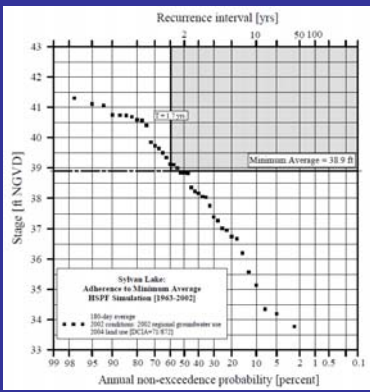


Draft Final Report

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MINIMUM LEVELS REEVALUATION: SYLVAN LAKE SEMINOLE COUNTY, FLORIDA Model Review



Prepared for:

The St. Johns River
Water Management District

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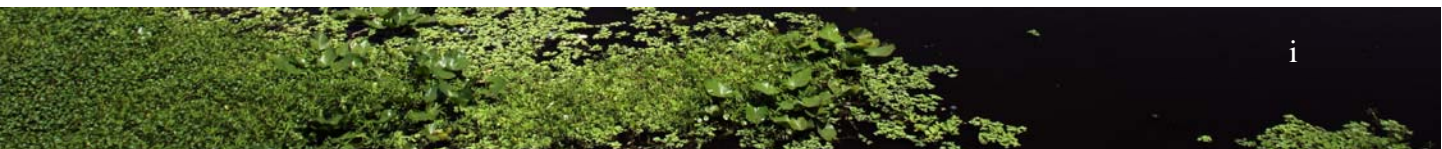
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Introduction

The St. Johns River Water Management District has re-evaluated the minimum level for Sylvan Lake (Hall 2010). The minimum level defines the level below which significant harm will occur. The District uses the event occurrence frequency and duration (Neubauer 2004) in the evaluation of minimum flows and levels (MFL). The 2010 report documents the re-evaluation of the minimum level the District previously set for Sylvan Lake (CDM 2005). For the 2005 study, a hydrologic model was developed of the basin and the lake to evaluate potential changes in the lake level due to future conditions. The developed HSPF model was then modified to represent current land use/land cover conditions during the 2010 study. Prior to adopting an MFL, the District's policy is to peer review MFL studies. With this goal in mind, the watershed hydrology component of the Sylvan Lake Watershed was reviewed to assure the model was conceptualized, constructed, and calibrated using current and proper engineering practices and that the best available data was used in the MFL development.

In the review process, emphasis was placed on the replication of the lake stage and the basin water balance. The water budget of the basin directly impacts the stage of the lake. The model was used to predict the water balance of the basin in order to determine the stage of the lake. The predicted lake stage can be compared against the observed lake stage. While observed lake stage was available, no observations exist to compare or verify the model performance against water balance metrics.

HSPF Introduction

The Hydrologic Simulation Program—FORTRAN or HSPF is a comprehensive hydrologic model. The model is used to simulate the hydrologic water balance of regional watersheds. The model has been applied for use in the evaluation of water supply impacts, minimum flows and levels, pollution load reduction goals, and total maximum daily loads. The HSPF model has been successfully applied to many watersheds in the state of Florida. It can properly represent the hydrologic response from pervious basins, impervious basins, and water bodies. It has the capability to simulate a wide variety of conditions.

Model Conceptualization

The conceptualization of the Sylvan Lake watershed was reviewed to assure the model represents the basin in a manner that maintains the mass balance of the watershed as well as maintaining a correct representation of the physical processes. The model objective was to simulate the lake stage to support the development of the Sylvan Lake minimum level.





Model Discretization

Model discretization is the process in which the landscape of the model domain is divided into discrete parts. This is typically the first part of constructing a numerical representation of the model domain. The discretization uses the basic building blocks of the hydrologic model in the conceptual design of the model. In the case of HSPF, the basic building blocks are pervious land segments (PERLND), impervious land segments (IMPLND), and reach reservoirs (RCHRES). Both time and space must be sub-divided into discrete computations segments within the numerical model.

The Sylvan Lake watershed was discretized into 1 PERLND, 1 IMPLND, and 1 RCHRES. Basin areas were grouped into these segments based on land use and assumed DCIA for each associated land use. More details on the temporal and spatial discretization are included in the following sections.

Time Discretization

The time step used in the Sylvan Lake model is 1.0 hour. Many of the HSPF parameters are sensitive to the time step. This means the predictive models must use the same time step as the calibration. The model uses rain data and ET from the WDM file. The rain and ET time series are stored on a daily time steps. The daily time step reduces the rainfall intensity by dividing the daily rain evenly for each hour through the use of the HSPF div function on the EXTERNAL SOURCES. The reduced intensity will cause the model to simulate less runoff because HSPF simulates runoff as infiltration excess. This means runoff is generated when the rainfall intensity exceeds the infiltration capacity of the soil. Intense rain events typically are short in duration (and also small scale; see rainfall section below). Long time steps in the model or rainfall time series tend to average down these intensities. The model calibration will produce average events, as opposed to high intensity and low intensity events. An investigation on the availability of hourly rain data should be performed. Using hourly rainfall will make the model better able to replicate high intensity event responses. That being said, given the lack of calibration targets for the surface water model, the daily rainfall is probably adequate.

Land Use HRU

Sub-dividing the basins into Hydrologic Response Units (HRU) is the best conceptualization for a hydrologic model. The watershed hydrology model for Sylvan Lake did not utilize the HRU approach in the model conceptualization. The surface water conceptualization started with the hydrologic basin boundaries. These boundaries should be developed using topographic divides and define the watershed that ultimately contributes to Sylvan Lake. Maintaining the basin boundaries is critical in the numerical representation in the model construction. Preserving the contributing area is essential to numerically mimic the water balance of the basin.





The basin could have been sub-divided into HRUs using the land use mapping. Instead, all the land use conditions were lumped into either the impervious land segment or the pervious land segment. Further subdividing the basin based on the land use/land cover would improve the numerical representation. For example, the pervious land segment lumped together upland forest and the pervious portion of residential. When starkly different hydrologic conditions are aggregated, the hydrologic response of the model is dramatically impacted. The aggregated parameters must be averaged, causing the model to respond with average results. Again, given the lack of calibration targets and the relatively small spatial scale of the model, the model conceptualization is probably adequate.

Developed Lands – Pervious and Impervious Fractions

It is common practice in HSPF to simulate developed lands with two segments: Pervious Land Segments and Impervious Land Segments. Using this technique prevents the lumping of starkly different conditions. By definition, impervious land segments do not have infiltration, while pervious land segments have infiltration losses as well and soil based storages. The Sylvan Lake model followed this common practice.

DCIA and Land Use Classification

Directly connected impervious areas (DCIAs) are utilized in storm water calculations in order to estimate the basin storm water runoff rates and infiltration losses. DCIA refers to only those impervious areas that are hydraulically connected to a conveyance system and hence to the outlet point of the basin without flowing over any pervious areas or through any storage ponds (SWFWMD, 1995). Total impervious area is the summation of two areas: directly connected impervious area and indirectly connected impervious area (ICIA). ICIA is comprised of impervious areas which flow over pervious areas or into stormwater retention ponds prior to entering a conveyance system.

Percent of the directly connected impervious areas (DCIA) used by the Sylvan Lake HSPF model is shown in the table below.

Table 1. Sylvan Lake DCIAs

Low-density residential	10 % impervious area
Medium-density residential	25 % impervious area
High-density residential	50 % impervious area
Industrial	70 % impervious area
Commercial	80 % impervious area
Transportation	80 % impervious area
Institutional	50 % impervious area





Large DCIA percentages will result in large IMPLND areas. Because impervious land produces large quantities of runoff, most of the watershed runoff is generated from these IMPLND areas as compared to the pervious areas. The DCIA at these ratios are fairly rare and usually get routed through some stormwater storage element.

Wetlands and Open Water

The Sylvan Lake model conceptualized isolated wetlands and open water land forms lumped into the HSPF Pervious Land (PERLND) module. The isolated wetlands (many of which are stormwater treatment ponds) are capable of dramatically modifying the basin response, specifically the impervious land segment discharge quantities. The storage of the stormwater wetlands if not directly accounted for can be compensated by lowering the effective DCIA percentages. The District may want to investigate the impacts the stormwater wetlands would have on the simulated results. Given the uncertainty in the actual basin response it may not impact the overall project results: the defined MFL.

Model Boundary Conditions

As with all models, boundary conditions must be defined within HSPF. The most significant model boundary conditions are rainfall and ET. These boundaries are defined with time series which define the boundary condition of the basins and describe the inflows and outflows of the model. Descriptions of the significant boundary conditions are found in the following sections.

Rainfall

Precipitation is the largest component of the annual hydrologic budget. There are a variety of difficulties associated with representing the correct spatial and temporal distributions of rainfall within a basin. Precipitation in Florida can generally be classified into two types of events: frontal and convective. Frontal events are typically long lasting and widespread, sometimes covering the entire state. This type of event is commonly associated with cold fronts in the winter season. Frontal storms, due to their size, timing, and relative homogeneity, are simpler to observe and accurately represent in a hydrologic model. Conversely, convective storms (thunderstorms) in Florida are typically 15 miles in diameter, last less than an hour and move anywhere from zero to ten miles in that time, unless they are part of a larger faster-moving system. Spatial and temporal variability of rainfall within the cell can be very high. Tropical storms and mesoscale convective systems have higher spatial extent and can last longer, sometimes producing very large ground accumulations of rainfall. However the temporal and spatial distribution of rainfall within these systems is also high. A convective cell is usually much smaller than a basin (no so much in the case of Sylvan Lake but the location of the rain gauge in relationship to the basin is still an issue), which leads to spatial variability





of rainfall within the basin. The high rainfall intensity associated with convective activity makes it impossible to accurately represent these storms with long numerical time steps.

Potential Evapotranspiration

Potential evapotranspiration (PET) is the potential rate at which the atmosphere can uptake water from the watershed. The actual evapotranspiration (AET) rate is the rate that water actually leaves the system via the atmosphere. The AET is limited by the available moisture supply and vegetation type of the basin. The available moisture is supplied from the storages within the basin. In the case of water bodies, that remain wet all year, there is no limit of moisture or limitation due to vegetation.

Model Construction

After the model is conceptualized, model construction can commence. The construction typically includes the processing of spatial data as well as temporal data. The spatial data processing using GIS estimate model parameters for the numerical model. The temporal data preparation develops the boundary conditions for the model.

Basin Area

In the Sylvan Lake model, the basin was found to have small errors estimated at about a 3% error. The contributing area of the lake should have been located south of the small dirt road in the northwest corner of the lake. Figure 1 shows the basin area discrepancy. The yellow polygon is the modeled basin the green is the estimated correction to the basin. Given the uncertainties in the model calibration this error would not pose a significant issue in the application of the model.

The watershed hydrology model for Sylvan Lake used common practices in HSPF to define the basin area. Mass Links were defined to route water leaving the PERLND and IMPLND modules (PERO and SURO variables) to the receiving water body simulated as a RCHRES (IVOL variable). The SCHEMATIC block was then used to connect the modules as well as enter the area of each module.

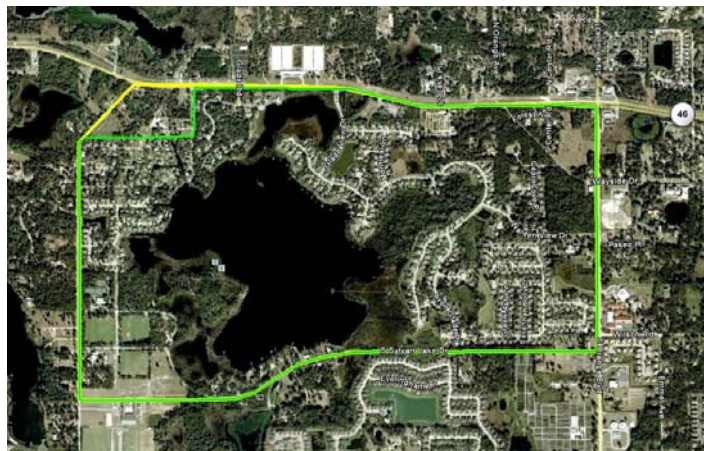


Figure 1. Sylvan Lake Basin Area Discrepancy





Boundary Conditions

Both the rainfall and ET input time series were examined in the input WDM file. Both time series are stored in a daily format. This causes the intensities to be averaged down since the daily value is evenly distributed over each hour of the day.

In a normal year in Florida, total annual rainfall averages approximately 50-52 inches and is consequently approximately equal to annualized PET. The PET and rainfall time series utilized for the Sylvan Lake model appear reasonable with one exception in the PET record, shown in Figure 2. There is an anomaly in the data record on June 7, 1992. An excerpt from the record is shown in Table 2. As shown in the table, the anomalous value is approximately 5 to 6 times higher than the values on the surrounding days. If this value is an error, it should be corrected in the time series. If it is not an error, an explanation for the value should be documented. The error would not, however, have any significant impact on the model results and therefore the defined MFL.

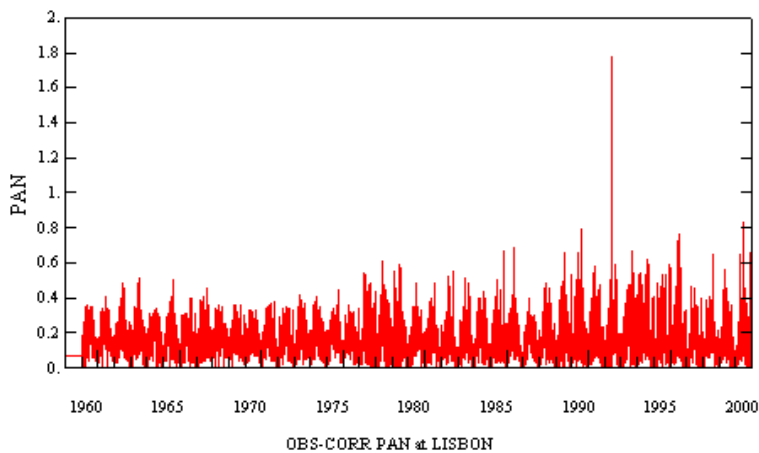
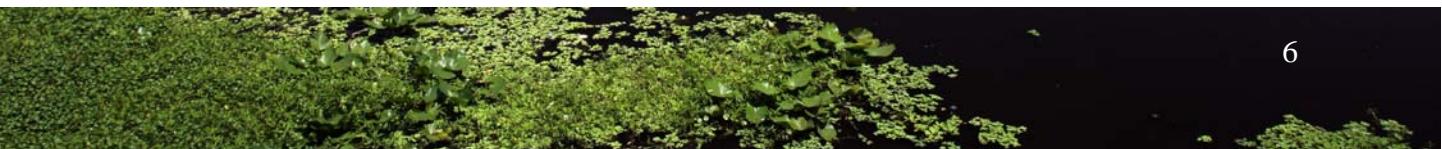


Figure 2. PET Data

Table 2. DSN 402 Excerpt

6/1/1992	0.21
6/2/1992	0.23
6/3/1992	0.06
6/4/1992	0.25
6/5/1992	0.25





6/6/1992	0.29
6/7/1992	1.78
6/8/1992	0.23
6/9/1992	0.31
6/10/1992	0.21
6/11/1992	0.26
6/12/1992	0.27
6/13/1992	0.52
6/14/1992	0.07
6/15/1992	0.29

The Sylvan Lake model uses daily rainfall. Daily rainfall assumes the rain is distributed evenly to every hour. It will force the model to treat a 1 inch event into 24 0.04 inch events. The reduced rainfall intensity will dramatically reduce the simulated runoff from the pervious land segments. The pervious land segment simulated runoff quantities of only 0.003 inches per year (see SURO in water budget discussion). Most of the pervious outflow is derived from the active groundwater.

Initial Conditions

The initial conditions are not a critical element of a long term simulation. Since the Sylvan Lake model extends for 40 years, the initial conditions are not a sensitive component of the model and therefore this review.

Special Actions

The special actions in HSPF enable the hydrologic model to be programmed to do added functionality. For example, special actions can enable HSPF to modify the processes during a simulation. Some of these modifications enable BMPs to be simulated. In the case of the Sylvan Lake model, special actions were used to compute the lake leakage to the confined aquifer.

Lake Leakage

Baseflow in HSPF is represented only as an outflow from basins or the PERLND module. The HSPF baseflow flux only represents fluxes that enter water bodies from the shallow aquifer only; it does not represent the deep aquifer exchanges. The Active Groundwater Outflow (AGWO) or HSPF baseflow flux can enter the water bodies that are represented with RCHRES modules. The RCHRES module, without special actions, does not interact with the aquifer and, as previously mentioned, can only receive shallow aquifer outflow (HSPF can not simulate losses). In Florida, significant fluxes into





and more importantly, out of water bodies can be present. The lack of aquifer interaction would impact the model performance and its ability to represent the processes present in the St. Johns River Watershed. Therefore, it was essential for the District to represent the lake losses as a special action to account for the significant water budget term.

Area Correction

In standard HSPF, the areas of reaches change with the relationship defined in the F-Table. The F-Table defines the non-linear relationship of stage, storage, area, and discharge of the RCHRES. The changing area in the reach should be offset with changes in the associated basin area. Standard HSPF is incapable of automatically changing the basin area. It is possible to use special actions to correct for the mass balance issues that arise from double accounting for basin area.

Unfortunately, the area correction was not performed in the Sylvan Lake model. Reaches were allowed to change in area without correcting the mass balance of the overall watershed. The mass balance becomes more of an issue for small basins with relatively large changes in lake area. The Sylvan Lake model has a basin area of 943 acres the Lake, on the other hand, fluctuates from 0 acres to 322 acres. The mass balance correction would maintain rainfall and PET fluxes and therefore the overall simulated mass balance. It is recommended the District evaluate the mass balance issue further.

Model Calibration

As with development of all models, calibration is a very important step in the model development process. Calibration is the adjustment of the model parameters to improve the fit of the model as compared to observed fluxes and events. A good calibration matches the observed storages and fluxes while maintaining the parameters within reasonable or literature ranges.

The only observed target in the Sylvan Lake model is the lake stage. This lack of calibration data results in a high level of uncertainty to the model solution and therefore the model calibration. Since both inflows and outflows of the Lake are unknown, no unique solution exists. The fact that the simulation is a non unique solution means there are an infinite number of inflow and outflow combinations that will allow the lake stage calibration to perform well. This is of critical concern since model results could change based on which non-unique solution it defined by the model.

The water budget of the Sylvan Lake modeling components is shown in Table 3. The following sub-sections will refer to this table and review each of the major water budget terms.





Table 3. Sylvan Lake Water Budget Components

Land Segment	Constituent	Mean	Max	Min
P:100	SUPY	51.1	69.3	32.4
	SURO	0.0029	0.0083	0.000391
	AGWO	5.7	13.4	1.2
	IFWO	0.0629	0.593	0.0039
	PERO	5.7	13.5	1.2
	AGWI	5.8	15.3	0.7
	IGWI	2.48	6.56	0.294
	PET	46.6	53.4	39.7
	TAET	42.6	48.5	36.4
I:100	SUPY	51.1	69.3	32.4
	SURO	38.7	53.2	22.8
	IMPEV	12.4	17.6	7.4

Simulated Pervious Runoff

Pervious runoff in HSPF is simulated through infiltration excess. It is therefore based on the infiltration capacity of the soils and the intensity of the precipitation. In the Sylvan Lake model there is essentially no runoff (SURO) from the pervious portion of the basin. This is most likely due to the daily rain and the large upper zone storage capacity (UZSN).

Simulated Impervious Runoff

As shown in the table, the impervious runoff term was fairly large in comparison to the rainfall, averaging 38.7 inches per year. This is consistent with imperviousness given there is no infiltration losses as found on pervious land. The basin is developed and includes significant drainage infrastructure. However, the concern in the model performance is in the area considered to directly drain to the lake. The developed land includes several stormwater retention/detention ponds. The model could simply account for these ponds by increasing the RETSC or retention storage capacity. Currently RETSC is set at 0.05 inches. Given the size and number of retention ponds found in the basin, an increase in this parameter is warranted.

Interflow

By definition, interflow is the lateral movement and ultimate discharge of infiltrated water within the vadose zone or before the water enters the saturated aquifer. In much





of Florida, the vadose zone or depth to the water table is so thin and the slopes are so shallow it can not support a significant interflow flux. The Sylvan Lake model includes very little interflow in the basin water balance. This is consistent with the landscape of the basin.

Active Groundwater and Inactive Groundwater

Active groundwater and inactive groundwater represent the shallow (active) and deep (inactive) groundwater components of the hydrologic cycle. HSPF can only simulate downward movement of water into these storages. It can not handle regional discharge zones where the deep aquifer is discharging into the shallow water table. HSPF also assumes that all the water moving into the active groundwater storage is available for either ET or outflow (notice the large AGWO term in the water balance). The Sylvan Lake water balance shows an average of 5.8 inches moving to active groundwater and 2.5 inches moving to inactive or deep groundwater. These numbers are considered well within the range of reasonable values supported by comparison with rates published by Boniol et al (1993).

Simulated TAET

HSPF simulates the total actual ET (TAET) based on the user defined parameters and the available moisture. TAET is the second largest water budget term of the watershed. The Sylvan Lake model simulates an average AET of 42.6 inches per year. Although this term may be slightly high, given the developed nature of the basin, it is well within the ranges found in the literature for the area.

Conclusions and Recommendations

The Sylvan Lake model is developed with the best available data. This is consistent with the MFL statutory requirements. The selection of the HSPF model is well suited for the development of MFLs. HSPF has been applied to many MFLs in SJRWMD and SWFWMD. However, a complex model such as HSPF needs to be calibrated in order to constrain the results. The Sylvan Lake application only has lake stage as a calibration target and has no observed flow targets. The lack of flow calibration means the model parameters and the modeling application yields a non-unique solution (basin inflows are simply offset with lake outflows). Nevertheless, there exists a large knowledge base of literature ranges for the model parameters. Most of the model parameters for the Sylvan Lake model fell within reasonable ranges as reported in other modeling studies using HSPF. Even though the knowledge base is not a hard constraint to the model calibration it does help limit the results to a possible of even probable range. Since the Sylvan Lake application has little constraint on the water balance, a simpler statistical approach such as multiple linear regression or artificial neural networks may be applicable to the





development of MFLs without the burden of sophisticated model and model calibration. Overall the Sylvan Lake application used the best available data and followed current engineering practices.

If future re-evaluations are called for Sylvan Lake then following recommendations are offered as possible action items:

- Utilize special actions to correct for mass balance inconsistencies
- Further study DCIA percentages or specifically account for retention ponds
- Carefully delineate basin and determine areas that truly contribute to Sylvan Lake
- Collect some calibration data to constrain model calibration
 - Observe Sylvan Lake outflows
 - Observe major inflow locations
- Conduct sensitivity analysis of key parameters (i.e., DCIA)
- Evaluate a statistical approach relating lake stage to aquifer levels.





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