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1.3 MODEL CHARACTERISTICS

The South Florida Water Management Model (SFWMM) is a regional-scale hydrologic model that simulates physical processes in the natural (coupled surface water and groundwater) and man-made (canals, structures and reservoirs) systems in South Florida. It includes management and operational rules established, mostly by the U.S. Army Corps of Engineers (USACE or Corps), for operating the Central and Southern Florida Project (C&SF Project) for flood control and other purposes. As a planning tool, the model can be used to predict the response of the hydrologic system to proposed changes in hydraulic infrastructure and/or operating rules. The design of the model takes into consideration the distinct hydrologic and geologic features of subtropical South Florida which includes: 1) the strong interaction between canals and the highly permeable surficial aquifer, especially in the eastern portion of the region; and 2) the effects of rainfall, evapotranspiration, overland flow and groundwater movement within the Water Conservation Areas (WCAs) and Everglades National Park (ENP). To jointly simulate these complex processes, a distributed parameter/cell-based network is used. The SFWMM integrates hydrologic processes with the hydraulic infrastructure and associated policy-based rules and guidelines related to water management in South Florida.

Figure 1.3.1 shows the model boundary relative to South Florida. The model is conceptualized at varying levels of detail (as described below) for three different major geographic areas: (1) for Lake Okeechobee, (2) for the combined extent of the Everglades Agricultural Area (EAA), the Everglades Protection Area (EPA) and the Lower East Coast (LEC) and (3) for non-EAA Lake Okeechobee Service Area (LOSA) basins. The necessity to break the model into these areas is primarily due to issues of data availability which, in turn, require different computation methods. The SFWMM employs both lumped and distributed modeling techniques in its approach to model these areas.

Lake Okeechobee is modeled as a lumped system, or regarded as a single point in space without dimensions where simulated water levels and/or flow rates are spatially averaged. The amount, timing and distribution of structure flows in and out of Lake Okeechobee are dictated by management rules related to flood control, water supply, and environmental restoration. One might note that some of these rules (e.g. regulation schedules and supply-side management) are actually in operation but a few more are incorporated in the model to address proposed operating policies, specifically those related to the Everglades environmental restoration.

The gridded portion of the model domain describes the extent of the finite difference solution to the governing overland and groundwater flow equations and is defined just south of Lake Okeechobee. The network is comprised of 2-mile square grid cells that cover the large coastal urban areas of Palm Beach, Broward and Miami-Dade Counties; the EAA; the WCAs and ENP. The total coverage of the model is 1,746 grid cells. The model assumes homogeneity in physical as well as hydrologic characteristics within each grid cell. With this assumption, a grid cell may also be referred to as a nodal point or simply, a node. In addition to water levels at grid cells, and surface and groundwater flow between cells, the model also calculates discharges for the major hydraulic structures within the model grid.

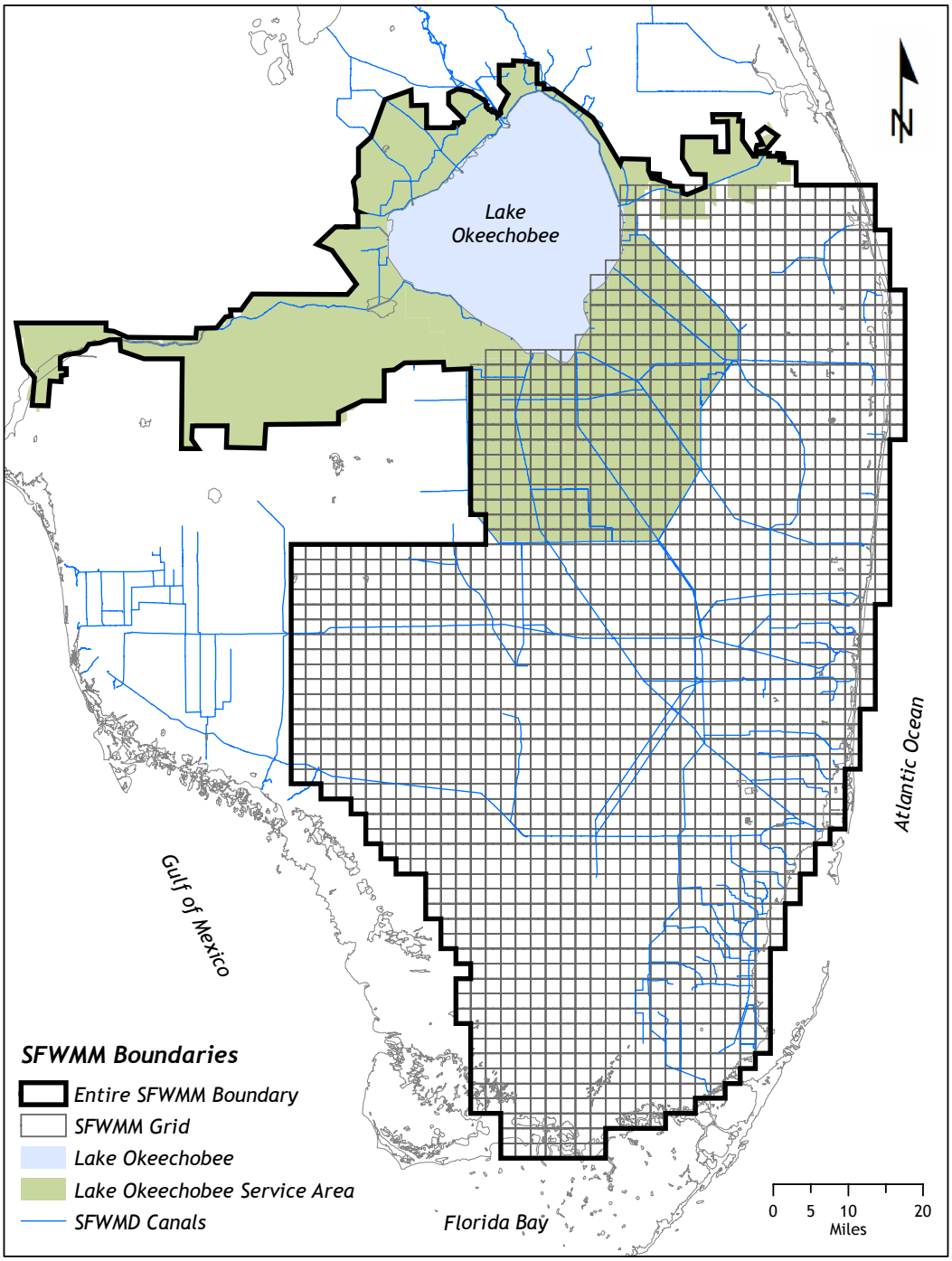

Figure 1.3.1 South Florida Water Management Model Boundaries

Finally, a simple flow balance procedure is used for the rest of the LOSA excluding the EAA. In these basins, pre-processed user-input demand and runoff characteristics are combined with appropriate system operational rules to calculate flow distributions. Hydrologic characteristics such as rainfall and evapotranspiration amounts and basin internal flux terms are accounted for in the pre-processing tools. As a result of the way in which these basins are conceptualized, water levels, overland flow and groundwater flow are not simulated in this portion of the LOSA. They are assumed to be consistent with the time series of demand and runoff quantities which are otherwise calculated in the gridded portion of the model domain.

A fixed time step of one day is used in the model; however, for overland flow, time slicing is used as discussed in Section 2.3. The selection of this time step is consistent with the minimum time increment for which hydrologic data such as rainfall, evaporation and structure discharge are generally available. Rainfall and potential evapotranspiration (PET) are the primary driving processes. Therefore, the longest total simulation time for the model is a function of the available historical (or an estimate of historical) rainfall and PET data. The SFWMM version 5.5 can be run for as short as one month and for as long as 36 years from January 1, 1965 through December 31, 2000. The hydrologic processes are generally modeled sequentially within one time step. A continuous unconfined groundwater system is assumed to underlie the gridded portion of the model domain. To simplify programming and reduce computational time, no iteration is performed between surface water and groundwater routines within a time step. Calculations for more transient phenomena, such as channel flow routing, are performed before less transient phenomena, such as groundwater flow, within a time step. The bulk of the computer code, on the other hand, is comprised of the operational rules that drive the human management of the entire system. The close relationship between the natural hydrology and hydraulic infrastructure in South Florida makes the SFWMM unique.

Data required to describe the physical features of the modeling domain such as land elevation and land use types are readily available from the District's Geographical Information System (GIS) database. Many physical parameters such as seepage rate factors, overland flow roughness coefficients and aquifer transmissivity were estimated within reasonable ranges. A calibration of the model was recently performed to ascertain the values of these parameters. In general, the purpose of this effort was to verify and/or improve the predictive capability of the model by: (1) incorporating the best available data; (2) introducing new/improved algorithms into the model; and (3) adjusting calibration parameters to obtain a close agreement between model output and historical flow and/or stage data. Included in this report is a representative sample of calibration results in different areas within the system (refer to Chapter 4).

Sun™ FORTRAN was the programming language used in coding the SFWMM and the Sun™ GCC compiler is used to create the executable code. In version 5.5, the source code has a total of about 77,000 lines of code grouped into more than 95 subroutines and 150 functions. The subroutines are liberally documented and each subroutine has a short description of the purpose of the subroutine. The model can be run on a Sun Sparcstation™ under the SunOS™ 8.0 (or later) operating system. Flat: text or American Standard Code for Information Interchange (ASCII) format; binary: Grid_io (Van Zee, 1993); and Hydrologic Engineering Center's Data Storage System (HECDSS) (U.S. Army Corps of Engineers, 1994) formats are used on both input and output. Total execution time varies according to central processing unit (CPU) speed,

network traffic and the scenario being simulated. As of this writing, the execution time is about 1.5 hours on a Sunblade 2000™ workstation; however, execution times can exceed 2 hours depending upon the management options selected.

The general hydrologic processes simulated by the gridded portion of the SFWMM are depicted in Figure 1.3.2. The loss of water to the atmosphere by evapotranspiration is considered by the model to occur from above and below the land surface. This distinction makes it possible to produce a water budget for the entire layer of the soil column as well as the saturated and unsaturated zones that comprise the subsurface region of the model. Overland flow can be partitioned into a cell-to-cell transport of surface water (sheetflow) and movement of surface water directly into a receiving canal (drainage). Other processes such as seepage across levees, and leakance/seepage into and out of canals fall under the general category of groundwater flow and are discussed in more detail in the following sections. Finally, canal flow describes the passage of water from one water body, typically a canal reach, across a hydraulic structure into another water body such as a downstream canal reach, reservoir or detention facility.

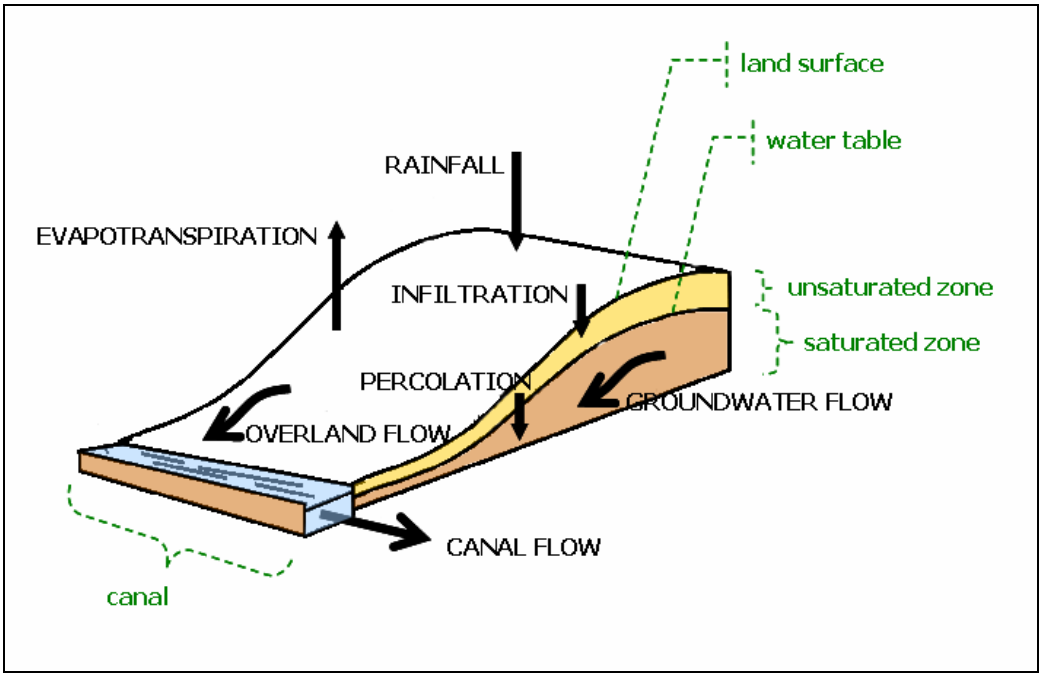

Figure 1.3.2 General Hydrologic Processes in the South Florida Water Management Model

The degree of complexity increases as one superimposes the hydraulic structures and corresponding operational rules on the system. Thus, Figure 1.3.2 only shows the natural hydrology simulated in the model. The operational and management component is more complex and the discussion of the corresponding processes will be made with respect to the areas where they apply. Figure 1.3.3 is a simplified flowchart of the overall organization of the model. An expanded "call tree" flowchart is given in Appendix H. A written presentation of the model process description is provided in Appendix J. A short description of the purpose of each subroutine used in the model is given in Appendix I. The SFWMM v5.5 source code is shown in Appendix K.

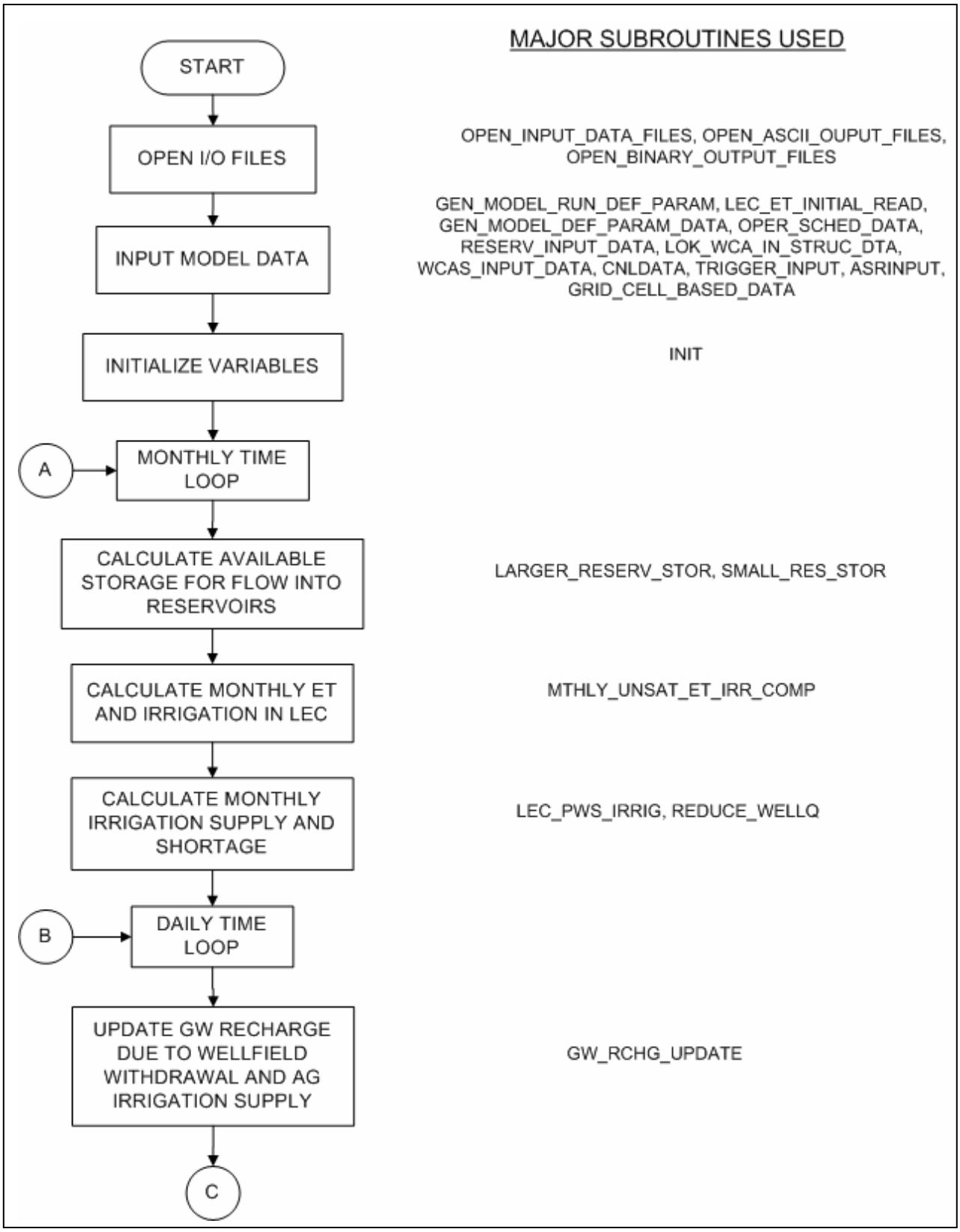

Figure 1.3.3 Simplified Flowchart for the South Florida Water Management Model v5.5

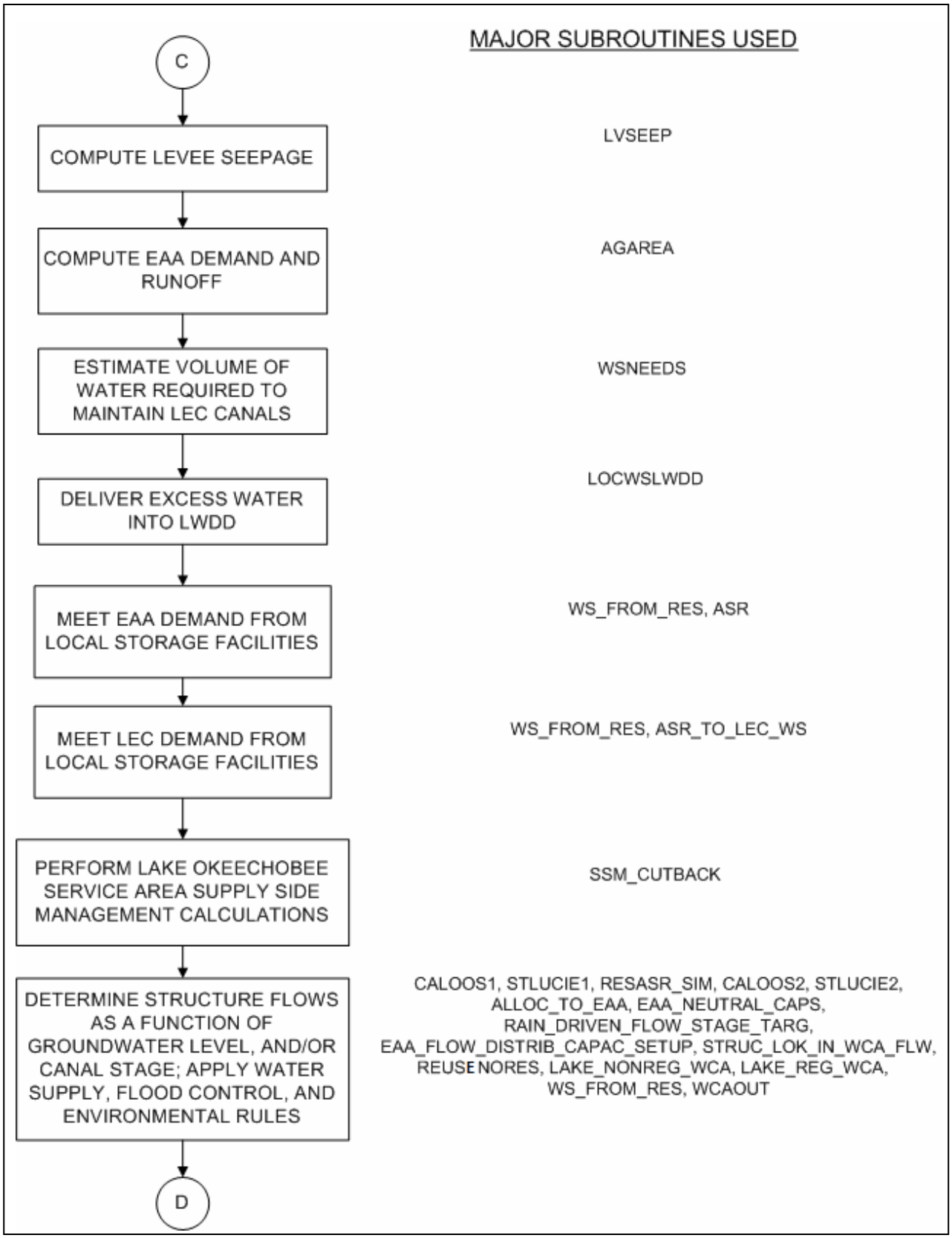

Figure 1.3.3 (*cont.*) Simplified Flowchart for the South Florida Water Management Model v5.5

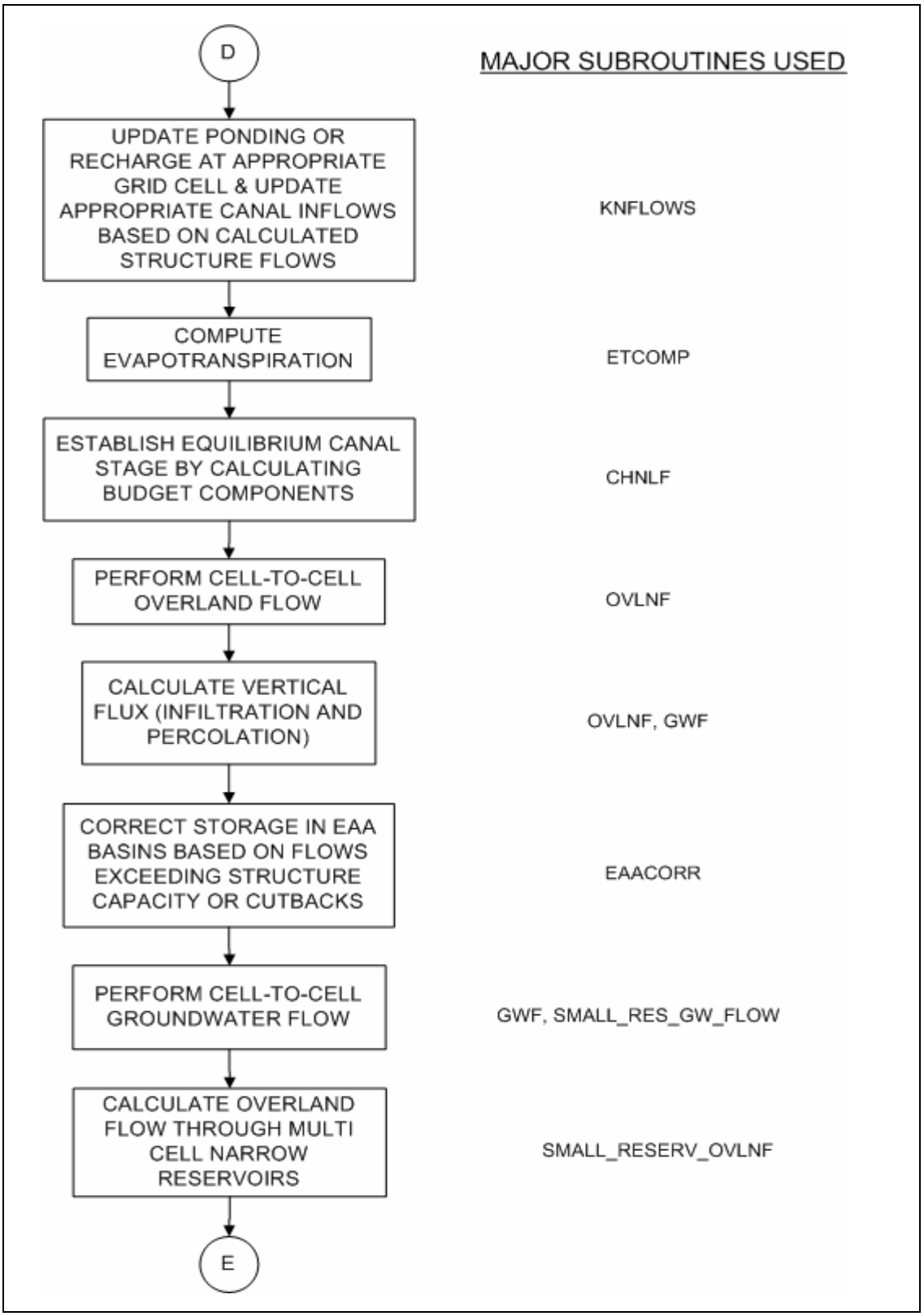

Figure 1.3.3 (*cont.*) Simplified Flowchart for the South Florida Water Management Model v5.5

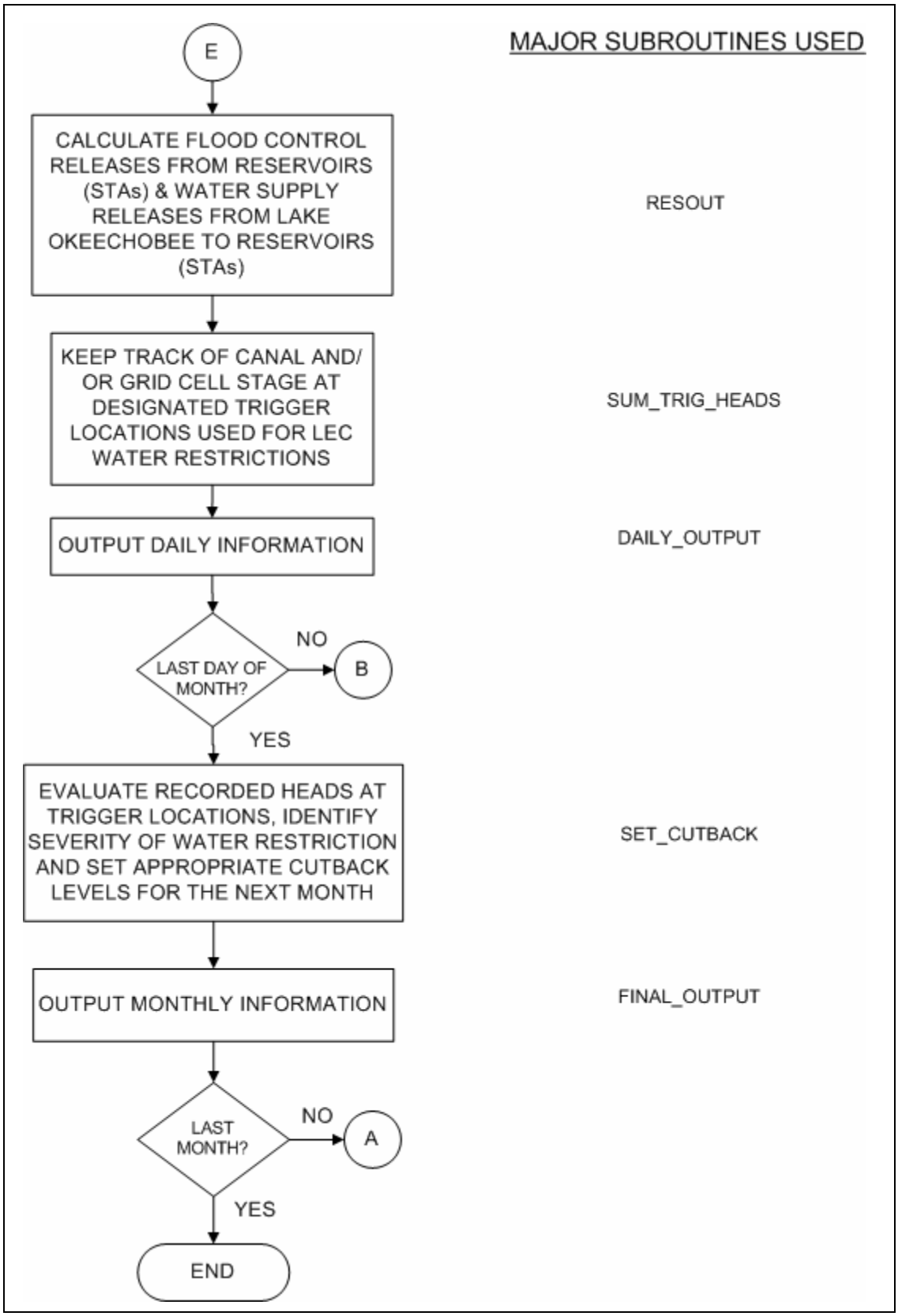

Figure 1.3.3 (*cont.*) Simplified Flowchart for the South Florida Water Management Model v5.5

Figure 1.3.4 illustrates how the SFWMM relates to a variety of support utilities (pre- and post-processors). Due to the enormous amounts of input required and output generated by the model, an entire suite of utility programs has been developed. A substantial increase in efficiency in evaluating modeling scenarios is realized by using these programs. The interaction between data and computer programs shows that the model should not be considered only as a single computer program but as an entire modeling system or package.

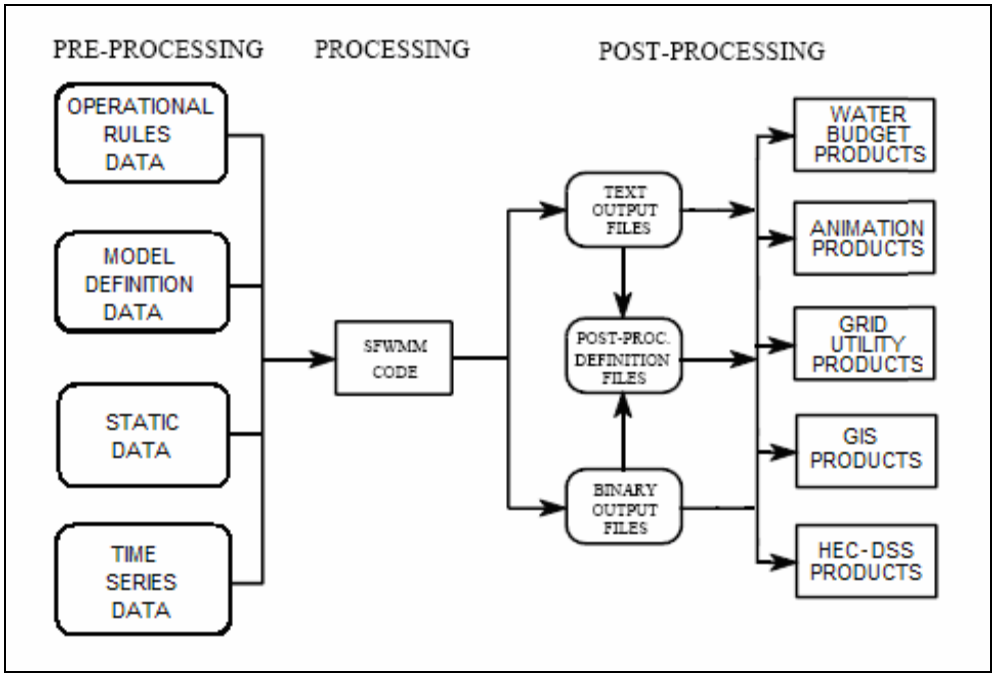

Figure 1.3.4 The South Florida Water Management Modeling System

One of the most effective ways of summarizing model output is by way of water budgets. A water budget is an accounting of all components of the hydrologic cycle within a bounded region. In the SFWMM, a water budget provides a quantitative breakdown of these components across the boundaries of areas in South Florida idealized as series of horizontal and vertical segments separating 2-mile by 2-mile grid cells. Figure 1.3.5 shows the major geographical areas included in the SFWMM. With the exception of some of the smaller LOSA basins, and small inflow basins north of Lake Okeechobee, water budget summaries are produced by the water budget program. Knowledge of water budgets for different subregions within the model enables one to make relative comparisons of the quantity and distribution of water within the entire modeling domain. Within the EAA (shown in Figure 1.3.5), water budgets for several subregions are generated which include Stormwater Treatment Areas (STAs), Wildlife Management Areas (WMAs), and storage reservoirs (when modeled). A discussion of input and output files, and performance measures is provided in Appendix A. Also included is a discussion of post-processing programs. Appendix B presents the UNIX “manpages” that describe the input files in detail.

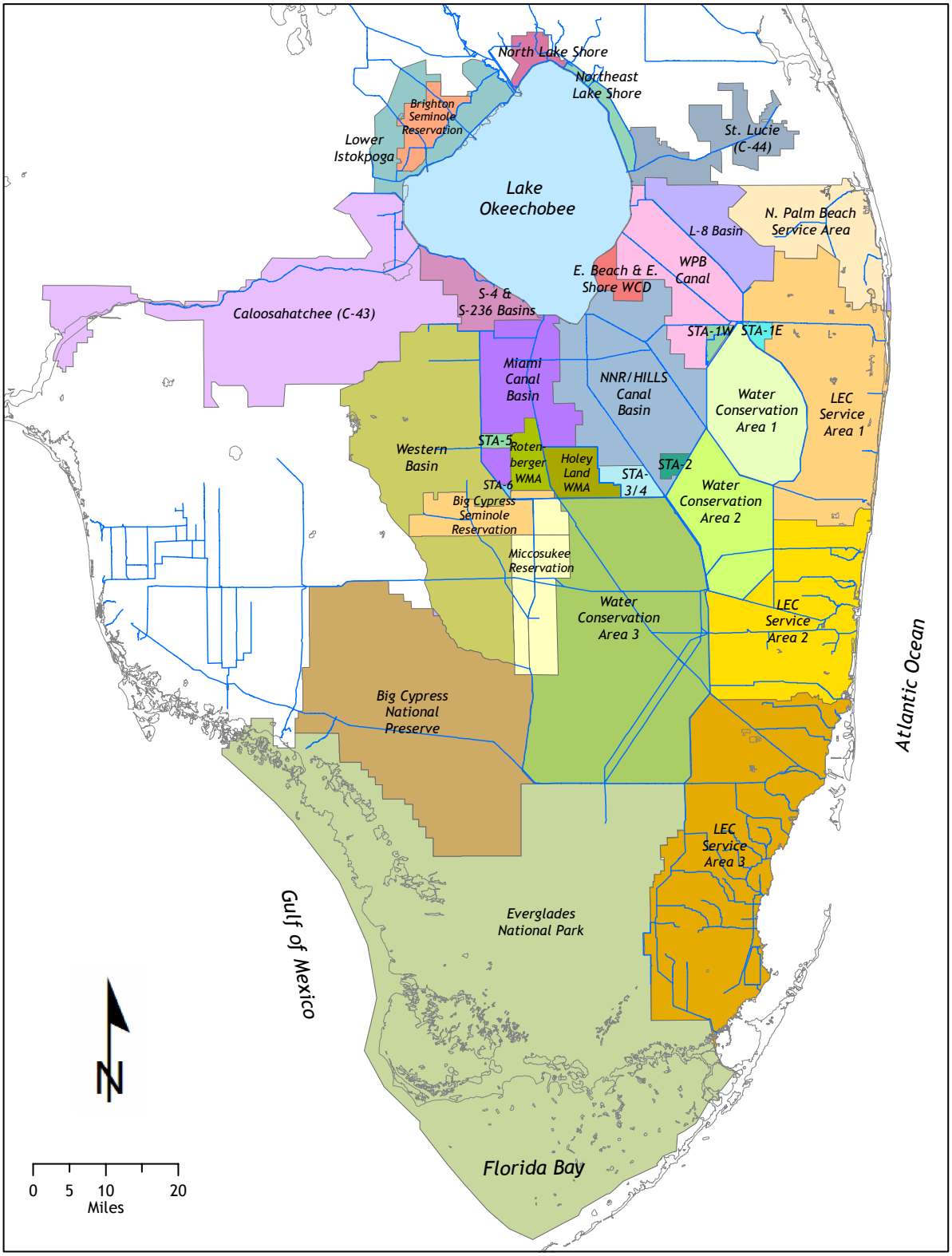

Figure 1.3.5 Major Geographical Areas within the South Florida Water Management Model