMP. The City will use the stormwater model as a management tool to address regional stormwater related issues which may include identifying and mitigating flooding impacts from proposed land use changes as well as identifying the necessary phasing of proposed regional facilities (dependent on development schedules and conceptual plan approvals). To maintain the effectiveness of the stormwater model, City personnel will need to perform periodic updates as appropriate.

This appendix documents the MSMP strategy developed for the Lake Hart basin that can be implemented to control potential impacts to the natural stormwater system

resulting from man's activities. The strategy includes a combination of land development regulations, capital improvement projects, and shared private and public partnerships (integrated resource planning) as needed to achieve the desired LOS for flood protection and water quality protection. The plan also discusses the phasing of recommended improvements to help the City implement proposed regulations and capital improvement projects in a cost-effective and timely manner.

Levels of Service

Proper LOS decisions are an essential component of the Lake Hart basin MSMP. While LOS includes retrofit, the decisions are primarily for new development. The LOS decisions will directly affect the size and cost of regional facilities and structures in the PSWMS. The OUSWMM defines primary conveyance facilities as “systems designated as outfalls from, or connections between, natural lakes and artificial regional detention facilities.” For the purposes of this case study, the primary conveyance facilities are the PSWMS.

After discussions with City staff, the LOS criteria presented in OUSWMM were amended to more clearly define existing problem areas in the Lake Hart basin. Figure A-3 illustrates the four LOS criteria considered for this study. They were formulated to protect or enhance public safety. For example, Class D provides for flood protection of first-floor elevations (FFE), while Class B provides control of flood waters so that one-half of the road is not flooded (arterial road crowns). Table A-1 lists water quantity LOS goals used to define potential problem areas (retrofit needs) in the Lake Hart basin MSMP.

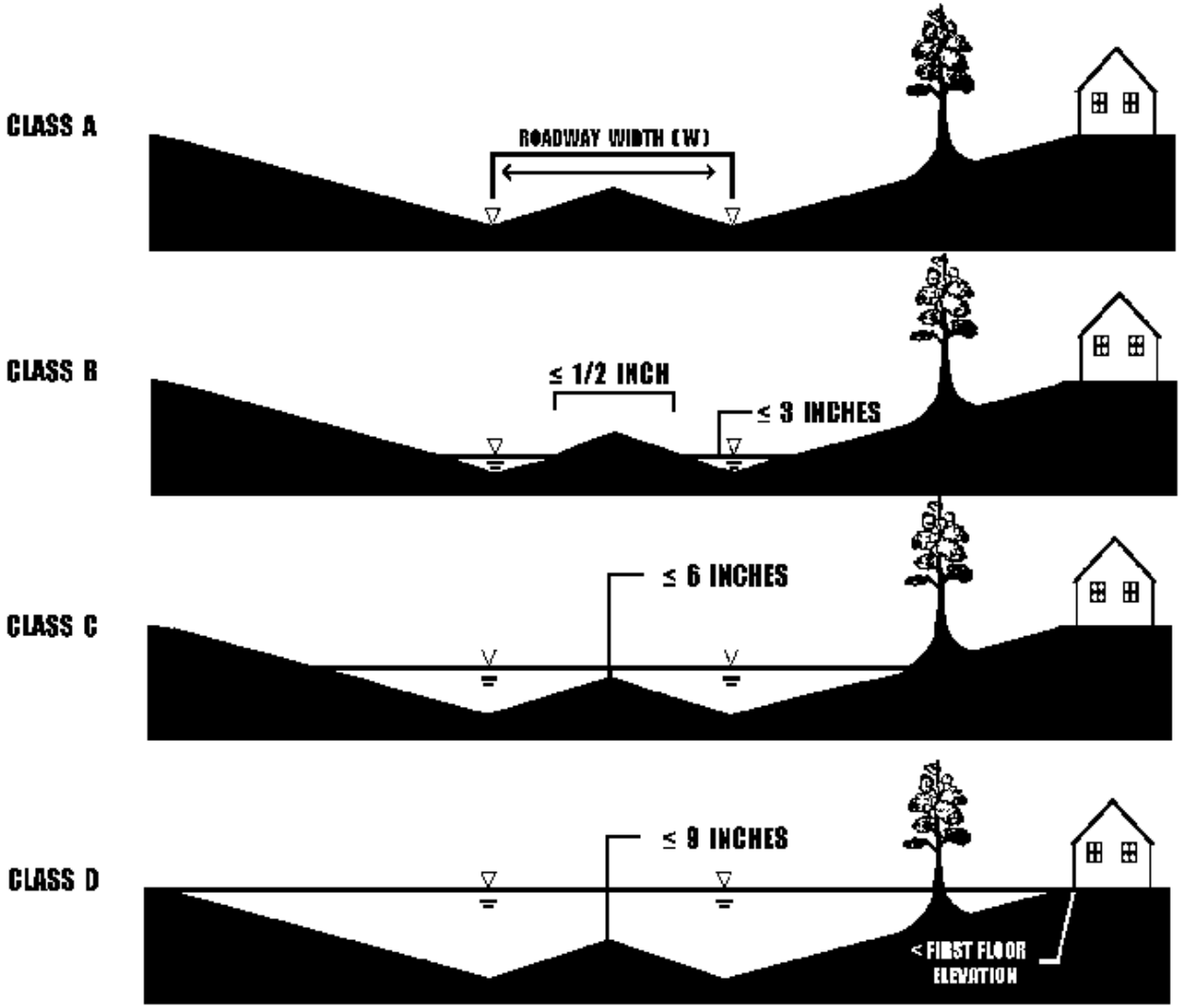


Figure A-3. Water quantity levels of service. (Reprinted courtesy of the City of Orlando, FL)

Table A-1. Existing Levels of Service For Water Quantity[1]

	10-Year		**25-Year**		**100-Year**	
Structure/Facility	10-Year	Class	25-Year	Class	100-Year	Class
Houses/Buildings	<FFE[5]	D	<FFE	D	<FFE	D
Arterial Roads [2]	½ W[6]	A	½ W	B	½ W	B
Collector Roads [3]	½ W	B	½ W	B	½ W	B
Minor Roads [4]	<0.5 ft	C	<0.75 ft	D	<1 ft	NA

Notes:
1 All storm durations are 24 hours, except the 100-year, which is 72 hours.
2 Arterial streets and highways are those which are used primarily for fast or heavy traffic.
3 Roads which carry traffic and minor streets to the major system of arterial streets and highways, including the principal entrance streets of a residential development and streets for circulation within such a development.
4 Roads which are used primarily for access to the abutting properties.
5 FFE = First Floor Elevation
6 W = Width of Road

For new development, the design criteria that are outlined in OUSWMM or this MSMP must be met. A summary of select key design criteria for primary conveyance facilities is given below:

- The design storm for new primary conveyance facilities is a 25-year/24-hour storm event. In addition, a determination of the flood stage resulting from a 100-year/three-day storm event will be made as a check of the system.

- The systems shall be designed so that existing and proposed building floor elevations shall be above the 100-year flood elevation, as determined by analyzing the 100-year/three-day event and designed to protect existing roadways from inundation during the 25-year/24-hour storm.

Note that the water quantity design criteria for new roads/development are, in some cases, greater than the LOS used for problem area identification.

Methodology

Stormwater Modeling

The primary aspect of this Lake Hart basin (MSMP) is the proper evaluation of water quantity (flooding) and water quality. A good understanding of water quantity helps determine the most effective methods of controlling flooding and protecting public safety. A proper understanding of water quality and its control is essential to ensuring the high quality of environmental protection desired by the City. Recent versions of the RUNOFF and EXTRAN blocks of the United States Environmental Protection Agency Stormwater Management Model (EPA-SWMM, Version 4.3) for water quantity were used because these models best meet the requirements of the program. The models have been verified in stormwater master plan uses throughout Florida.

The hydrologic model, RUNOFF, simulates rainfall, runoff, and infiltration characteristics of an area. It also performs simple hydrologic routing in channels, pipes, and lakes where gradients are known. RUNOFF output is electronically delivered to EXTRAN, which is a hydraulic routing model. EXTRAN provides dynamic flood routing in channels, lakes, and control structures such as bridges, culverts, and weirs. EXTRAN accounts for conservation of mass, energy, and momentum thereby predicting looping, flow reversals, and similar phenomena should they occur.

The water quality modeling framework involves identification of the water quality problems addressed by the modeling study, the structure of the model software, and the assumptions and guidelines used with the model to represent the Lake Hart basin. The Watershed Management Model (WMM) was used for the water quality analysis because this model provides evaluations consistent with EPA, NPDES and SFWMD permit requirements.

Hydrologic Model

The RUNOFF block of the EPA SWMM, which was originally developed by CDM, simulates the rates of runoff developed from subbasins using a kinematic wave approximation. Hydrologic routing techniques are then used to route the overland flows through the pipe, culvert, and channel as required. Program results can be saved for input to the EXTRAN block of Stormwater Management Model (SWMM) to perform hydraulic routing in downstream reaches. A more complete documentation of the model's background and theory can be found in the SWMM 4.3 user's manual.

Hydraulic Model

SWMM EXTRAN is a hydraulic flow routing model for open channel and/or closed conduit systems. It uses a link-node (conduit-junction) representation of the stormwater management system in an explicit finite difference solution of the equations of gradually varied, unsteady flow. EXTRAN receives hydrograph input at specific junctions by file transfer from a hydrologic model, such as RUNOFF or TR20, and/or by manual input. The model performs dynamic routing of stormwater flows through the PSWMS to the points of discharge or outfalls. Since it is dynamic, it simultaneously considers both the

storage and conveyance aspect of stormwater management facilities. The program will simulate branched or looped networks; backwater due to tidal or nontidal conditions; free-surface flow; pressure flow or surcharge; flow reversals; flow transfer by weirs, orifices, and pumping facilities; and storage at online or off-line facilities. Types of conduits that can be simulated include circular, rectangular, horseshoe, elliptical, and basket handle pipes, plus trapezoidal or irregular channel cross sections. Simulation output takes the form of water surface elevations and inundated areas at each junction and flows and velocities at each conduit. The SWMM 4.3 user's manual includes further details.

Water Quality Model

WMM is a screening level water quality model used to develop relative projections of long-term pollutant loadings on an annual basis. Relative comparisons of land use and BMP implementation impacts on pollutant loads can be made. Application of the screening level model incorporates detailed data collected for each hydrologic unit used in the water quality model SWMM. WMM was applied to provide a relative evaluation of nonpoint source pollution management strategies that address water quality problems over long-term periods. WMM is a spreadsheet model for estimating annual nonpoint source loads from direct runoff based upon land use specific event mean concentrations and runoff volumes. Data required to use the nonpoint source model include event mean concentrations (EMCs) for each pollutant type, land use, average annual precipitation, annual baseflow, and average baseflow concentrations. A detailed discussion of the methodology applied in WMM can be found in the CDM WMM users manual (CDM, 1992).

The WMM model does not consider the potential in-lake or in-stream chemical, biological, or physical modification of the pollutants, nor is it intended for this purpose. WMM estimates the total load from runoff (and baseflow) to receiving waters and, as such, represents the worst case (i.e., the loading without improvement or assimilation in the receiving waters). As a next step, ecological management planning can define biological water quality levels of service so that in critical areas, more detailed, in-lake and in-stream water quality modeling can be completed to augment the Lake Hart MSMP results.

For the Lake Hart basin MSMP, WMM was used to generate estimates of average annual pollutant loadings for existing and future conditions based upon local rainfall statistics. The model relies upon EMC factors for different land use categories to calculate pollution loadings. Because the model is spreadsheet based, it can be easily applied to screen the pollutant loading reductions that can be achieved by various BMP alternatives. A series of different BMP alternatives can be screened to identify BMP requirements that will adequately mitigate existing and projected long-term water quality problems within the watershed.

Hydrologic Parameters

Hydrologic model parameters used for the model simulations are described below.

Subbasin and Hydrologic Unit Areas

For modeling purposes, the Lake Hart basin was subdivided into 51 subbasins for which land use, soil, and topographic characteristics were compiled. Subbasin area averaged approximately 150 acres with a minimum of 17 acres and a maximum of 1300 acres. For the alternative evaluations, these subbasins were further partitioned into 103 hydrologic units to account for the proposed regional facilities.

Rainfall Intensities and Quantities

There are three rainfall stations within the vicinity of the Lake Hart study area. The Boggy Creek rain gauge and the Lake Hart rain gauge are maintained and operated by Orange County, FL. The third rain gauge is the Orlando-McCoy Airport (Orlando International Airport) Station Number 6628 and 6638, and is monitored by the U.S. Department of Commerce, National Climatic Data Center. The Boggy Creek rain gauge is approximately one mile to the west of the study area and has been recording rainfall data at five minute intervals since August 1987. The Lake Hart rain gauge is approximately one mile to the southeast of the study area (within the same basin) and has been in existence since March 1995. The station at the Orlando International Airport station is one mile east of the study area and records rainfall data in 15 minute intervals. The average annual rainfall for the 1942 to 1993 period of record is 49.7 inches. The general locations of these rain gauges are shown on Figure A-4.

Rainfall For Water Quality Modeling

Wet and dry season rainfall quantities for determining nonpoint source pollutant loading projections were also determined. The rainfall volume for the wet season, which occurs from June through September, is approximately 28.1 inches. The rainfall volume for the dry season, which occurs from October through May, is approximately 21.6 inches.

Rainfall for Runoff Modeling

Design rainfall data for the Lake Hart MSMP were obtained from the OUSWMM and the South Florida Water Management District in the form of rainfall quantities and distributions (30-minute intervals) for each design storm (2-, 10-, 25-year, 24-hour, and the 100-year, 72-hour). Rainfall quantities are:

- 100-Year/72-Hour - 14.4 inches of rainfall
- 25-Year/24-Hour - 8.6 inches of rainfall
- 10-Year/24-Hour - 7.4 inches of rainfall
- 2-Year/24-Hour - 4.8 inches of rainfall

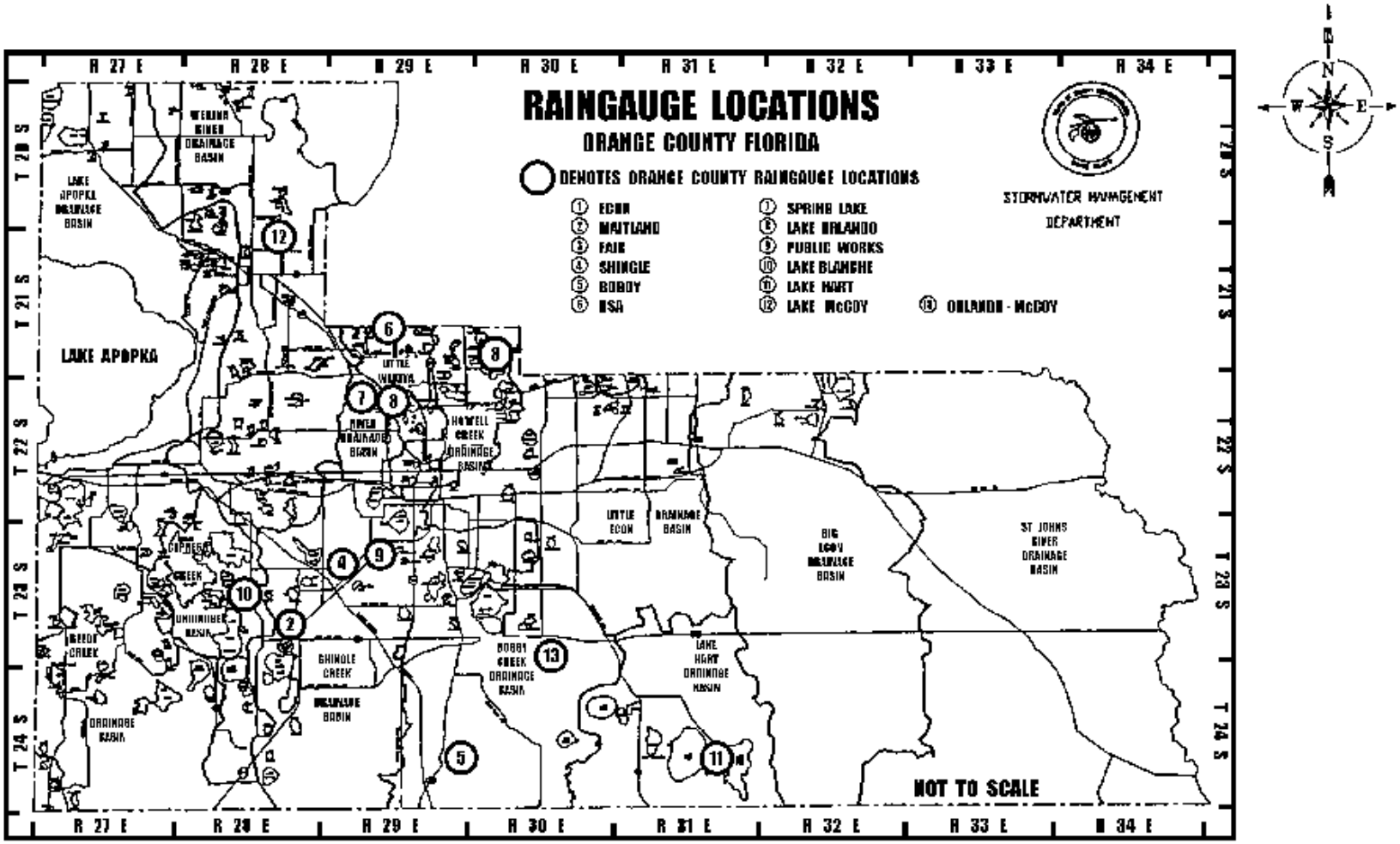


Figure A-4. Rain gauge locations. (Reprinted courtesy of the City of Orlando, FL)

For the 2-, 10-, and 25-year, 24-hour design storm events the Soil Conservation Service Type II Florida modified rainfall distribution (also called Type III) was selected based on the requirements of OUSWMM. The 100-year, 72-hour rainfall distribution was taken from the SFWMD permit manual. Rainfall intensities were then generated for each design storm.

Soil Types and Capabilities

Soils data are used to evaluate stormwater runoff, infiltration, and recharge potential for pervious areas. Information on soil types was obtained from the National Resources Conservation Service (NCRS), formerly the Soil Conservation Service (SCS). Each soil type has been assigned to a soil association, a soils series, and to one of the four Hydrologic Soil Groups (HSG) designated A, B, C, or D. HSG A is comprised of soils having very high infiltration potential and low runoff potential. HSG D is characterized by soils with a very low infiltration potential and a high runoff potential. The other two categories fall between the A and D soil groups.

For the Lake Hart study area, the majority of the soils types are within Smyrna-Bassinger-St. Johns soil association which are characterized by nearly level, poorly drained, and very poorly drained soils that are sandy throughout. The soils in the vicinity of Lake Nona, Red Lake and Buck Lake are classified as part of the Smyrna-Pomello-Immokalee association which are nearly level and have poorly drained soils to very well drained soils that are sandy throughout.

The predominant soils series within these subbasins include Sanibel Muck which has a depth to seasonal high groundwater table between zero and one foot and Smyrna Fine Sands which has a depth to seasonal high groundwater of one foot above the ground surface to one foot below the ground surface. The remainder of the soils are classified as part of the Pomello Fine sands which have a depth to seasonal high groundwater table between two and 3.5 feet or the St. Johns Fine Sands which have a depth to seasonal high groundwater table between zero and one foot.

Soil infiltration rates were taken from the NRCS Soil Survey for Orange County, FL based upon the soil hydrologic group. The RUNOFF Block of SWMM uses both soil storage and infiltration rates. Soil capacity (or soil storage) is a measure of the amount of storage (in inches) available in the soil type for a given antecedent moisture condition. The average antecedent moisture condition (AMC II) was used for all design storm analyses. Soil capacities were estimated based on available depth-to-water-table data and the use of equations as outlined in the SFWMD manual which uses equations developed by the NRCS. The high water table and low infiltration capacity conditions were considered in the best management practice (BMP) evaluations in subsequent sections to ensure that chosen alternative would function properly.

The Horton soil infiltration equation was used to simulate rain water percolation into the soil. The Horton equation uses an initial infiltration rate to account for moisture already in the soil, a maximum infiltration rate, and a decay infiltration rate. Additionally, a total

maximum infiltration depth is computed based on the moisture capacity of the soil. In this study, the maximum depth was determined from the information provided in the Soil Survey of Orange County which documents seasonal high water tables or depths to the impervious layer (first impermeable boundary condition).

Once these infiltration parameters were computed and calibrated for each HSG, area-weighted parameter values were computed based on the percent of each HSG within a catchment. Detailed information on the use of the Horton infiltration equation is described in the SWMM 4.3 users manual.

Table A-2 lists the global infiltration parameters used to calculate the hydrologic input data used in this study. The global Horton infiltration equations presented in Table A-2 resulted in peak water surface elevations similar to those predicted by the Federal Emergency Management Agency (FEMA). This is based on CDM experience with over 30 stormwater management programs in Florida, including extensive calibration and verification to historic storms.

Table A-2. Global Horton Infiltration Parameters

Hydrologic Soil Group	Maximum Infiltration Rate (in/hr)	Minimum Decay Rate (in/hr)	Decay Rate (1/sec)	Maximum Soil Storage (in)
A	14.0	0.75	0.000556	5.4
B	10.0	0.50	0.000556	4.0
C	7.0	0.25	0.000556	3.0
D	5.0	0.10	0.000556	1.4

In order to manage the volume of data required to generate the SWMM RUNOFF data sets, spreadsheets were developed to semi-automate the process. Flow path data, land use data (including percent imperviousness), soil data, and tributary area measurements for each subbasin were input into a spreadsheet. The spreadsheet calculated area-weighted averages using the global Horton infiltration parameters and the hydrologic data to generate subbasin information that could be directly input to the SWMM RUNOFF data set.

Overland Flow Parameters

The RUNOFF module of SWMM uses overland flow data in the form of width, slope, and Manning's roughness coefficient to create a physically based overland flow runoff plane to route runoff to conduits and storage for further routing. The overland flow length (L) is the weighted-average travel length to the point of interest. The need for weighting becomes apparent when considering areas with odd geometry where a long, thin portion of the area may bias the hydraulic length. For ponded areas, the point of interest chosen was the centroid of ponding. For areas where ponding does not occur,

the point of interest is the outflow from the area. Overland flow length is used to better estimate subbasin width for the RUNOFF overland flow routing by use of the equation:

$$A = LW$$

where:

A	=	subbasin area (sq. ft.)
L	=	overland flow length (ft.)
W	=	overland flow width (ft.)

Overland flow slope is the average slope over the hydraulic length and is calculated by dividing the difference in elevation by the hydraulic length. Length and slope information were obtained from 1985 aerial photogrammetry one-foot topographic data. These data were augmented by available subdivision plans and survey data.

Land Use and Impervious Areas

Land use data are used to estimate impervious areas for use in runoff calculations. Existing land use for the portion of the Lake Hart basin annexed by the City was obtained from 1985 aerial photography (1 in = 200 feet), 1995 aerial photography, and as-built information provided by the major property owners within the study area.

The majority of the study area consists of undeveloped lands (55%), wetlands (24%), and water bodies (15%). The remaining six percent of the total is a mixture of low density residential, golf course, commercial and major road land uses. Of the major property owners within the study area, only Lake Nona has constructed phases of their development plan.

The estimate of future land use was compiled from information provided by each of the major property owners within the basin and from information provided by the City of Orlando Planning Department. The developable land in the basin is projected to become low density residential (17% of study area), medium density residential (17% of study area), and supporting industrial/commercial land uses (12% of study area). The balance of the developable land (9%) is planned for schools, high density residential, golf courses and open space.

Using the existing and future land use data and the source maps, the percentage of each land use category within each subbasin was determined. Note that the future land use scenario represents a combination of City of Orlando information and the desires of the major property owners within the study area. The City has not adopted a future land use plan for this area.

The percent imperviousness of each subbasin is one of the parameters used by the SWMM RUNOFF model to determine the volume and rate of surface water runoff. For this study, a percent imperviousness value for each of the eleven land use categories was determined. A summary of the eleven land use categories is presented in Table A-

3. Additionally, the table lists the percent of Directly Connected Impervious Area (DCIA) and the percent of Non-DCIA (NDCIA) assigned to each land use category. The DCIA represents all the impervious surfaces which are directly connected to the stormwater system. The NDCIA represents the impervious surfaces that have a pervious buffer between them and the stormwater system.

Hydraulic Parameters

PSWMS (refer again to Figure A-2) for the Lake Hart basin consists of a series of interconnected lakes, streams, and wetlands that discharge to 10 different discharge points from the study area. There are 15 miles of open channels/interconnected wetlands (51 model segments), 33 structure crossings (e.g., culverts, bridges), and 35 existing storage areas representing lakes and depressional areas. Additional detention ponds were modeled for future land use. Characteristic data of this system were obtained from as-built drawings, field reconnaissance, one-foot contour topographic maps, and survey.

A necessary task of any stormwater master plan is the creation of a simplified representation of the actual system for input into the stormwater models. This task typically begins with the development of a model schematic which also aids in checking input data and interpreting output data. An overall RUNOFF/EXTRAN existing model schematic of the PSWMS for the entire Lake Hart study area is shown in Figure A-5. The schematic shows the hydrologic unit load points for inflow, conveyance channels, and structures, as well as the storage and linking junctions. It also illustrates how the RUNOFF and EXTRAN programs were set up to simulate each area's runoff hydrograph and the routing of the runoff through the stormwater management system. Identification numbers for various system elements are also shown on the schematic. The schematic provides a quick reference for correlations between the actual physical situation and the modeled system.

Table A-3. Imperviousness by Land Use Category

Land Use Category		Impervious[1] (%)	DCIA[2] (%)	NDCIA[3] (%)	Pervious (%)
1.	Forest, Open, & Park	1	1	0	99
2.	Agricultural & Golf Courses	1	1	0	99
3.	Low Density Residential	25	12.5	12.5	75
4.	Medium Density Residential	35	25	10	65
5.	High Density Residential	65	55	10	35
6.	Institutional	50	45	5	50
7.	Industrial	80	80	0	20
8.	Commercial	90	90	0	10
9.	Wetlands	100	100	0	0
10.	Water bodies	100	100	0	0
11.	Major Roads	98	98	0	2

Notes:
1) Total Impervious Area
2) Directly Connected Impervious Area (DCIA)
3) Non-Directly Connected Impervious Area (NDCIA)

Structures/Facilities

A major component of this study was the inventory of the stormwater management structures along the PSWMS. This information forms the foundation for the model representation of the hydraulic system. The hydraulic characteristics of the structures and facilities in the Lake Hart study area were collected from design drawings of improvements (e.g., culverts, bridges, detention ponds) that have occurred within the study area.

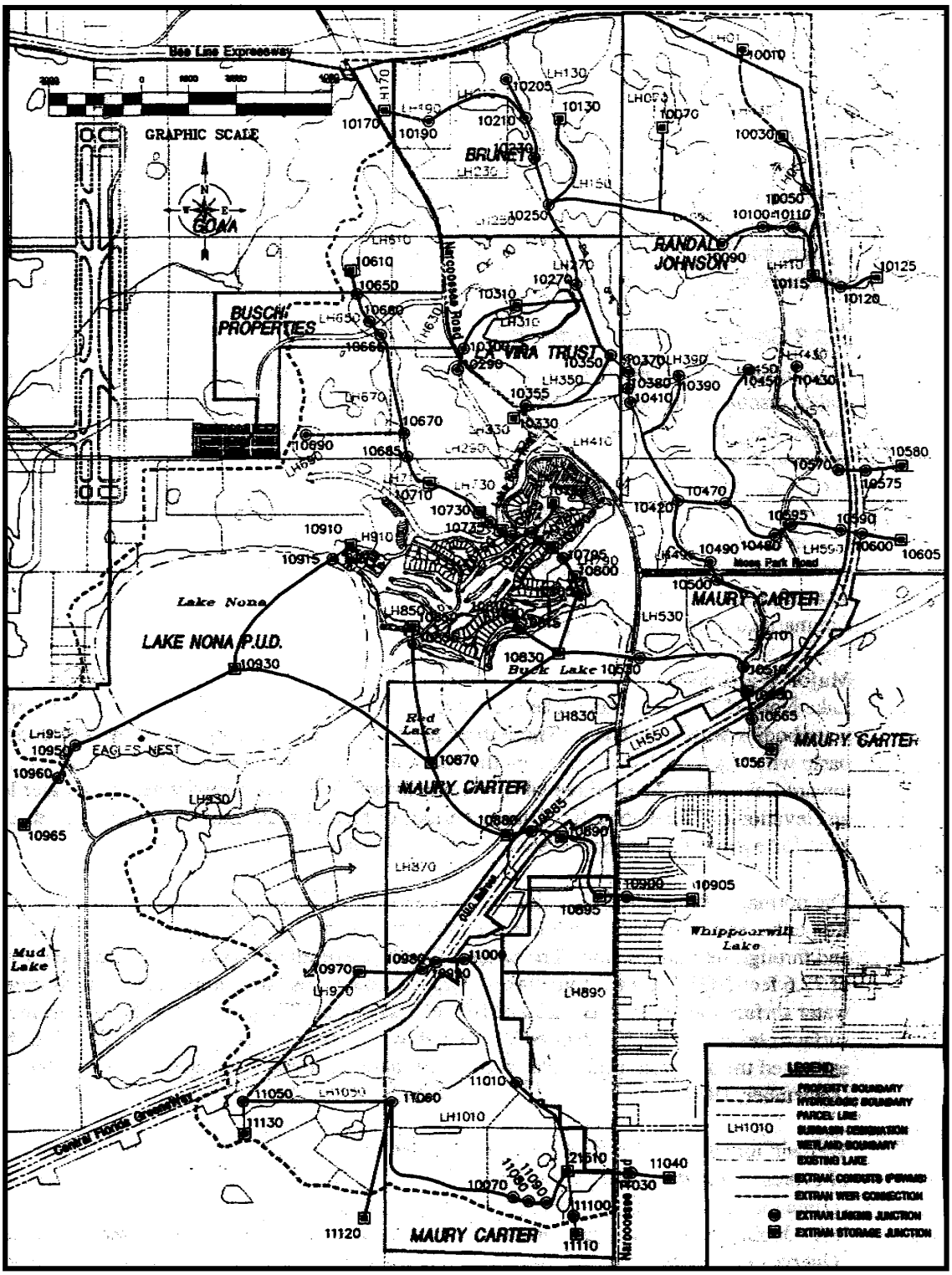


Figure A-5. Existing PSWMS nodal schematic map. (Reprinted courtesy of the City of Orlando, FL)

Stage-Area Relationships

Stage-area information was developed by planimetering topographic contours for major depressional areas which could not be uniformly incorporated into channel/wetland cross sections. This process was done to more accurately reflect floodplain storage. The same procedure was applied to the existing detention ponds. Stage-area relationships for existing facilities were obtained from topographic data shown on the as-built plans provided by the property owners within the basin. The volume of storage was internally calculated by stormwater models using the trapezoidal method.

Stage and Discharge Data

A desirable component of any water resources investigation is the availability of measured stages and/or discharges at selected points of interest, or the availability of calibrated hydrologic/hydraulic models from the area to serve as a "reality check" or verification. Stages and/or discharges are used in conjunction with known rainfall amounts/distributions and other hydrologic/hydraulic conditions to calibrate and verify models. These calibrated and verified models can then be used in evaluations of present problem area solutions or future conditions planning. Data in at least hourly intervals are often desired so that relatively short-term, yet potentially damaging, flood peaks can be predicted and planned for. For the Lake Hart basin, there are limited stage data and no discharge data available for use in the master planning process. The data that are available are summarized in the following paragraphs.

Lake Nona (575 acres), Red Lake (120 acres), and Buck Lake (115 acres) are the three major water bodies within the basin. These three lakes collect the majority of stormwater runoff from the basin which is then discharged from the lakes into a series of streams and wetlands that meander toward Lake Hart. These three lakes become hydraulically connected when their water level exceeds an elevation of 75.5 ft-National Geodetic Vertical Datum (NGVD). During periods of high rainfall, Lake Nona will also discharge into Mud Lake through a channel system located on the southwest side of the lake.

The normal water surface elevations and the seasonal high water surface elevations for Lake Nona, Red Lake, and Buck Lake were obtained from the Orange County Lake Index and through field inspection. The index reports a normal water elevation of 77.6 feet-NGVD for the three lakes. Orange County also took nine random measurements of the water surface elevation in Buck Lake between the years 1970 and 1975. The highest recorded water surface elevation was 77.8 feet-NGVD which was recorded on July 1, 1974. The FEMA also estimated the 100-year peak water surface elevation for these three lakes to be 79.6 feet-NGVD.

Wetland jurisdiction limits extend from the lake's open water body landward to where the dominance of cypress (*Taxodium distichum*), bay (*Gordonia lasianthus*), and tupelo trees (*Nyssa* sp.), ferns (*Osmunda* spp.) and shiny lyonia (*Lyonia lucida*) disappear. Upland areas include the canopy tree layer dominated by slash pine (*Pinus elliottii*), scrub live oak (*Quercus geminata*), and turkey oak (*Quercus laevis*), while saw palmetto

(*Serenoa repens*) dominate the understory. Extending the seasonal high water line and normal pool elevations landward would provide a reasonable wetland boundary around each lake. Hydric soils and hydrologic indicators would also need to be assessed to confirm the wetland jurisdiction line.

Biological indicators of wetland water levels were also used to approximate the normal pool and seasonal high water elevations at five sites within the Lake Hart basin. This was done using SWFWMD guidelines. The wetland jurisdictional determination methodologies implemented by Florida Department of Environmental Protection, and St. Johns River Water Management District (SJRWMD), and U.S. Army Corps of Engineers were also used to determine plant community zonation (i.e., obligate, facultative and facultative upland plant species) and to approximate temporal water inundations and conditions.

Using these guidelines, hydric soils characteristics, hydrophilic vegetation, and other biological information were compared with known topographic elevations to estimate normal pool and seasonal high water levels. No water level recorders or staff gages were present or were installed. The results of the field inspection for the five sites are summarized in Table A-4.

Table A-4. Field Estimated Normal Pool and Seasonal High Water Elevations

Site No. (invert)	Normal Pool (feet-NGVD)	Seasonal High (feet-NGVD)	Existing Water Level (feet-NGVD)	Indicators Used
1	78.1	78.6	77.3	Stain line Moss line
2	74	75.4	73.3	Stain line Moss line
3	76.9	77.7	76.4	Stain line Moss line
4	79	80	78.7	Stain line
5	73.1	75.1	72.4	Stain line Moss line

The results of the biological indicators at the five sites indicate that the maximum difference between the normal pool and seasonal high water elevations range from 0.5 feet to two feet. Various constrictions (e.g., inadequately sized culverts, culverts in

poor condition, or inverts above than the 100-year flood event) may cause flow constrictions. The biological indicators provide fluctuation patterns, not duration.

The biological results provide a difference of water level fluctuation indicators for specific wetland species that adapt to prolonged inundation (i.e., adventitious roots and epiphytic algae) or are intolerant to sustained inundation (foliose lichens). Facultative and obligate plant indicators that occur along the landward extent of the wetlands can assist in the determination of the normal pool and seasonal high water levels. Many aquatic plants occur in specific horizontal zones along the slope and the changing water levels. Each species has adapted to a specific inundation period (duration). These hydrologic factors were used to differentiate the water distribution pattern and the extent of wetlands around each lake.

Floodplains and Floodways

A floodplain is the area inundated, or flooded, by a particular rain or tidal event. Floodplains are usually described by their frequency of occurrence (e.g., 25-year or 100-year). FEMA establishes nationwide flood levels and flood insurance standards. The FEMA flood insurance study (FIS) for Orange County, FL and associated Flood Insurance Rate Maps (FIRMs) identify portions of the Lake Hart basin annexed by the City as flood prone and provide estimates of the 100-year flood stages in order to provide guidance for home building and road elevations. For this study, available data were compiled in order to estimate stormwater flood boundary conditions for subsequent evaluations.

The City of Orlando requires that a Floodplain Development Permit be obtained for any development activities for any building or structure located in an area of special hazard. The general requirements for the permit application require that the applicant submit drawings to scale showing the nature, location, dimensions, and elevations of the area in question; existing and proposed structures; fill; storage or materials; and drainage facilities. Specifically, the following information is required:

- Base flood elevation (100-year flood)
- Habitable flood elevation
- Nonresidential floodproofing elevation
- Floodproofing certification
- Alteration of watercourse

Once this information is received, the City Engineer will review the application for compliance and issue a permit as appropriate. The City Engineer's review includes notification of other applicable regulatory agencies prior to any alteration or relocation of a watercourse, the verification of flood and structure elevations, determination of whether a building or development is within an Area of Special Hazard based on the applicable FEMA FIS and accompanying maps, and advise an applicant whether or not a Letter of Map Amendment or Revision from FEMA is required.

OUSWMM also has requirements for development in the floodplain. For example, encroachment will be allowed in the 100-year floodplain with compensating storage. All proposed developments within the 100-year floodplain as delineated on an official FIRM or as determined by the City Engineer need to comply with these requirements:

- City will establish the 100-year/24-hour base flood elevation
- If the area is not in a 100-year flood prone area, an analysis will be done to determine the 100-year elevation
- The design storm event to be used to establish the 100-year on-site elevation shall be a 100-year/72-hour event of 14.4 inches of rainfall
- The minimum finished floor elevation shall be one foot above the 100-year elevation
- Floodproofing may be substituted for elevating finished floor elevations for commercial and industrial developments
- Compensating flood storage must be provided for all floodwater displaced by development below the elevation of the 100-year/24-hour flood (generally, between the 100-year flood elevation and the wet season water table)
- Compensating storage may be claimed in retention/detention ponds when they are above maintained water elevations and they can be inundated during the 100-year flood.
- Off-site increases in flood stage will not be allowed by encroachment within a floodway.

Details on each of these summaries can be found in the appropriate chapters of the City Code and OUSWMM.

Water Quality Parameters

The following paragraphs discuss state surface water classifications, historical water quality data in the study area, trends exhibited by the data, and the methodology used to estimate nonpoint source pollutant loads. Data from the EPA's STOrage and RETrieval (STORET) database are included as appropriate.

Selection of Water Quality Loading Factors

In order to meet the objectives of the Lake Hart MSMP, pollutants that may affect water quality were identified and quantified. This section identifies stormwater related-pollutants in the study area and describes the methodology for determining appropriate event mean concentrations (EMCs) for use in the WMM.

Identification of Pollutants

The major sources of pollutants in a watershed are typically stormwater runoff from urban and agricultural areas, discharges from wastewater treatment plants (WWTPs) and industrial facilities, and contributions from improperly installed or maintained septic tanks. Stormwater runoff pollution and septic tank loadings have been historically referred to as nonpoint source pollution (NPS). A WWTP or industrial discharge is typically referred to as point source pollution because it releases pollution into streams at a discrete point. The Lake Hart MSMP targets the pollutants which are most frequently associated with stormwater including:

1. Sediment
   - Total suspended solids (TSS)
   - Total dissolved solids (TDS)

2. Oxygen demand
   - Biochemical oxygen demand (BOD)
   - Chemical oxygen demand (COD)

3. Nutrients
   - Total phosphorus (TP)
   - Dissolved phosphorus (DP)
   - Total Kjeldahl nitrogen (TKN)
   - Nitrate + nitrite nitrogen (NO_3+NO_2)

4. Heavy metals
   - Lead (Pb)
   - Copper (Cu)
   - Zinc (Zn)
   - Cadmium (Cd)

Estimates of the annual loads of these pollutants are required as part of the National Pollution Discharge Elimination System (NPDES) stormwater permitting analysis.

Selection of Stormwater Pollution Loading Factors

The nonpoint pollution loading module of WMM computes nonpoint pollution loads based on factors which relate local land use patterns and rainfall and percent imperviousness in a watershed to pollutant loadings. Nonpoint pollution loading factors (e.g., pounds/acre/year) for different land use categories are based upon annual runoff volumes and EMCs for different pollutants. The EMC is a flow-weighted average concentration and is defined as the sum of individual measurements of stormwater pollution loads divided by the storm runoff volume. Selection of EMCs factors depends upon the availability and accuracy of local monitoring data, as well as the effective transfer of literature values for nonpoint pollution loading factors to a particular study area. Reviewed here are monitoring data collected throughout Florida, as well as

available literature values for estimating event mean concentrations for use in the Lake Hart MSMP.

Over the past 15 years, nonpoint pollution monitoring studies throughout the U.S. have shown that "per acre" discharges of urban stormwater pollution (e.g., nutrients, metals, BOD, fecal coliforms) are positively related to the amount of imperviousness in the land use (i.e., the more imperviousness the greater the nonpoint pollution load) and that the EMC is relatively consistent for a given land use. Soil types affect hydrology more than EMC, especially in areas dominated by impervious surfaces.

Land Use Load Factors

Recommended EMCs for the urban land use categories (residential, commercial, and industrial) in this plan are based upon a detailed analysis of available monitoring data recently collected under the EPA NPDES Part II Stormwater Permit application process. The process was conducted between November 1990 and May 1993 for over 34 NPDES municipal stormwater applications throughout the country including the states of Florida and Georgia. As part of the permit application process, representative stormwater outfalls were monitored in cities and counties with populations greater then 100,000. These "representative" outfalls typically discharged stormwater from areas with predominantly residential, commercial, or industrial land uses. Each outfall was monitored and sampled during a minimum of three separate storm events. The analysis included a total of 98 storm events that were monitored by selected cities and counties under the Florida Stormwater NPDES permitting process. Previously, the EPA sponsored Nationwide Urban Runoff Program (NURP) monitored stormwater pollution from urban areas in about 80 storm events in Tampa during 1978-1983.

Under the NPDES permitting process, flow-weighted composite samples were collected during storm events according to detailed sampling protocols prescribed by the EPA. Samples were analyzed for about 140 pollutants including those targeted for the Lake Hart MSMP. Statistical analyses of available NPDES data were used to determine appropriate EMCs for watershed management applications. Data from the City of Orlando NPDES monitoring sites were included in this analysis.

Some citrus and cattle growing/pasture land use exists or has existed in the study area. The pasture land use is in the northwest portion of the study area and the citrus is in the southeast. These two land uses are not well monitored nor documented for water quality in the literature. In particular, pasture EMCs can range dramatically if cattle are allowed to free range through streams and wetlands for water and forage. EMCs for total P can range from 0.3 mg/l to 1.0 mg/l or higher.

Total N can range from 1.45 mg/l to over 5 mg/l. Therefore, the most applicable central Florida values were used for these land uses to estimate existing land use pollutant loadings from these highly variable sources.

For central and south Florida, provides estimates of stormwater EMCs based on a literature review of monitoring studies performed at various sites in Florida. Dade County also prepared a literature review of selected EMC values to be used in the Dade County Stormwater Management Master Plan.

Open/Nonurban Land Use Load Factors

The only open/nonurban monitoring site included in the Florida NPDES sites analyzed was monitored by Sarasota County. This site did not include cattle pasture/growing or citrus.

Water Bodies

The primary sources of pollution to water bodies are runoff from upstream areas and pollutants associated with precipitation falling on the water surface. Since pollution discharged from upstream areas is already accounted for by the other land use category loading factors, loading factors for water bodies consider only the pollution derived from precipitation.

Urban atmospheric monitoring studies performed under NURP and other studies have documented that there is a pollution load associated with precipitation. Pollutant loading factors for water bodies were derived from the Tampa NURP atmospheric monitoring studies and a report containing a compilation of atmospheric deposit data. The loading factors used in this plan differ from those used in the Lake Hart MSMP based on an update of more recent and extensive data.

Major Roads

Highway runoff data reported by the Federal Highway Administration (FHWA) were considered for application to the major highway land uses in Florida watersheds. The FHWA study analyzed stormwater runoff monitoring data obtained at 31 highway sites covering a total of 993 separate storm events. Highway stormwater runoff data were collected under several previous studies during the past 10 to 15 years. Also, many of the previous FHWA monitoring studies were performed during periods when the use of leaded gasoline was more prevalent than today. These studies demonstrated that highway runoff may contain solids, metals, nutrients, oil and grease, bacteria, and other pollutants.

Recommendation of Stormwater Pollutant Loading Factors

From the databases described above, EMCs obtained from water quality monitoring studies completed in the state of Florida were used in this evaluation. These EMC values were compared with those obtained from studies throughout the eastern United States. Based on this comparison, the final EMC values were selected. These EMC values represent the best available information (most recent up-to-date database) and are applicable for pollutant load estimates in the City of Orlando. Table A-5 presents the recommended event mean concentrations and impervious percentages for the Lake Hart MSMP. Listed with each pollutant group is the reference source for these recommended EMCs.

Table A-5. Event Mean Concentrations and Impervious Percentages Recommended for the Watershed Management Model

Land Use Category	Avg. Percent Imp.	Oxygen Demand and Sediment (mg / L)					Nutrients (mg / L)					Heavy Medals (mg / L)				
		BOD	COD	TSS	TDS	SOURCE	TP	DP	TKN	NO23	SOURCE	Pb	Cu	Zn	Cd	Source
1. Forest, Open and Park	1.00%	1	51	11	100	A,B	0.05	0.004	0.94	0.31	A	0.000	0.000	0.000	0.000	B
2. Agriculture and Golf	1.00%	4	51	55	100	A,B	0.34	0.23	1.74	0.58	A	0.000	0.000	0.000	0.000	B
3. Low Density Residential	25.00%	15	71	27	286	C	0.44	0.33	1.34	0.63	C	0.002	0.009	0.051	0.002	C
4. Medium Density Residential	35.00%	9	65	59	59	C	0.45	0.27	1.77	0.27	C	0.013	0.007	0.057	0.001	C
5. High Density Residential	65.00%	8	53	42	141	C	0.20	0.09	1.03	0.67	C	0.011	0.022	0.065	0.001	C
6. Institutional	50.00%	7	50	41	114	C	0.15	0.08	1.24	1.05	C	0.012	0.018	0.079	0.001	C
7. Industrial	80.00%	14	83	77	130	C	0.28	0.20	1.47	0.40	C	0.023	0.024	0.132	0.001	C
8. Commercial	90.00%	8	53	42	141	C	0.20	0.09	1.03	0.67	C	0.011	0.022	0.065	0.001	C
9. Wetlands	100.00%	5	51	5	100	A,B,E	0.19	0.10	1.10	0.40	A,B,E	0.006	0.003	0.005	0.000	A,B,E
10. Waterbodies	100.00%	3	22	5	100	D,E	0.17	0.09	1.10	0.20	E	0.006	0.003	0.005	0.000	E
11. Major Roadways	98.00%	11	99	121	189	C	0.40	0.15	1.51	0.34	C	0.039	0.022	0.189	0.002	C

SOURCES:

A: "Estimation of Stormwater Loading Rate Parameters," Harvey H. Harper, 1992, Table 21.
B: Nationwide Urban Runoff Program (NURP), 1983.
C: NPDES Part II Stormwater Permit Applications for the Cities of Jacksonville, St. Petersburg and Orlando, and the Counties of Palm Beach and Sarasota, 1992-93.
D. "Washington Metropolitan Area Urban Runoff Demonstration Project," Northern Virginia Planning District Commission, January 1983, Table 24.
E: Mean concentrations reported for wetfall monitored as part of the Tampa NURP study and Mote Marine data compilation.

NOTES:

1. Dissolved - P concentrations for wetlands and Watercourses / Waterbodies are generally 55 percent of the recommended total - P concentration (Harper, 1992; Florida NPDES data, 1992 - 1993).
2. TKN and NO2 + NO3 concentrations for the non-urban land use categories were assumed to be 75 percent and 25 percent, respectively, of the recommended total - N concentration (Florida NPDES data, 1992 - 1993).
3. Averages reported are based on parametric statistics with a lognormal distribution.
4. Concentrations reported below the detection limits were assumed to 50% of the detection limits for the statistical analysis.
5. Golf courses were not explicitly included in the NPDES monitoring networks.

WMM converts the EMCs described above into nonpoint pollution loading factors (expressed as pounds/acre/year) based on the runoff volume for each land use within a watershed. Pollution loading factors vary by land use and the percent imperviousness associated with each land use. The pollution loading factor M_{LU} is computed for each land use (LU) based on the EMCs presented in Table A-5 using the following equation:

$$M_L = EMC_L * R_L * K$$

Where:

M_{LU}	=	loading factor for land use LU (lb/ac/year)
EMC_{LU}	=	event mean concentration in runoff from land use LU (mg/l). EMC_L varies by land use and by pollutant
R_{LU}	=	total average annual surface runoff from land use LU (in/year)
K	=	0.2266, a unit conversion constant ((lb-l)/(mg-ac-in))

The total annual pollution load from a watershed is computed by multiplying the pollutant loading factor by the acreage in each land use and summing for all land uses.

Delivery Ratio/Travel Time

Wet-weather travel times on the order of 24 hours or more are typically required to achieve significant decay of pollutants during instream transport. While in-stream settling occurs on an annual basis, the resuspension of sediments in streams is likely to carry pollutants downstream. Therefore, in order to provide more conservative estimates of the nonpoint source loads, a delivery ratio of 100 percent was assigned to all areas within the City of Orlando for pollutants suspended in the water column.

Point Source Discharge

Pollutant loadings from point source dischargers, such as regional WWTPs, are usually estimated to determine the relative contributions of point versus nonpoint pollution loadings. The Lake Nona wastewater treatment facility is within the study area. However, it is not considered to be a point source discharge because effluent from the WWTP is discharged into a holding pond that is used for slow-rate spray irrigation at the golf course so that it does not directly discharge into the PSWMS.

BMP Pollutant Removal Efficiencies

WMM applies a constant removal efficiency for each pollutant to all land use types to simulate treatment BMPs. Recommended pollutant removal efficiencies for retention basin, detention basin, and swale BMPs are discussed below.

The design of retention systems is generally based on a specified diversion volume. Relying on extensive field investigations and simulations using 20 years of rainfall data, average yearly pollutant removal efficiencies were estimated for fixed diversion volumes for onsite (small) watersheds, as presented in Table A-6. The diversion depth is the

depth of runoff water which must be stored and percolated from the total upstream drainage area that discharges to the retention pond.

The EPA NURP study monitored several wet detention ponds serving small urban watersheds in different locations throughout the U.S. For wet detention ponds with significant average hydraulic residence times (e.g., two weeks or greater), average pollutant removal rates were on the order of 40 to 50% for total-P and 20 to 40% for total-N. For other pollutants which are removed primarily by sedimentation processes, the average removal rates were as follows: 80 to 90% for TSS; 70 to 80% for lead; 40 to 50% for zinc; and 20 to 40% for BOD or COD.

Pollutant removal efficiencies for dry extended detention ponds are based on settling behavior of the particulate pollutants. Table A-6 summarizes average pollutant removal efficiencies for dry extended detention ponds based on settling column data and field monitoring data. Settling column data from NURP studies and from the FHWA study were evaluated to establish the removal efficiencies for TSS and metals.

Removal efficiencies for the nutrients were determined by evaluating the results of two field monitoring studies of dry extended detention ponds in the metropolitan Washington, D.C. region. These efficiencies are applied to the percentage of total annual pollutant washoff captured for treatment in the extended dry detention pond.

The removal efficiencies summarized in Table A-6 for swales represent swales designed for infiltration and capture of 80 percent of the annual runoff volume. These efficiencies are based upon NURP findings and CDM experience. Finally, the pollutant removal rates for retention swale pre-treated upstream of a wet detention pond are based on retaining the first 0.25 inches over the tributary area coupled with full wet detention treatment.

Surface Water Quality Classifications

Section 403.021 of Florida Statutes declares that the public policy of the state is to conserve the waters of the state to protect, maintain, and improve the quality thereof for public water supplies, for the propagation of wildlife, fish, and other aquatic life, and for domestic, agricultural, industrial, recreational, and other beneficial uses. It also prohibits the discharge of wastes into Florida waters without treatment necessary to protect those beneficial uses of the waters. Furthermore, Congress, in Section 101(a)(2) of the Federal Water Pollution Control Act, as amended, declared that achievement by July 1, 1983 of water quality sufficient for the protection and

Table A-6. Average Annual Pollutant Removal Rates for Retention Basin, Detention Basin and Swale BMPs (Note: All values are percent.)

	Extended Dry Detention [1]	Wet Detention [2]	Retention[3]	Swales [4]	Retention Swales With Wet Detention[5]
BOD5	30	40	90	30	76
COD	30	40	90	30	76
TSS	90	90	90	80	96
TDS	0	40	90	10	76
Total-P	30	50	90	40	80
Dissolved-P	0	70	90	10	88
NO2+NO3	0	30	90	40	76
TKN	20	30	90	40	72
Cadmium	80	80	90	65	92
Copper	60	70	90	50	88
Lead	80	80	90	75	92
Zinc	50	50	90	50	80

NOTES:

1. Extended dry detention basin efficiencies assume that the storage capacity of the extended detention pool is adequately sized to achieve the design detention time for at least 80 percent of the annual runoff volume. For most areas of the United States, extended dry detention basin efficiencies assume a storage volume of at least 0.5 inches per impervious acre.

2. Wet detention basin efficiencies assume a permanent pool storage volume which achieves average hydraulic residence time of at least two weeks.

3. Retention removal rates assume that the retention BMP is adequately sized to capture at least 80 percent of the annual runoff volume from the BMP drainage area. For most areas of the United States, the required minimum storage capacity of the retention BMP will be in the range of 0.50 to 1.0 inch of runoff from the BMP drainage area, but the required minimum storage capacity should be determined for each location.

4. Source: California Stormwater Best Management Practice Handbooks, (CDM, et. al., 1993). These efficiencies are applied to the percentage of total annual pollutant washoff captured for treatment in the extended dry detention pond BMP.

5. This efficiency reflects removal efficiencies for series BMPs with 0.25 inches of retention swale pre-treated upstream of a wet detention pond.

propagation of fish, shellfish, and wildlife, as well as for recreation in and on the water, is an interim goal to be sought wherever attainable. Congress further states, in Section 101(a)(3), that it is the national policy that the discharge of toxic pollutants in toxic amounts be prohibited.

Therefore, the present and future most beneficial uses of all waters of the state have been designated by the FDEP using the classification system set forth in Chapter 62-302, of the Florida Administrative Code. These water quality standards and associated criteria have been established to protect designated uses which are:

1. OFW Outstanding Florida Waters, which include waters in state and federal parks, wildlife refuges, and other environmentally sensitive areas.

2. Class I: Potable Water Supplies.

3. Class II: Shellfish Propagation or Harvesting.

4. Class III: Recreation, Propagation and Maintenance of a Healthy, Well-Balanced Population of Fish and Wildlife.

5. Class IV: Agricultural Use.

6. Class V: Navigation, Utility, and Industrial Uses.

Accordingly, the FDEP has established minimum, general, and specific criteria for surface waters in the state. These criteria provide limits for various detectable sources of pollution (e.g., nutrients, metals, organics). Water quality data are needed to document adverse impacts to Water bodies/watercourses and flora/fauna. Stormwater generates nonpoint source pollutant loads which can degrade water quality. Traditionally, water quality data are collected in regular intervals (e.g., quarterly) to record ambient conditions in a given location. However, stormwater sampling is needed during specific storm events to properly monitor for the "flush" of pollutants in rivers and streams.

By using these water quality data, water classifications, and criteria, recommendations can be made regarding the BMPs to use to achieve the standards established for, or mitigate the adverse impacts to, the receiving body of water. The following sections discuss available water quality data and potential water quality trends in the study area. The receiving waters in this study area are Lake Hart, Red Lake, Buck Lake and Lake Nona which are designated as Class III waters.

Historical Water Quality Monitoring Data

Historical water quality data are available for Lake Nona, Red Lake, and Buck Lake. The following paragraphs present a brief summary of current water quality.

To measure water quality of Florida lakes, an index of bio-physical and chemical parameters (trophic classification system) has been developed. Lakes containing similar (cluster) analysis results of seven indicators (primary production (pp), chlorophyll a (CHA), total organic nitrogen (TON), total phosphorus (TP), Secchi disc transparency

(SD), conductivity (COND), and a cation ratio (CR) due to Pearsall (1922)) were classified into four trophic levels and ranked (Brezonik and Shannon, 1971). The trophic state index is delineated by numerical values into four classes: oligotrophic (0-49), mesotrophic (50-60), eutrophic (61-69), and hypereutrophic (70-).

The Orange County Environmental Protection Department conducted annual water quality studies for all the county lakes beginning in 1990 to the present. The department measures four of the original seven parameters: chlorophyll a (a component of algae), Secchi depth (water clarity or transparency), total phosphorus, and total nitrogen (nutrient indicators). As a natural lake ages (eutrophication), a shift from oligtrophic (few nutrients) to eutrophic (well nourished) conditions occurs. Industrial, agricultural, and urbanization activities around a lake accelerate this process. Table A-7 provides the annual trophic state index (TSI) results of the calculations which rank the Lake Hart basin.

The TSI results show that natural eutrophication has occurred basin wide. Each lake shows a slight increase in value during the five year study. Red Lake and Lake Nona have retained their oligotrophic status. Buck Lake and Lake Whipporwill have recently changed from oligotrophic to mesotropic conditions. Lake Hart has maintained a mesotrophic level being within five increments of the range. In contrast, the two oligotrophic lakes have no or minimum urbanization activities. Overall the water quality in Lake Nona, Red Lake and Buck Lake is good. The Orange County TSI survey showed that Lake Nona was ranked second out of 136 lakes, with Buck Lake 68, Lake Whipporwill 76, and Lake Hart 109. The results are summarized in Table A-8.

Biological quality of selected lakes in Orange County were measured in 1994. Table A-9 provides the Diversity Index (a measurement of the variety of biological organisms which exists within a community), Equitability (a measurement of the distribution of the various types of biological organisms within a community and Taxa Richness (an average number of the species present at the site sampled.

Table A-7. The Annual Trophic State Index Results for the Lake Hart Basin

Lake Name	1990	1991	1992	1993	1994
Buck	45	--	54	50	50
Hart	53	50	56	57	58
Nona	30	20	15	28	22
Red	39	44	44	49	40
Whipporwill	34	38	52	46	51

Table A-8. 1994 Summary of Lake Secchi Disk Measurements, Chlorophyll-a Concentrations and Nitrogen and Phosphorus Concentrations in the Lake Hart Basin

Lake Name	Secchi Disk m	Chlor-a ug/l	NO_2-NO_3 mg/l	TKN mg/l	TN mg/l	TPO_4 mg/l	TSI Index
Buck	1.8	7.5	0.02	0.95	0.97	0.03	50
Hart	0.5	2.9	0.1	1.06	1.16	0.03	58
Nona	3.8	1.6	0.01	0.27	0.28	0	22
Red	2.3	3.5	0.02	0.64	0.66	0.02	40
Whipporwill	1.3	9.5	0.02	0.55	0.57	0.02	51

Source: Orange County Environmental Protection.

The results of the lakes in Table A-9 reflect a moderate pollution condition (eutrophic) in comparison to other lakes in central Florida. The results of the next two lakes are outside the Lake Hart basin that show one lake with eutrophic conditions and one lake with oligotrophic conditions, respectively. Lake Rowena was sampled on January 13, 1993, had a TSI of 57, a Diversity Index of 1.38, an Equitability of 0.3, and a Taxa Richness of 12. Lake Wauseon was sampled on December 29, 1993 had a TSI of 30, a Diversity Index of 3.2, an Equitability of 0.52, and a Taxa Richness of 30.5.

Table A-9. Biological Quality of Selected Lakes in Orange County

Lake	Date	Diversity Index	Equitability	Taxa Richness
Hart	2/8/93	2.45	0.64	11
Whipporwill	2/8/93	2.52	0.67	12

Source: Orange County Environmental Protection.

Evaluation of Best Management Practices

Best Management Practices Considerations

Best Management Practices (BMPs) are techniques, approaches, or designs that promote sound use and protection of natural resources. Various types of BMPs are discussed extensively in Chapter 6 of the FDER Land Development Manual, 1989. This

section summarizes alternatives which can be used to control flooding and avoid water quality problems.

Alternative Best Management Practices
BMPs that were considered for use in the Lake Hart basin MSMP are listed below where they are grouped as structural (constructed facilities) and non-structural (regulations or ordinances):

Structural Stormwater Controls

1. Extended dry detention ponds
2. Wet detention ponds (with and without retention swales)
3. Exfiltration trenches
4. Shallow grassed swales
5. Retention basins
6. Porous pavement
7. Water quality inlets
8. Underdrains and stormwater filter systems
9. Alum injection
10. Aeration
11. Skimmers

Non-Structural Source Controls

1. Land use planning
2. Public information programs
3. Stormwater management ordinance requirements
4. Fertilizer application controls
5. Pesticide use controls
6. Solid waste management
7. Street sweeping
8. Aquifer recharge and minimization of directly connected impervious area
9. Illicit connections (non-stormwater discharges) identification and removal
10. Control of illegal dumping
11. Erosion and sediment
12. Source control on construction sites
13. Operation and maintenance

The use of a specific BMP depends on the site conditions and objectives such as water quality protection, flood control, aquifer recharge, or volume control. In many cases, there are multiple goals or needs for a given project. Therefore, BMPs can be "mixed and matched" to develop a "treatment train." The treatment train concept maximizes the use of available site conditions from the point of runoff generation to the receiving water discharge in order to maximize water quantity (flood control), water quality (pollutant load reduction), aquifer recharge, and wetlands benefits.

The City currently applies the treatment train concept for wet detention facilities as described in OUSWMM. The runoff generated by the first inch of rainfall is stored in an off-line retention facility that is separate from the detention facility. Once the retention volume is exceeded, stormwater runoff flows into a separate detention facility for flood control where it is gradually discharged to receiving water as necessary. For the South East Annexation Area (SEAA), the City will consider alternative innovative options to meet the goals of OUSWMM. This is discussed in further detail in this “Evaluation of Best Management Practices.”

Figure A-6 and Figure A-7 show, respectively, a schematic flowchart of the treatment train concept and the City's "two pond" wet detention system.

Operation and Maintenance (O & M)

A recent survey by FDEP reported that nearly 70% of existing treatment facilities in Florida are not properly maintained and, therefore, do not provide the intended pollutant removal effectiveness. Because of this, one of the most effective non-structural BMPs is routine maintenance of existing treatment facilities. For publicly owned treatment facilities, routine maintenance and inspection should be considered for facilities that are within water quality sensitive basins. For the other "non-critical" areas, maintenance of treatment facilities may be considered on an as needed basis based on periodic inspection reports.

For privately owned facilities, maintenance is not typically performed by a municipality. There are several options that can be pursued by a municipality to help insure that proper maintenance is being conducted. These options may include a certification program initiated by a municipality that requires all approved private subdivision ponds to be recertified by the owner on a predetermined time interval. The re-certification may be done by a state certified/trained inspector or engineer. Enforcement of maintenance of privately owned facilities is one of the most difficult problems for a municipality. A potential enforcement measure is City intervention, after sufficient notification, where critical maintenance is done by the City and the cost of the maintenance is billed to the owner. Another option would be to consider stormwater utility credits for certified maintenance and rehabilitation.

Regional Versus Onsite Structural Best Management Practices

In much of the undeveloped portions of the City of Orlando, regional detention of flood control and water quality protection for relatively flat areas with high water tables appear to be the solution of choice because they provide the needed multiple benefits. The following discussion is provided for detention pond applications, which tend to be cost-effective where sited regionally.

Onsite Approach

In the case of future urban development, the onsite (also known as piecemeal approach to stormwater control) involves the delegation of responsibilities for BMP deployment to local land developers. Each developer is responsible for constructing a structural BMP

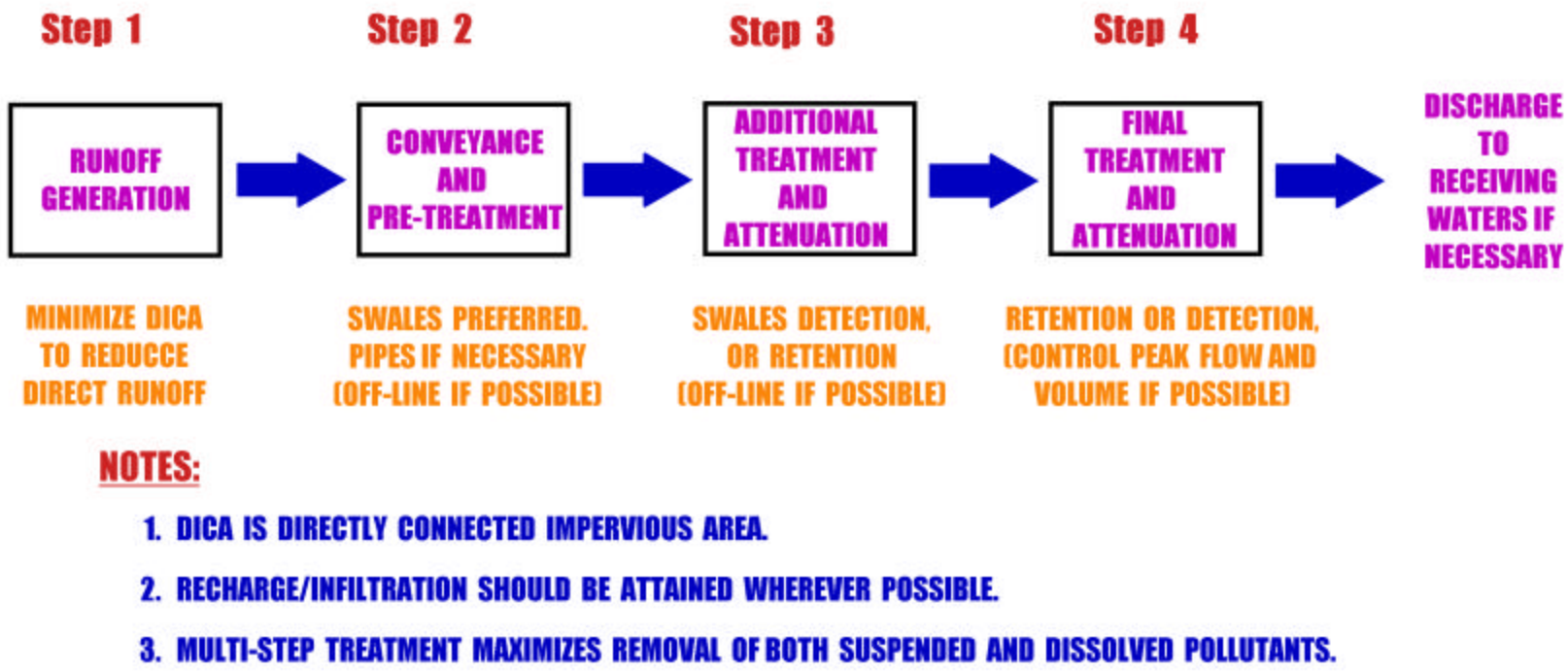
at the development site to control nonpoint pollution loadings from the site. Detention pond BMPs provided onsite typically have contributing areas of 20 to 50 acres. The local government is responsible for reviewing each structural BMP design to ensure conformance with specified design criteria, for inspecting the constructed facility to ensure conformance with the design, and for ensuring that a maintenance plan is implemented for the facility. The onsite approach is illustrated in Figure A-8.

Regional Approach

The regional approach to stormwater control involves strategically siting regional structural BMPs to control nonpoint pollution loadings from multiple development projects. The front-end costs for constructing the structural BMP are assumed by the developer and/or the local government entity that administers the regional BMP plan. BMP capital costs can then recovered from upstream developers on a pro-rata basis as development occurs. Individual regional BMPs are phased in as development occurs rather than constructing all regional facilities at one time. Maintenance responsibility for regional structural BMPs can be assumed by the developer (or designee with certified maintenance bonds) or by the local government. The regional approach addresses concurrence for the entire watershed while the onsite approach does not address this issue. The regional approach is also shown in Figure A-8.

In developing stormwater and watershed management programs during the 1970s, local governments often elected to use the piecemeal approach because it required no advanced planning and, therefore, appeared relatively easy to administer. While the lack of planning requirements does give the piecemeal approach an up-front advantage, in comparison with the regional approach, the long term disadvantages outweigh this benefit.

A regional BMP system offers benefits that are equal to or greater than onsite BMP benefits at a lower cost. Most of the advantages of the regional approach over the onsite approach can be attributed to the need for fewer structural facilities that are strategically located within the watershed. The specific advantages of the regional approach are summarized below



NOTES:

1. DICA IS DIRECTLY CONNECTED IMPERVIOUS AREA.
2. RECHARGE/INFILTRATION SHOULD BE ATTAINED WHEREVER POSSIBLE.
3. MULTI-STEP TREATMENT MAXIMIZES REMOVAL OF BOTH SUSPENDED AND DISSOLVED POLLUTANTS.

Figure A-6. Best management practice "treatment train" concept (Reprinted Courtesy of the City of Orlando, FL).

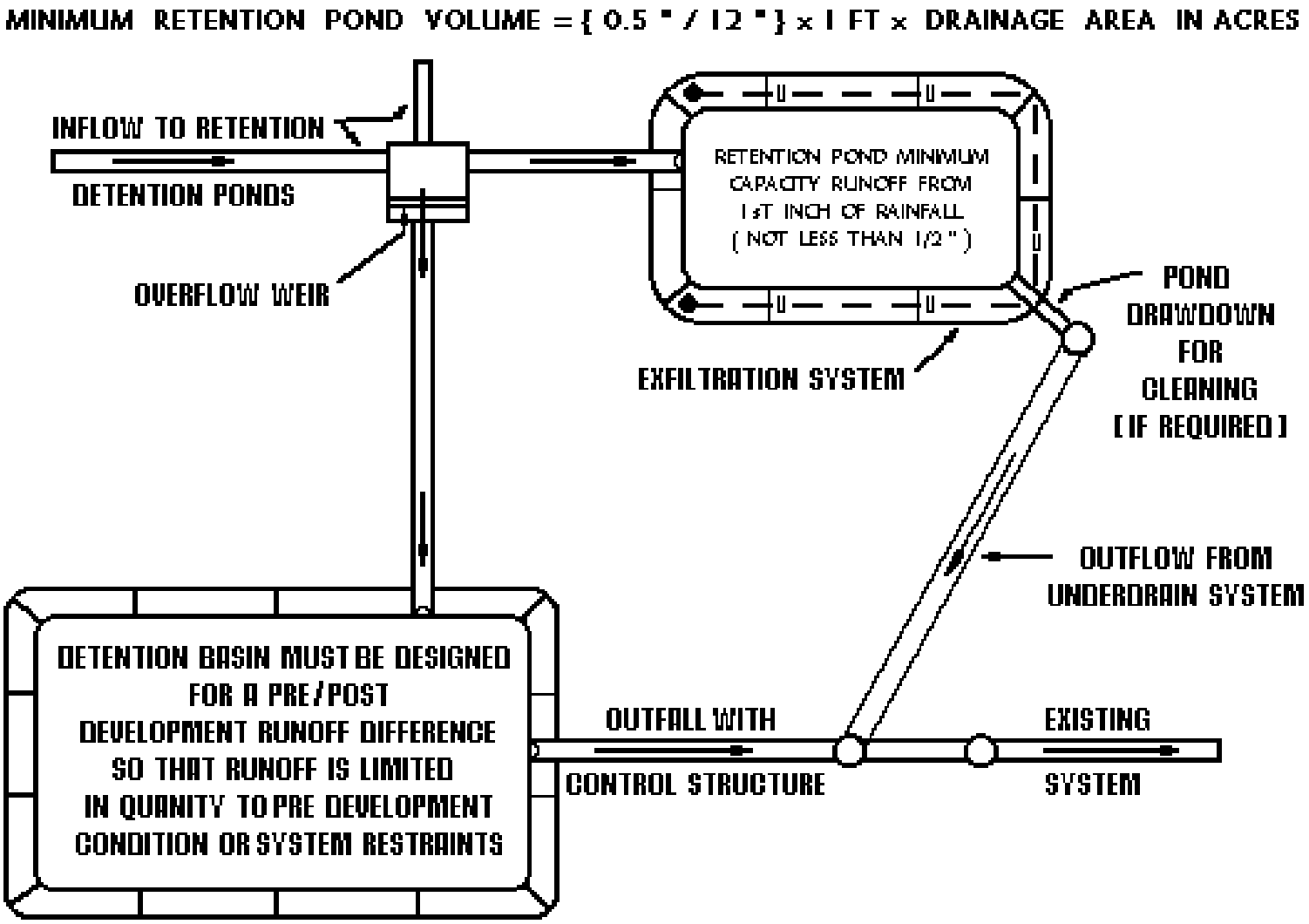


Figure A-7. Design for retention/detention facilities (Reprinted Courtesy of the City of Orlando, FL).

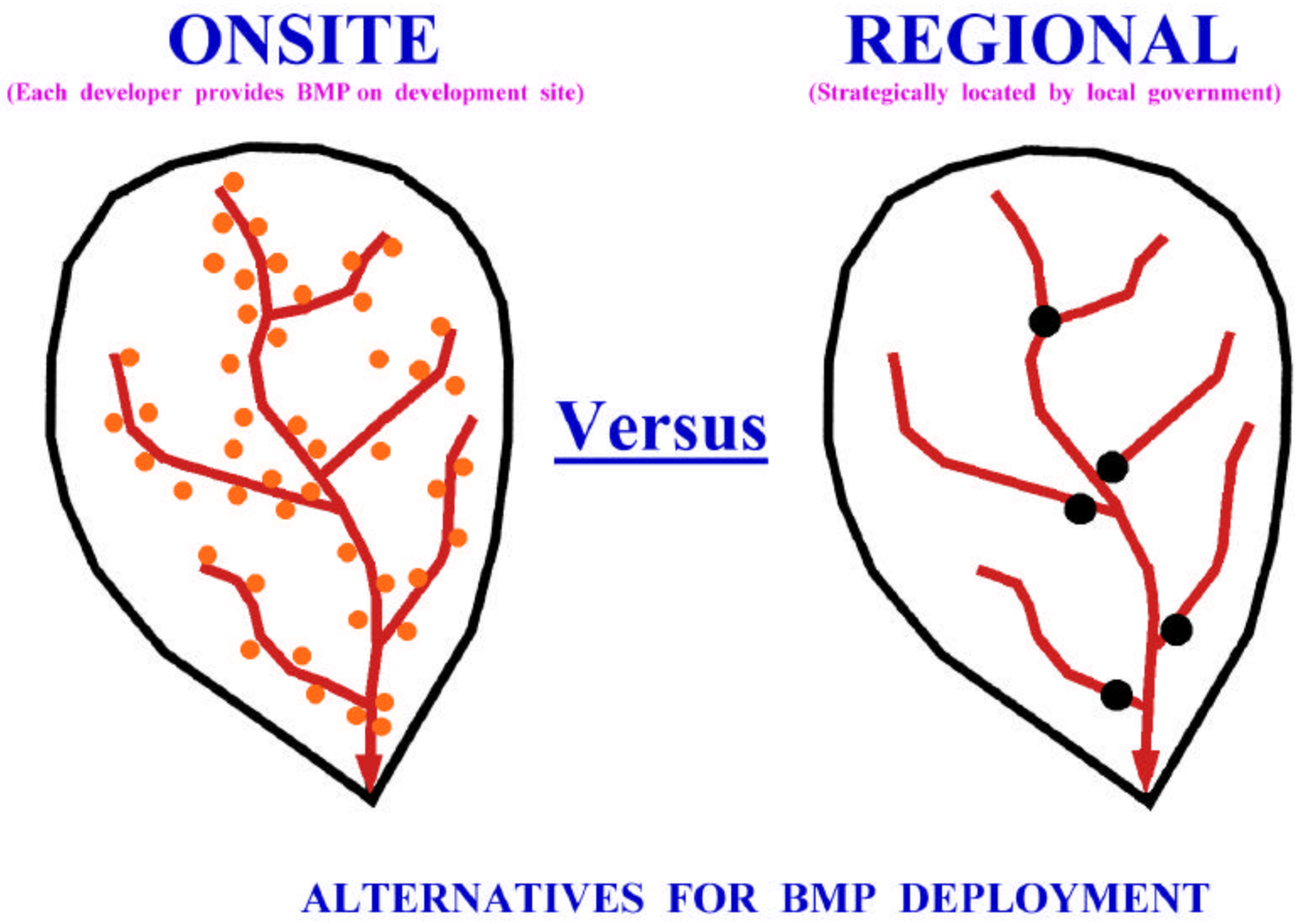


Figure A-8. Onsite versus regional best management practices (Reprinted Courtesy of the City of Orlando, FL).

- Reduction in maintenance costs: Since there are fewer stormwater detention facilities to maintain, the annual cost of maintenance programs are significantly lower. Moreover, because the regional detention facility recommended in the master plan can be designed to facilitate maintenance activities, annual maintenance costs are further reduced in comparison with onsite facilities. Examples of cost saving design features that are typically only feasible at regional BMP facilities include: access roads that facilitate the movement of equipment and work crews onto the site (by comparison, detention facilities implemented under the onsite approach are often located in residential backyards), additional sediment storage capacity (e.g., sediment forebay) to permit an increase in the time interval between facility clean-out operations, and onsite disposal areas for sediment and debris removed during clean-out.

- Greater reliability: A regional BMP system will be more reliable than an onsite BMP system because it is more likely to be maintained. With fewer facilities to maintain and design features that reduce maintenance costs, the regional BMP approach is much more likely to result in an effective long-term maintenance program. Due to the greater number of facilities, the onsite BMP approach tends to result in a large number of facilities that do not get adequate maintenance and, therefore, soon cease to function as designed. Many municipalities start off with the onsite approach but eventually switch to the regional approach to address the lack of maintenance of the onsite systems and to increase the overall effectiveness of the stormwater management program. Regional facilities, however, cannot be so large that incremental water quality protection is lost. For instance, if a regional detention facility is at the bottom of a 10 square mile basin, no water quality protection would be provided to the upstream rivers and streams as urbanization occurs. This could be detrimental to the existing plants and wildlife species. Another problem with an excessively large regional facility is the impact of the facility on existing wetlands. In rural areas, an excessively large pond would inundate large wetland areas which would make permitting of the structures extremely difficult. Experience shows that a regional pond should be limited to a 100 to 600 acre tributary area.

- Opportunities to manage existing non-point pollution loadings: Nonpoint pollution loadings from existing developed areas can be affordably controlled at the same regional facilities that are sited to control future urban development. This is because the provision of additional storage capacity to control runoff from existing development in the facility's contributing area is reasonable in cost as a result of economies-of-scale. By comparison, the costs of retrofitting existing development sites with onsite detention BMPs to control existing nonpoint pollution loadings may be prohibitively expensive.

- Fairness to land developers: Land developers recognize that economies-of-scale available at a single regional BMP facility should produce lower capital costs in comparison with several onsite detention facilities. They

also tend to prefer the regional BMP approach because it eliminates the need to set aside acreage for an onsite facility other than pretreatment and conveyance to the regional pond. This could permit an increase in the number of dwelling units within the development site while still providing sufficient stormwater management. The additional cost of a pond sized for future development can be passed on to the developer. Developers can "buy" into the regional system and eliminate on-site BMP requirements, thus minimizing cost to the public. Regional facilities also offer the ability to maximize mining of fill material which will be necessary in the Lake Hart basin.

- Multi-purpose uses: Regional facilities can often be landscaped to offer recreational and aesthetic benefits. Jogging and walking trails, picnic areas, ball fields, and canoeing or boating are some of the typical uses. For example, portions of the facility used for flood control can be kept dry, except during floods, and used for exercise areas, football or soccer fields and softball or baseball diamonds. Wildlife benefits can be provided in the form of islands or preservation zones which allow observation of nature within the park schemes. Gradual swales can also be worked into the park concept to provide pretreatment around paved areas, such as parking lots or access roads. Figure A-9 illustrates a typical multi-purpose stormwater facility.

Best Management Practices Implementation Considerations

In determining the best stormwater management facility or combination of facilities (treatment train), various factors need to be considered. Examples are:

- Physical constraints or requirements of the site such as permeability of the soil, the location of the wet season high water table, and the amount of land available on the site to construct the facility.

- Permitability of the facility or facilities.

- Needed benefits to solve problems and guide future development in a given area.

- Benefits provided by the facility such as control of peak discharge for flood control, reduction in the total volume of discharge, groundwater recharge, erosion control, wetlands management, reduction of pollutant loads to receiving waters, and/or optimized maintenance. Table A-10 lists requirements and benefits that can be used as a guide in the selection of a stormwater BMP type.

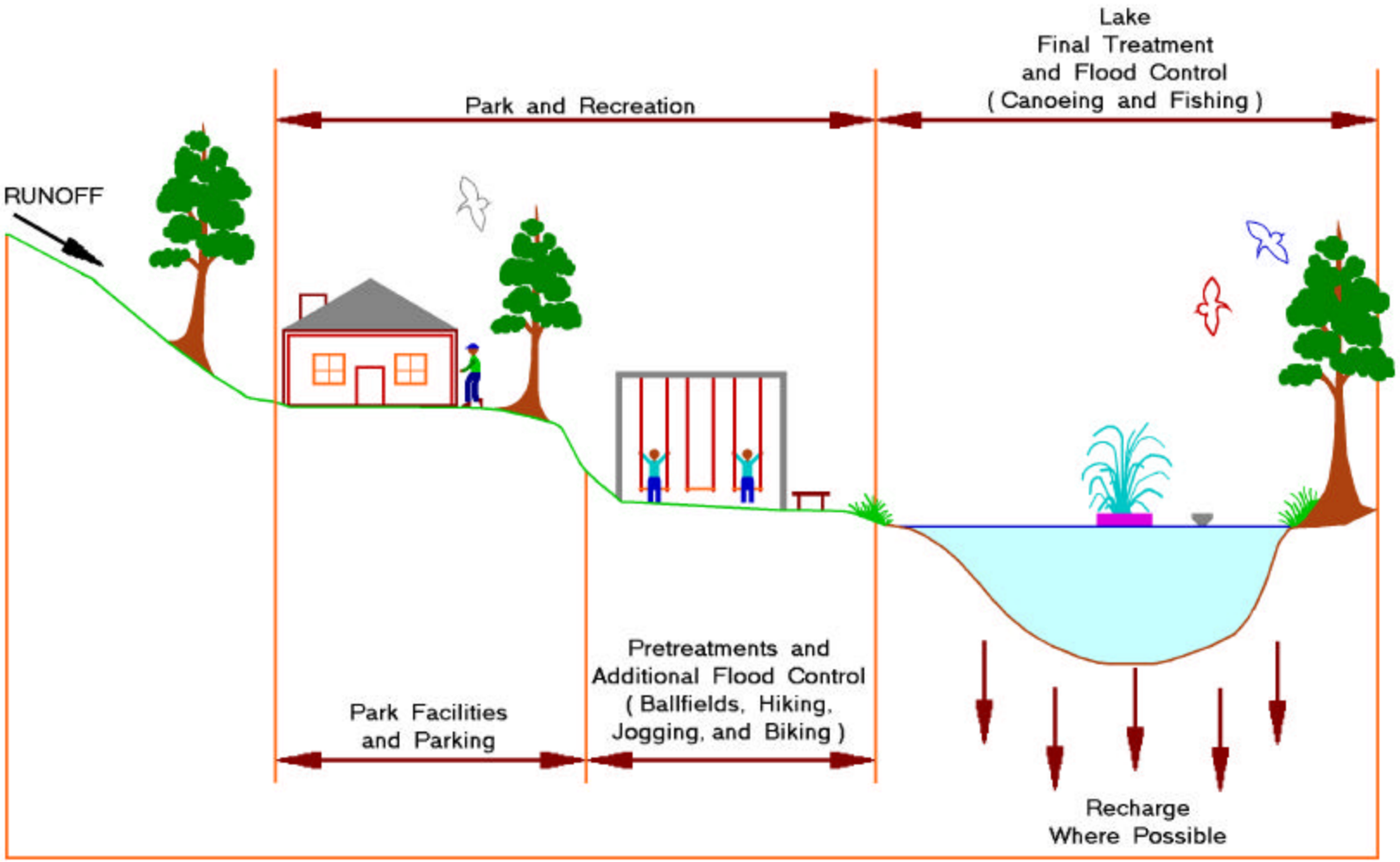


Figure A-9. Typical multi-use stormwater facility (Reprinted Courtesy of the City of Orlando, FL).

Table A-10. BMP Selection Features:: Requirements Versus Benefits

BEST MANAGEMENT PRACTICE					
Extended Dry Detention Ponds	Wet Detention	Exfiltration Trenches	Shallow Grassed Swales	Retention Basins	Filtration
Requirements:					
1. Available Space	1. Available Space	1. Limited Space Available	1. Moderate to Limited Space Available	1. Available Space	1. Available Space
	2. Water Table at or Near Pond Normal Pool Level	2. Water Table > 2 Ft Below Trench Bottom	2. Water Table > 1-2 Ft Below Swale Bottom	2. Water Table > 2-3 Ft Below Basin Bottom	2. Minimal Base Flow
	3. Relatively Impermeable Soils	3. Highly Permeable Soils	3. Permeable Soils		
Benefits:					
1. Peak Discharge Control	1. Peak Discharge Control	1. Aquifer Recharge	1. Peak Discharge Control	1. Peak Discharge Control	2. Aquifer Recharge
2. Load Reduction for Suspended Pollutants	2. Load Reduction for Dissolved and Suspended Pollutants	2. Pollutant Load Reduction On-Line	2. Volume Discharge Control	2. Volume Discharge Control	
3. Multiple-Use Park Areas	3. Aesthetic Permanent Pool and Fountain		3. Aquifer Recharge	3. Aquifer Recharge	
	4. Wildlife Habitat		4. Pollutant Load Reduction Off-Line or On-Line	4. Pollutant Load Reduction Off-Line or On-Line	
	5. Multi-Use Park Areas		5. Pre-Treatment	5. Multiple-Use Park Areas	

Recommended Best Management Practices

Introduction

The previous section titled "Evaluation of Best Management Practices" presented a discussion of various BMP types, and their benefits and limitations. The recommended BMPs, as discussed in the section, are proposed to become the foundation for a South East Annexation Area (SEAA) Stormwater Management Manual (SWMM). As already noted, two general categories of controls can be implemented to improve or enhance stormwater runoff with respect to water quality and water quantity (flooding). Structural controls are constructed facilities that treat, store, or convey stormwater runoff. Non-structural controls, on the other hand, focus on the prevention of pollution and the reduction of runoff. This section presents the recommended BMP treatment train.

The BMPs discussed in the previous section were screened for applicability to the Lake Hart basin study area based on site constraints, cost-effectiveness, efficiency, maintenance requirements, and current OUSWMM guidelines. Since the basin is largely undeveloped with few existing problems, the focus of the alternative analysis was planning regional facilities for the control of runoff from future development (quality and quantity control). The Lake Hart basin has the following physical characteristics:

1. Relatively flat terrain.
2. High groundwater table.
3. Need for flood storage.
4. Need for treatment of solids and soluble pollutants.
5. Need for fill for development and improvement projects.

Because of these physical characteristics, wet detention BMPs were considered to be the most appropriate control measures to meet the program goals.

Based on the LOS goals of the program, system constraints, SFWMMD permitting requirements, the Narcoossee Road improvements, and developer needs, a BMP Treatment Train has been formulated with three major components: DCIA minimization, pretreatment (0.25 inches) and regional wet detention ponds.

OUSWMM requires that wet detention facilities use a two pond system. The first pond uses retention to provide water quality treatment and the second separate pond uses detention for flood control. Because of the high groundwater table in the Lake Hart basin developable areas (typically one to two feet below the ground surface), deeper retention pond systems (two to four feet) may not function as desired. Therefore, shallow pretreatment practices may be incorporated into landscaping swales and lot grading plans as an alternate. The BMP treatment train would build upon the foundations of OUSWMM by providing nearly equivalent innovative technology considerations for areas with these site constraints:

- Lakes as receiving waters.
- Karst topography.

- Twenty-four percent of the basin is comprised of wetlands.

The BMP treatment train for the Lake Hart basin would consist of several pretreatment practices primarily within the secondary stormwater management system in series with regional wet detention ponds protecting the PSWMS. This innovative approach will achieve both the water quantity and water quality goals of OUSWMM while allowing for a cost-effective regional facility concept for future development. In addition, this concept is consistent with annexation agreements between the City, County, and local land owners. The recommended BMPs (pretreatment and wet detention) for the Lake Hart basin are discussed below.

Pretreatment Best Management Practices

The pretreatment BMPs are a series of structural and non-structural controls that will provide a reduction in runoff volumes and/or pollutant loads from urbanized areas prior to their discharge into the regional wet detention ponds and the downstream wetlands. The structural pretreatment BMPs will provide treatment for approximately 0.25 inch of runoff over the tributary area. Structural controls include retention swales with raised inlets to allow overflows, wet detention ponds, and oil-water separators for individual areas. Non-structural BMPs include reducing DCIA by diverting rooftops and portions of driveways and parking lots to shallow, grassed, or landscaped swale areas, and runoff pollutant source reduction methods -- many of which are voluntary but would help to achieve benefits. The recommended pretreatment BMPs are discussed below.

Minimization of Directly Connected Impervious Area

Minimizing DCIA involves ensuring that as much runoff as possible from impervious areas is routed over relatively large pervious areas and, in some cases, choosing an alternative surface to pavement or concrete that allows for some degree of infiltration. Figure A-10 is an illustration of a parcel that has been modified to convert a portion of the DCIA into non-directly connected impervious area by rerouting the roof gutters over the lawn (properly graded between houses). A portion of the DCIA could be converted to pervious area by using a porous surface.

Landscaped Swales and Grass-Lined Swales

Landscaped swales should be used around parking lots, houses, and other structures. The swales will provide pretreatment and also provide conveyance to larger secondary or primary stormwater management systems. Properly designed swales are useful for proper grading around houses as well as detention/retention prior to discharge into a

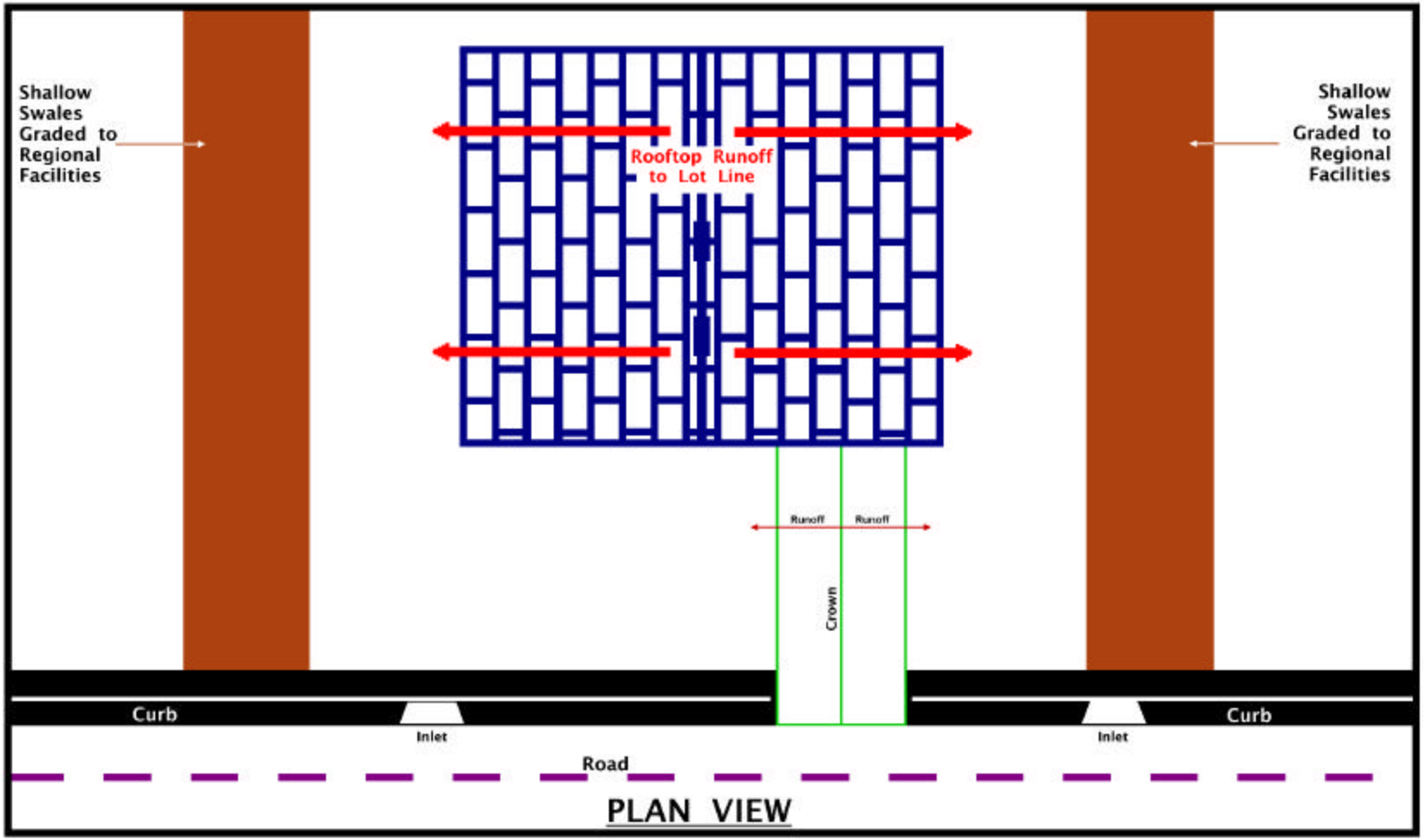


Figure A-10. Minimization of directly connected impervious area and use of grass lined swales. (Reprinted Courtesy of the City of Orlando, FL).

secondary or primary system. Fill from the shallow swale area may be used elsewhere on the property to improve the grading plan. Landscaped swales would typically be 0.5 to 1.0 foot deep and should have side slopes no steeper than 4:1 (H:V), with side slopes of 6:1 or greater being less noticeable and more attractive.

Grass-lined swales should be constructed around parking lots and commercial centers as recessed planters for landscaping. The swales could be part of the landscaping and incorporate raised inlets into the design, which will allow for the initial 0.25 inch retention volume for pretreatment. Although groundwater tables in the developable area are generally within one to two feet of the surface, recovery times for retention volumes of approximately 0.25 inch should be sufficiently small to allow the use of limited retention. Minimum infiltration rates of 0.1 inch/hour are expected to be advisable, allowing a relatively quick drawdown. Swales incorporated within commercial areas can enhance aesthetics and be used as credit towards green space and landscaping requirements. Figure A-11 shows an example of a landscaped swale with a raised inlet. Runoff will serve to reduce irrigation needs.

Curb Connections to Swales

Connections from the curbs to roadside swales should be provided to route street flow to grass-lined swales before discharge to the secondary or primary stormwater management system. Because roadway runoff may contain a greater pollutant load than runoff most other surfaces, providing swale pretreatment of roadway runoff will reduce pollutant loads to the regional ponds and improve the overall efficiency of the BMP treatment train. The swale space required for pretreatment of roadway runoff in roadside swales can be incorporated into OUSWMM green space requirements and be used to enhance the aesthetics of the roadways.

The connections between the curb and the swale can be implemented in two ways. The first method is to provide regularly spaced flumes in the curb as the connection to the swale. This method would be less expensive and will be aesthetically appealing. Another way, as illustrated in Figure A-12, is to provide a four to six inch diameter pipe approximately every 200 feet between the curb and the swale. This method may provide better erosion control at the edge of the curb by preventing water from flowing over the turf between the curb and the swale. The disadvantage to this method is the potential for clogging of the small pipes and thus the requirement for increased maintenance.

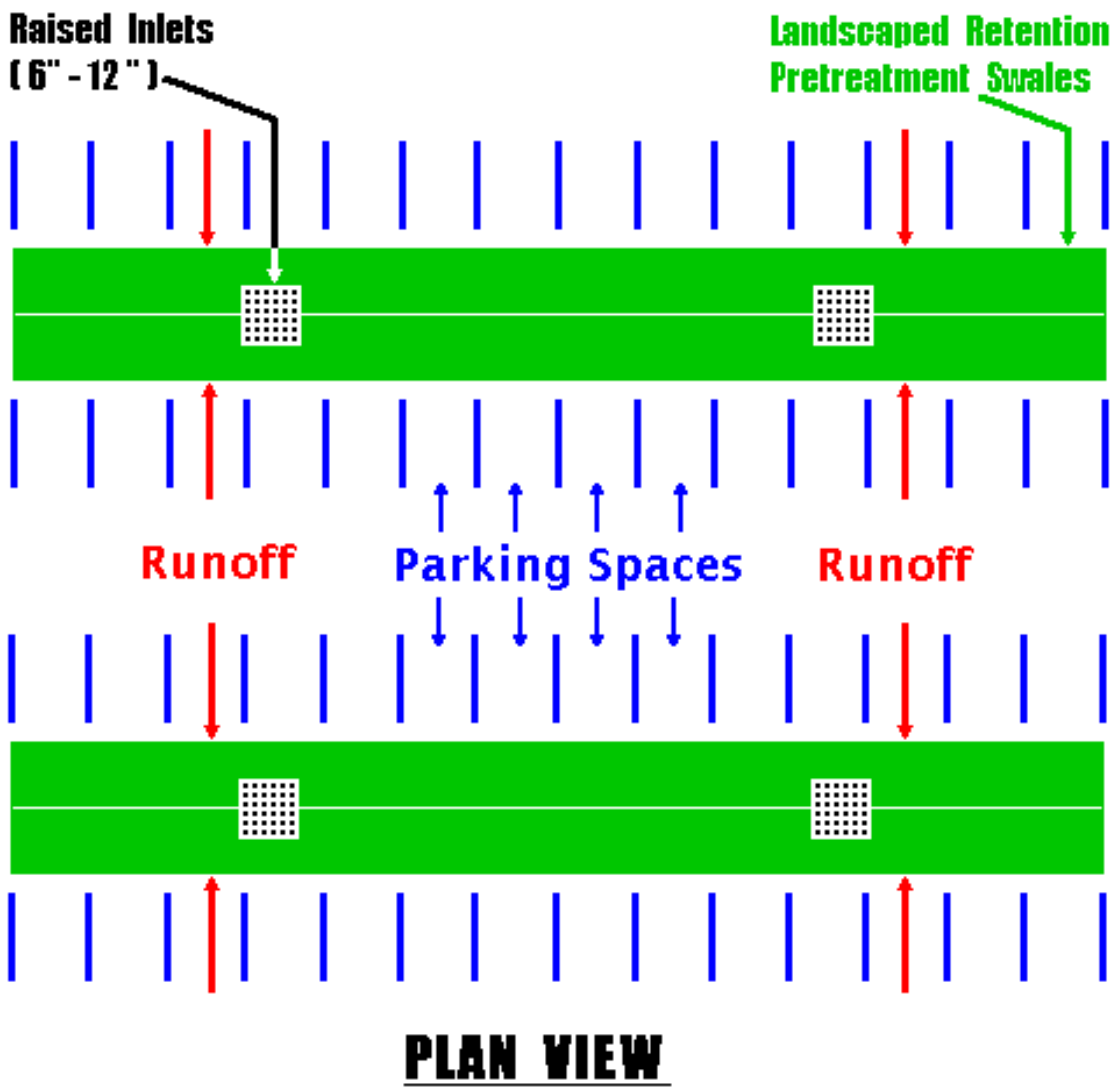


Figure A-11. Landscaped retention pretreatment swales with raised inlets (Reprinted Courtesy of the City of Orlando, FL).

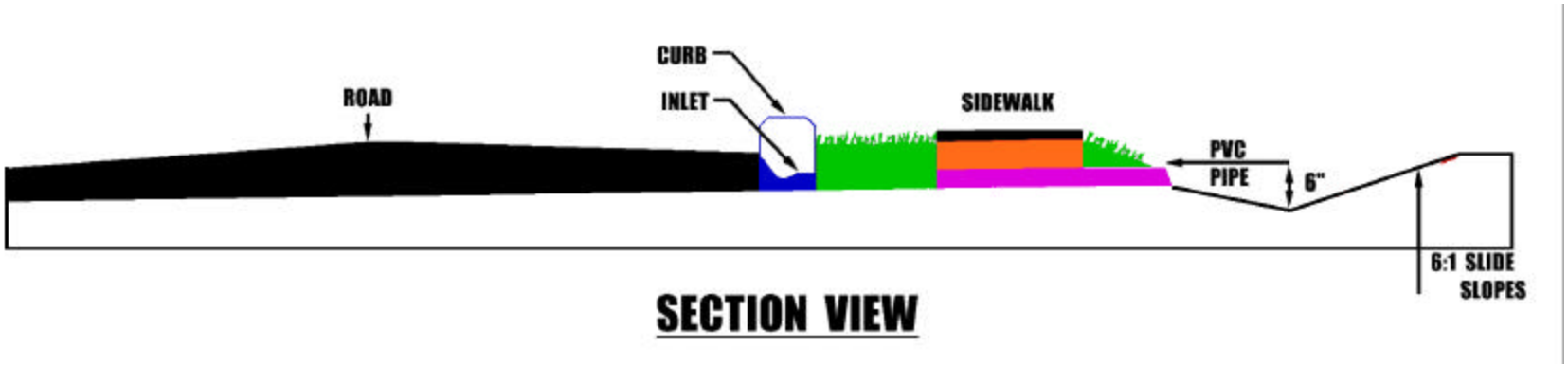


Figure A-12. Use of pipe to convey roadway runoff to roadside swale (Reprinted Courtesy of the City of Orlando, FL).

Capture Ratios of Swales

The Storage, Treatment, Overflow, and Runoff Model (STORM) was used to evaluate the effectiveness of the pretreatment swales at capturing a percentage of the annual runoff and, therefore, the annual pollutant volume. STORM is a continuous simulation model developed by CDM for the United States Army Corps of Engineers (USACOE) Hydrologic Engineering Center (HEC) that translates a continuous, long-term rainfall record (1942 through 1993 was used for this study) into a series of runoff events based on hydrologic conditions, routes the runoff through a "treatment facility," and calculates statistics on outputs such as runoff volumes and pollutant loads.

In the mode used for this analysis, the characteristics of the treatment facility were described by a storage volume(e.g., 0.25 inches) and a treatment rate. The treatment rate in this case is equal to the infiltration rate in the swale normalized to the total contributing area. Characteristic swales were established for both residential and commercial areas using the swale configuration previously discussed. Because there will be variability based on site conditions and application, a range of treatment rates and storage volumes around the expected values were used to establish the sensitivity to the results. Results from these simulations are shown in Figure A-13 for medium density residential areas. The average annual runoff volume capture ratio is approximately 60% for a 0.25 inch retention volume and typical soils in the area. Treatment efficiencies for the BMP treatment train were adjusted accordingly since the wet detention ponds would treat and attenuate about 40% of the average annual runoff volume.

Oil-Water Separators

Potential sources of high oil and grease, such as gas stations and light industrial land uses, should be required to provide either oil-water separation devices or off-line retention. Off-line retention offers additional pollutant removal benefits beyond oil and grease removal, provides additional volume control, and requires typical maintenance. However, off-line retention is also more space intensive and may result in groundwater contamination if sufficient quantities of pollutants are released into the retention basin. Oil-water separators require less space and initial capital expense. They need to be maintained at least monthly and offer some control of floating and settleable solids.

Sediment Forebays

Sediment forebays should be designed into the regional wet detention ponds. Forebays are designed to be easier to maintain than the rest of pond. The use of forebays will lower maintenance costs and extend the time between maintenance dredging of the remainder of the pond. Figure A-14 shows a typical forebay.

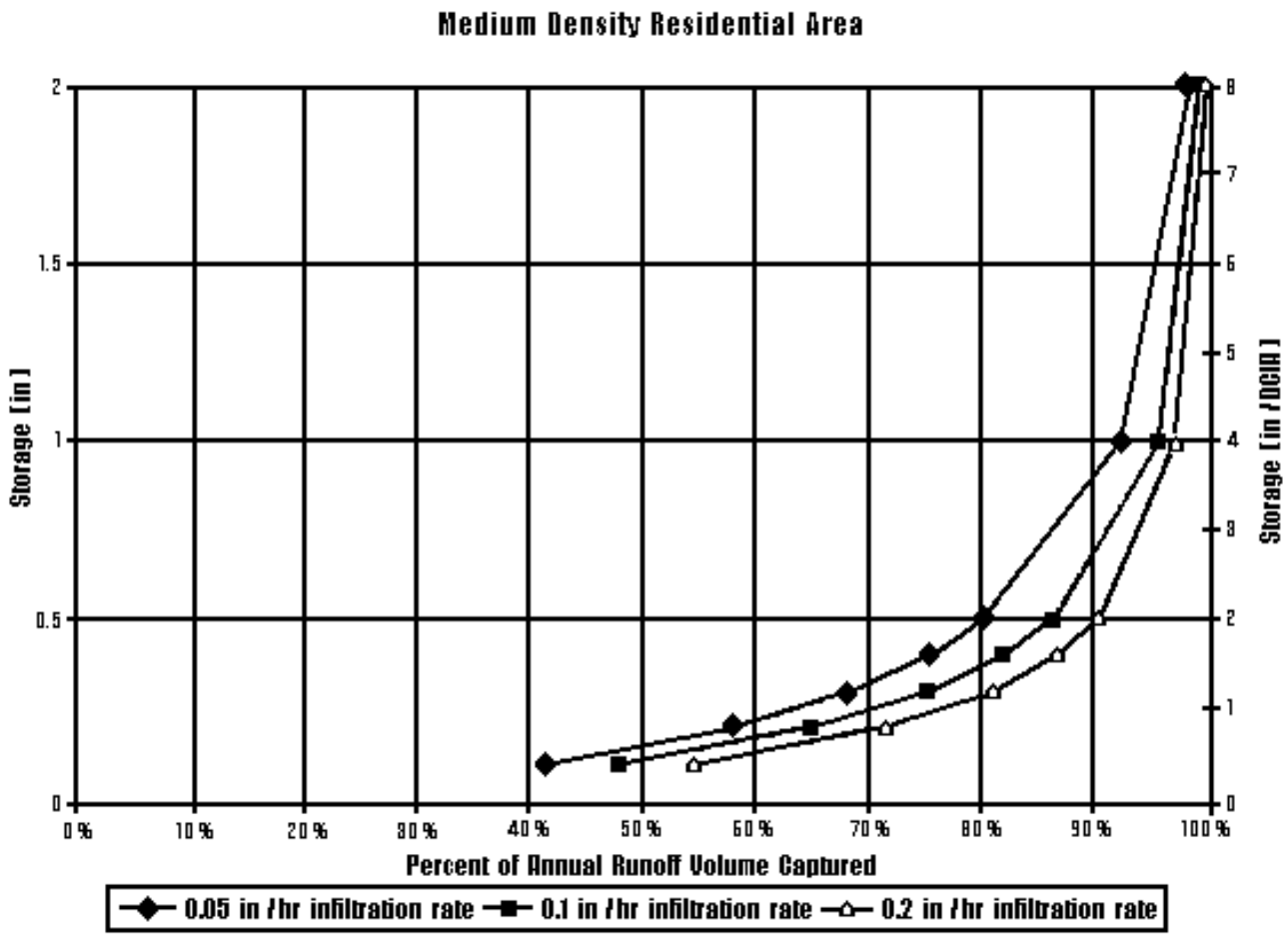


Figure A-13. Percent of annual runoff volume captured for medium density residential (Reprinted Courtesy of the City of Orlando, FL).

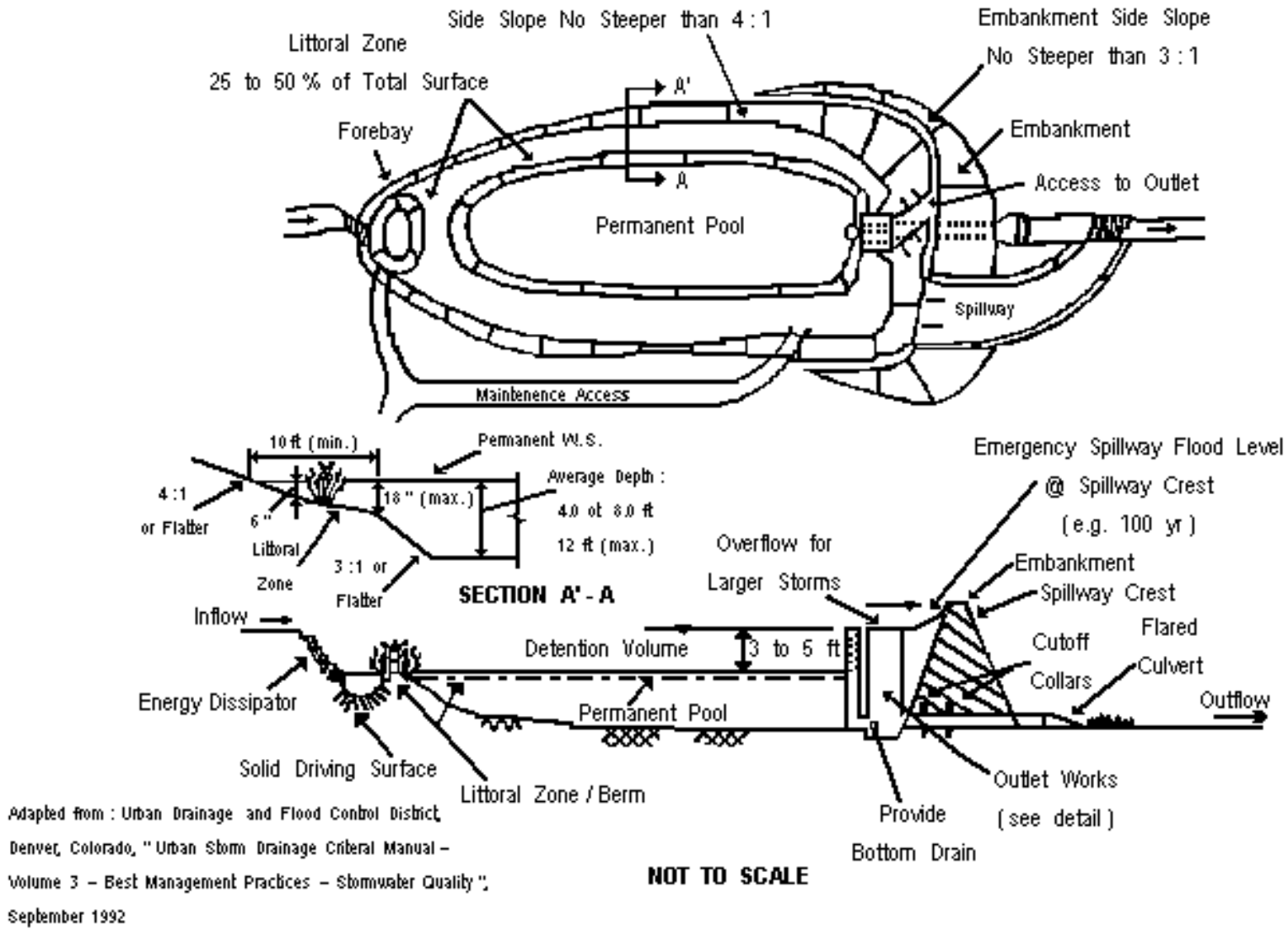


Figure A-14. Typical wet pond with forebay (Reprinted Courtesy of the City of Orlando, FL).

Source Reduction

Control of pollutants at the source of generation is a very effective and economical pretreatment BMP. Source reduction requests for illicit corrections and illegal dumping are needed for the EPA NPDES permit order. Source reduction relies almost entirely on the education of citizens living and working in the area. Examples of education programs for source reduction of pollutants are fliers instructing how to use the minimal amount of lawn fertilizer and pesticide and stenciled messages on storm drains.

Wet Detention Location and Sizing Criteria

The following paragraphs discuss the general criteria used to site the proposed regional facilities as well as the methodologies used to size them.

Regional Facility Location Criteria

A major component of this MSMP was the cooperative effort between the City of Orlando and private property owners during the siting of the proposed regional facilities. This was accomplished through a series of group and individual meetings with the major property owners and their engineers to discuss the advantages and disadvantages of each proposed regional facility location. Criteria discussed during these meetings included siting the regional facilities such that program goals of flood control, water quality protection, aquifer recharge and wetland protection could be achieved. In addition, other implementation considerations were incorporated, such as maximizing road frontage, developable property, waterfront property, and tributary area served. Additionally, accessibility of the regional facilities by maintenance crews was considered during the siting process. From an environmental perspective, the regional facilities were sited adjacent to wetlands (wherever possible) and conceptually designed with V-notched weirs that would discharge into the wetlands in such a manner that the existing wetlands would be preserved.

Coordination of the Narcoossee Road widening project with proposed development in the study area was also a key factor in siting the proposed regional facilities. There are potentially seven regional ponds that would provide stormwater management for both Narcoossee Road and surrounding proposed developments. By serving a dual purpose, fewer ponds would be required which represents capital operation and maintenance cost savings to both the City and private property owners.

Regional Facility Sizing Methodology

The proposed regional facilities were sized using the guidelines documented in the City of Orlando Urban Stormwater Management Manual (OUSWMM) and the SFWMD Management and Storage of Surface Waters (MSSW) Permit Information Manual Volume IV. A discussion of these guidelines and their application to wet detention is present below. Two volumes are used in sizing a wet detention system. They are the live pool (sometimes called treatment pool volume) and the permanent pool. Combined, these two components have a regulated discharge to detain water and settle pollutants to achieve the desired water quality goals.

Live Pool Volume

Chapter 5.2.1 of the SFWMD MSSW Permit Information Manual provides guidelines on determining the required treatment pool volume for a wet detention system. The requirements state that "wet detention volume shall be provided for the first inch of runoff from the developed project, or the total runoff of 2.5 inches times the percentage of imperviousness, whichever is greater". The same criterion is used in Chapter 2.8.4 of the OUSWMM. Therefore the live pool volume computed for each of the proposed facilities was determined using the following equations:

Maximum of

```
V SUB L ~ = ~ { R1*A*Ia } OVER { 12 ~ inch )foot }
```

```
V SUB L ~ = ~ { R2*A } OVER { 12 ~ inch )foot }
```

or

where:

V_L	=	Live pool volume (acre-feet)
R1	=	2.5 inches of rainfall
R2	=	1.0 inches of runoff
A	=	Tributary area (acres)
Ia	=	Average impervious area (percent)
	=	(NDCIA + DCIA)/100
NDCIA	=	Non directly connected impervious area (percent)
DCIA	=	Directly connected impervious area (percent)

Because of the high seasonal groundwater tables identified for the study area, the maximum treatment pool depth was assumed to be one foot above the permanent pool to ensure proper flood protection. This criterion became one of the key elements in determining the pond surface area requirements.

Live Pool Volume Bleed-Down Requirements

The criteria in the OUSWMM manual also requires that 50% of the live pool volume can be discharged in the first 60 hours following a storm event with total volume recovery occurring in 14 days. The bleed-down requirements presented in the SFWMD MSSW Permit Information Manual Volume IV (Chapter 7.2) are for a release of no more than 0.5 inches per 24 hours.

The SFWMD basis of review requires that bleed-down mechanisms be V-notches for wet detention systems. The discharge through a V-notch opening is a weir can be estimated by:

```
Q ~ = ~ 2.5*tan ( 2 ) 2 ) *H SUP { 2.5 }
```

where:

Q	=	Discharge (cfs)
2	=	Angle of V-notch (degrees)
H	=	Head on vertex of notch (feet)

Since SFWMD criteria specified that this bleed-down mechanism be sized to discharge one-half inch of detention volume in 24-hours, the following formula provides the required size:

```
2 ~ = ~ 2*tan SUP {-1} ~ {( 0.492*Vdet )} OVER H SUP {2.5}
```

where:

2	=	V-notch angle (degrees)
Vdet	=	One-half inch of detention volume (acre-feet)
H	=	Vertical distance from weir crest to vertex angle (feet)

For the Lake Hart MSMP, the SFWMD criteria were used for sizing the V-notch control weirs.

Permanent Pool Volume

Chapter 2.8.4 of the OUSWMM manual lists the following requirements for the permanent pool volume:

- "The volume in the permanent pool (below the maintained water level) must be sufficient to provide a residence time of at least 14 days. This volume may be determined as 2-inches over the impervious portion of the drainage basin, plus ½-inch over the pervious portion of the drainage basin"

- "A littoral shelf shall be incorporated into the facility from maintained water level or a depth of 2.5 feet at a slope no steeper than 6:1"

- "The facility shall be configured such that the mean depth is 3 to 10 feet. Recommended depth ratios are:"

Percent Area	Depth, feet
< 10	> 8
50-70	4-8
25-50	0-4

Using these requirements, the permanent pool volume was calculated as follows:

```
Vp~ = ~ {[A*Ia*R3+A*(1-Ia)*R4]} OVER {12 ~ inch)foot}
```

where:

Vp	=	Required permanent pool volume (acre-feet)
A	=	Tributary area (acres)
Ia	=	Average impervious area (percent)
	=	(NDCIA + DCIA)/100
R3	=	2.0 inches of rainfall over the impervious area
R4	=	0.5 inches of rainfall over the pervious area

There are no specified permanent pool volume requirements identified in the SFWMD MSSW Permit Information Manual. However, the SFWMD has identified similar criteria to that in the OUSWMM for geometric considerations of a wet detention system (Chapter 7.4). A summary of these criteria are as follows:

- The facility must have a minimum wet detention surface area of 0.5 acres.
- The wet detention facility should have a 2:1 length to width ratio (applicant can request a waiver of this criteria if there is a single owner, or the entities involves have a full time maintenance staff with an interest in maintaining the areas for water quality purposes).
- The littoral area should be shallower than six feet as measured below the control structure elevation. The littoral area shall be 20% of the wet detention area or 2.5% if the total wet detention area (including side slopes) plus the contributing area. The SFWMD also recommends that 25 to 50% of the wet detention area be deeper than 12 feet.
- Side slopes shall not be steeper than 4:1.
- Bulkheads shall be allowed for no more than 40% of the shoreline length, plus compensating littoral zone must be provided.

For planning purposes, the required depth of the permanent pool for each facility was estimated for the OUSWMM criteria or as 70% of the area would have a depth of six feet and 30% of the area would have a depth of one foot which results in an average depth of 4.5 feet. Individual ponds could be constructed deeper to the SFWMD maximum values if additional fill is needed. This would provide a longer residence time. Aerating fountains are also recommended to control water quality (higher dissolved oxygen).

Flood Control Requirements

Chapter 2.9 of the OUSWMM lists the flood control requirements of the City. These requirements are summarized as follows:

- The additional volume of runoff generated by development shall be controlled and released at a rate not to exceed the peak rate for the site in the undeveloped condition. The design criterion shall be the 25-year/24-hour storm event.

- For landlocked primary basins, volumetric controls apply. The excess runoff from development for the 100-year/24-hour storm event shall be held on-site.

- Normally, the detention for flood control must be accomplished in an area separate from that used to provide pollution abatement. For the Lake Hart MSMP, this criterion was modified to include a second alternative by the City to allow single ponds with the pretreatment of 0.25 inches runoff onsite.

Chapter 2.10 of the OUSWMM addresses flood prone areas. Definitions included in this section include:

- The floodplain is the area inundated during the 100-year/24-hour storm event.

- The floodway is that portion of the floodplain which must be clear of encroachment in order to limit the increase in flood stage to one foot.

The requirements for flood prone areas as presented in this section are summarized as follows:

- Encroachment will be allowed within the 100-year floodplain, with compensating storage.

- All development within the 100-year floodplain established by FEMA or the City shall comply with the following:

- If the project is not within a 100-year flood prone area, an analysis shall be performed to establish the site's 100-year elevation.

- The design storm event to establish the 100-year onsite elevation shall be the 100-year/72-hour storm event.

- The minimum finished floor elevation shall be at least one foot above the elevation from the 100-year/24-hour storm, or at the maximum stage for the 100-year/72-hour storm.

- For commercial or industrial developments, flood proofing may be substituted for elevating the finished floor (careful consideration should be given prior to implementing this alternative).

- Compensating storage must be provided for all floodwater displaced by development below the 100-year/24-hour storm event. Compensating storage may be claimed in the retention/detention ponds provided it is above the maintained water elevations and berm elevations are such that the pond can be inundated during the 100-year storm and still provide 25-year flood protection.

- Off-site increases in flood stage and/or velocity will not be allowed by encroachment within a floodway. (The 100-year/72-hour design storm top width in flow should be considered as the floodway along the wetland tributaries.)

- A letter of map revision will be required for development within the defined FEMA floodplain.

Chapter 6 of the SFWMD MSSW Permit Information manual lists water quantity criteria. A summary of these criteria area is as follows:

- Offsite discharge rate is limited to rates not causing adverse impacts to existing offsite properties and historic discharge rates, rates determined in previous SFWMD permit actions, or rates specified in SFWMD criteria.

- Unless otherwise specified by SFWMD permits or criteria, a 25-year/72-hour storm event shall be used in computing offsite discharge rates. Alternate discharge rates can be requested from the SFWMD if adequate justification can be provided.

- Building floors shall be above the 100-year flood elevation as determined from the FEMA FIRM or from the 100-year/72-hour storm event. Lower elevations will be considered by the SFWMD for non-residential uses.

- In cases where flood protection of roads is not specified by local government, the 5-year/24-hour storm event shall be used for flood protection. The minimum roadway crown elevation shall be at least two-feet higher than the control elevation.

- No net encroachment into the floodplain, between the average wet season water table and that encompassed by the 100-year event, which will adversely affect the existing rights of others, will be allowed.

Based on these criteria, the regional facilities were sized so that peak flows and elevations from the 25-year/24-hour and 100-year/72-hour design storm events were not increased at any of the ten discharge points. This was accomplished using the stormwater model developed for this study.

Regional Stormwater System Review Considerations

A critical element in the implementation of the Lake Hart basin MSMP will be the review by the City of the stormwater facility design plans from developers to ensure that recommendations for the Lake Hart basin are being satisfied. Ultimately a detailed checklist should be prepared that will assist reviewers in determining if the recommendations are being met. The items listed below are an outline for a preliminary checklist to be filled in by the designer and used by the reviewers:

1. Basin number.
2. Tributary area (ac).
3. Land use and soil parameter consistency.
4. Pretreatment volume (ac-ft).
5. Pond treatment volume (live and permanent pools, ac-ft).
6. Forebay.
7. Pond flood volume (ac-ft, this can include the live treatment volume).
8. Connection to PSWMS (method).
9. Control structure (details).
10. Flow, stage, and velocity (summaries).

After the completion of this study, the checklist and more detailed statistics could be produced to provide the step-by-step outline needed for implementation.

Water Quality Results

Introduction

The Lake Hart basin MSMP included an evaluation of nonpoint source pollutant loads caused by land use changes and their associated BMPs. The nonpoint source pollution assessment was performed to estimate the annual average and seasonal stormwater pollutant loads for the twelve EPA NPDES indication parameters, including biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), total nitrogen (TN), total Kjeldahl nitrogen (TKN), total phosphorus (TP), dissolved phosphorus (DP), cadmium (Cd), copper (Cu), lead (Pb), and zinc (Zn). From this analysis, a base set of pollutant loads was established under existing land use conditions with the existing BMPs. Under future land use conditions, pollutant load projections are made with both the existing and proposed BMPs and compared to the existing loads. The relative changes in present and future pollutant load projections are used as an indicator of the potential for water quality impacts. This comparison then helps to identify the effectiveness of SFWMD and City criteria for controlling pollutant load increases as well as assisting in determining the level of control that will be required in the future.

Scenarios

Average annual nonpoint pollutant source loads from the study area were projected using the Watershed Management Model (WMM) described earlier. NPS pollutant loadings projected with WMM are based on annual runoff volumes and storm event mean concentrations (EMCs) for each pollutant type and each land use category. Pollutant loads were projected under both present and future land use conditions using the following scenarios:

- Existing land use with existing BMPs: This scenario is best described as "existing conditions" and will be used in the evaluation as the baseline for comparison.

- Future land use with existing BMPs: This scenario represents the loading from future land uses if no new BMPs are built. When compared with the results from existing land uses in the existing BMPs, this scenario illustrates the increases in loading due to future growth if such growth is not regulated.

- Future land use with existing BMPs and proposed BMPs: This scenario represents the loading for future land uses once the proposed regional wet detention facilities with pretreatment have been constructed. When compared with the results from future land uses without control, this scenario illustrates the reduction in pollutant loading from the implementation of the recommended plan.

The recommended BMP Treatment Train is discussed in the previous section titled "Recommended Best Management Practices." The removal efficiencies composite of retention swales and wet detention is based on the average annual runoff volume capture estimated with STORM.

Future Land Use with Recommended BMPs

As discussed earlier, a BMP treatment train is recommended for the future development in the Lake Hart basin in order to minimize water quality impacts. The primary structural controls are 0.25 inch of pretreatment swale retention volume in series with regional wet detention ponds. Removal efficiencies were calculated for these BMPs in series based on primarily a volumetric reduction from the retention plus an additional removal of the remaining pollutants from the wet detention ponds. Combined removal efficiencies were projected to range from 72% for TKN to 96% for TSS. The average annual and seasonal pollutant loads under existing and future land use (with recommended BMPs) conditions are presented in Table A-11.

Compared to existing loads, future annual nonpoint source oxygen demand loads with the recommended BMPs are projected to increase for BOD and decrease for COD and future annual sediment loadings are projected to decrease or remain approximately the same. BOD loads are projected to be approximately 1.1 times greater than existing

loads and COD loads are projected to decrease by approximately 0.9 times. TSS loads under future conditions with the recommended BMPs are projected to be approximately

0.4 times the existing TSS loads and TDS loads are projected to be approximately 0.9 times.

Total average annual nonpoint source nutrient loadings are projected to decrease for one of the four constituents. The other three are projected to decrease only slightly, therefore, remaining virtually the same. Total-P, TKN and NO_2+NO_3 are projected to approximately remain the same. Dissolved-P is projected to be approximately 0.9 times the existing loads.

Annual nonpoint source heavy metal loadings are projected to decrease for one of the four constituents. Only one constituent increases and the other two remain approximately the same. Lead, is projected to be approximately 0.7 times lower. Zinc loadings are projected to be approximately 1.3 times greater. Copper and cadmium remain approximately the same as existing loads.

In summary, five of the 12 constituents are projected to decrease and five are projected to remain the same under future land use conditions with the recommended BMPs. Loadings of two of the constituents are projected to be greater than existing loadings. The constituents projected to increase are BOD and zinc. BOD increases can be controlled by the use of fountains (i.e., oxygenation) in the wet detention ponds. Slight increases in zinc loadings are not expected to be a problem because wetland plants utilize this metal in a beneficial manner. As previously shown, the overall pollutant loadings from future land use conditions with the recommended BMPs suggest that the recommended BMPs will be effective at minimizing future impacts to water quality.

Table A-11. Average Annual Loadings for Existing and Future Land Use Conditions with Recommended Best Management Practices for the Future Condition

Basin: Entire Lake Hart Study Area

Constituent	Existing Land Uses With Existing BMP's			Future Land Uses With Recommended BMP's		
	Wet Season Loads in Surface Runoff (lbs/yr)	Dry Season Loads in Surface Runoff (lbs/yr)	Annual Loads in Surface Runoff (lbs/yr)	Wet Season Loads in Surface Runoff (lbs/yr)	Dry Season Loads in Surface Runoff (lbs/yr)	Annual Loads in Surface Runoff (lbs/yr)
BOD	90,687	69,821	160,508	102,622	79,009	181,631
COD	997,277	767,815	1,765,092	890,577	685,665	1,576,242
TSS	214,771	165,355	380,126	85,860	66,105	151,965
TDS	2,361,045	1,817,796	4,178,841	2,171,423	1,671,803	3,843,226
Total P	3,906	3,007	6,913	3,795	2,921	6,716
Dissolved P	1,916	1,475	3,391	1,658	1,276	2,934
TKN	25,203	19,404	44,608	24,713	19,027	43,741
NO_2+NO_3	7,652	5,891	13,544	7,434	5,724	13,158
Lead	125	96	221	90	69	159
Copper	66	51	116	64	49	113
Zinc	196	151	347	248	191	439
Cadmium	1	1	2	1	1	2
Runooff (ac-ft/yr)	8,529	6,567	15,096	12,372	9,526	21,898
Runoff (in/yr)	14	10	24	20	15	35
% Impervious			41			68
Basin Area (acres)			7,578			7,578

Water Quantity Results

Introduction

The driving force behind the need for the Lake Hart Basin MSMP was the City's desire to identify stormwater infrastructure needs in this urbanizing basin. Infrastructure needs include improvements necessary to resolve existing problems in the PSWMS as well as avoid potential problems resulting from proposed development. In this study area includes over 4,500 acres of developable property. In terms of water quantity, problems may be in the form of building or road flooding or areas with excessive velocities that could cause significant erosion. For these types of analyses, stormwater model calibration is valuable. Model calibration is essentially a "reality check" to show that the modeled system adequately represents the actual system.

Once SWMM was calibrated, it was used in this plan to identify current levels of service (LOS) and infrastructure needs to accomplish the desired LOS. This was done by comparing peak flood stages from the model results with known critical elevations, such as top-of-road elevations, and any resulting overtopping was compared to the desired level of service for the determination of potential flooding problems and infrastructure or ordinance needs. Likewise, peak velocities in each element in the system were compared to threshold values for the determination of potential excessive velocity problems. Another important element of this study was establishing PSWMS flood stages under future land use conditions and existing hydraulic conditions. Existing and future flood stages are important for guiding future development and determining the relative

Model Calibration

Model calibration refers to the adjustment of model parameters so that the model results (e.g. peak water surface elevations) are in reasonable agreement with a set of observed data. A reasonable range of values for the adjustment of parameters is established through review of the hydrologic literature, and adjustments outside of those ranges are only made if some unusual hydrologic condition exists. The model is considered well-calibrated when it is in reasonable agreement with the data for a comparable independent event without any model adjustments. This process is called model verification. Calibration and verification are desirable to establish a "reality check" of predicted stages, flows, and velocities.

The two primary data requirements for model calibration are gauged rainfall and runoff for the study area. When selecting a calibration storm, the rainfall and runoff data must be sufficiently documented in appropriate time intervals so that variations in rainfall intensity and the associated runoff can be described. Data should be recently acquired so that the current conditions existing in the study area are accurately represented. Additionally, to account for the spatial distribution inherent in Florida rainfall, data should be available at various rainfall stations throughout the study area.

For this study, three rainfall stations were identified within one mile of the study area (Boggy Creek rain gauge, Lake Hart rain gauge, and the Orlando International Airport rain gauge). These three stations record rainfall data on a continuous basis. Because of their proximity to the study area, they were considered to be acceptable for use in model calibration. The data collection phase of the Lake Hart Basin MSMP revealed that flow data were not available for any site in the study area and stage data were limited.

Based on the available data, a normal water surface elevation of 77.0 feet-NGVD was selected as a initial condition in the stormwater model for Lake Nona, Red Lake, and Buck Lake. The normal water surface elevation presented in the Orange County Lake Index Report (77.6 feet-NGVD) was reduced based on the historical measurements obtained from Orange County.

A sensitivity analysis was performed to determine the influence the normal water surface elevation has on the simulated peak water surface elevations in Lake Nona, Red Lake, and Buck Lake. The normal water surface elevations selected for the three lakes were 75.5 ft-NGVD for the low end of the range (known invert elevation of discharge point) and 77.6 ft-NGVD for the upper end of the range (normal water surface elevation reported by Orange County). Using these ranges, the 100-year/72-hour design storm event was simulated for existing land use conditions. The resulting peak water surface elevation ranges were 78.3 to 80.0 ft-NGVD for Lake Nona and 79.4 to 80.1 ft.-NGVD for both Red Lake and Buck Lake.

Using the selected normal water surface elevation of 77.0 ft-NGVD, the simulated 25-year/24-hour peak water surface elevations for Lake Nona, Red Lake, and Buck Lake (from this study) were 78.5, 78.8, and 78.8 ft-NGVD, respectively. This is within 0.2 feet of the 25-year/24-hour peak water surface elevation for Lake Nona and within 0.1 feet of the 25-year/24-hour peak water surface elevations for Red Lake and Buck Lake obtained from the Lake Nona conceptual permit issued by the SFWMD.

Level of Service and Problem Area Definitions

For the 100-year/72-hour design storm event, the simulated peak water surface elevations were 79.5, 79.7, and 79.7 ft-NGVD for Lake Nona, Red Lake, and Buck Lake, respectively. For Lake Nona, the simulated 100-year/72-hour peak water surface elevation is 0.1 feet less than the 100-year peak water surface elevation obtained from FEMA. For Red Lake and Buck Lake, the 100-year/72-hour peak water surface elevation simulated as part of this study is 0.1 feet more than the 100-year peak water surface elevation reported by FEMA. A summary of these comparisons is presented in Table A-12. Based on the results of this comparison, the model was considered calibrated for master planning purposes.

Table A-12. Comparison of Reported and Simulated Peak Surface Water Elevations

Location	Model Node	25-Year Design Storm			100-Year Design Storm		
		SFWMD 1994 Permit (ft-NGVD)	CDM 1996 (ft-NGVD)	Elevation Difference (ft-NGVD)	FEMA 1989 (ft-NGVD)	CDM 1996 (ft-NGVD)	Elevation Difference (ft-NGVD)
Lake Nona	10930	78.7	78.5	-0.2	79.6	79.5	-0.1
Red Lake	10870	78.7	78.8	-0.1	79.6	79.7	0.1
Buck Lake	10830	78.7	78.8	-0.1	79.6	79.7	0.1

Water Quantity Evaluation of Existing PSWMS

The PSWMS for the Lake Hart Basin was modeled in RUNOFF and EXTRAN to determine and quantify potential problem areas under existing and future land use conditions, using the 2-, 10-, and 25-year /24-hour design storm events and the 100-year/72-hour design storm event. As appropriate for master planning, existing structures within the PSMS were assumed to be in a maintained condition. This maintenance is costed and summarized in the "Recommendations" section of this appendix. It is also important to understand what a frequency of a design storm (e.g., 25-year frequency) event implies. A 25-year frequency does not mean that the rainfall event will occur once every 25 years. A 25-year frequency means the event has a 4% (1 in 25) chance of occurring or being exceeded in any given year.

Resultant flood stages in the PSWMS were developed for the existing and future land use scenarios. Increases in depth from existing to future land use conditions range from approximately 0.0 ft to 0.4 ft. The relatively small increases in stage, despite the increases in imperviousness, are a result of two conditions. First, the PSWMS has a very large storage capacity in the lakes and wetlands with very flat floodplains, so increases in flow rates will not cause large increases in stage. Second, because the seasonal high groundwater table is close to the surface over much of the study area (limited soil storage capacity), the decrease in pervious area from present to future land use conditions does not result in a large loss of storage in the soil column. The high groundwater table causes the pervious areas of the basin to effectively become impervious after minimal rainfall.

Therefore, regulating floodplain storage and floodway conveyance in this basin, along with the regional wet detention ponds and identified capital improvements, is important.

Based on the level of service criteria previously discussed, deficiencies in the PSWMS were:

- Problem P-1 is the flooding of Narcoossee Road by 0.3 feet during the two-year design/24-hour storm event and by as much as 1.2 feet during the 100-year/72-hour design storm event (model node 10895). This problem is

caused by the tailwater condition established for node 10905 from Orange County stage data, field inspection, and 1 foot photogrammetry. The location of this problem area is shown on Figure A-15.

- The peak simulated velocities for in the PSWMS elements are presented in Table A-13 for the two-year and 10-year events under future land use conditions. High velocities for lower return period events are an indicator of potentially excessive erosion which can cause structure failure and degrade water quality.

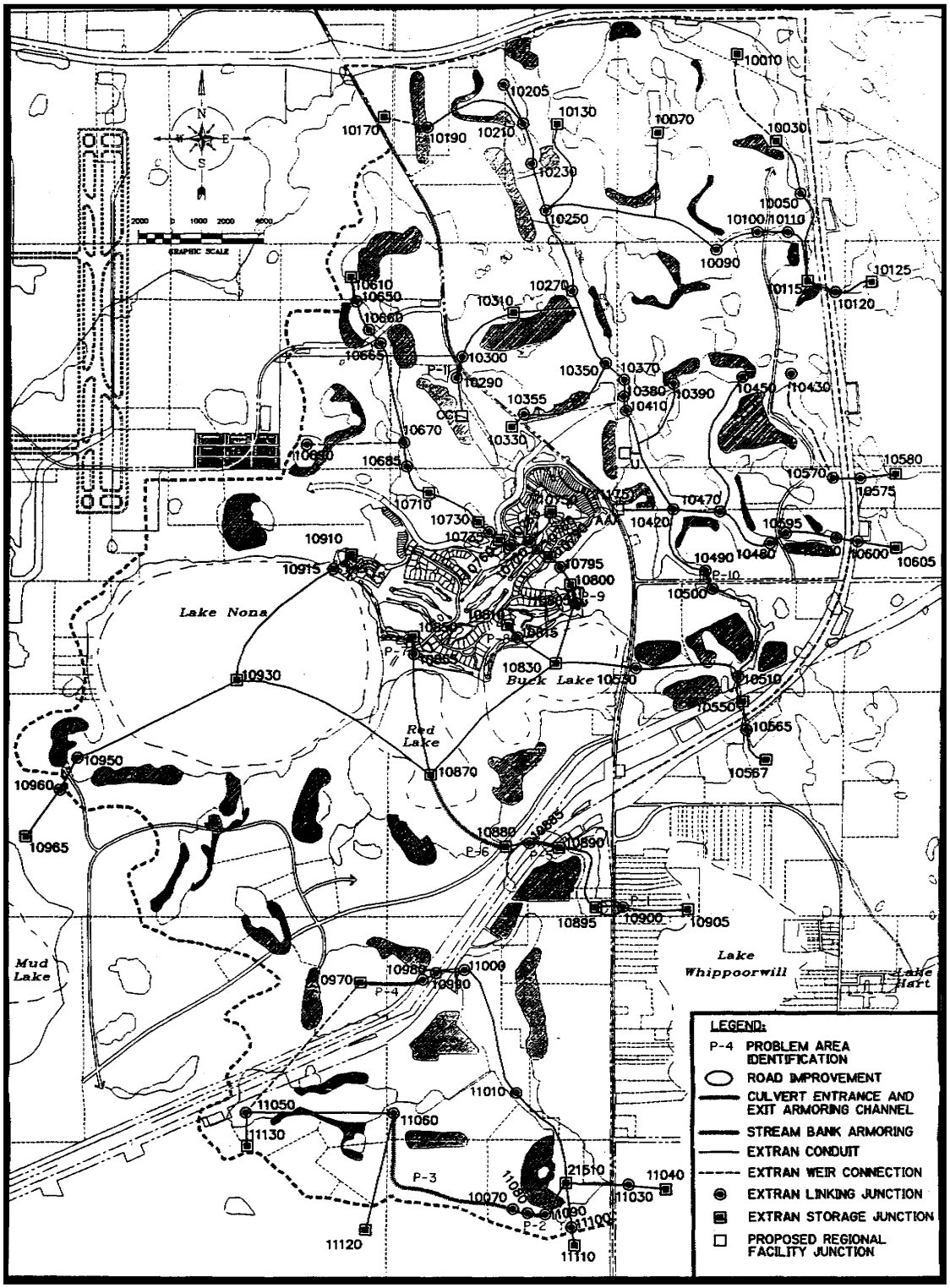


Figure A-15. Problem area identification map (Reprinted courtesy of the City of Orlando, FL).

Table A-13. Excessive Velocity Determination for Future Land Use

Channel ID	Channel Type (1)	2-Year Event (2)	10-Year Event (2)	Problem ID(3)
11080	C		2	P-2
11060	N		1	P-3
10970	C		2	P-4
10885	C		2	P-5
10870	C	2	2	P-6
10851	C	2	2	P-7
10811	C	2	2	P-8
10801	C	2	2	P-9
10492	C	2	2	P10
10491	C	2	2	P-10
10290	C		2	P-11

(1) Channel Type: C = culvert, bridge, storm sewer, or paved channel. N = natural earthen channel.
(2) Problem Type: 1 = Natural channel velocity > 3ft/sec. 2 = Culvert, bridge, sewer, or channel velocity > 7 ft/sec.
(3) Velocity problem areas have been assigned Ids.

Proposed Regional Wet Detention Facilities

The siting of the proposed regional wet detention facilities was accomplished through a cooperative effort between the City of Orlando and the major property owners in the study area. Through this cooperative work effort, regional facilities were strategically located to meet public, private, and environmental interests to the maximum extent practicable. Through this process, a total of 52 wet detention ponds, nine of which are existing borrow pits, were conceptually designed for this study area. The facilities provide regional flood control and water quality protection associated with urbanization. Conceptually, stormwater runoff would be collected in a pretreatment and conveyance system and delivered to the proposed regional facility, treated (via wet detention), attenuated for peak flow and velocity, and discharged into the PSWMS through a V-notch weir/swale spreader system.

A conceptual plan view of a proposed facility is presented in Figure A-16. As can be seen in the figure, the proposed regional facilities were located along existing wetlands in an elongated manner. The wet detention facilities can also provide other benefits such as waterfront property, potential recreational areas, and hydrate wetlands thus protecting them from potential development impacts.

The locations of the proposed regional wet detention facilities in the study area are presented on Figure A-17. The facility footprints shown on the figure represent the 100-year/72-hour peak water surface elevation predicted to occur at each site using the stormwater model developed for this study.

Use of Existing Borrow Pits as Stormwater Facilities

Existing waterbodies may be used for detention purposes as long as the SFWMD grading criteria pertaining to ponds or lakes near wetlands are met (Section 4.10 of the SFWMD MSSW Permit Application Manual Volume IV). Additionally, the SFWMD requires that side slopes be no steeper than 4:1 to a depth of two feet below the control elevation. Existing borrow pit acreage within the study area and, if necessary, increased surface area requirements are presented in Table A-14. As previously stated, there are nine existing borrow pits identified as potential regional wet detention facilities. These include potential sites P, V, RR, TT, UU, VV, SS, ZZ, and WW shown on Figure A-18.

Flood Control Benefits

The proposed regional facilities were evaluated using SWMM for each design storm event under future land use conditions. The resulting peak water surface elevations were determined from the hydraulic analyses. The elevations are compared to existing and future land use conditions without the proposed regional facilities. The simulated peak water surface elevation for the 2-, 10-, 25-year/24-hour design storm events and the 100-year/72-hour design storm event under future land use conditions with the proposed regional facilities are less than or equal to the simulated peak water surface elevations under existing land use conditions at almost every point within the study area.

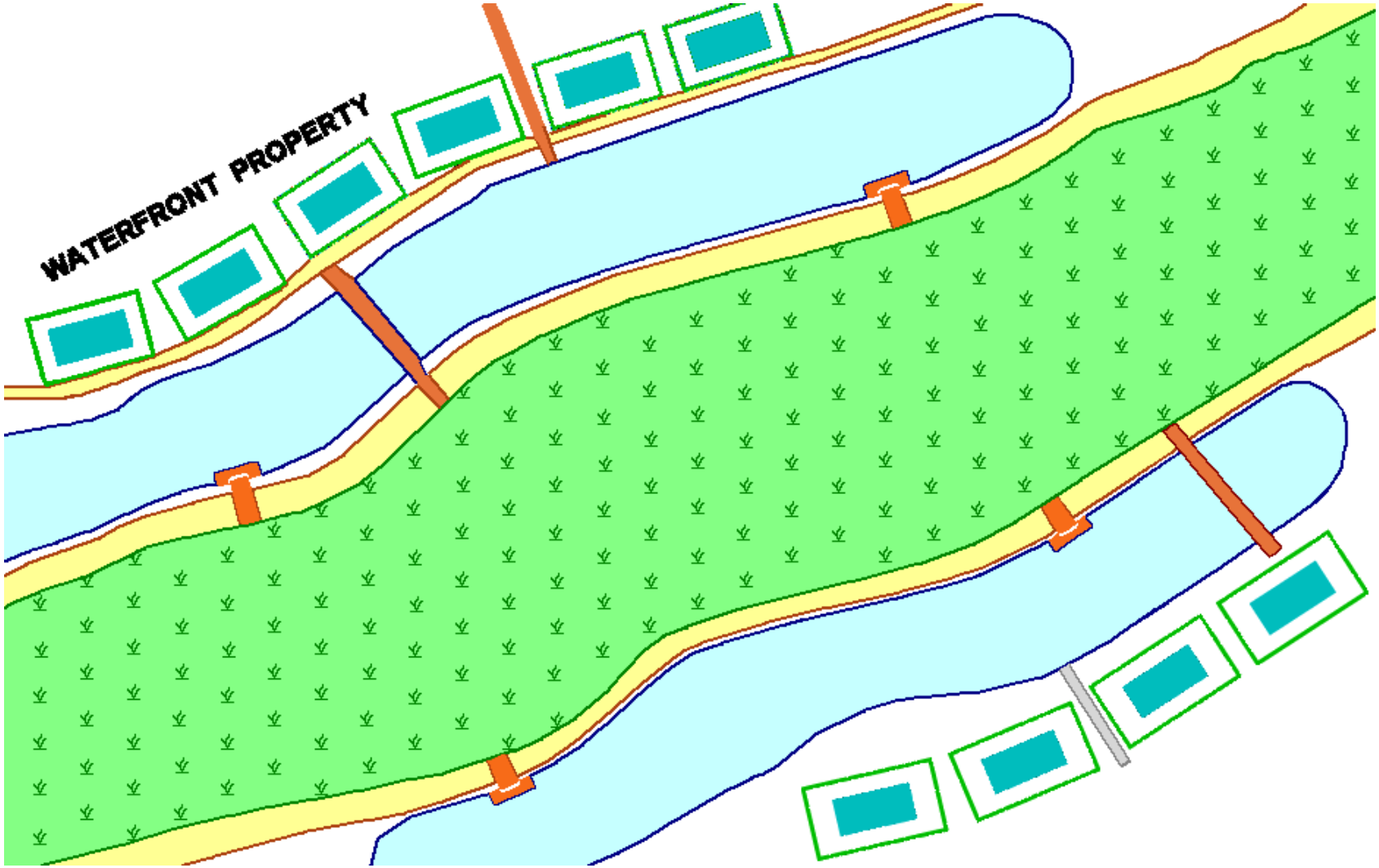


Figure A-16. Typical wetlands and ponds layout (Reprinted courtesy of the City of Orlando, FL).

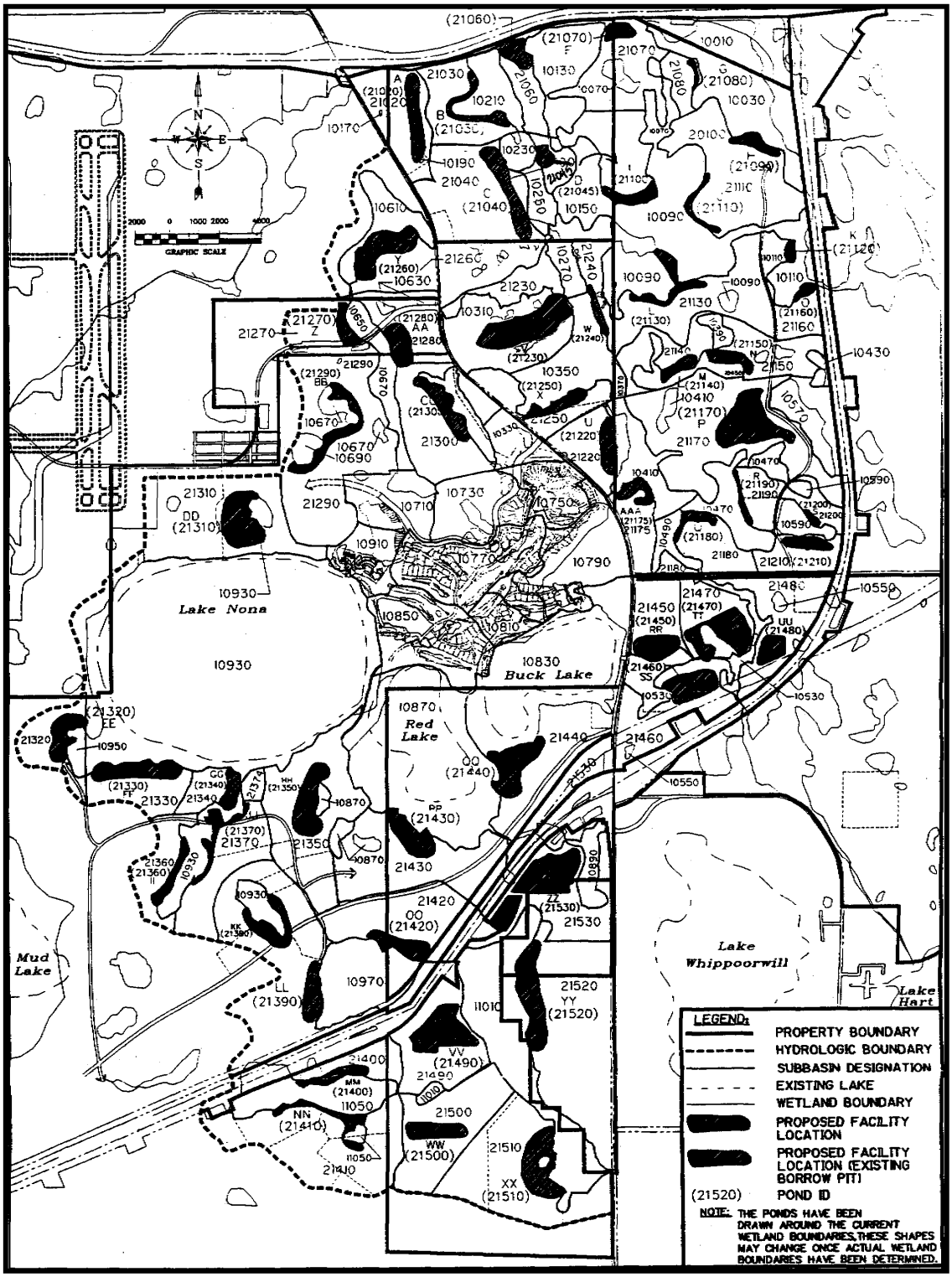


Figure A-17. Proposed regional wet detention facilities (Reprinted courtesy of the City of Orlando, FL).

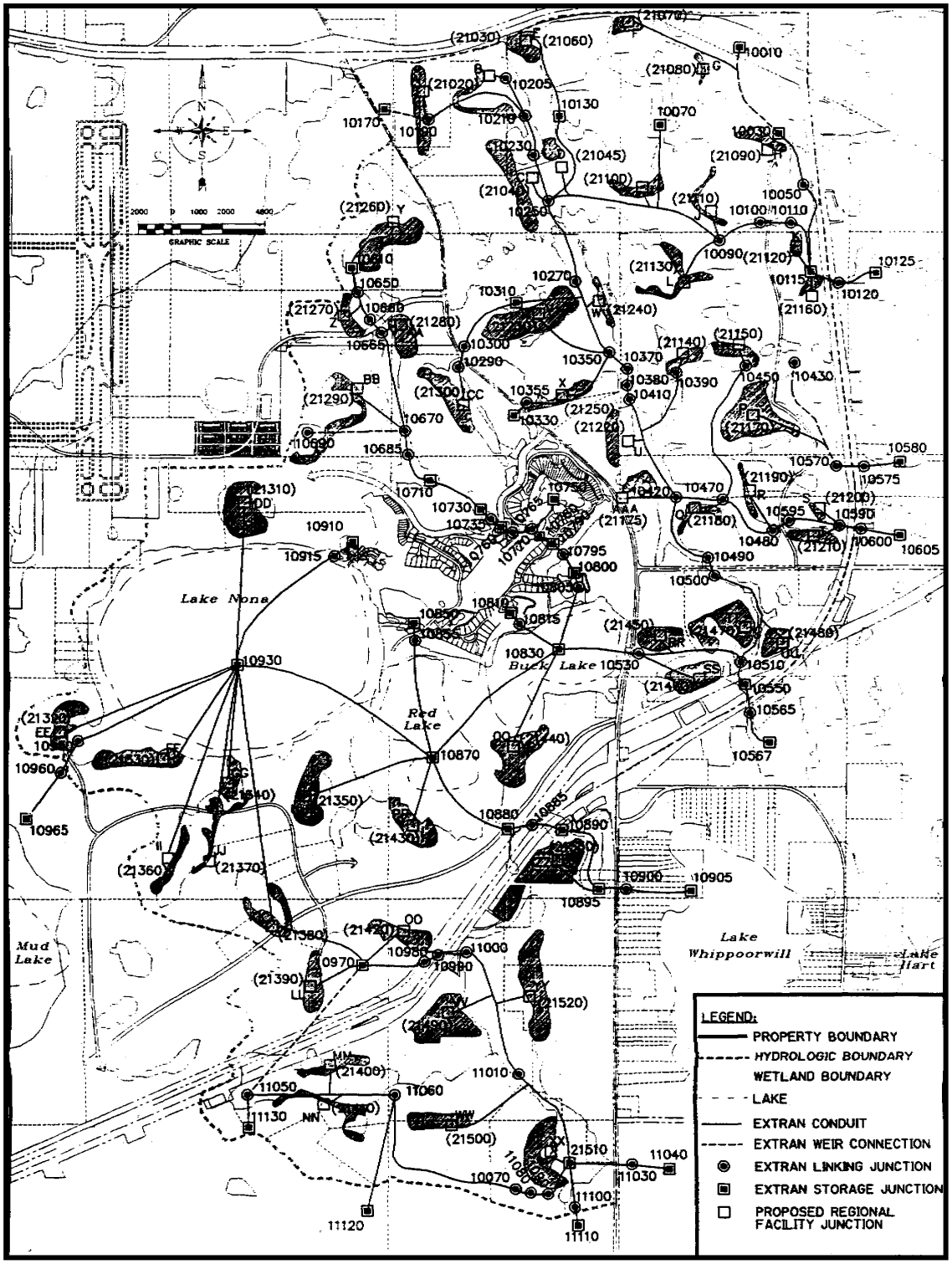


Figure A-18. Alternative PSWMS nodal schematic (Reprinted courtesy of the City of Orlando, FL).

Table A-14. Changes in Surface Area of Sites Currently Existing as Borrow Pits

Pond Node ID	Existing Surface Area of Borrow Pit (Acres)	Required Surface Area for 100-YR (Acres)	Increase in Surface Area of Borrow Pits (Acres)
21170 (P)	33	34	1
21230 (V)	32	33	1
21450 (RR)	6	12	6
21460 (SS)	12	15	3
21470 (TT)	22	22	0[1]
21480 (UU)	9	15	6
21490 (VV)	26	27	1
21500 (WW)	5	12	7
21530 (ZZ)	36	37	1

1. The existing surface area is greater than what is required. Therefore, no increase in the surface area of the existing site is necessary.

Peak flows at the discharge points of the study area were also compared to show that downstream (Orange County) peak flows and peak water surface elevations are controlled under post-development conditions. With the proposed facilities, significant flow rate reductions are obtained when compared to flow rates simulated under future land use conditions without the regional facilities. The predicted flow reductions obtained by incorporating the proposed facilities into the PSWMS are also below those predicted at the discharge points from the study area under existing land use conditions. This analysis shows that the proposed regional wet detention facilities are effective in providing flood control for future development.

Recommendations

Introduction

A summary of the recommendations for the Lake Hart basin MSMP is provided in this section. The Capital Improvements Program (CIP) is outlined along with operation and maintenance considerations, nonstructural controls, and stormwater monitoring.

Capital Improvement Program for Structural Controls

Review of Factors

As previously discussed, six major factors were considered in the formulation of the CIP program recommendations. These factors are:

1. Technical feasibility and reliability
2. System maintainability
3. Sociopolitical acceptability
4. Economics
5. Environmental consistency
6. Financial ability

Technical Feasibility and Reliability

The recommendations have been formulated to be feasible and reliable from a technical standpoint. Flooding problems are solved within the level of service guidelines defined for this study and cost-effective water quality control is provided (pretreatment and wet detention). Conveyance solutions are all gravity-driven and regional storage of water (swales, ponds) is proposed as needed for proposed development and the Narcoossee Road Improvement Project.

System Maintainability

The proposed project needs to address operation and maintenance (O&M) issues. For example, the proposed regional approach promotes the need for fewer stormwater management facilities compared to the onsite approach which requires many ponds to achieve the same level of service. The larger regional facilities are more likely to be maintained on a regular basis.

Sociopolitical Acceptability

The recommendations address flooding and water quality concerns and are consistent with existing regulations. Public information may become an important aspect of the recommendations in the future since improved watershed protection can be achieved though public education and involvement. The recommended plan reduces nonpoint loads to the lakes, maintains or lowers existing flood stages, and does not adversely impact healthy wetlands which are a large component of the PSWMS.

Additionally, because the Lake Hart MSMP serves City, public, and private developer interests, the project needed to be conducted cooperatively between interested parties to the extent practicable. This was accomplished through coordination meetings with City staff, regulatory agency staff, and private developers.

Economics

The recommended plan provides sound technical, environmental, and social benefits, as well as providing for the most cost-effective water quantity and water quality controls. The recommendations appear to be cost-effective for joint private/public funding

partnership of stormwater management capital improvement projects as development occurs.

Environmental Consistency

The recommendations have been formulated to minimize wetland impacts and to promote aquifer recharge, where possible. No ponds or BMPs were sited in known wetlands.

Financial Ability

An important consideration in this project is the ability to fund the recommended plan. Funding of the regional facilities will likely be a public/private venture. The project needs to have a reasonable chance of being funded without causing financial hardship. Because of the large number of recommended regional facilities, phasing of capital improvements will be concurrent with the development phasing in the basin.

CIP Summary

Based on these six criteria, 52 regional wet detention facilities (nine are modified existing borrow pits) are recommended for the Lake Hart basin. Each facility would serve a dual purpose of flood control and water quality protection. The location of each facility reflects the cooperative siting efforts between the City and private land owners. Because of the high groundwater table in the study area, it is recommended that pretreatment be provided (0.25 inches) upstream of each facility instead of the retention requirements for wet detention facilities in OUSWMM. The pretreatment requirement is considered to be applied innovative technology for the basin and is viewed as an enhancement to OUSWMM.

In addition to the proposed regional facilities, it is recommended that the Narcoossee Road (Problem P-1 at model node 10895) crossing of the tributary flowing southward from Red Lake to Lake Whippoorwill be raised to an elevation above the 25-year/24-hour designs storm event under future land use conditions with the proposed regional facilities in place (77.8 ft-NGVD).

Based on the results of the December 5, 1995 field inspection, it is also recommended that the culvert and conveyance channel under the dirt road just downstream of Red Lake be restored. The culvert and approach channel appeared to be in poor condition from cattle traffic.

Excessive velocities were identified in 11 conduits in the basin. All but one of the conduits (11060) is a culvert pipe. Conduit 11060 is an excavated drainage canal. For this canal, visual inspection for erosion problems should be made and where erosion is evident the bank should be stabilized. For the closed conduits (culvert crossings), channel bank and bottom armoring is recommended for a distance of 30 feet upstream and downstream of the culvert crossing. Three of the culverts with high velocities are associated with outlet works from existing facilities within the Lake Nona development

(Model nodes 10850, 10810, and 10800). Armoring downstream of these structures should be done as part of these capital improvements.

A map showing the overall recommended CIP plan is presented in Figure A-19. CIP planning level costs for these improvements are summarized in Table A-15.

Project Phasing

Phasing of capital improvements was based on scheduled and planned construction projects. The first planned change in the basin is the City's Narcoossee Road Improvement Project scheduled for construction in 1997. In order to address stormwater management for this project, the proposed regional facilities that can serve both new development and Narcoossee Road are going to be constructed first. The City will develop a cost sharing plan with private development for these dual purpose facilities. The first phase of pond construction will serve Narcoossee Road (funded by City). Private land owners can then expand these facilities as development occurs.

The remaining facilities should be built as development plans are approved and scheduled for construction. The City plans to use the stormwater model developed for this Lake Hart basin MSMP to identify which facilities will be needed for each new development. The phasing of these structures will require coordination between City staff and land developers planning to build within the basin.

Operation and Maintenance

Operation and maintenance are critical elements of the MSMP. Control measures that are not maintainable provide short-lived, expensive solutions. Additionally, stormwater management systems that are not adequately maintained cannot be relied upon to provide the desired levels of service. The control measures recommended were developed with consideration of maintenance issues. For example, forebays have been recommended for all regional wet detention facilities to reduce the maintenance requirements and extend the effectiveness of the facilities. The City is considering taking over the operation and maintenance responsibility for the regional facilities constructed under a cost sharing program. The City would fund the cost of the operation and maintenance through their existing stormwater utility.

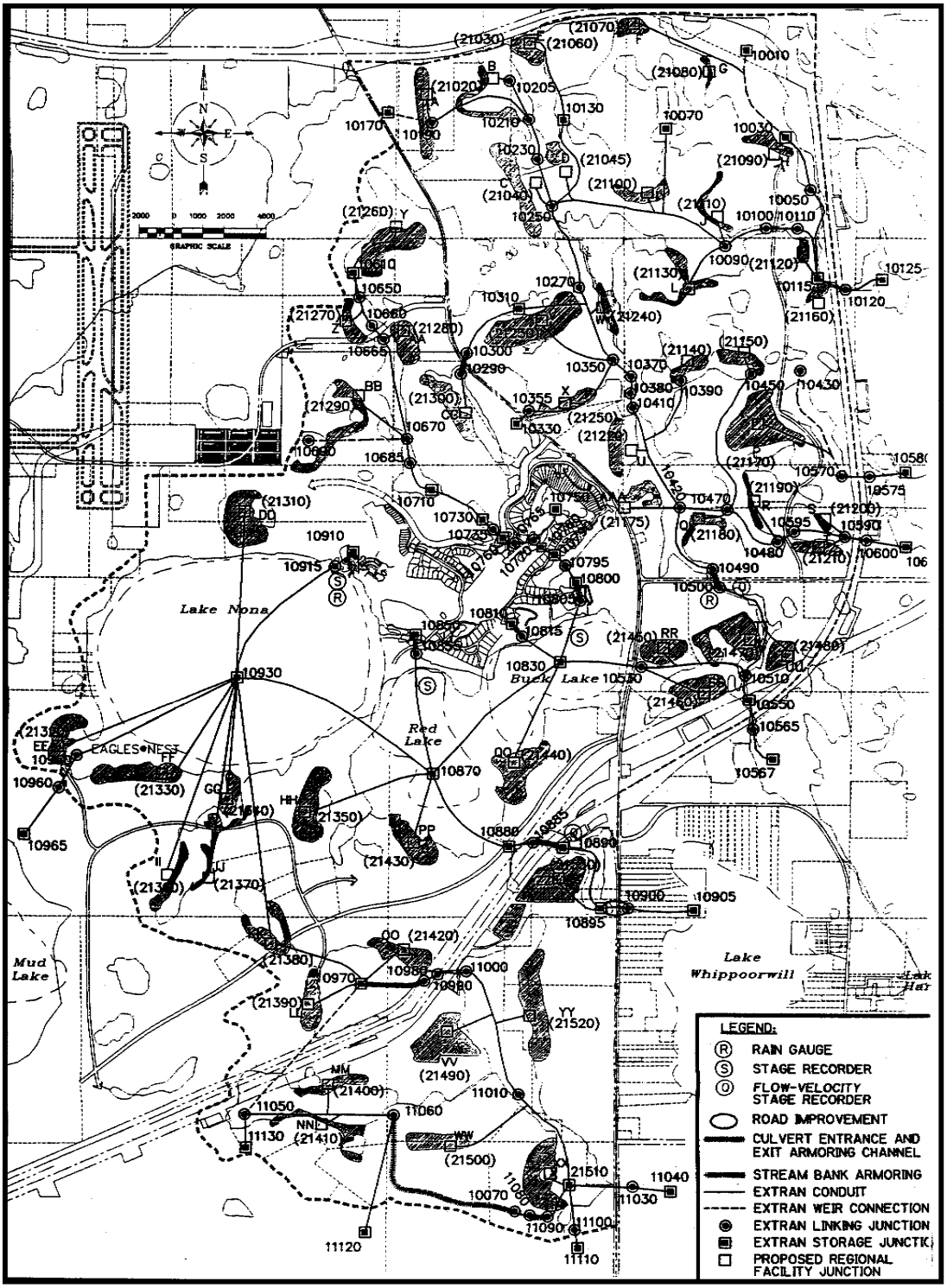


Figure A-19. Capital Improvements Plan Map (Reprinted courtesy of the City of Orlando, FL).

Table A-15. Conceptual Capital Cost Estimate for Lake Hart Basin Southeast Annexation Area

	Pond ID	Capital Cost ($)
City Ponds	21250 (X)	984,000
	21260 (Y)	2,234,000
	21300 (CC)	1,485,000
	21450 (RR)	662,000
	21175 (AAA)	521,000
Subtotal		5,886,000
Developer Ponds	21020 (A)	1,133,000
	21030 (B)	764,000
	21040 ©	1,456,000
	21045 (D)	325,000
	21060 (E)	644,000
	21040 (F)	430,000
	21080 (G)	150,000
	21090 (H)	545,000
	21100 (I)	634,000
	21110 (J)	400,000
	21120 (K)	195,000
	21130 (L)	951,000
	21140 (M)	447,000
	21150 (N)	591,000
	21160 (O)	241,000
	21170 (P)	165,000
	21180 (Q)	447,000
	21190 (R)	272,000
	21200 (S)	150,000
	21210 (T)	545,000
	21220 (U)	582,000
	21230 (V)	190,000
	21240 (W)	371,000
	21270 (Z)	529,000
	21280 (AA)	899,000
	21290 (BB)	1,320,000
	21310 (DD)	1,786,000
	21320 (EE)	1,035,000
	21330 (FF)	1,425,000
	21340 (GG)	560,000
	21350 (HH)	1,583,000
	21360 (II)	605,000
	21370 (JJ)	651,000
	21380 (KK)	1,035,000
	21390 (LL)	885,000
	24100 (MM)	771,000
	21410 (NN)	1,674,000
	21420 (OO)	945,000
	21430 (PP)	1,200,000
	21440 (QQ)	1,771,000
	21460 (SS)	189,000
	21470 (TT)	182,000
	21480 (UU)	470,000

Table A-15. Continued.

	Pond ID	Capital Cost ($)
	21490 (VV)	119,000
	21500 (WW)	589,000
	21510 (XX)	1,816,000
	21520 (YY)	1,861,000
	21530 (ZZ)	182,000
Subtotal		35,710,000
Channel Armoring Ponds	P-2	13,000
	P-3	33,000
	P-4	13,000
	P-5	13,000
	P-10	76,000
	P-11	13,000
Subtotal		161,000
Total		41,757,000

1 City pond capital costs include $15,000/acre for land acquisition (land acquisition costs are not included in developer pond costs).
2
3 Capital costs are for stormwater related facilities only and do not include stormwater related utility rehabilitation and replacement.
4
5 Costs are in 1996 dollars.
6
7 These costs include a 40% contingency for engineering, surveying, permitting, and contractor's overhead and profit as well as mobilization and standard contingencies.
8
9 Excavation costs may be reduced by the use or sale of fill material.
10
11 Field verification of problem areas is recommended prior to channel armoring.

Annual operation and maintenance costs are summarized in Table A-16. These costs include the costs associated with maintaining the existing facilities and recommended control measures.

Table A-16. Annual Operation and Maintenance Cost Summary for Lake Hart Basin Southeast Annexation Area

Item	Cost ($/yr.)
1) Maintain 53 regional facilities. This includes labor and equipment to provide annual grounds maintenance and inspection of control structures, channels, silt levels, erosion, and vegetation. Also included are three mowings per year and removal of excess silt and Vegetation every five to seven years.	424,000
2) Maintain 33 bridges/culverts within the primary stormwater management system (once every two years with annual inspection).	33,000
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS	457,000

1. Routine maintenance of natural channels was not considered since the majority of the PSWMS consists of natural wetlands.
2. Maintenance of channels for a distance of 50 ft. upstream and downstream of culverts is included in culvert maintenance costs.
3. Problem ID P-6, reach 10870, is a small trail crossing which should be maintained if an erosion problem is identified from field inspection.

Nonstructural Controls

Nonstructural controls were considered to help control both water quantity and water quality aspects of stormwater. Nonstructural controls are not constructed capital projects but rather are source controls, ordinances, and regulations that depend on participation by municipalities and residents to minimize the water quantity and quality impacts associated with development. A summary of recommended nonstructural controls follows:

1. Public information program
2. Fertilizer application control
3. Pesticide and herbicide control
4. Solid waste management and control of illegal dumping
5. Directly connected impervious area (DCIA) minimization
6. Water conservation landscaping
7. Illicit connections - identification and removal
8. Erosion and sediment control on construction sites
9. Stormwater management ordinance requirements
10. Stormwater management system maintenance

The following provisions are recommended to supplement the existing OUSWMM

1. 100-Year Floodplain Protection: This provision already exists in OUSWMM, but

2. because of its importance in preventing future flooding, it is re-emphasized in this section of the report. To assure proper flood hazard management, it is recommended that compensating storage be required for all construction, development, or site alteration so that existing 100-year floodplain storage in the City is maintained; and therefore, flood stages are not increased or moved onto adjacent lands by the development.

3. Aquifer Recharge: Although the potential for aquifer recharge in this basin is low due to the soils and the groundwater table, the overall concept is an important consideration. A general consideration is to retain the first three inches of runoff over the DCIA on SCS Hydrologic Group A soils and two inches of runoff over the DCIA on SCS Hydrologic Group B soils. In addition, it is recommended that swale pretreatment for these areas be provided to increase the amount of soil treatment before discharge into the aquifer.

4. First-Floor Elevations: Variances to construct dwelling first-floor elevations below the 100-year floodplain should not be allowed or variances should be deed-recorded with sale of the property. Variances encourage people to build in flood prone areas around lakes and streams. It is inevitable that these dwellings will eventually be flooded. This can cause public pressure on the City to drain wetlands and regulate or drain lakes -- a policy that is inconsistent with fishery habitat, aquifer recharge, and water quality.

5. Floodway Management: SFWMD allows the filling of a floodway as long as it does not cause more than a one-foot increase in the flood stage within the floodway (Federal Emergency Management Agency standard). This can have a severe cumulative impact on property in or adjacent to the floodway farther downstream. It is recommended that floodway encroachment be prohibited. It is recommended that no net encroachment be allowed within the future land use top-width-in-flow for the 100-year storm.

6. Water Quality: It is recommended that the City continue to require water quality performance standards as outlined in Chapter 40, Florida Administrative Code, that are based upon receiving water classifications, until more detailed watershed specific data are known from monitoring and/or state water policy mandates from the Florida legislature occur.

7. Reuse: The conservation of water resources is increasingly encouraged where it is applicable. The use of landscaped swales is recommended to promote reuse of some of the stormwater runoff.

Monitoring

A comprehensive monitoring program includes many facets of data collection and is used to accurately define the hydrologic and hydraulic characteristics of a watershed. This report recommends that the City augment existing monitoring data with an overall program in order to provide additional data necessary to evaluate the stormwater quantity and quality of the Lake Hart basin. The monitoring program should address the following:

1. Identification of rainfall and flow/stage data at key points of interest to calibrate and verify model analysis tools.

2. Current status of water quality including ambient data, dry weather flow from stormwater outfalls, and wet weather runoff as event mean concentration (EMC) values for land use types.

3. Trends in water quality due to land use changes and BMP implementation.

4. Regulatory assistance with state and federal permitting.

5. Compliance monitoring to document permit compliance.

The City can benefit from a monitoring program that addresses the preceding. A monitoring program will support implementation of the Lake Hart basin MSMP and the NPDES MS4 program. The overall monitoring program recommended for the City is described below.

Recommended Monitoring Program

Rainfall

This plan recommends that the City supplement the existing rainfall stations operated and maintained by Orange County and NOAA (airport rain gauge) with two stations. One would be combined with the stage recorder proposed for Lake Nona and the other would be combined with the flow-velocity recorder proposed at Moss Park Road. These rainfall stations should record rainfall data at a minimum of 15-minute intervals. The general locations of these stations are presented in Figure A-18.

Water Quality

It is recommended that the City maintain the ambient water quality monitoring program conducted by Orange County for Lake Nona, Red Lake, and Buck Lake as to further document the long-term water quality.

Water Quantity

The City should consider a joint effort with USGS to establish a stream gauge monitoring program for the Lake Hart basin. Daily stages should be recorded for Lake

Nona, Red Lake, and Buck Lake. Stations that measure flow and velocity are also recommended on the downstream side of Moss Park Road (model node 10500), the downstream side of Narcoossee Road (flows from Buck Lake, model node 10530), and on the downstream side of the Central Florida Greenway (flows from Red Lake to Lake Whippoorwill, model node 10890). Stream gauges at these locations will help the City monitor flow from the major tributaries that outfall into Orange County. It is recommended that the City propose that USGS establish, operate, and maintain the gauge and data. The locations of these facilities are also presented on Figure A-18.

Mosquito Control

As part of the evaluation of various alternatives, it is recommended that the City consider the potential for mosquito breeding. Some minor modifications and considerations in the design of various BMPs are needed to minimize the breeding of mosquitoes. The primary concern is stagnant water, which provides a breeding ground for mosquito larvae. Water that stands for periods of greater than 72 hours provides a suitable environment for the breeding of mosquito larvae.

To effectively control mosquitoes, it is suggested that the following guidelines be considered for the design of BMPs in the Lake Hart basin:

1. Use only Hydrologic Group A soils (or well drained Hydrologic Group B or C soils, water table at least one to two feet below grade) for retention type facilities (e.g., shallow grassed swales). It is suggested that seasonal high groundwater tables and soils be tested for each area on a case-by-case basis to verify that complete storage recovery will occur within 72 hours

2. For wet ponds, use a minimum depth of greater than 18 inches so that minnows can be sustained. Additionally, maintain vegetative density low enough for minnows to access (minnows feed on mosquito larvae)

3. When developing a site for a detention or infiltration pond, use a minimum of 20 feet for the buffer/maintenance strip.

Data Sources and Bibliography

Referenced reports, studies, digital data, and maps were obtained and reviewed for this study. This section is intended to be a data bibliography which lists the sources and types of data used. The following references were evaluated for potential applicability to this Lake Hart MSMP.

- 1993 Annual Report, Orange County Environmental Protection Department, 1993.

- Orange County, Environmental Protection Department, 1993 Lake Ranking for Orange County Lakes by Trophic State Index, by (April 1994).

- 1994 Orange County lake ranking by tropic state index, Orange County Environmental Protection Department, 1995.

- Aerial (color) photogrammetry maps by Belt Collins, FL from Lake Nona Corporation (2.5 inches = 1 mile and 2.33 inches = 1 mile, March 1994).

- Aerial photogrammetry maps for Lake Hart-Lake Mary Jane Drainage Basin with 1 foot contours from Orange County, Florida (1 inches = 200 feet, 1985).

- Aerial photogrammetry maps from Orange County, FL (1 inch = 300 feet, 1990).

- Applications for Development Approval for Developments of Regional Impact (DRIs) for Lake Nona, Lake Hart, St. James Park, and Campus Crusade.

- Basis of Review for Environmental Resource Permit Applications with the South Florida Water Management District (August 1995).

- Brunetti Bal Bay Tract Concept Plan prepared by Berryman and Henigar
- (1 inch = 600 feet, August 1994).

- City of Orlando Engineering Standards Manual Second Edition from the Public Works Department (June 1993).

- City of Orlando Florida Southeast Annexation Area Lake Hart Basin Master Stormwater Plan, February 1996, prepared by Camp Dresser & McKee Inc. and WBQ Design & Engineering, Inc.

- City of Orlando Florida Southeast Annexation Stormwater Management Needs Assessment, June 1995, prepared by Camp Dresser & McKee Inc. This report was the first phase of the Lake Hart MSMP.

- Digital FEMA MAP of the Lake Hart Study Area from the City of Orlando, FL.

- Digital soils file of the Lake Hart area from the City of Orlando, FL.

- Eastern Beltway - Bee Line Interchange Plans from the Orlando-Orange County Expressway Authority.

- Eastern Beltway roadway and drainage as-built plans from the Orlando-Orange County Expressway Authority.

- Eastern Beltway roadway and drainage plans from the Orlando-Orange County Expressway Authority (Sections 454, 455, and 457).

- Existing Drainage Map of Randall/Johnson Trust Property from Miller-Sellen Associates, Inc.

- Existing Survey in the Lake Hart Area. This survey was completed for the Boggy Creek watershed study which includes cross-sections between Lakes Nona, Red and Buck and of the Myrtle Bay Area.

- Existing Survey in the Lake Hart Area from Transportation Engineering, Inc. (1995).

- Existing Survey in the Lake Hart Area computed by DeGrove Surveyors from FEMA (1992).

- FEMA; FIS for the Unincorporated Area in Orange County, FL (December 8, 1989).

- Flood Insurance Rate Maps from Federal Emergency Management Agency (FEMA) (Panels: 400, 425, 550 and 575).

- Future Development Plan for Randall/Johnson Trust from Miller-Sellen Associates, Inc.

- Greendale Master Plan prepared by Davis and Associates (1" = 300', May 1994).

- Growth Management Plan Southeast Annexation Study approved October 17, 1994 from the City of Orlando, FL..

- Lake Hart Master Plan Development Plan from Post, Buckley, Schuh and Jernigan (1 inch = 1333 feet, 1994).

- Lake Nona Application for Conceptual Approval Surface Water Management Permit with the South Florida Water Management District prepared by Miller and Einhouse, Inc. from Lake Nona Corporation (October 1988).

- Lake Nona Construction Plans and as-builts for stormwater facilities provided by Lake Nona Corporation.

- Lake Nona Master Drainage Plan for Phase 1-A (1 inch = 300 feet, December 1988).

- Lake Nona Preliminary Master Plan 6 Future Development Plan prepared by Belt Collins, Florida from Lake Nona Corporation (1" = 1000', September 1994).

- Lake Nona Preliminary Master Plan 6 Future Development Plan prepared by Belt Collins, Florida from Lake Nona Corporation (1 inch = 1000 feet, March 1995).

- Lake Nona South Existing Conditions Drainage Map prepared by Einhouse and Associates, Inc. from Lake Nona Corporation (1 inch = 600 feet).

- Lake Nona Surface Water Management Permit Modification Application for Conceptual Permit No. 48-00195-S with the South Florida Water Management District prepared by Miller and Einhouse, Inc. from the Lake Nona Corporation.

- La Vina Trust Land Use Plan prepared by Burkett Engineering, Inc. (1 inch = 300 feet, May 1995).

- Master Drainage Plan of Randall/Johnson Trust Property from Miller-Sellen Associates, Inc. (1 inch = 400 feet).

- Miscellaneous Permits in the Southeast Study Area from the South Florida Water Management District.

- Narcoossee Road Construction Plans for the City of Orlando from WBQ Design & Engineering, Inc. (May 1995).

- Narcoossee NW, Narcoossee, St. Cloud North, and Pine Castle Fish and Wildlife Service National Wetland Inventory Maps (1988).

- Narcoossee NW, Narcoossee, St. Cloud North, and Pine Castle USGS Quadrangle Maps 7.5 minute series (photo revised: 1980, 1970, 1987 and 1980, respectively).

- Orange County Future Land Use Maps Series of the Lake Hart Study Area from Orange County, FL (August 1993).

- Orange County Lake Index *, 1995 Report* from Orange County Public Works.

- Orlando/Orange County Joint Planning Area Map from City of Orlando Planning and Development Department (May 1994).

- Orlando Urban Stormwater Management Manual (OUSWMM) prepared by Dyer, Riddle, Mills, and Precourt, Inc. Volume 2 Design Criteria, Second Edition from the City of Orlando, Florida.

- Physical and Chemical Data and Plankton Summaries for Lakes Nona, Red and Buck for the period of record from (1972 - 1994), from Orange County Pollution Control Department.

- Rainfall data for the period of record (1974-1992) at the Orlando-McCoy Airport in Florida, rain gauge from the National Climatic Data Center (NCDC).

- Rainfall data for the period of record (1987-1995) at the Boggy Creek rain gauge and for the period of record (1995) at the Lake Hart rain gauge from the Stormwater Management Department of Orange County, FL.

- Randall/Johnson Trust conceptual approval permit from the South Water Management District (Control Number: 48-00653-S, January 1992).

- Realignment of Dowden Road Plans provided by Busch Properties.

- Seventh International Conference on Urban Storm Drainage, Hannover, Germany, 9-13 September 1996. Proceedings Volume I, II, III.

- Soil Survey of Orange County, FL, 1989. This is a typical United States Department of Agriculture Soil Conservation Service (SCS) soils report that provides various surficial-layer soils information for the County. Total soil storage, infiltration rates, and data on surficial "hard pan" layers were used for this study.

- South Florida Water Management District, Management and Storage of Surface Waters Permit Information Manual, Volume IV (May 1994).

- Southeast/Orlando International Airport Future Growth Center Plan Conceptual Framework from the City of Orlando Planning and Development Department (May 1995).

- Southeast Study Area Map with property owners boundaries from the City of Orlando Planning and Development Department (November 1993).

- Southeast Study Area Map with the property owners proposed roadways and the City of Orlando's preferred roadways from the City of Orlando Planning and Development Department (June 1995).

- Survey completed by Regional Engineers, Planners and Surveyors, Inc. (REPS) for use in the Stormwater Modelling (October 1995).

- Upper Kissimmee River Watershed Map of Major Basins from the South Florida Water Management District (SFWMD) (8.5 inches x 11 inches).
- Urban Drainage and Flood Control District, Denver, Colorado, "Urban Storm Drainage Criteria Manual - Volume 3 - Best Management Practices - Stormwater Quality", September 1992.

- Water Quality Data Summary for Lakes Nona, Red, and Buck prepared by Envirosmiths, Inc. (November 1994).