APPENDIX B — HYDROLOGICAL ANALYSES

INTRODUCTION

In addition to the work conducted to determine the most relevant environmental criteria for priority water bodies, another critical step is to assess whether these criteria are protected under current withdrawal conditions, which requires substantial hydrological analysis. Several steps were involved in performing the hydrologic analysis, including:

1. Review of available data for compiling long-term datasets;
2. Historical groundwater pumping impact assessment;
3. Development of lake level datasets representing no-pumping and current-pumping conditions; and
4. Estimating available water (freeboard or deficit).

Figure B-1 shows the flowchart for the hydrologic analysis. This document describes the first three steps and associated results. Appendix C includes the description of the last step.

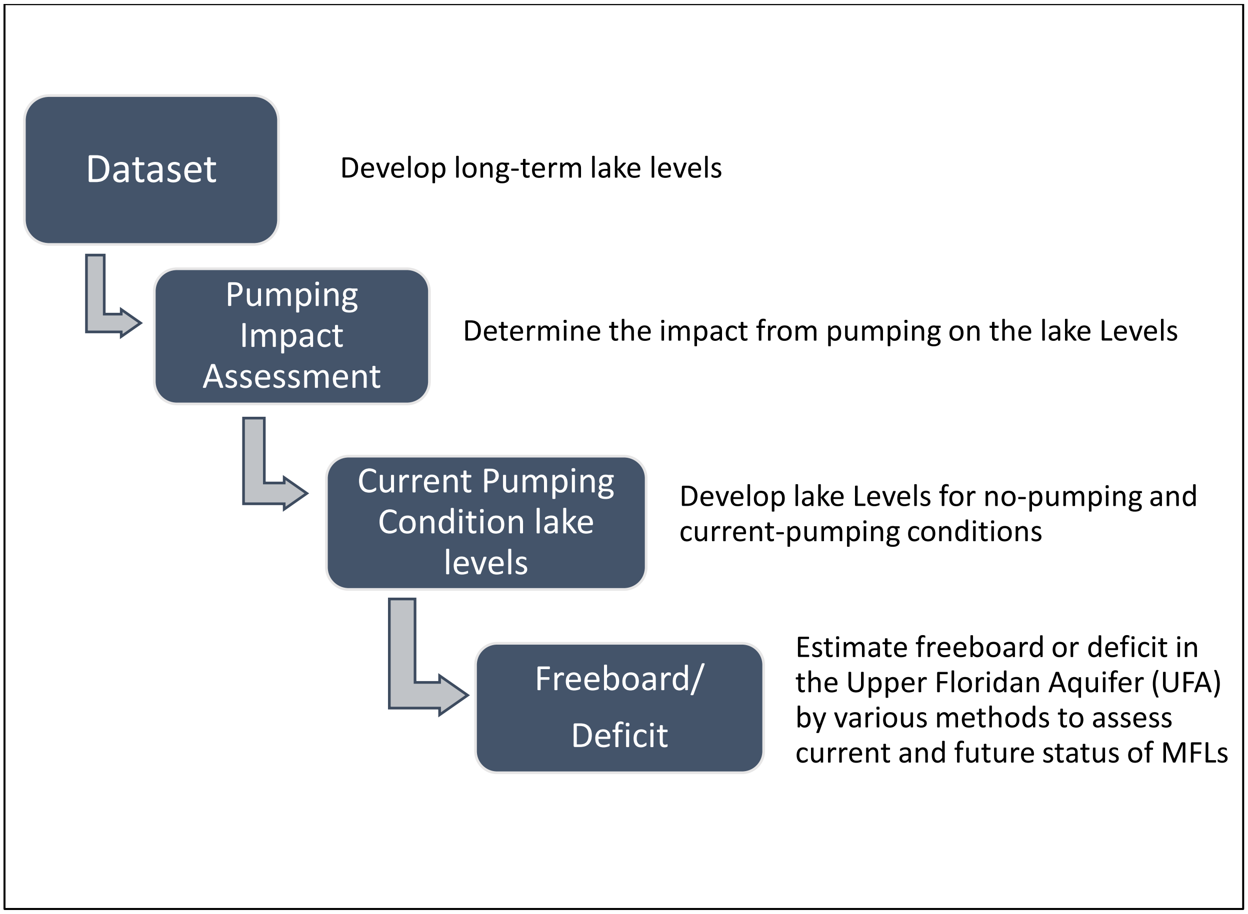

Figure B-1. Flowchart for Hydrologic Analysis Process

BACKGROUND

Sylvan Lake is located in Seminole County, Florida, in the Sanford/Lake Mary area. It is a large lake (nearly 200 acres) within the Yankee Lake Watershed (Figure B-2).

The St. Johns River Water Management District (SJRWMD) contracted with CDM Smith, LLC (CDM Smith) to develop and calibrate a continuous simulation hydrologic model of Sylvan Lake using HSPF (CDM Smith, 2017; see attached for model report). This model was completed in late 2017. The model was calibrated based on model results and observed lake stages for the period of 2008 through 2016 and validated for the period of 1997 through 2007. The model was extended for the long-term simulation (1948-2018) which was then used to develop lake level datasets representing no-pumping and current-pumping conditions for MFL status assessments.

Because minimum levels proposed for Sylvan Lake are based on an event-based approach associated with return periods (e.g., the recommended minimum frequent low level should be achieved once every five years, on average), MFL assessment requires frequency analysis of lake levels. Due to the presence of short- and long-term climatic cycles (e.g. El Nino Southern and Atlantic Multidecadal Oscillations), the frequencies of lake levels could be significantly different in wet periods such as in 1960s than dry periods such as in 2000s. Thus, it is important to perform frequency analysis using long-term lake levels so that the effect of short- and long-term climatic variations on lake levels can be captured.

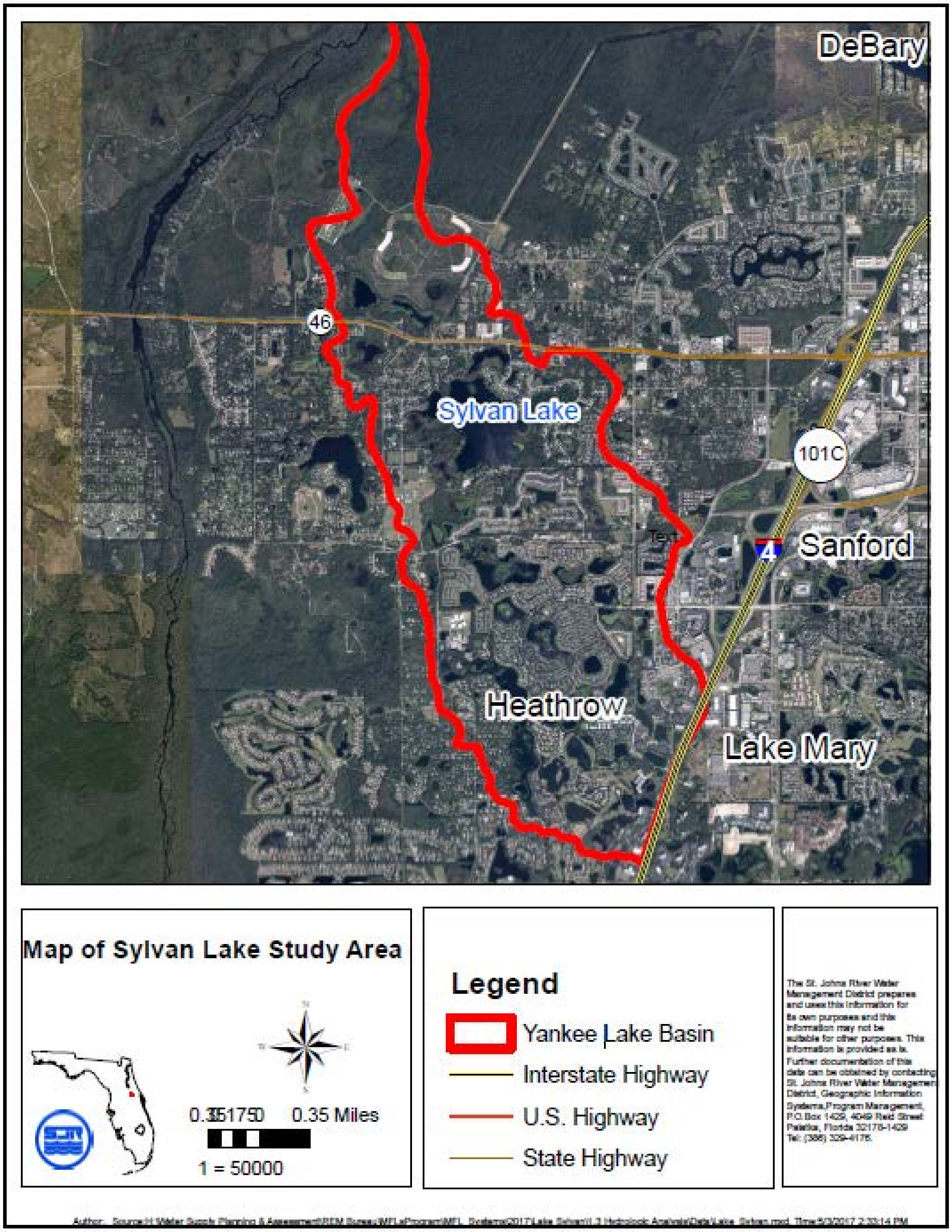

Figure B-2. Site location map

Review of Available Data

Rainfall and Potential Evapotranspiration (PET)

Rainfall data were compiled using data from two stations. Table B-1 shows a list of the rainfall stations.

Table B-1: Rainfall stations used in Sylvan Lake model

Rainfall Station Name, ID	Collection Agency	Period Used
Sanford, 08-7982	NOAA	1948-2007
Sylvan Lake Park, 284759081232100	USGS	2007-2018

Potential Evapotranspiration (PET) was computed with temperature data obtained from the Sanford station using the Hargraves-Samani (1985) method. The Hargraves-Samani method was scaled with monthly coefficients to correspond with the USGS GOES Priestly-Taylor evaporation estimate (WSIS, 2012). The monthly coefficients were obtained by regressing mean Hargraves-Samani PET against USGS mean PET. Figure B-3 shows the annual rainfall and PET data and descriptive statistics are presented in Table B-2.

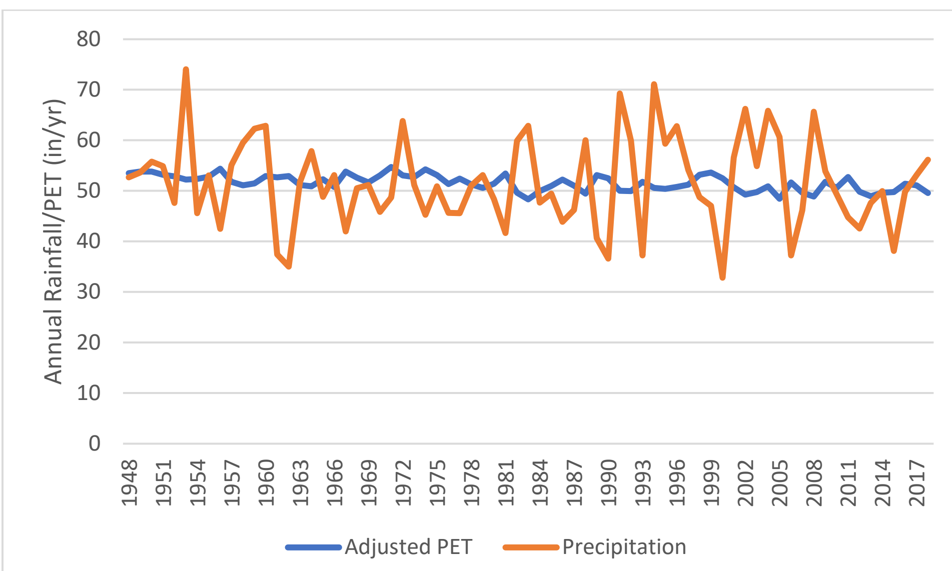

Figure B-3. Annual average rainfall and PET

Table B-2. Summary Statistics of the annual Precipitation and PET

Statistical Parameter	Annual Precipitation (in)	Annual PET (in)
Mean	51.65	51.59
Median	51.07	51.48
Standard Deviation	8.96	1.55
Minimum	32.83	48.33
Maximum	74.06	54.74

Lake Levels

The water level dataset for the lake was retrieved from the Seminole County Water Atlas database (Table B-3). Sylvan Lake has a random observation record (n=426) from 1978 through 2018. Figure B-4 shows the observed stage.

Table B-3. Summary of available water level data

Station	Station ID	Period of Record	Count
Sylvan Lake	SCPW-L-SYL	1978 – Present*	N=426 (1978-2018)

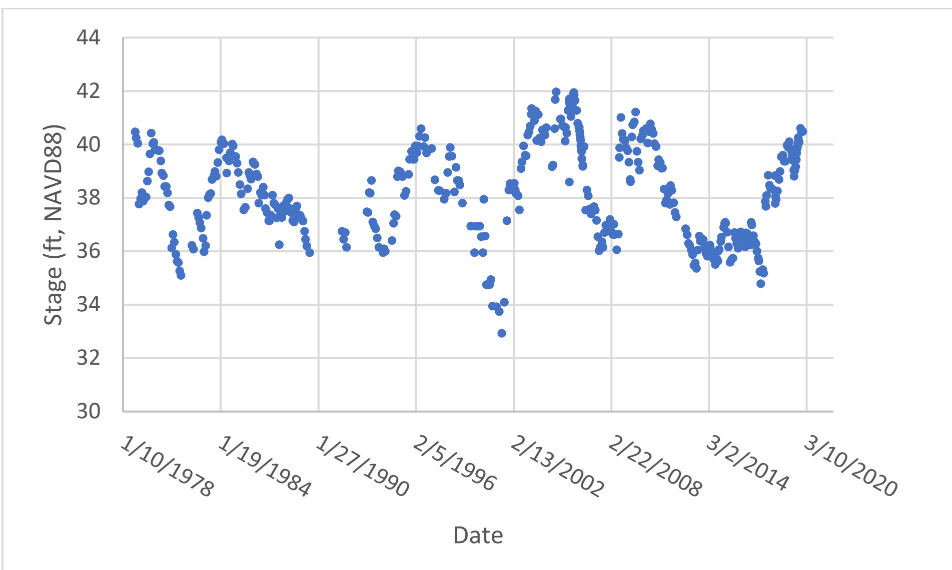

Figure B-4. Water Levels of Sylvan Lake

A summary of water level statistics for Sylvan Lake is provided in Table B-4.

Table B-4. Water level (WL) summary statistics for Sylvan Lake; elevations in feet, NAVD88

Descriptive Statistics	Sylvan WL
Mean	38.3
Median	38.2
Standard Deviation	1.8
Range	9.0
Minimum	32.9
Maximum	42.0
Count	426

Groundwater Levels

Five Upper Floridan well levels (Figure B-5) were considered for use in the model (S-0718, V-0101, L-0045, L-0043 and OR-0047). The S-0718 well was at the lake and was the preferred data source. Data were available at that well for the period of February 2009 through current, including daily records from July 29, 2009 onward and single measurements in February 2009, April 2009 and May 2009. Time series data from the other wells were analyzed to determine which had the best correlation between levels at the well(s) and levels at well S-0718 (Figure B-6). Their locations correlation and distances from the S-0718 well, and the regression results are given in Figure B-6 and Table B-5, respectively. The two with the best correlations were along the central ridge like the lake, while the other two were in the lowlands north and east.

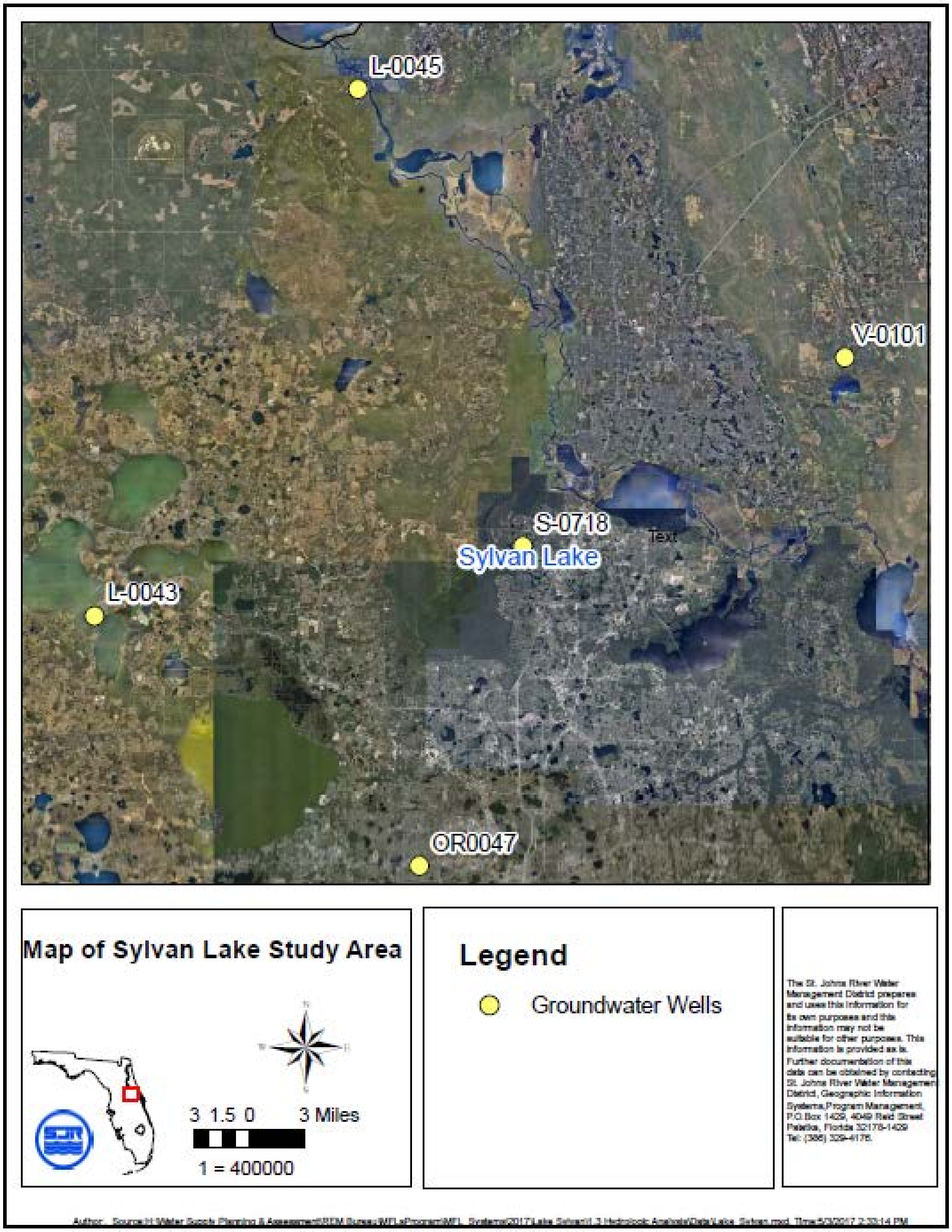

Figure B-5. Upper Floridan aquifer wells

Table B-5. Distance and Correlation of Nearby Wells to S-0718.

Well	Distance (miles)	Correlation (R-squared)
L-0043	23.7	0.64
L-0045	26.5	0.33
OR-0047	18.3	0.82
V-0101	20.4	0.28

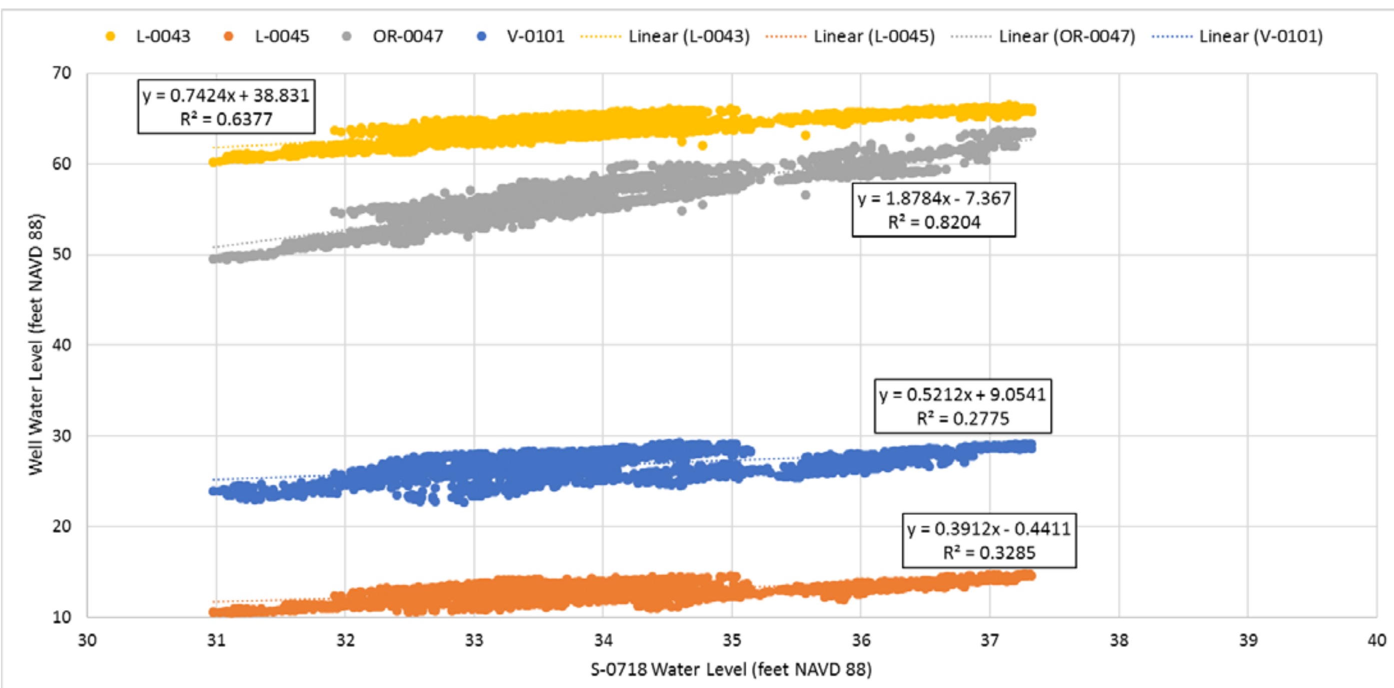

Figure B-6. Comparison of Water Levels of Nearby Wells to S-0718

Of the four other wells, well OR-0047 levels showed the best correlation with S-0718 well levels. Consequently, records from this well were used to synthesize well levels at S-0718. More information on these wells is provided in Table B-6.

Table B-6. UFA Groundwater Stations near Sylvan Lake

STATION NUMBER	STATION NAME	LATITUDE	LONGITUDE	Data Start	Data End
30342858	S-0718 Sylvan Lk Wells at Sanford (WL) FA	28° 28' 50.106"	-81° 13' 48.903"	2/11/2009	Current
09272094	OR0047 Obs Well at Orlo Vista (WL) FA	28° 19' 31.4322"	-81° 17' 0.0378"	9/30/1930	Current

SYLVAN LAKE LONG-TERM SIMULATIONS

The CDM Smith model, which simulates the calibration and verification years (1997–2016), was extended for long-term simulation over the period of 1948-2016 by SJRWMD in 2019. The model was further extended through the year 2018 by SJRWMD in 2020. The long-term simulation required the extension of the hourly rainfall, hourly Potential Evapotranspiration (PET), and daily Upper Floridan Aquifer (UFA) groundwater level timeseries for input into the model. In addition, the Sylvan Lake outflow structure was improved in 2014. The long-term simulation used the stage-discharge relationship of the new lake outfall structure, which represented the current conditions. Additional analysis, performed by SJRWMD, compared the results of the current discharge structure with the pre-2014 structure, which is discussed later in this technical memorandum.

Long-term Groundwater Levels

As specified previously, the S-0718 well was at Sylvan Lake and was the preferred data source, with recorded well data since 2009. The OR-0047 well was used fill the data through the long-term simulation period, as the levels showed the best correlation with S-0718 well levels. Synthesized values based on well OR-0047 were used to fill the data gaps at well S-0718 prior to July 2009 in the calibration/verification model. The synthesis applied the USGS program Streamflow Record Extension Facilitator (SREF) version 1.0 (Granato, 2008), using the maintenance of variance extension type 3 (MOVE.3) method.

The following equation, which was developed using the MOVE.3 method, was applied:

(1) S-0718 Elevation (feet NAVD) = 1.633 * (OR-0047 Elevation) $^{0.7521}$

The same method and equation were used to extend the Sylvan UFA groundwater timeseries from January 1, 1948 to December 31, 2018. The actual and synthesized levels are shown in Figure B-7 and the extended groundwater timeseries used in the long-term simulation is shown in Figure B-8. The long-term levels had a downward trend, but the levels have appeared to stabilize since the 1980s.

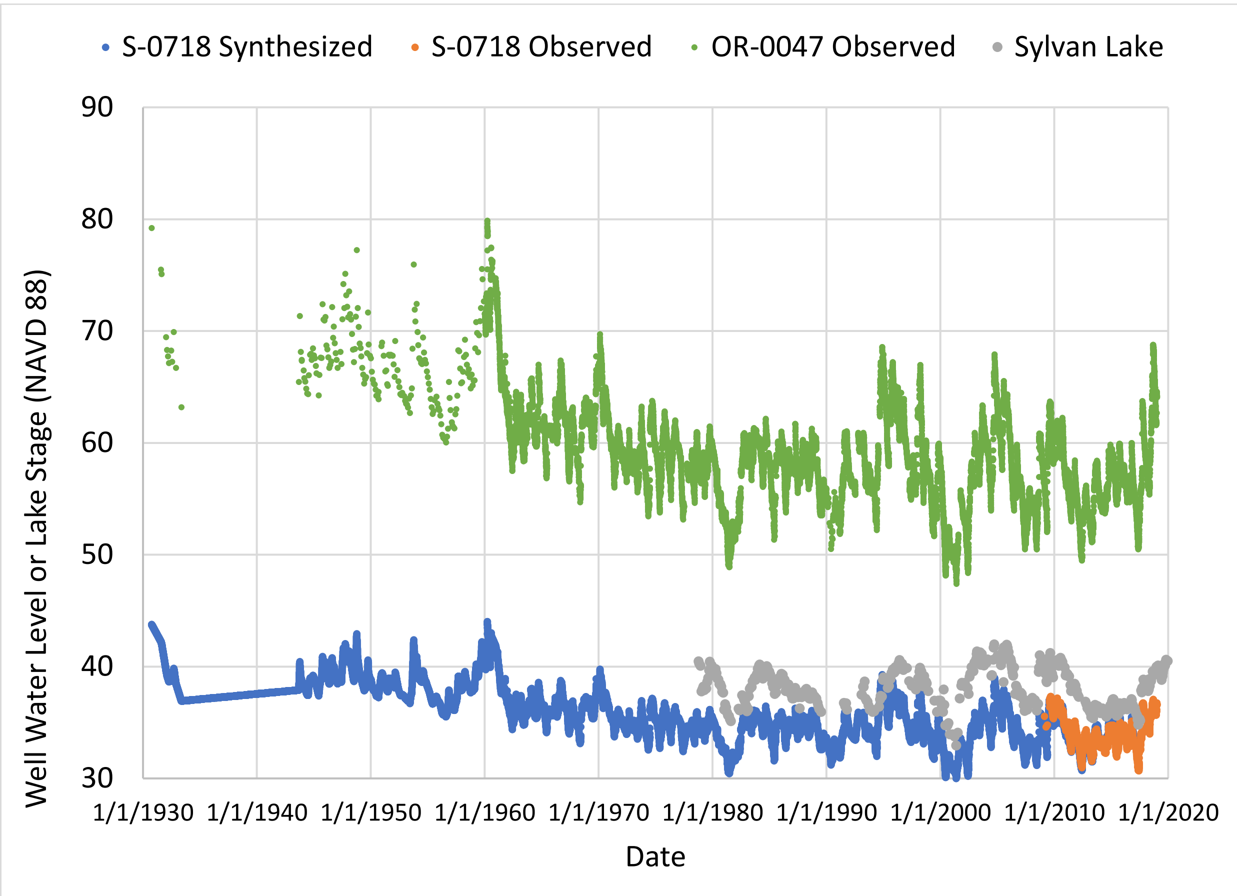

Figure B-7. Actual and Synthesized S-0718 Well Levels.

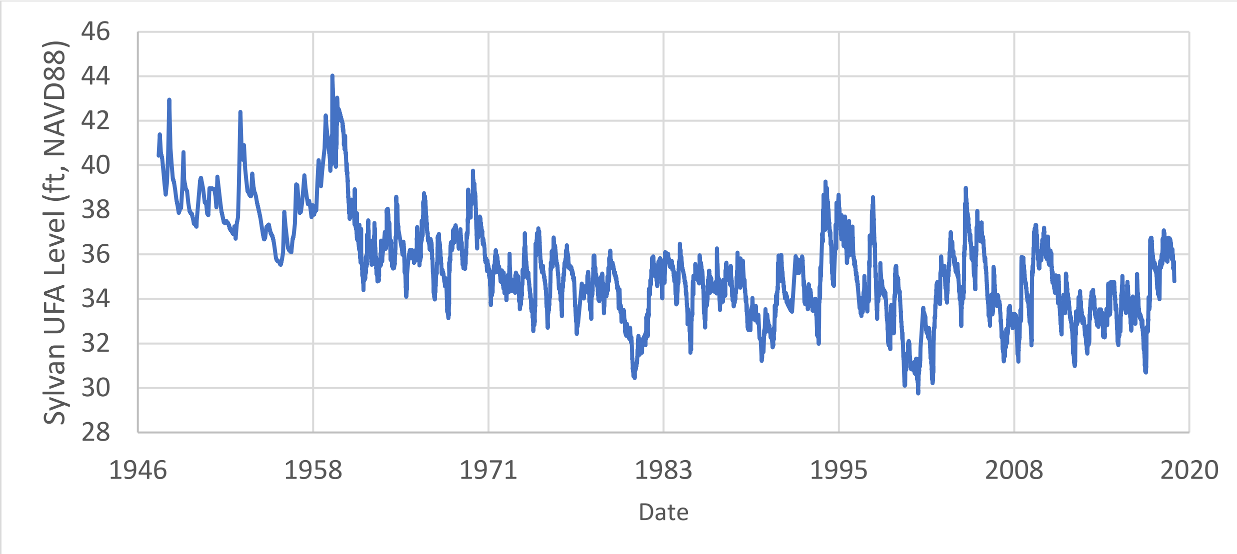

Figure B-8. Extended long-term UFA groundwater levels for Sylvan Lake through 2018.

Historical Long-term Lake Levels

After the extensions of the hourly rainfall, PET, and daily UFA groundwater levels, the calibrated model was run from January 1, 1948 to December 31, 2018. All the hydrologic parameters were kept the same.

Sylvan Lake had an irregular observation record (n=426) from 1978 through 2018. Figure B-9 shows the long-term simulated stage compared with the observed stage. It appears that in general, the long-term simulation was within reasonable range of historic values, and the modeled stage varied up and down in a similar pattern to the observations. There was a period during 7/13/1979-8/11/1980 that simulated stages were much lower than observed values; the opposite occurs between 1988-1991. This could be explained by the lack of continuous long-term local rainfall data prior to 2007, when the more distant (Sanford) rainfall gage was used. The local (Sylvan Lake) gage was used after 2007, which was better at capturing localized storm events and vice versa. Changes in land use, in addition to estimation of groundwater levels and inaccuracies in the observed lake stages, could be other reasons for the mismatch in stage.

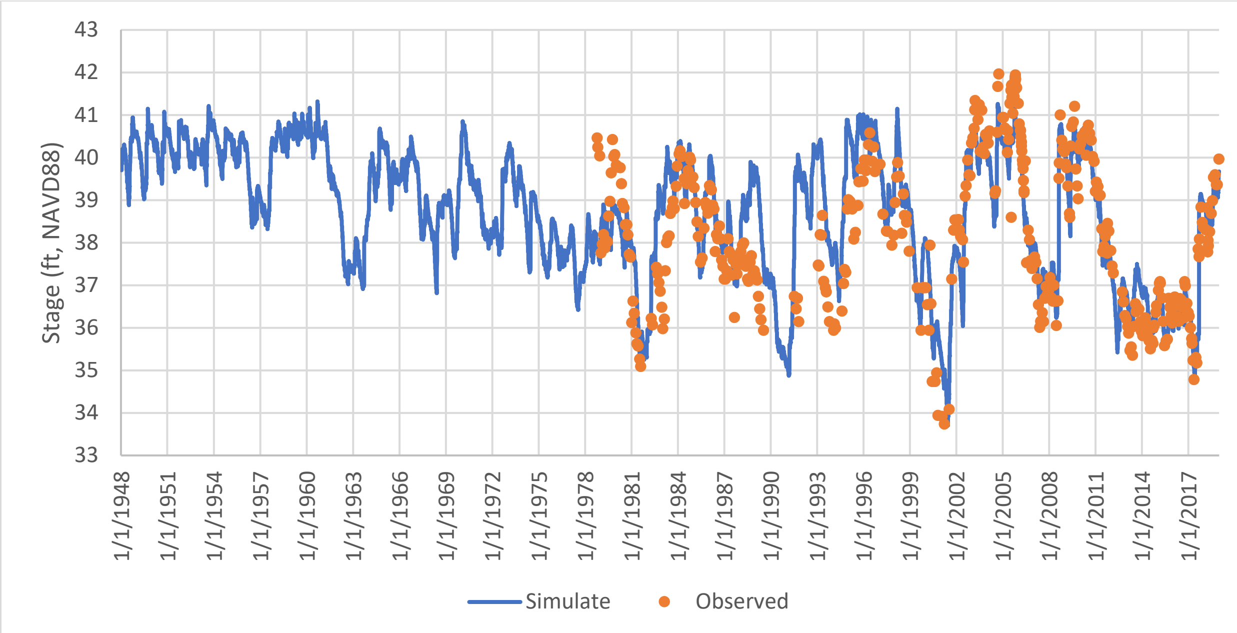

Figure B-9. Comparisons of simulated and observed long-term Sylvan Lake Levels (ft, NAVD88).

A list of goodness-of-fit statistics is provided for long-term simulations in Table B-7. Overall, the model performed reasonably well in simulating the long-term lake levels considering the calibration period is from 1997 to 2017 and the observed data is relatively sparse.

Table B-7. Goodness-of-fit statistics of long-terms Simulations

Statistics	Value
Mean Absolute Error (feet)	0.73
RMSE (Root Mean Square Error) (feet)	0.99
R (Pearson Correlation Coefficient)	0.86
R^2 (Coefficient of Determination)	0.73
PBIAS (Percent Bias)	0.78
NSE (Nash-Sutcliff Efficiency)	0.71

Old Culvert Analysis

Prior to the construction of the current outflow structure (invert at 40.5 ft NAVD88), there was a vegetative channel and box culvert that had discharges above 40.8 ft NAVD88 (Table 4 of Appendix A, CDM Smith 2017). Figure B-10 shows the long-term simulated stage under the condition of the old culvert compared with the new culvert. As expected, the water level was slightly higher under the old culvert conditions during high water level times. The maximum stage in the old culvert scenario was 42.04 ft NAVD88 compared to 41.28 ft NAVD88 in the new culvert scenario. The culvert height did not have a significant impact at low water levels; the minimum stage for the old culvert and new culvert scenarios were both 33.89 ft NAVD88. In addition, there was not much effect on the lake levels over the long-term simulation period, as the average water level was only slightly higher in the old culvert scenario compared to the new culvert scenario (37.81 ft and 37.72 ft NAVD88, respectively).

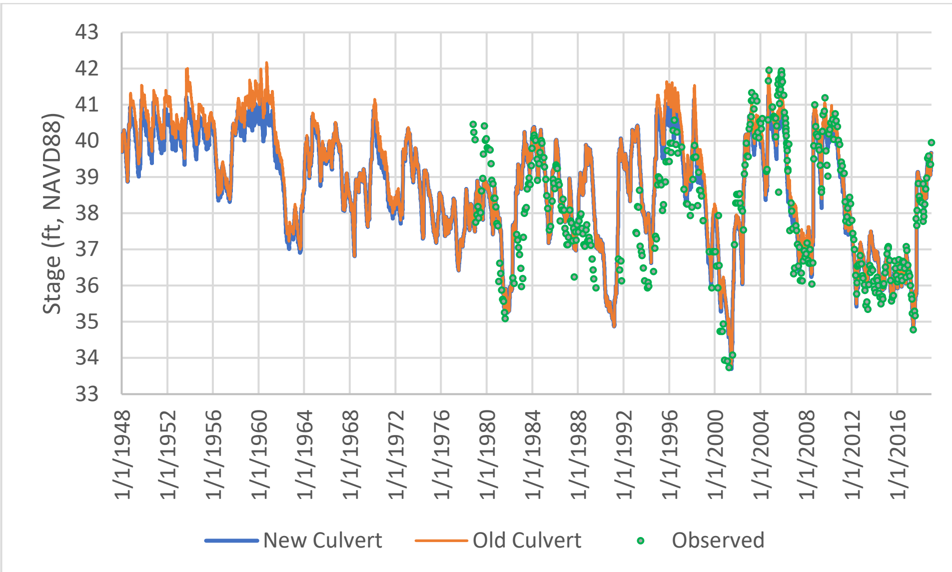

Figure B-10. Comparison of simulated Sylvan Lake stage under old culvert vs. new culvert scenarios

DEVELOPMENT OF NO-PUMPING AND CURRENT-PUMPING LAKE LEVELS

The current and future status of minimum levels developed for Sylvan Lake needed to be assessed. The objective of the current status assessment is to determine whether the Sylvan Lake minimum levels are being achieved under the current pumping condition. Because of our limited understanding of possible future climatic conditions and difficulties in predicting future lake levels using global climate model forecasts, historical lake levels were considered to be the best available data and were adjusted for groundwater pumping impact to assess the current status of minimum levels.

The adjustment of historical lake levels required considering the effect of current groundwater pumping on lake levels not only for the recent years but also for the entire period-of record (from 1948 through 2018). Two sets of adjusted lake levels were developed – no-pumping condition and current-pumping condition lake levels. The no-pumping condition lake levels constituted a reference hydrologic condition in which lakes were not under the influence of any groundwater pumping from 1948 through 2018. The current-pumping condition lake levels represented a reference hydrologic condition in which lakes were under the influence of current groundwater pumping constantly from 1948 through 2018. Current groundwater pumping was defined as the average groundwater pumping from

2014 through 2018. An average of the past five years of groundwater pumping was used to calculate the current-pumping condition so that it is more representative of the most recent average groundwater demand condition.

Figure B-11 shows the process for developing lake levels for no-pumping and current-pumping conditions.

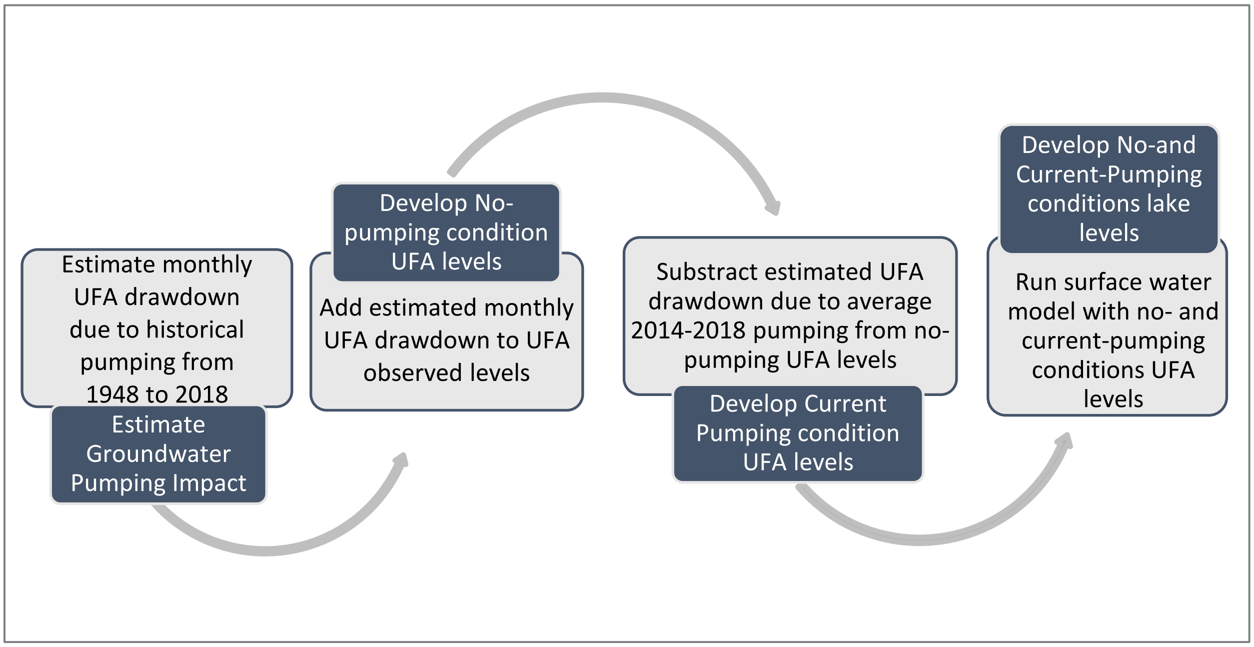

Figure B-11 Process for developing no-pumping and current-pumping condition lake levels

The HSPF model was used to develop no-pumping and current-pumping condition lake levels. To simulate no-pumping and current-pumping condition lake levels, no-pumping and current-pumping groundwater levels near lakes were required. As previously discussed, water level data from groundwater monitoring wells were used with some adjustments to compute the exchange of flows between the UFA and Sylvan Lake in the model.

The first step in developing the current-pumping condition groundwater levels was to develop the no-pumping condition groundwater level dataset. This dataset was developed by adding an estimate of impact due to historical pumping (i.e., the UFA drawdown due to pumping) to the observed/extended groundwater levels. The current-pumping condition groundwater level dataset was developed by subtracting an estimate of impact due to current pumping (average groundwater pumping from 2014–2018) from the no-pumping groundwater levels. No-pumping and current-pumping condition groundwater levels were later input into the surface water model to simulate no-pumping and current-pumping condition lake levels.

Historical Groundwater Pumping Impact Assessment

Groundwater Use

It was assumed that most of the impact on Lake Sylvan has been caused by the UFA groundwater pumping within a radius of 10-mile. Figure B-12 shows the extent of 10-mile buffer zone.

Therefore, to estimate the impact on groundwater levels from pumping, monthly groundwater use data was compiled all stations within a 10-mile radius of the Lake Sylvan centroid from 1957 to 2018 (Figure B-13).

The groundwater pumping data was estimated from 1948 through 2018 using the data available from different sources. The pumping data from 1995 to 2014 was from the CFWI effort which was a collective effort between WMDs and stakeholders. Data for 2015 to 2018 was from the SJRWMD historical water use database with actual monthly use and station-level details. The data from 1965 to 1995 were based on the United States Geological Service (USGS) published county-level water use (available every five years starting in 1965) and the annual SJRWMD county-level Annual Water Use Survey (AWUS), starting in 1978. Using these two sources, the water use data was aggregated to the county for every five years and some years in between from 1965. Any missing years for each county were estimated using an exponential growth assumption to create a complete aggregate table. If the USGS and AWUS estimates do not match, the published AWUS data were used. To estimate annual groundwater use by county for the period before 1965, per capita groundwater use was estimated for each county. Multiplying the 1965 per capita water use by the historic county-level population from U.S. Census, the annual groundwater uses by county were estimated for the period before 1965. The U.S. Census data was reported in 10-year intervals. An exponential growth was assumed to estimate the annual population between 10-year intervals. The 1995 proportion of county water use captured in the 10-mile lake domain was multiplied to the county aggregate from 1948 to 1994 to estimate the water use within the Lake Sylvan 10-mile buffer domain.

To disaggregate the annual data to monthly groundwater use, the average monthly proportions by county, estimated from the monthly SJRWMD database from 2004 to 2014, were applied to the annual data.

It should also be noted that the groundwater pumping within the 10-mile buffer was only used as a proxy to understand the variation of regional groundwater pumping from 1930 to 2018. The impact of groundwater pumping on lake levels was assessed based on all groundwater pumping within the groundwater model domain (described further below).

As shown in Figure B-13, the total groundwater use in these counties reached its highest in 2006 (50.8 mgd) and declined more than 25% after 2006. The average total groundwater use in these counties over the past five years (2014–2018) was approximately 37.4 mgd, which is similar to groundwater use in the early 1980s.

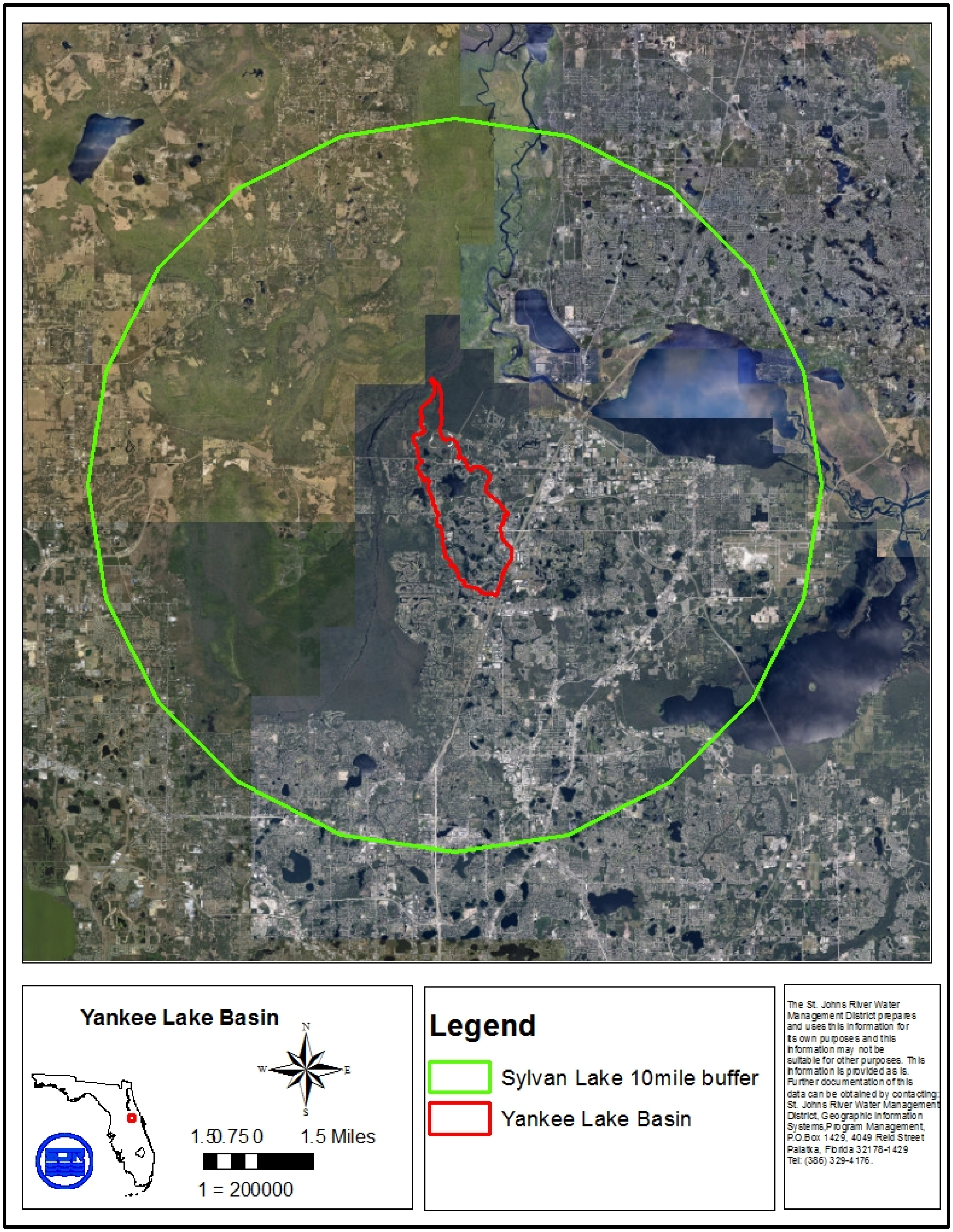

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Figure B-12 Sylvan Lake 10-mile buffer zone

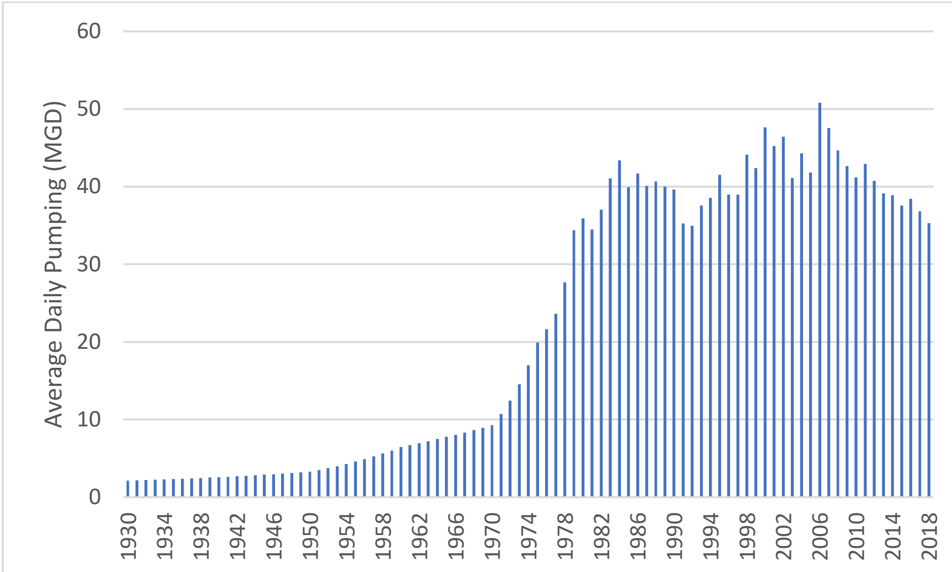

Figure B-13. Estimated historical groundwater uses in Sylvan Lake basin area.

Groundwater Modeling

The East-Central Florida Transient Expanded (ECFTX) groundwater model was used for the groundwater pumping impact assessment (CFWI HAT, 2020). The ECFTX model consists of an initial stress period representing steady state conditions for the year 2003, followed by 132 monthly transient stress periods representing the years 2004 through 2014. The ECFTX model was calibrated to match average water levels and flows within the 2004-2012 period, with 2013-2014 serving as a verification period. Figure B-12 shows the 10-mile boundary area of the ECFTX model comprising Lake Sylvan that was used in the groundwater pumping impact assessment.

Estimated historical impact on groundwater levels

An estimate of daily Upper Floridan Aquifer (UFA) drawdown beneath Sylvan Lake resulting from regional pumping for the period of 1948 to 2018 was needed to develop the no-pumping simulations. Due to the fact that the ECFTX model was not designed to simulate monthly conditions over this long-term period (i.e. from 1948 to 2018), a methodology was developed that used available ECFTX model data to estimate the impact of regional pumping on groundwater levels outside of the model simulation period. This methodology included the development of a relationship between groundwater pumping and UFA drawdown beneath Sylvan Lake using the ECFTX model. To develop this relationship, and capture a wide range of pumping conditions, the following ECFTX model simulations were used:

- Pumping reduced by 50%
- Pumping reduced by 25%

- Calibration
- Pumps off

For each simulation, the simulated UFA level beneath Sylvan Lake was extracted from the ECFTX model for each transient monthly stress period (2004 through 2014) by taking a weighted average of the simulated UFA levels at all model cells intersecting the lake boundary. Subsequently, the pumping impact, or change in UFA levels beneath Sylvan Lake, was calculated for each pumping scenario by subtracting the pumping scenario simulated UFA levels from the pumps off simulated UFA levels. For example, the impact for the calibration simulation was calculated by subtracting the simulated calibrated model UFA levels from the simulated pumps off UFA levels beneath Sylvan Lake. This calculation was repeated for the 50% and 25% reduced pumping scenarios. This resulted in 132 simulated impact values for each pumping scenario, corresponding to each month in the transient simulation. Groundwater pumping information was also extracted from the ECFTX model for the calibration, 25% reduced pumping and 50% reduced pumping scenarios. For each scenario, the total pumping in model layers 3 through 11 (Upper UFA to LFA) was extracted from the 10-mile Sylvan Lake buffer area (Figure B-12) and summarized for each transient monthly stress period in the model. Groundwater pumping in the 10-mile buffer area were considered as a proxy to develop the relationship and capture the variation of regional pumping over time. The modelled impact and pumping data for each scenario and transient stress period were combined into a single table, yielding a total of 396 model pumping-impact paired data values to use to fit a relationship between impact and groundwater pumping. A linear regression model was fit to the modelled impact (response variable) and groundwater pumping (predictor variable) data for Sylvan Lake. Figure B-14 shows the regression plot for Sylvan Lake. A strong linear relationship ($R^2 = 0.98$) existed between UFA modelled impact beneath Sylvan Lake and groundwater pumping (Figure B-14).

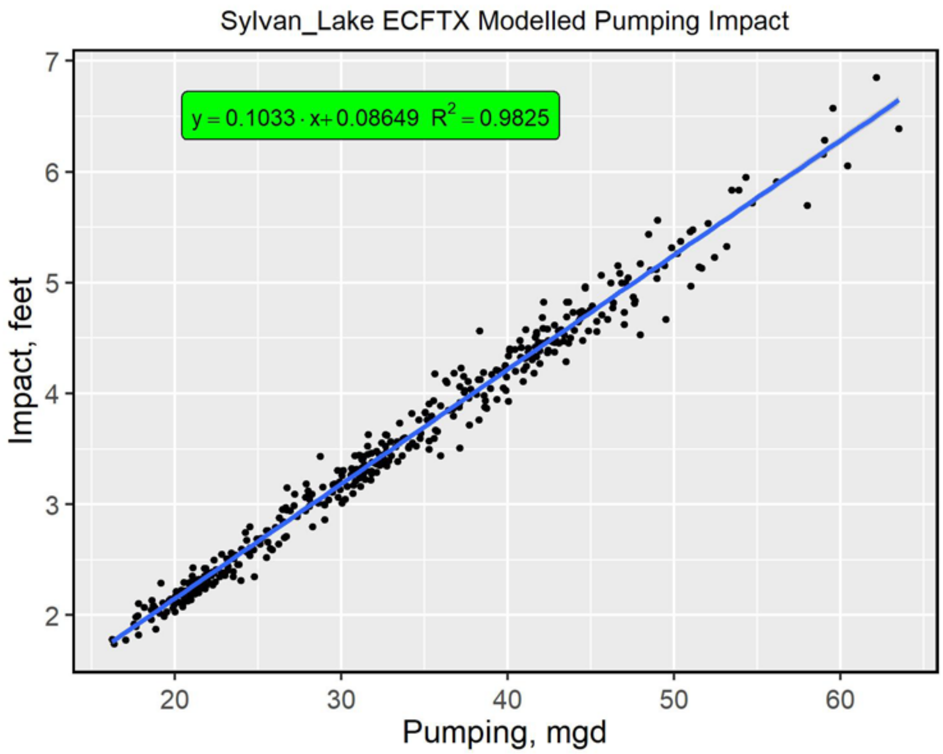

Figure B-14. Relationship between UFA drawdown near Sylvan Lake and groundwater pumping in the Sylvan Lake 10-mile buffer area

The linear regression equation shown in Figure B-14 was used to calculate a monthly historical impact from long-term (1948 to 2018) estimated monthly pumping data within the 10-mile Sylvan Lake buffer area (Figure B-12). The monthly estimated long-term historical impact due to pumping was disaggregated to a daily time series extending from 1948 to 2018 using linear interpolation.

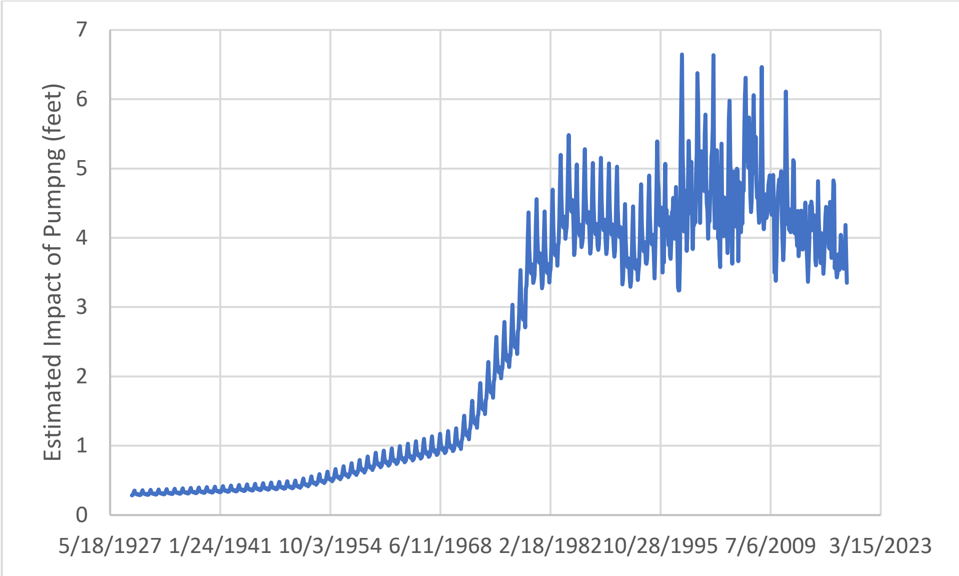

Figure B-15. Estimated impact of pumping on UFA levels near Sylvan lake

No-pumping condition groundwater levels

The long-term daily estimated impacts from pumping shown in Figure B-15 were added to the daily observed/extended groundwater level data at Sylvan Lake to create the no-pumping condition groundwater level dataset for Sylvan Lake.

Current-pumping condition groundwater levels

To generate the current-pumping condition groundwater levels, the average estimated pumping in the 10-mile Sylvan Lake buffer area between the years 2014 to 2018 was calculated. The linear regression (Figure B-14) was used to calculate the current pumping impact for the 2014 to 2018 average pumping. The impact from the average 2014 to 2018 pumping was then subtracted from the no-pumping condition groundwater levels. Figure B-16 shows both the daily no-pumping and current-pumping condition groundwater levels for Sylvan Lake.

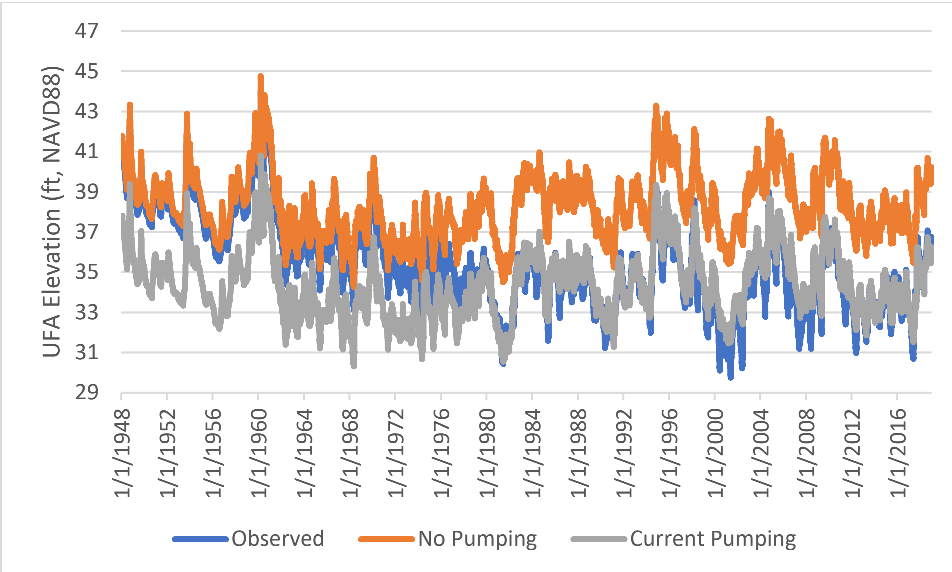

Figure B-16. Estimated no-pumping and current-pumping UFA levels near Sylvan Lake

Lake Level Datasets for MFL Analysis

The no-pumping and current-pumping Sylvan Lake levels were simulated by inputting the no-pumping and current-pumping groundwater levels (Figures B-16) to the HSPF model.

Figures B-17 shows both no-pumping and current-pumping conditions lake levels for Sylvan Lake. The monthly datasets were later disaggregated into daily lake levels by linear interpolation. Table B-8 shows the descriptive statistics of existing, no-pumping and current-pumping condition lake levels.

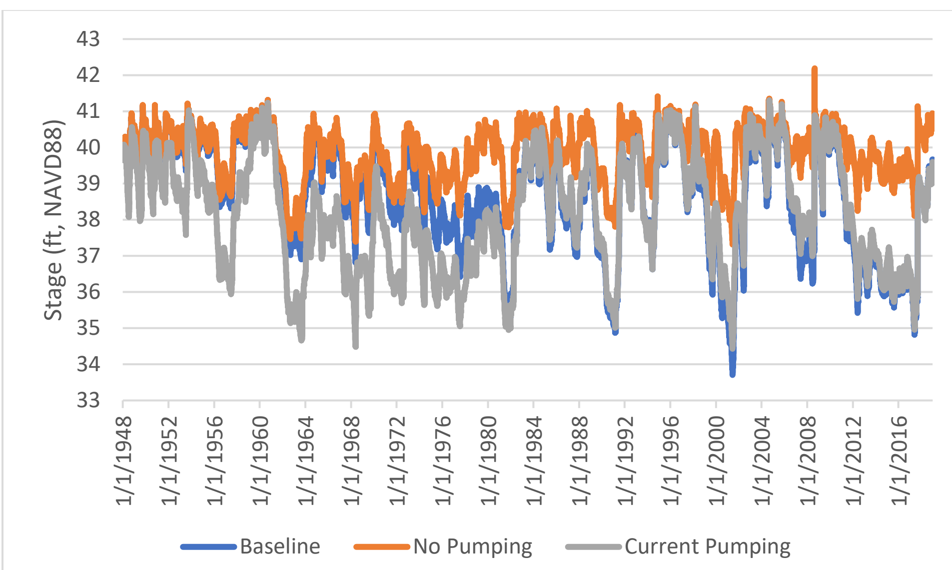

Figure B-17. The estimated no-pumping and current-pumping condition levels for Sylvan Lake

Table B-8. Descriptive statistics of simulated Sylvan Lake stages

Statistical Parameter	No-pumping condition lake level (ft, NAVD88)	Historical condition lake level (ft, NAVD88)	Current-pumping condition lake level (ft, NAVD88)
Mean	39.87	38.73	38.19
Standard Error	0.005	0.009	0.01
Median	40.04	38.97	38.23
Standard Deviation	0.76	1.50	1.57
Minimum	37.31	33.70	34.43
Maximum	42.19	41.31	41.31

The current-pumping condition lake levels represent a reference hydrologic condition of the lakes in which the total regional groundwater pumping impacting the lakes was constant from 1948 to 2018 at a rate of averaged pumping from 2014 to 2018. Assuming climatic, rainfall, and other conditions present from 1948 to 2018 are repeated over the next 60 years, the current-pumping condition lake levels would reflect the future condition of the lake levels if the average regional groundwater pumping does not change from 2014–2018 condition. Because of our limited understanding of possible future climatic conditions and uncertainties in global climate model predictions, using historical conditions to generate current-pumping condition lake levels is reasonable. Therefore, the no-pumping and current-pumping condition lake level datasets shown in Figure B-17 were used to assess the MFLs at Sylvan Lake.

LITERATURE CITED

CDM Smith, 2017. Sylvan Lake MFL Evaluation

CFWI HAT, 2020. Model Documentation Report East-Central Florida Transient Expanded (ECFTX) Model. Prepared by Central Florida Water Initiative (CFWI) Hydrologic Analysis Team (HAT). February 2020.

WSIS, 2012. SJRWMD Water Supply Impact Study. Technical Publication SJ2012-1

ATTACHMENT TO APPENDIX B

CDM 2017

Surface water model report

***NOTE*: Provided as Reference.**

Not part of Peer Review Scope

Sylvan Lake MFL Evaluation

Executive Summary

This executive summary and attached documents summarize the work completed for the St. Johns River Water Management District (District) by CDM Smith Inc. for the Sylvan Lake Minimum Flows and Levels (MFL) Evaluation, under Work Order #17 of Contract #27776. The work order included four tasks (A through D). This final report, which consists of an executive summary and attachments that reflect work from other tasks, is Task D.

Background

A hydrologic model was developed in 2005 to evaluate the MFLs set for Sylvan Lake, which is currently being reevaluated and scheduled for completion in late 2017. An updated hydrologic model was needed for the reevaluation of the MFLs for Sylvan Lake.

The District requested assistance from CDM Smith with hydrologic modeling in support of Sylvan Lake MFLs reevaluation. Specifically, CDM Smith reviewed data provided by the District, updated the Sylvan Lake 2005 HSPF hydrologic model, calibrated the updated model, and validated the updated model.

Data Review

Task A involved the review of data required for the HSPF model development and simulation. Details are included in **Appendix A**, which summarizes the data review.

CDM Smith reviewed data provided by the District, which included the following:

- Hourly rainfall records
- Evapotranspiration data
- Sylvan Lake stage data
- Groundwater elevations from existing observation wells
- Tributary area, topographic, and hydrographic data
- Recharge data
- Land use data
- Soils data
- Lake bathymetry

The data provided were considered sufficient to develop a model that could be used to evaluate long-term lake stages and achievement of established MFLs.

Through the data evaluation and discussion with District staff, several data decisions were made. These included the following:

- **Missing Well Data.** Synthesized values based on well OR-0047 were used to fill the data gap at well S-0718 prior to July 2009.
- **Study Area Boundary**. The total tributary area to the lake includes "direct" tributary area (area that is expected to contribute runoff and surficial groundwater inflow to the lake) and "indirect" tributary area (area that is expected to contribute only surficial groundwater to the lake). Total tributary area (direct plus indirect) was based on the District's boundaries, and the direct tributary area was based on the previous study delineation, provided topographic information, and a field visit on June 22, 2017.
- **Rainfall Data.** CDM Smith found that a more local USGS rainfall gage has collected data in Sylvan Lake Park from October 2007 to the present. It was decided that these data should be used as part of the model calibration covering the years 2008 through 2016.

Model Update

Task B involved the use of data acquired in Task A to update the HSPF model of the Sylvan Lake and associated tributary area. Specific considerations included refinement of the tributary area and its land use distribution, lake bathymetry, and seepage from the lake to the Upper Floridan aquifer. Model refinements were in keeping with recommendations from the INTERA peer review of the previous 2003 model. Details are included in **Appendix B**, which summarizes the model update, and in **Appendix D**, which lists INTERA comments and how comments were addressed in the update.

Specific refinements included the following:

- **Tributary Area.** The original 2005 lake tributary area delineation considered only the area that was expected to contribute surface runoff and surficial aquifer groundwater discharge to the lake. The refined model considers both the "direct" tributary area (contributing both runoff and surficial groundwater) and "indirect" tributary area (contributing groundwater only). The direct tributary area is somewhat greater than the original 2005 MFL delineation with minor modifications based on the District subbasin boundary in that area and observations from the field visit under Task A. The indirect tributary area includes area between South Sylvan Lake Road and Markham Road. Area south of Markham Road and east of Merlot Drive is not expected to contribute any flow to Sylvan Lake. This is discussed in more detail in the Task C letter report.
- **Model time step.** The model runs on an hourly time step, as did the previous version, but in addition, the model is using hourly rainfall and potential evapotranspiration (PET) values provided by the District or USGS.
- **Vertical datum.** All lake stage and well elevation input, and lake stage model output, are now in the NAVD 88 vertical datum.

- **Land use**. The 2009 land use provided by the District was used to define the distribution of land use within the lake contributing area. The land use data were categorized into 13 land use types as directed in the scope, based on a lookup table developed from previous CDM Smith projects with the District. Values of percent imperviousness by land use category were set to be consistent with values used by the District and used in the 2015 MFL studies based on District comment.

- **Lake surface discharge.** An outfall structure was constructed in 2014 that modifies the relationship between lake stage and surface discharge at high lake levels. The model was refined to include both a relationship based on the new outfall structure, and a relationship that reflected the overland flow surface discharge prior to the new structure. Pre-project survey of the site was used to create a SWMM representation of the vegetated channels and culvert associated with the historical lake outfall. SWMM results were used to establish the depth-outflow relationship for the lake prior to the new outfall construction. Model validation to high lake stage conditions in 2004 and 2005 suggests that the established historical depth-outflow relationship is reasonable. Both the calibration and validation simulations applied the stage-outflow relationship prior to the new outfall structure, considering that most of that period precedes the new structure, and lake stages have been below the new structure discharge level since the structure's implementation.

Model Calibration and Validation

Task C involved the calibration of the Sylvan Lake HSPF model for the current MFL analysis. Details are included in **Appendix C**, which summarizes the model calibration effort.

After discussion with the District, CDM Smith selected the period of 2008 through 2016 as an appropriate calibration period for the HSPF model. This period features the best and most complete set of model input and calibration data (e.g., the most localized USGS rainfall data, PET data, lake stages, local groundwater well data), and is a recent period that is representative of the model land use conditions.

The calibration process considered the establishment of appropriate hydrologic parameters to determine the flow of surface runoff and groundwater to the lake, coupled with the seepage of water out of the lake to the Upper Floridan aquifer. Based on a review of the modeled response in lake stages to the large storm events, the values of infiltration and soil water storage parameters for pervious land areas were established. In addition, deep recharge values for pervious land areas, and lake seepage parameters, were established for consistency with the latest District recharge map.

The results of the model for the calibration period were compared to observed lake stages, according to the criteria established in the scope by the District. Goals of the calibration included:

- Maximizing the number of simulated lake stages that are within +/- 0.5 foot of observed values (achieving at least 85 percent within the target)

- Nash-Sutcliff score of at least 0.90.

The model results did achieve the Nash-Sutcliffe score (with a value of 0.93), and the goal of 85 percent of values within +/- 0.5 foot was nearly achieved (with a value of 72 percent). At the 85 percent level, the difference between observed and modeled lake stages was +/- 0.56 foot. The calibrated model does a very good job in following the trends of increasing and decreasing lake stages, and range of lake stages over the calibration period.

The calibrated model was tested further through model application to a separate validation period of 1997 through 2007. It was anticipated that the model results would not be as good as for the calibration, for several possible reasons:

- The localized USGS rain gage did not have data for most of this period
- The well data used to assess the lake leakage to the upper Floridan aquifer was based on synthesized well level values rather than observed values
- The direct tributary was undergoing development during the validation period (i.e., the model land use distribution may not be fully representative of conditions during part of the validation period)

Despite these potential issues, the model still did a very good job of matching the observed lake stages during the validation period. The model results achieved a Nash-Sutcliffe score of 0.90, which suggests that the model did a very good job of replicating the range of lake stages observed during the period. For the validation period, 57 percent of the modeled stages were within +/- 0.5 foot of corresponding observed stages. At the 85 percent level, the difference between observed and modeled lake stages was +/- 1.07 feet.

Summary

An updated HSPF model of Sylvan Lake and contributing area has been developed. The model was calibrated based on model results and observed lake stages for the period of 2008 through 2016, and validated for the period of 1997 through 2007. The model performs well at reproducing observed lake stages during dry and wet periods, and is considered appropriate for long-term model simulation in support of MFL analyses. When the long-term simulation is done, the District should use the lake stage-discharge relationship based on the surface outflow structure that was constructed in 2014, to represent current conditions.

Appendix A

Task A Letter Report

8381 Dix Ellis Trail, Suite 400
Jacksonville, Florida
tel: 904 731-7109

June 29, 2017 (updated September 30, 2017)

Dr. Xiaoqing Huang
St. Johns River Water Management District
PO Box 1429
4049 Reid St.
Palatka, FL 32178

Subject: Sylvan Lake MFL Evaluation – Task A: Data Review

Dear Dr. Huang:

This letter summarizes the work completed for the St. Johns River Water Management District (District) by CDM Smith Inc. in Task A of the Sylvan Lake Minimum Flows and Levels (MFL) Evaluation, under Work Order #17 of contract #27776. Task A involves the review of data required for the HSPF model development and simulation. Sylvan Lake was previously evaluated in 2005 using measured data and the USGS HSPF model to support the MFL program. This is an update of that work.

Review of Data Provided by the District

CDM Smith reviewed the data provided by the District, which included the following:

- **Hourly rainfall records.** The District provided time series rainfall data from 1914 through 2016 in a WDM (Watershed Data Management) file, which listed Sanford as the location of the data. CDM Smith reviewed the period from 1948 (corresponding to earliest potential evapotranspiration (PET) data described below) to 2016, and found that the average and range of the annual values (**Table 1**) appeared reasonable.

- **Evapotranspiration data.** The District provided time series of PET data from 1948 through 2016 in a WDM (Watershed Data Management) file, which listed Sanford as the location of the data. The PET data were calculated on a daily basis using maximum and minimum air temperature using the Hargreaves equation, and then disaggregated to hourly values using WDMUtil. An e-mail from District staff indicated that the time series values should be adjusted by a factor of 0.8888 for use in the HSPF model. The average and range of the annual, including the adjustment factor, (Table 1) appeared reasonable.

Table 1. Annual Totals and Statistics for Rainfall and Potential Evapotranspiration

Year	Annual Rainfall (in)	Annual PET (in)
1948	52.7	55.0
1949	53.7	55.5
1950	55.8	55.4
1951	54.9	54.7
1952	47.6	54.3
1953	74.1	53.6
1954	45.6	53.8
1955	53.1	54.3
1956	42.5	55.9
1957	55.1	53.4
1958	59.5	52.3
1959	62.3	52.9
1960	62.9	54.4
1961	37.4	54.1
1962	35.0	54.3
1963	51.7	52.4
1964	57.9	52.3
1965	48.8	53.8
1966	53.1	52.1
1967	42.0	55.4
1968	50.6	54.1
1969	51.2	53.0
1970	45.9	54.4
1971	48.7	56.3
1972	63.8	54.6
1973	51.2	54.2
1974	45.3	56.0
1975	50.9	54.8
1976	45.7	52.8
1977	45.6	53.7
1978	51.1	52.5
1979	53.1	52.0
1980	48.4	52.7
1981	41.7	54.7
1982	59.9	51.2
1983	62.9	49.5
1984	47.7	51.4
1985	49.5	52.4
1986	43.9	53.6
1987	46.2	52.3
1988	60.1	50.9
1989	40.7	54.6
1990	36.6	54.1
1991	69.3	51.5
1992	59.9	51.3
1993	37.2	53.0
1994	71.1	51.9
1995	59.3	51.7
1996	62.8	52.2
1997	54.1	52.7
1998	48.8	54.6
1999	47.0	55.1
2000	32.8	54.0
2001	56.6	52.3
2002	66.2	50.7
2003	54.9	51.2
2004	65.9	52.3
2005	60.7	49.8
2006	37.3	53.0
2007	46.2	51.1
2008	65.7	50.4
2009	53.9	53.2

2010	49.4	51.8
2011	44.8	54.2
2012	42.6	51.4
2013	47.6	50.5
2014	50.0	50.9
2015	38.1	51.2
2016	49.8	52.9
Minimum	**32.8**	**49.5**
Mean	**51.6**	**53.0**
Maximum	**74.1**	**56.3**

- **Sylvan Lake Stage Data.** The District provided a daily time series of lake stage data extending from October 1978 through April 2017. During that period, the lake stages ranged from 32.9 to 42.0 feet NAVD 88, with an average value of 38.3 feet NAVD 88. Stages were rounded to the nearest 0.1 ft for reporting.

  Figure 1 displays the lake stage data with respect to the minimum frequent high, average and minimum frequent low MFLs and the annual rainfall and PET values (with PET adjusted using the factor described earlier). The MFLs include a minimum frequent high (FH) level of 39.5 feet NAVD 88, a minimum average (MA) level of 38.0 feet NAVD 88, and a minimum frequent low (FL) level of 36.5 feet NAVD 88.

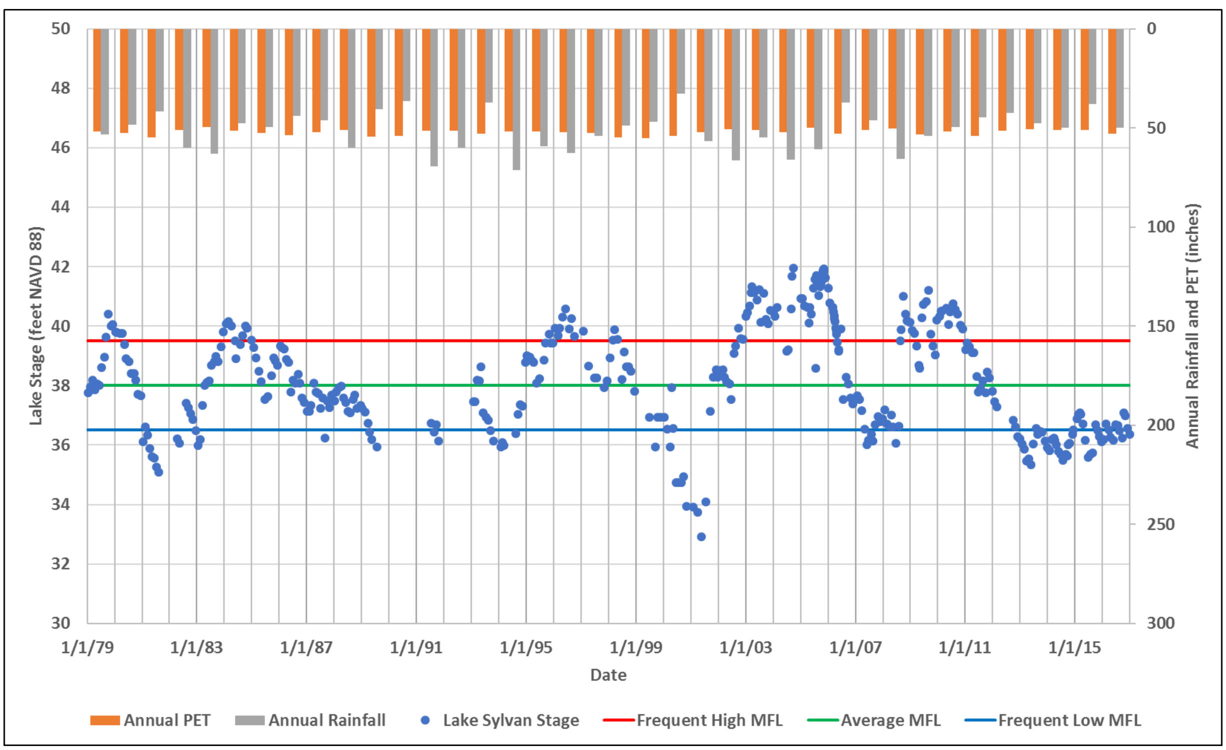

Figure 1. Sylvan Lake Historical Stage Data and Current MFLs

The rainfall and lake stage data seem to be consistent, with lake stages rising in response to higher rainfall years and dropping in lower rainfall years. The lowest measured lake stages are in 2001, after 3 years (1998-2000) of rainfall that are below average and are exceeded by the PET. The highest lake stages are in 2005, reflective of above average rainfall in excess of the PET for 2001 through 2005.

- **Groundwater elevations from existing observation wells.** The District provided time series of Upper Floridan well levels for five wells including S-0718, V-0101, L-0045, L-0043 and OR-0047 (**Figure 2**). The S-0718 well is at the lake, and is the preferred data source. Data are available at that well for the period of February 2009 through April 2017, including daily records from July 29, 2009 onward and single measurements in February 2009, April 2009 and May 2009.

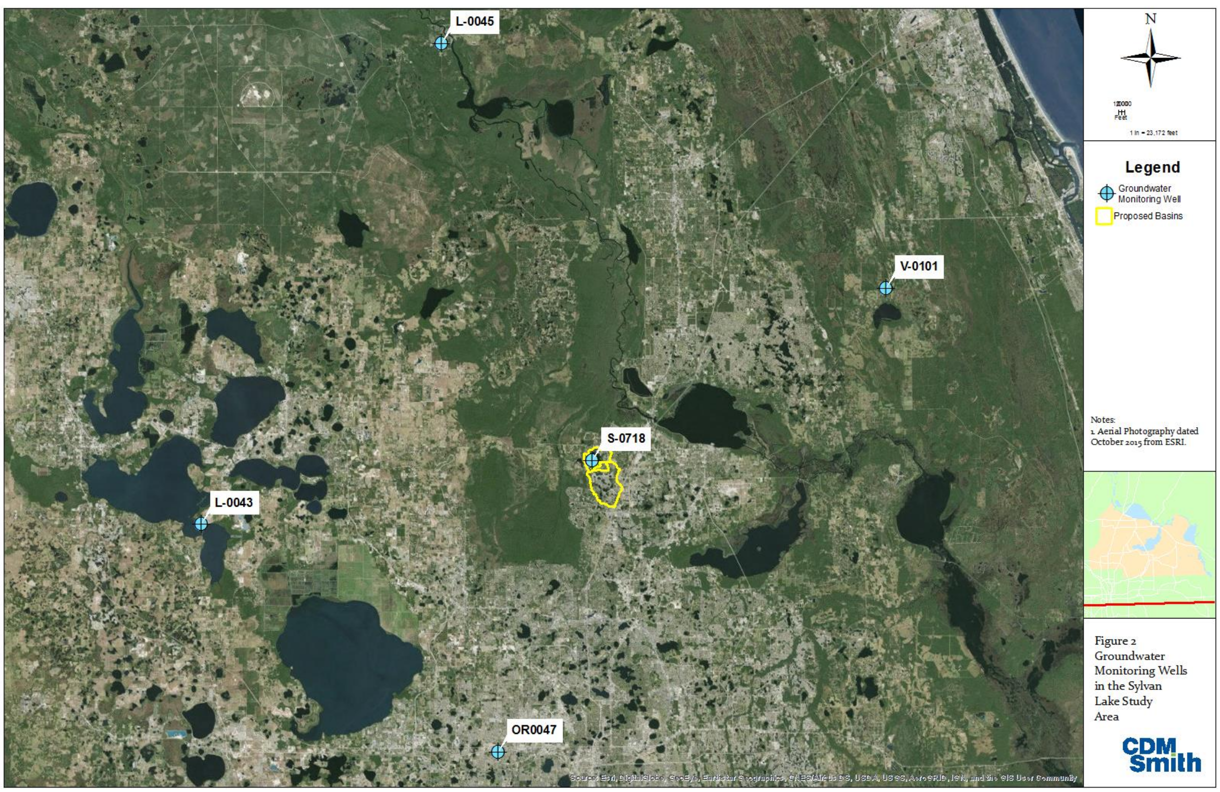

Figure 2. Location of Groundwater Monitoring Wells

CDM Smith reviewed the time series data from the other wells to determine which well(s) showed the best correlation between levels at the well(s) and levels at well S-0718 (**Figure 3**). Of the four other wells, well OR-0047 levels showed the best correlation with S-0718 well levels (**Table 2**). Consequently, records from this well were used to synthesize well levels at S-0718. The synthesis applied the USGS program Streamflow Record Extension Facilitator (SREF) version 1.0, using the maintenance of variance extension type 3 (MOVE.3) method. This is described in more detail later in the letter.

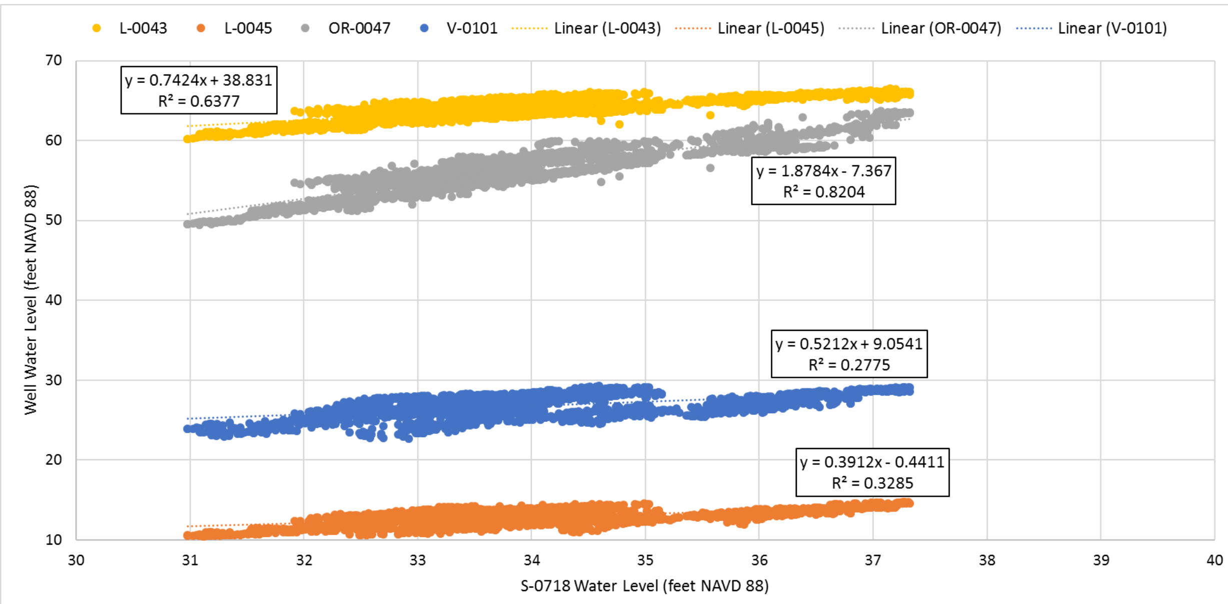

Figure 3. Comparison of Water Levels of Nearby Wells to S-0718

Table 2. Distance and Correlation of Nearby Wells to S-0718

Well	Distance (miles)	Correlation (R-squared)
L-0043	23.7	0.64
L-0045	26.5	0.33
OR-0047	18.3	0.82
V-0101	20.4	0.28

- **Tributary area, topographic, and hydrographic data.** The District provided the Yankee Lake Basin delineation that includes the immediate Sylvan Lake tributary area as well as areas north and south of the lake. The District noted that the Yankee Lake basin area south of Sylvan Lake, which was not included in the original MFL analysis of Sylvan Lake, may contribute inflow to Sylvan Lake. **Figure 4** illustrates the topography in the proposed basin boundaries for the Sylvan Lake MFL Study. These boundaries are presented and discussed further in a later section of this letter.

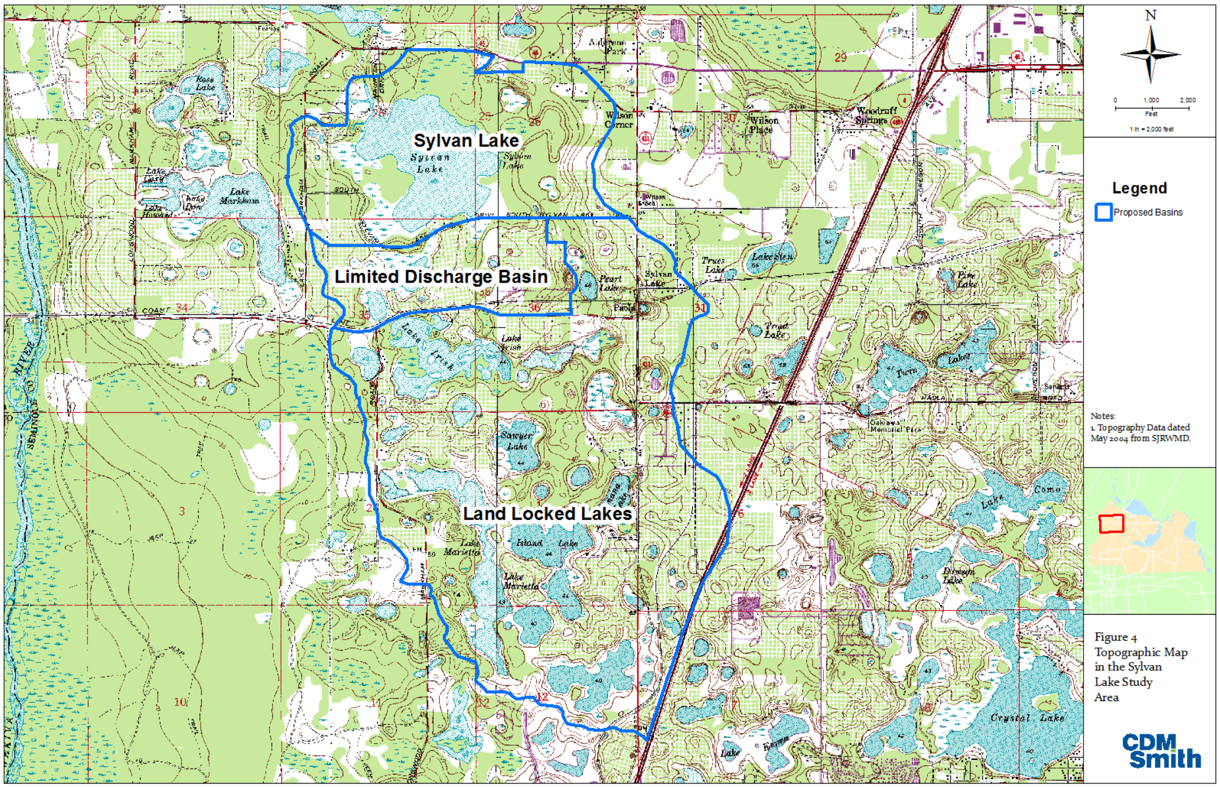

Figure 4. Topographic Map of Proposed Basin Boundaries for the Sylvan Lake Study Area

- **Recharge data.** CDM Smith also obtained the latest Floridan aquifer recharge map from the District (**Figure 5**). Review of the map indicated that the area within the original CDM Smith tributary area boundary is primarily classified as “medium” recharge (5 to 10 inches per year) around the lake, and “high” recharge (10 to 15 inches per year) east of Sylvan Lake. Virtually all the area that is south of the original CDM Smith tributary area boundary but within the District Yankee Lake Basin south of the original boundary is classified as “high” recharge. Thus, it is not clear that the additional area outside the original boundary will contribute much groundwater inflow to Sylvan Lake. This is discussed further in a later section of this letter.

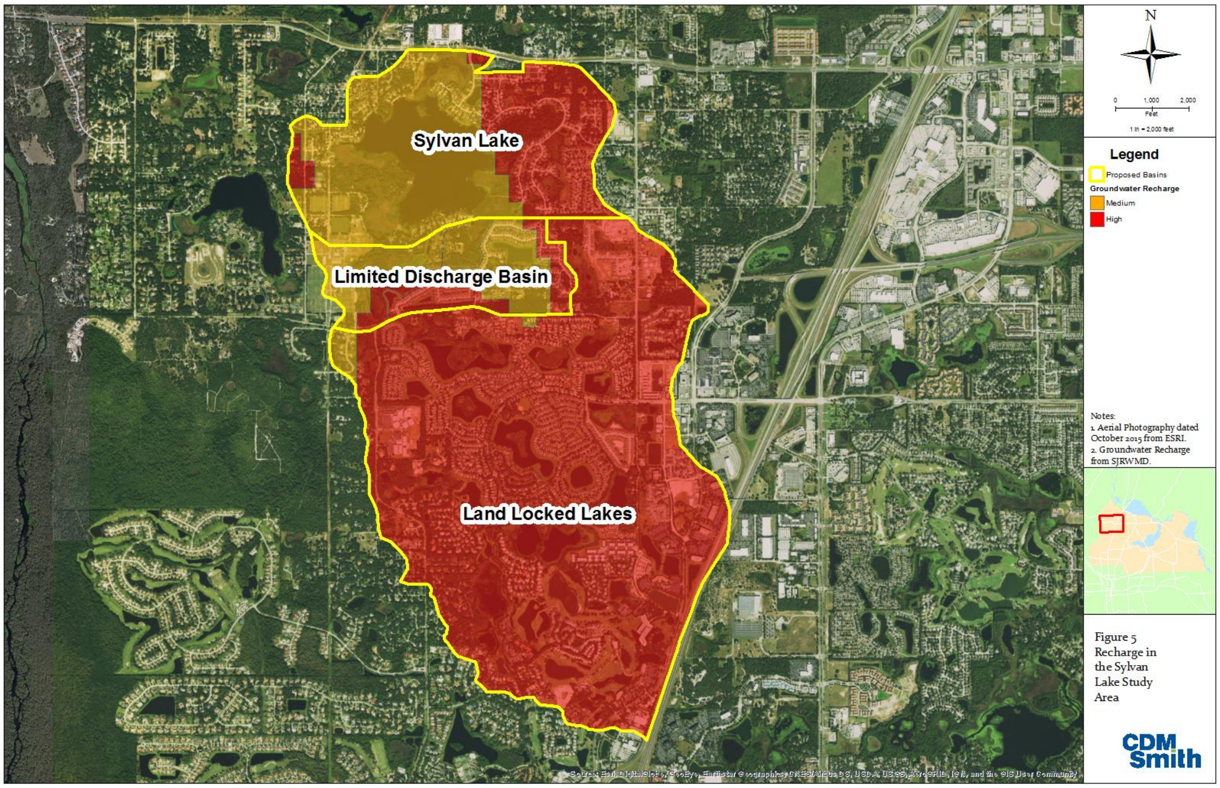

Figure 5. Recharge Map of Proposed Basin Boundaries for the Sylvan Lake Study Area

- **Land use data.** The District provided digital land use coverage for the year 2009. **Table 3** summarizes the land use in the area that is considered to be contributing directly to Sylvan Lake, subdivided into the 13 standard land use categories that have been used for HSPF modeling by the District. The updated land use will be used by CDM Smith to develop the model hydrology input such as impervious acreage, and acreage and associated hydrologic parameter values for various pervious land covers (e.g., residential, forest, pasture).

- **Soils.** The District provided digital soil coverage, illustrated on **Figure 6** and summarized in **Table 4**. The basin is 11.8 percent water and this is not included in Table 4. As described in the previous CDM Smith study, the lake is located in a sand hill karst region. Hydrologic parameters such as INFILT (index to infiltration) will be established accordingly in the HSPF model. It is anticipated that surface runoff from pervious land areas will be limited and most of the inflow to the lake will be either surficial groundwater inflow or direct rainfall on the lake surface.

Table 3. Percentage of Sylvan Lake Study Area in each Land Use Category

Land Use Classification	Percentage of Basin
1 - Low Density Residential	9.7
2 - Medium Density Residential	27.3
3 - High Density Residential	5.8
4 - Industrial and Commercial	10.0
5 - Mining	2.2
6 - Open Land and Barren Land	0.5
7 - Pasture	6.8
8 - Agriculture General	0.1
9 - Agriculture Tree Crops	2.4
10 - Rangeland	8.1
11 - Forest	14.5
12 - Water	12.8
13 - Wetlands	9.7

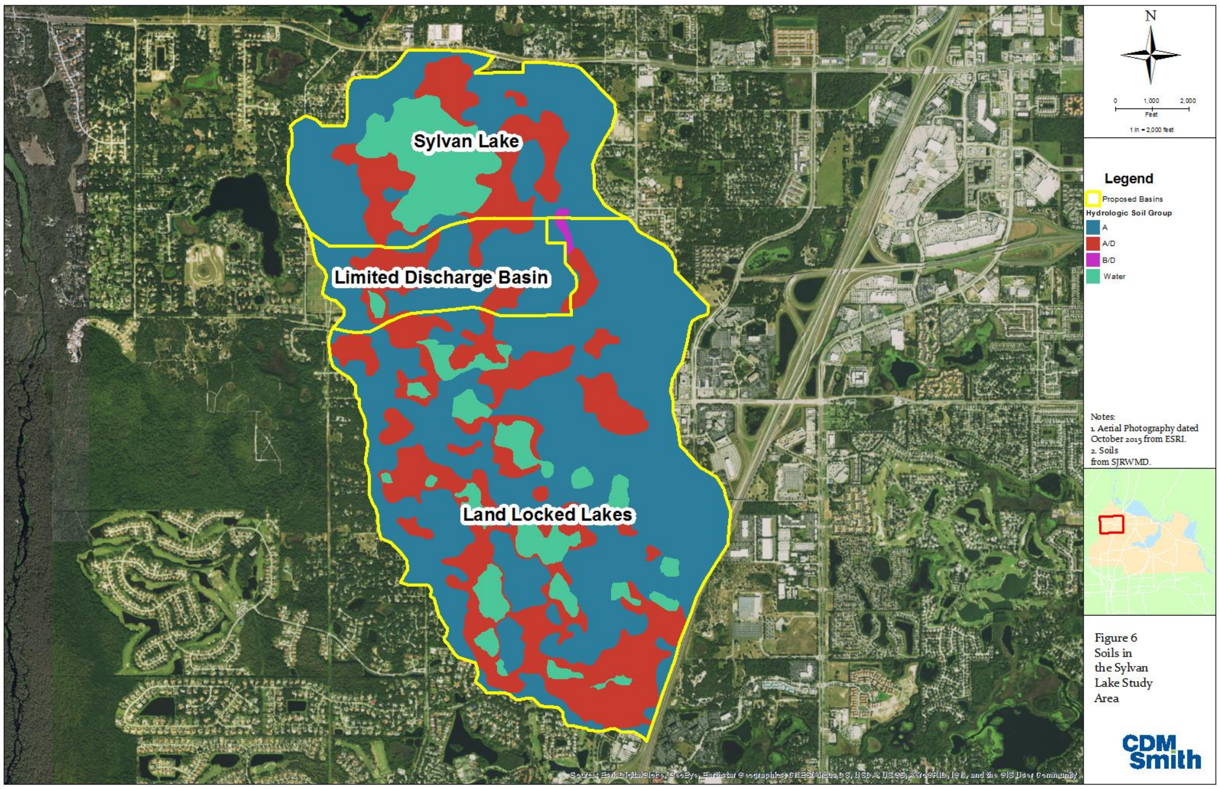

Figure 6. Soils Map of Proposed Basin Boundaries for the Sylvan Lake Study Area

Table 4. Percentage of Sylvan Lake Study Area in each Soils Category

Hydrologic Soils Group	Percentage of Basin
A	60.8
A/D	27.2
B/D	0.2

- **Lake Bathymetry**. The District provided paired elevation/area data from an elevation of 38.6 feet NAVD 88 down to a minimum elevation of 24.6 feet NAVD 88, and associated lake volumes (**Table 5**). A check of these data against the HSPF model data from the original Sylvan Lake MFL analysis by CDM Smith showed that the datasets were almost identical, generally within 5 percent of each other for the observed range of lake water elevations. Considering that lake levels above 38.6 feet NAVD 88 will be simulated, area/elevation data above that level will be established using available topographic data.

Table 5. Elevation, Surface Area, and Volume Information for Sylvan Lake HSPF model

Elevation (feet NAVD 88)	Surface Area (acre)	Volume (acre-feet)
24.6	5.6	0.1
26.6	31.9	34.9
28.6	54.1	121.1
30.6	84.3	255.3
32.6	116.5	456.7
34.6	142.1	718.3
36.6	161.8	1,023.9
38.6	180.4	1,365.4

Limited Well Data

As described earlier and detailed on **Figure 2 and in Table 2**, data from well OR-0047 has been evaluated for extending the period of S-0718 well record back to October 1978 (the start date of Sylvan Lake stages). For well OR-0047, synthesized S-0718 well values were developed based on the relationship between well levels at OR-0047 and S-0718 on days at which OR-0047 and S-0718 had concurrent observations.

Figures 7 and 8 illustrate the measured well values at S-0718 and OR-0047, plus the Sylvan Lake stage. Figure 7 includes data for the OR-0047 well elevation period of record (1943 through 2016) and Figure 8 focuses on the period 2009-2016, which includes the period of concurrent data at the two wells.

The relationship between the measured values at S-0718 and OR-0047 was established using the USGS Streamflow Record Extension Facilitator (SREF Version 1.0), a program that can extend and augment available gage date using long-term records from similar sites. The program was used to establish a regression relationship between the elevations at the two wells on days with concurrent data.

The established equation (expressed as Yi = 10^b * Xi^m) using the MOVE.3 method is as follows:

(1) S-0718 Elevation (feet NAVD 88) = 1.633 * (OR-0047 Elevation) $^{0.7521}$

The program determined this relationship based on a log-log regression of the data from the two wells. The Nash Sutcliffe score for the log-transformed data was 0.52 for well OR-0047, compared to values of 0.36 for well L-0043, 0.11 for well L-0045, and 0.05 for well V-0101. For the days with concurrent data at the two wells, the absolute difference was calculated and used to determine the mean absolute error, which was 0.5 foot.

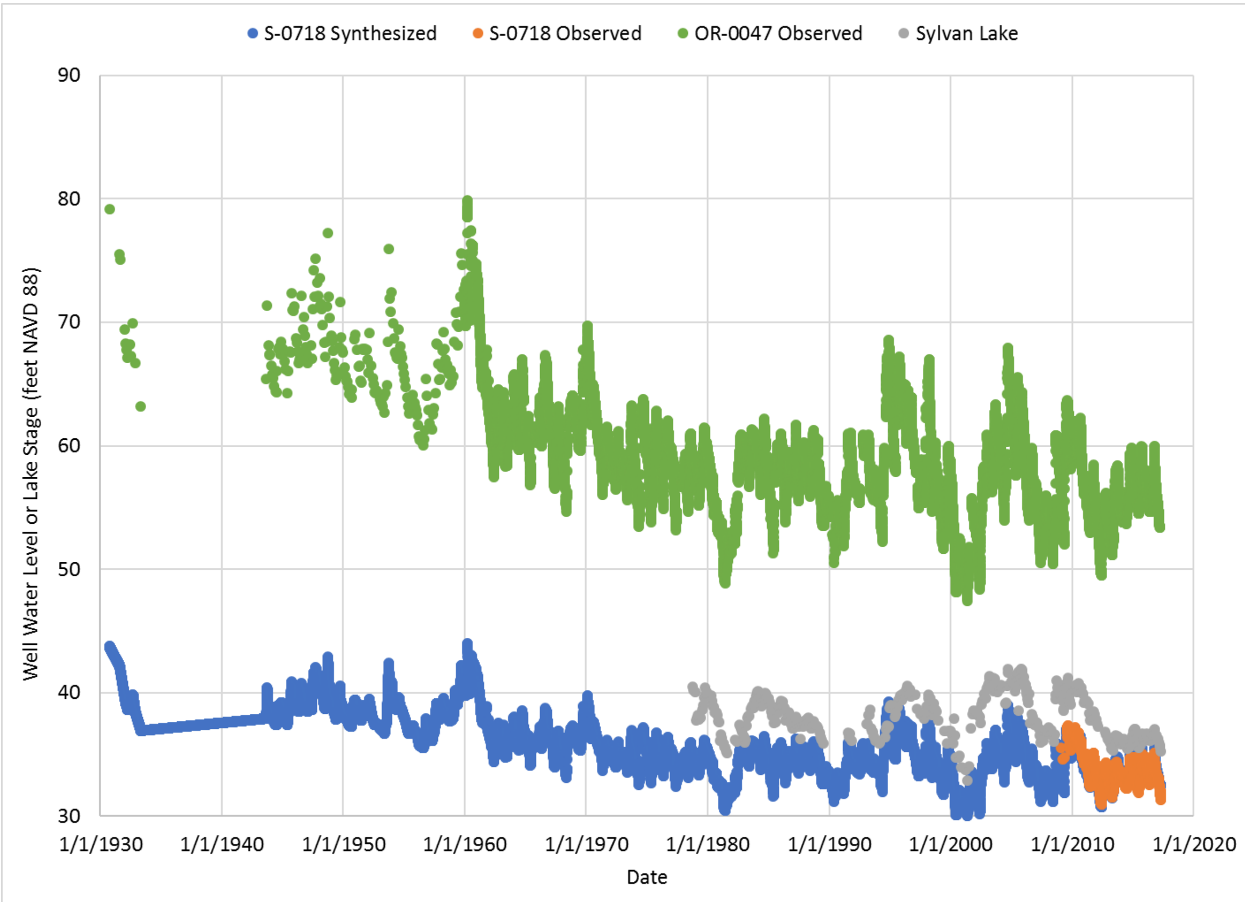

Figure 7. Actual and Synthesized S-0718 Well Levels for Period of Record

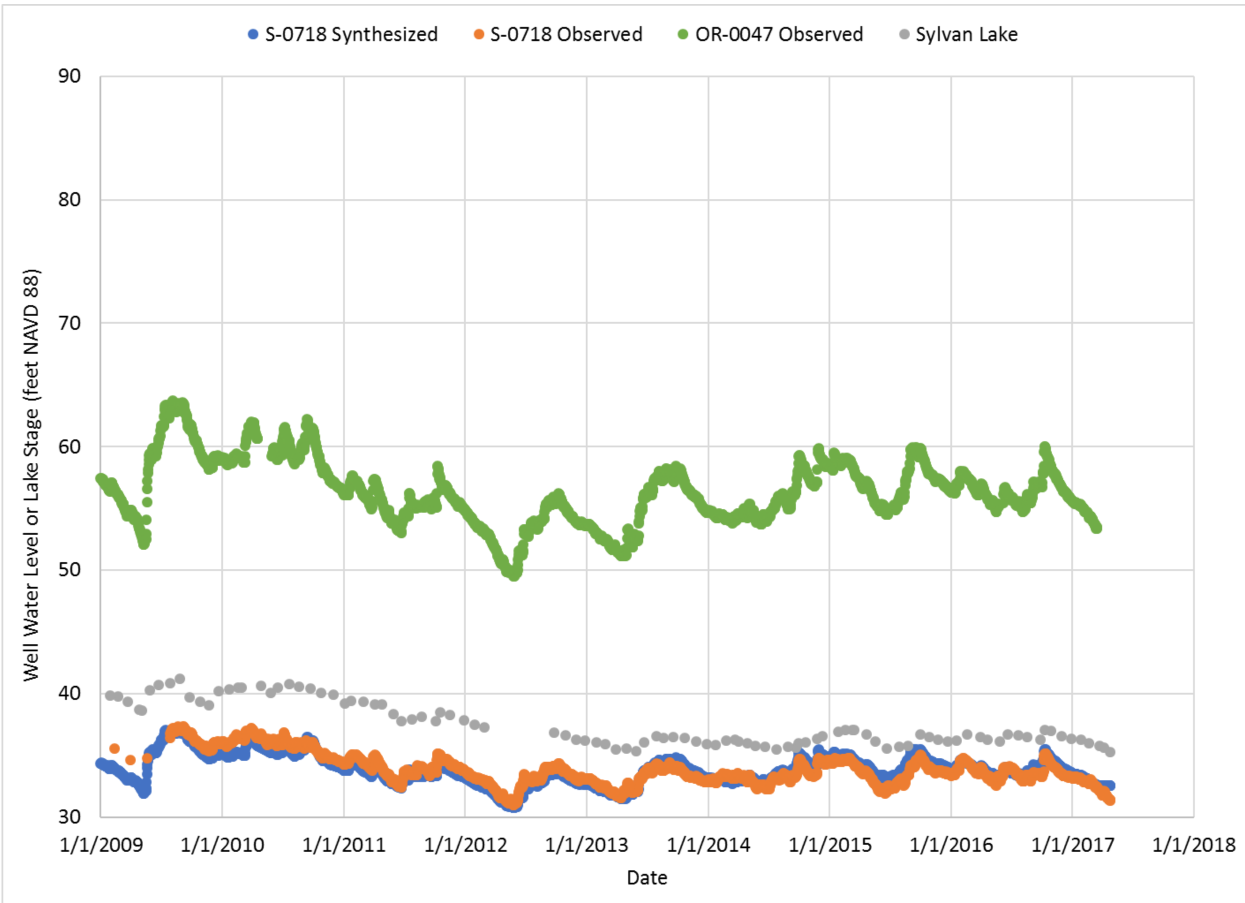

Figure 8. Actual and Synthesized S-0718 Well Levels 2009-2017

The values on Figure 8 show that the synthesized values tend to be low for the years 2009, 2010 and part of 2011, when the lake level is relatively high (above 38 feet NAVD 88). If the synthesized well levels are lower than they should be, this may lead to calculation of lake stages that are also lower than they should be during periods of relatively high lake stages. **Figure 9** illustrates that the synthesized well levels do not show a bias during high lake levels.

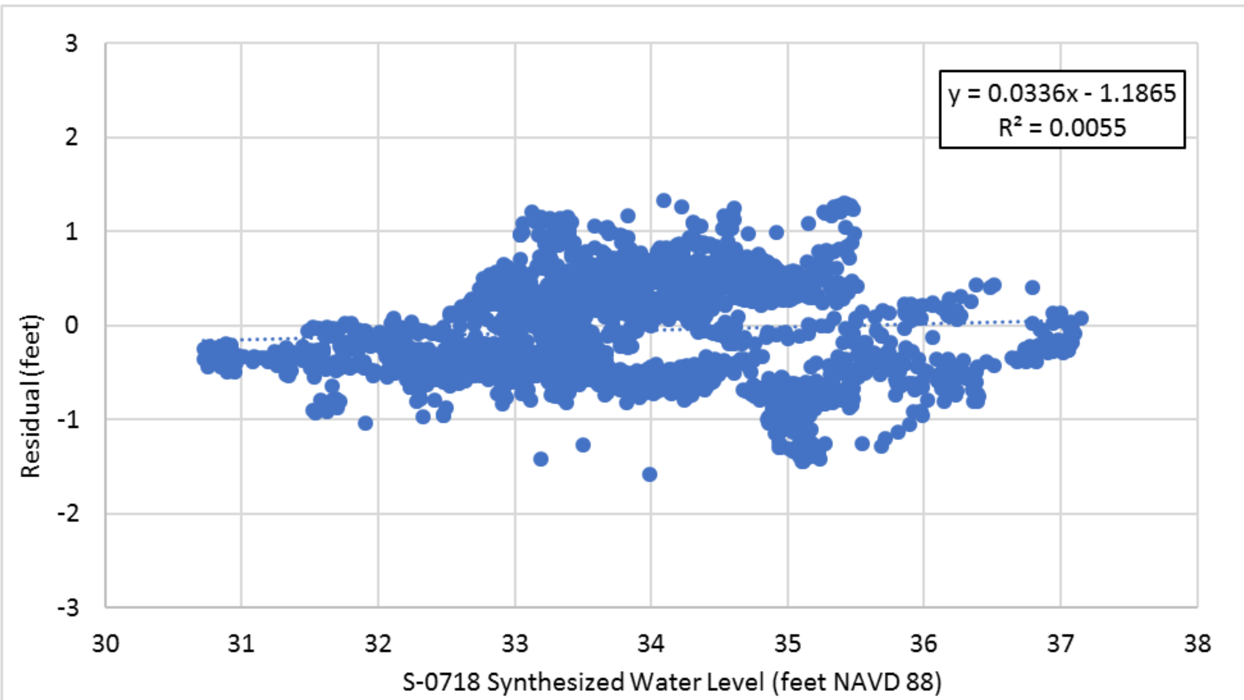

Figure 9. Residuals for Comparison of Observed and Synthesized S-0718 Water Levels

Tributary Basin Boundary

The lake tributary area boundary used in the previous Sylvan Lake MFL analysis by CDM Smith was 982 acres and was delineated based on available land surface topographic data, thus reflecting the area expected to contribute surface runoff (and groundwater inflow) to the lake. Much of the boundary reflected roadways that form a divide between area that will contribute runoff to the lake and areas that will discharge surface runoff elsewhere.

In the scope, the District showed the previous MFL analysis boundary and the Yankee Lake Basin delineation from the District, including area south of Sylvan Lake that is roughly three times the area of the previous MFL boundary. This area to the south includes a number of lakes and ponds that are expected to be "closed" systems (i.e., will not contribute surface flow to Sylvan Lake to the north), but may contribute groundwater inflow to Sylvan Lake.

Based on the field visit conducted by the District and CDM Smith staff on June 22, 2017, three distinct study area boundaries were established. These boundaries are shown on **Figure 10**, and include the following:

- Sylvan Lake basin, which is expected to contribute surface runoff and groundwater flow to the lake (823 acres).
- Limited Discharge basin, which may contribute surface runoff during extreme wet conditions but will primarily be limited to contributing groundwater to the lake (348 acres).
- Land Locked Lakes basin, which is expected to contribute only groundwater inflow to the lake (2,193 acres).

Much of the Limited Discharge basin may behave similarly to the Land Locked Lakes basin. The field visit indicated that the only surface connections between the Limited Discharge basin and the Sylvan Lake basin is a 12-inch culvert under South Sylvan Lake Drive, or overtopping of South Sylvan Lake Drive.

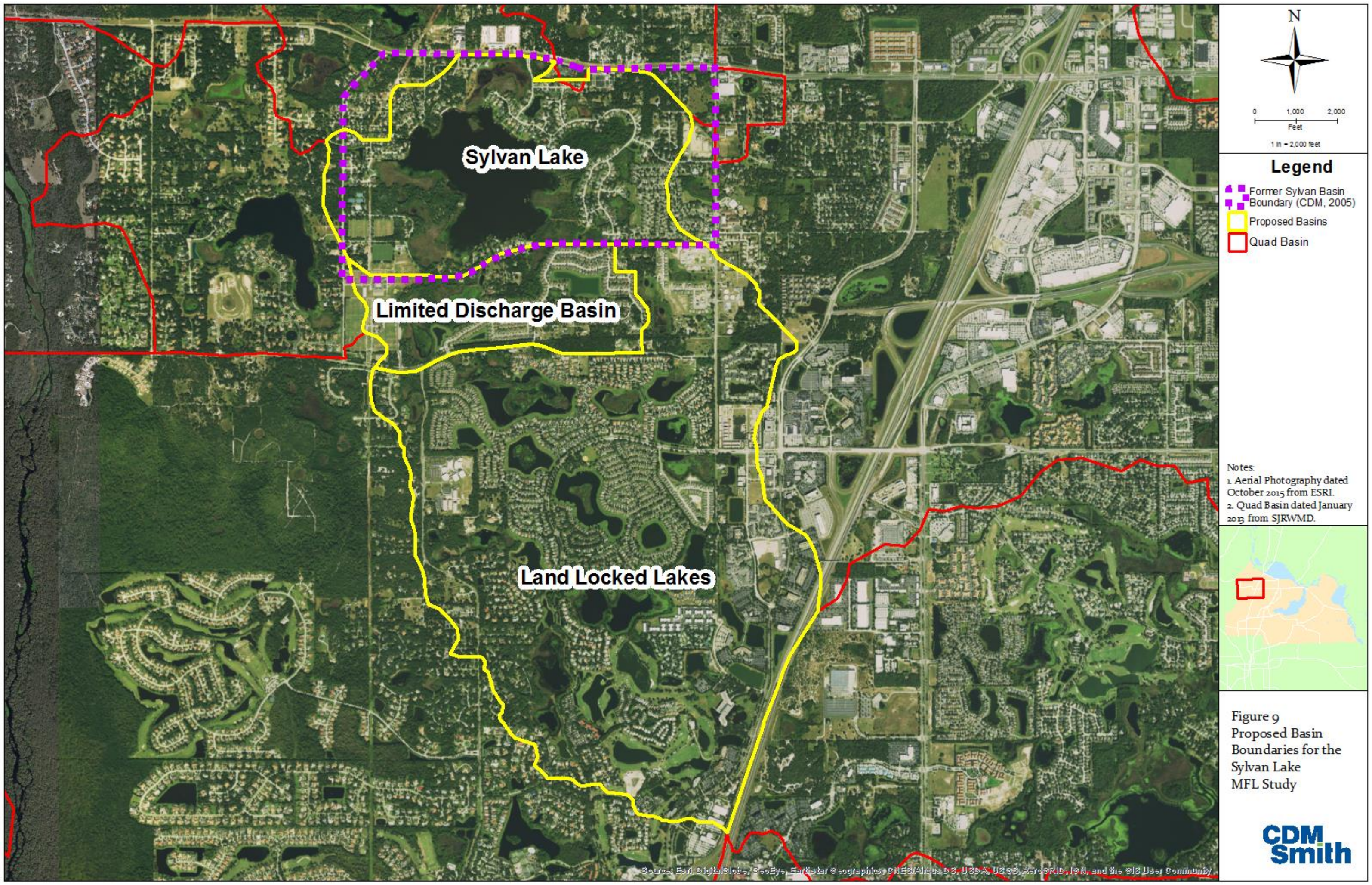

Figure 10. Proposed Basin Boundaries for the Sylvan Lake MFL Study

Please call me at (904) 527-6706 or e-mail me at wagnerra@cdmsmith.com if you have any questions, comments, or require further information.

Sincerely,

Richard A. Wagner

Richard Wagner, P.E., D.WRE
Principal Water Resources Engineer
CDM Smith Inc.

cc: File
Shayne Wood, CDM Smith
Joanne Chamberlain, SJRWMD
Andrew Sutherland, SJRWMD

Appendix B

Task B Letter Report

8381 Dix Ellis Trail, Suite 400
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tel: 904 731-7109

July 11, 2017 (updated September 30, 2017)

Dr. Xiaoqing Huang
St. Johns River Water Management District
PO Box 1429
4049 Reid St.
Palatka, FL 32178

Subject: Sylvan Lake MFL Evaluation – Task B: Model Update

Dear Dr. Huang:

This letter summarizes the work completed for the St. Johns River Water Management District (District) by CDM Smith Inc. in Task B of the Sylvan Lake Minimum Flows and Levels (MFL) Evaluation, under Work Order #17 of Contract #27776. Task B involves using the Task A data updates to update the 2005 Sylvan Lake HSPF model for the current MFL analysis.

CDM Smith has created an updated HSPF model that includes the following features specified by the District in the project scope and/or included in recommendations from the INTERA peer review of the previous model:

- **Tributary Area.** As discussed in the Task A Letter Report, there is a difference in the tributary area in the latest District boundary compared to the lake boundary used in the previous CDM Smith MFL evaluation of Sylvan Lake. The original lake tributary area delineation considered area that was expected to contribute surface runoff and surficial aquifer groundwater discharge to the lake. The District boundary includes additional area that is expected to contribute little or no surface runoff but may contribute surficial groundwater inflow to the lake. Consequently, CDM Smith has established a model that considers both the "direct" tributary area (contributing both runoff and surficial groundwater) and "indirect" tributary area (contributing groundwater only). The direct tributary area is very similar to the original 2005 MFL delineation with minor modifications based on the District subbasin boundary in that area, and the field visit documented in the Task A letter report. The indirect tributary area includes area south of Sylvan Lake, between the modified direct tributary area boundary and the District subbasin boundary for Yankee Lake.
- **Model time step.** The model runs on an hourly time step, as did the previous version, but in addition, the model is using hourly rainfall and potential evapotranspiration (PET) values provided by the District.

- **Vertical datum.** The stage correction parameter (STCOR, which represents the elevation at zero depth in Sylvan Lake (i.e., the "bottom" of the lake) was set at 24.6 feet NAVD 88 based on data provided by the District. Consequently, all lake stage model output will be in NAVD 88 as required by the scope.

- **Land use**. The 2009 land use provided by the District (shown on **Figure 1**) has been used to define the distribution of land use within the lake contributing area (which at this point has been limited to an area slightly smaller than the tributary area defined by CDM Smith in the previous Sylvan Lake MFL study). The land use data have been categorized into 13 land use types as directed in the scope, based on a lookup table developed from previous CDM Smith projects with the District. The distribution of land use in the current model is presented in **Tables 1 through 3** for the direct tributary area, limited discharge tributary area, and land-locked lakes tributary area, respectively. The values of percent imperviousness are consistent with values used by the District and used in the 2015 and 2016 MFL studies based on District comment.

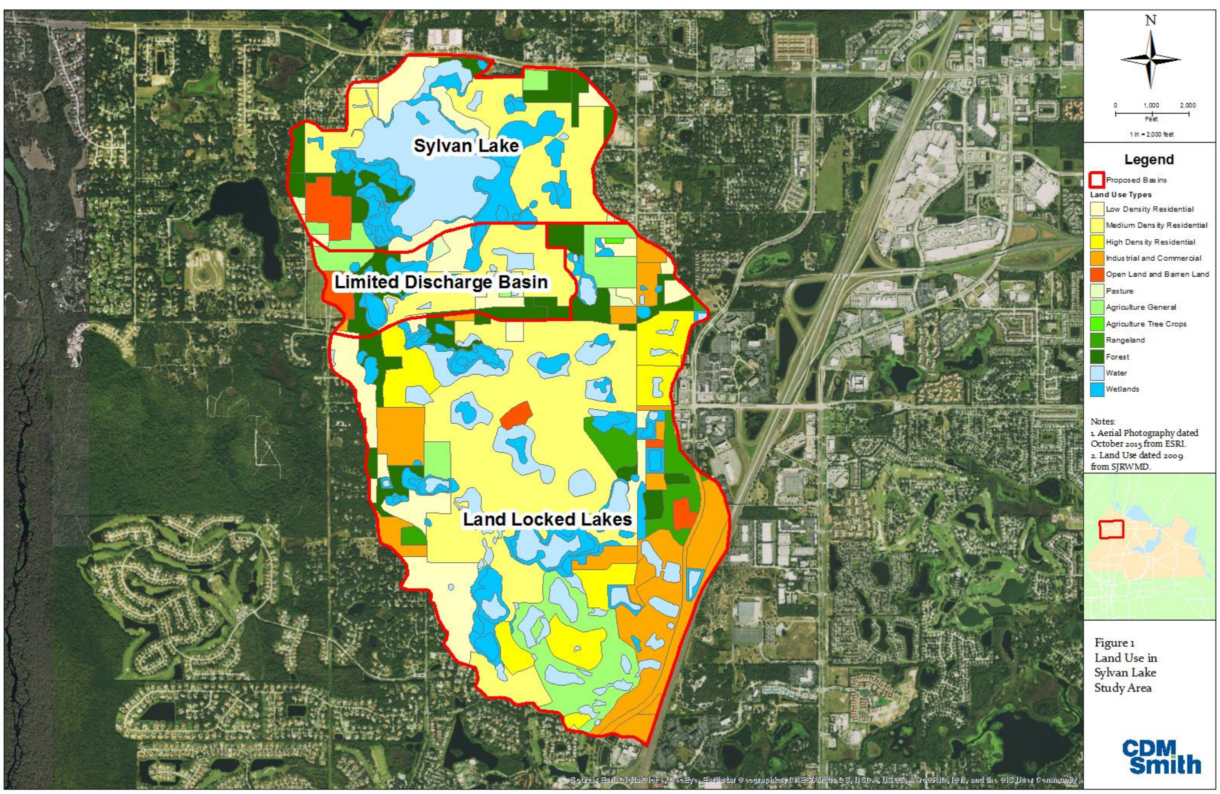

Figure 1. Land Use in Sylvan Lake Study Area

Table 1. Land Use Distribution in Sylvan Lake Direct Tributary Area

Land Use Type	Area (acres)	DCIA (%)	Impervious Acres	Pervious Acres
Low Density Residential	84	5%	4	80
Medium Density Residential	218	15%	33	185
Industrial and Commercial	4	50%	2	2
Open and barren land	35	0%	0	35
Pasture	4	0%	0	4
Agriculture general	26	0%	0	26
Forest	90	0%	0	90
Water	197	0%	0	0
Wetlands	166	0%	0	166
TOTAL	824	5%	39	588

Note: Sum of pervious and impervious acres does not equal total area because acres of water are not included.

Table 2. Land Use Distribution in Limited Discharge Tributary Area

Land Use Type	Area (acres)	DCIA (%)	Impervious Acres	Pervious Acres
Low Density Residential	45	5%	2	43
Medium Density Residential	125	15%	19	106
Industrial and Commercial	2	50%	1	1
Open and barren land	19	0%	0	19
Pasture	9	0%	0	9
Agriculture general	23	0%	0	23
Forest	61	0%	0	61
Water	17	0%	0	0
Wetlands	49	0%	0	49
TOTAL	350	6%	22	311

Note: Sum of pervious and impervious acres does not equal total area because acres of water are not included.

Table 3. Land Use Distribution in Land Locked Lakes Tributary Area

Land Use Type	Area (acres)	DCIA (%)	Impervious Acres	Pervious Acres
Low Density Residential	197	5%	10	187
Medium Density Residential	576	15%	86	490
High Density Residential	194	35%	68	126
Industrial and Commercial	330	50%	165	165
Open and barren land	22	0%	0	22
Pasture	4	0%	0	4
Agriculture general	179	0%	0	179
Agriculture tree crops	2	0%	0	2
Rangeland	80	0%	0	80
Forest	121	0%	0	121
Water	273	0%	0	0
Wetlands	216	0%	0	216
TOTAL	2,194	15%	329	1,592

Note: Sum of pervious and impervious acres does not equal total area because acres of water are not included.

For the direct tributary area, the "water" land use category is explicitly modeled by the reach (RCHRES) representing Sylvan Lake and the variability in land area for riparian land uses around the lake (e.g., wetlands, low density residential pervious area) is addressed using Special Actions. This is discussed further in a later section of this letter report.

For all the indirect tributary areas, the potential for groundwater contribution to Sylvan Lake was assessed based on water table elevation data acquired from the Floridan Aquifer Vulnerability Assessment (FAVA) conducted by the Florida Department of Environmental Protection (FDEP) and Florida Geological Survey (FGS). Review of the water table elevation map (which is presented and discussed further in the Task C letter report) suggests that the groundwater from the Land-Locked Lakes area south of Markham Road, and the Land-Locked Lakes area north of Markham Road and east of Merlot Drive, is unlikely to flow toward Sylvan Lake. These areas are also characterized as "high" Floridan recharge areas. Consequently, the model is not including any inflows from surface or groundwater from the Land-Locked Lakes area to Sylvan Lake.

For the Limited Discharge primarily indirect tributary area, the urban land use categories and the associated "water" land use category within the residential development (Buckingham Estates) is expected to contribute groundwater flow only to Sylvan Lake. Review of the Buckingham estates development plans suggest that the ponds are a combination of detention and retention ponds that are expected to contribute virtually no runoff to Sylvan Lake.

Initially, the remaining Limited Discharge land area was simulated as two separate land areas with associated storage south of South Sylvan Lake Road. The eastern portion of this area, based on field visit observation, can discharge surface flow to Sylvan Lake through a 12-inch culvert. Based on the 1-foot contours obtained from Seminole County, the roadway at this location is at elevation 41 feet NAVD 88, and the estimated invert of the culvert is at 38 feet NAVD 88. The western portion of this area will only discharge surface flow to Sylvan Lake if the road is overtopped, and the 1-foot contours indicate that overtopping would occur at an elevation of 44 feet NAVD 88. In both areas, the storage behind the road will be addressed by an FTABLE that will be assigned recharge characteristics consistent with Sylvan Lake, and will discharge surface flow to Sylvan Lake if the stage is high enough to discharge through the culvert or over the road.

Based on initial model simulations, it was decided that the eastern portion of the Limited Discharge area, which is connected by the 12-inch culvert under South Sylvan Lake Road, should be considered part of the direct tributary area to Sylvan Lake. The direct land area contributing to Sylvan Lake and the lake elevation-area-storage Ftable were modified to reflect this change.

The further delineation of the Limited Discharge area is shown on **Figure 2**.

- **Groundwater recharge.** Based on review of the latest District recharge map (shown on **Figure 3**), the defined direct tributary area is primarily categorized as a "moderate" recharge area (5-10 inches per year), with some area categorized as a "high" recharge area (10–15 inches per year). This suggests that the hydrologic modeling should consider a high value of the parameter DEEPFR (fraction of water passing from the lower soil zone that is directed to deep recharge rather than to active groundwater that ultimately discharges as baseflow). The Limited Discharge basin is similar to the direct contributing area, primarily "moderate" recharge with some "high" recharge. Seepage from the lake to the Floridan (discussed in a separate bullet below) will also be evaluated for consistency with "moderate" recharge.

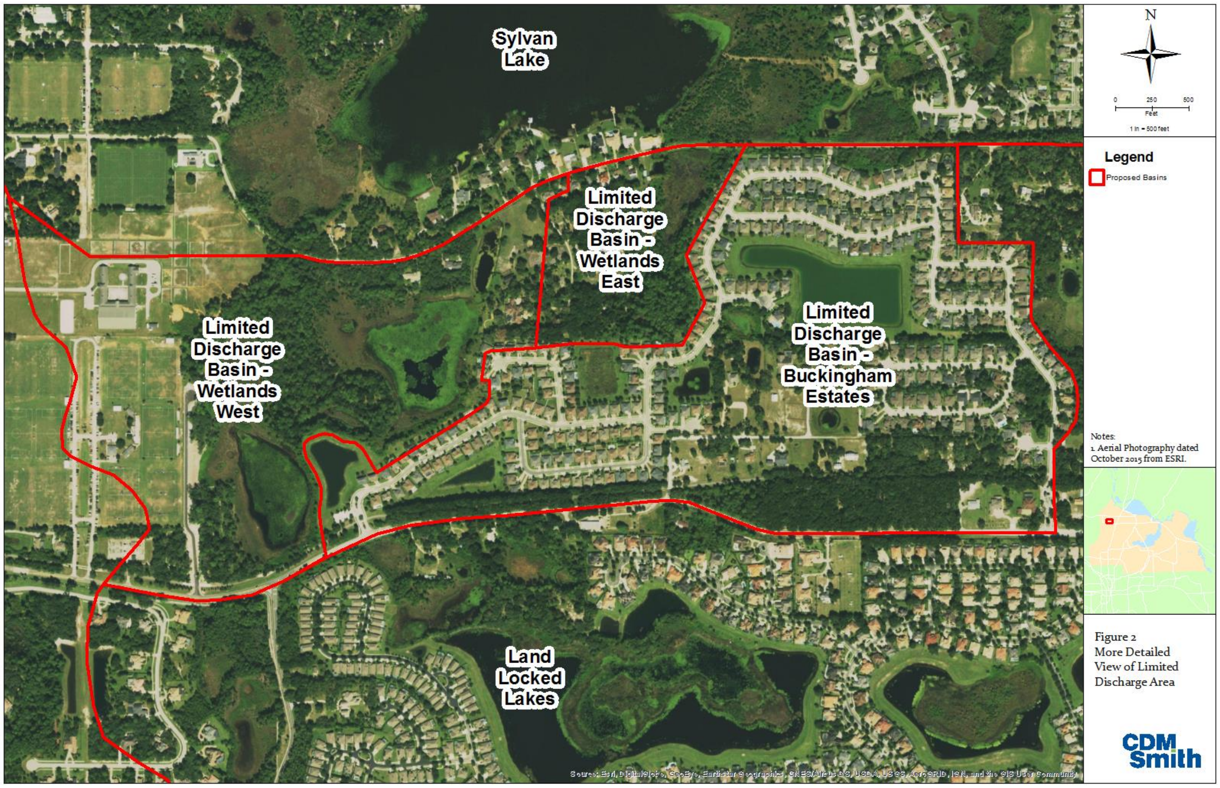

Figure 2. More Detailed View of Limited Discharge Area

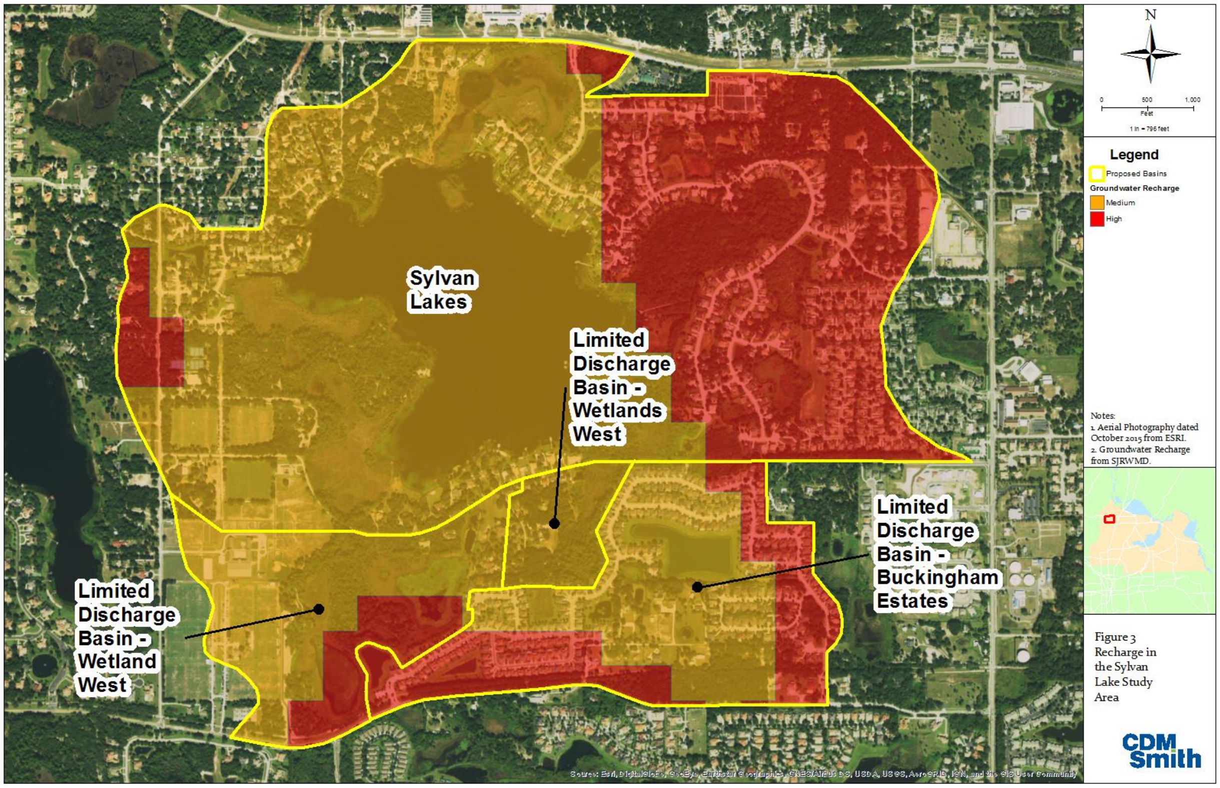

Figure 3. Recharge in Sylvan Lake Study Area

- **Lake seepage.** The seepage from Sylvan Lake to the Floridan aquifer will be simulated in a similar manner as the calculations done in the 2015 MFL studies (Lakes Gertie, Star, Wauberg and Trout) based on District comments. The calculated seepage will be based on the surface area of the lake (calculated by HSPF), the head differential between the lake water surface elevation calculated by HSPF and the time series input S-0718 well level, and a constant multiplier reflecting the conductivity. The multiplier value will be one of the model calibration parameters.

- **Lake surface area.** The contributing area of riparian wetlands, and possibly other riparian land area, will vary over time as the lake surface area changes. This will be established using the same Special Actions that were applied in the 2015 MFL studies based on District comments. In the Special Action, the contributing riparian area will be calculated as the total area of water surface plus riparian area, minus the lake surface area calculated by HSPF. Based on Table 1, the combined area of lake water surface and wetland area is 197 + 166 = 363 acres. At any given time in the simulation, the land-based contribution from the riparian wetlands will be based on a wetland area of 363 acres minus the lake water surface area at the time. In contrast, the estimated lake surface area at the highest measured lake stage (42.0 feet NAVD 88) is approximately 290 acres. Consequently, the combined water and wetland area is sufficient to account for the maximum lake inundation area.

- **Lake bathymetry and positive discharge**. CDM Smith will define the Sylvan Lake bathymetry based on data provided by the District supplemented by available topography to estimate lake surface area and associated storage at higher elevations. Values proposed for the lake FTABLE are listed in **Table 4**.

  With the current lake outfall structure, positive outflow from the lake occurs when the water elevation reaches the top of the gate. Plans show this gate elevation as 41.5 feet NGVD (equivalent to 40.5 feet NAVD 88). Consequently, outflow is zero up to an elevation of 40.5 feet NAVD 88 (depth of 15.9 feet). Above this water level, the outflow rate is estimated based on an inlet control nomograph for a box culvert of width 8 feet and depth of 1 foot (distance from top of gate to top of box culvert).

  Previous to the new outfall structure, outflow from the lake was controlled by shallow vegetated channel flow to a box culvert that has the same dimensions as the box conveying flow from the new outfall structure. The relationship between elevation and outflow for conditions before the new outfall construction were established based on a simple SWMM representation of the vegetated channel from lake to culvert, the culvert and vegetated channel downstream of the culvert. Pre-project survey data were used to define the invert elevations and dimensions of the vegetated channels and culvert. Model results for the period of 2004 and 2005, when observed lake levels were historically high, suggest that the depth-outflow relationship for the pre-project condition is valid.

The two outflow values in Table 4 represent the lake outfall structure pre- and post-construction which occurred in 2014. An as-built survey was provided to develop the values for post-construction in column 5. For the calibration and validation analyses, the pre-construction values were used, considering that the lake levels since the construction of the new outfall have never reached the stage at which positive outflow would occur. The post-construction values should be used by the District for the long-term simulation of the lake under current conditions.

Table 5 lists the proposed FTABLE data for the western area in the Limited Discharge area. The eastern area FTABLE has a limited amount of storage south of South Sylvan Lake Road and was considered part of the direct contributing area (i.e. included in Table 4). The western area has significantly greater storage before overtopping the road and is not likely to overflow except under very extreme wet conditions.

Table 4. FTABLE for Sylvan Lake

Depth (feet)	Area (acres)	Volume (acre-feet)	Outflow Pre-Construction (cfs)	Outflow Post-Construction (cfs)
0	5.6	0	0	0
2	32	35	0	0
4	54	121	0	0
6	84	255	0	0
8	116	457	0	0
10	142	718	0	0
12	162	1024	0	0
14	180	1365	0	0
15.9	236	1762	0	0
16.2	256	1838	0	1.8
16.4	270	1888	0.1	7.4
16.9	307	2032	1.5	20.8
17.4	345	2158	4.9	38.5
17.9	358	2371	21	47.2
18.4	371	2553	42	54.5

Note: Stage (feet NAVD 88) = Depth + 24.6 feet

Table 5. FTABLE for Western Limited Discharge Area

Depth (feet)	Area (acres)	Volume (acre-feet)	Outflow (cfs)
0.0	0.042	0.0	0
1.0	0.254	0.148	0
2.0	1.18	0.863	0
3.0	2.47	2.69	0
4.0	12.5	10.1	0
5.0	28.7	30.7	0
6.0	40.7	65.5	0
7.0	45.7	109	0
8.0	50.6	157	0
9.0	55.3	210	300

Note: Stage (feet NAVD 88) = Depth + 36 feet

- **Peer review comments**. A full list of INTERA comments, and the way in which these comments are addressed in this current MFL evaluation of Sylvan Lake, are included in **Appendix D**.

In summary, a modified HSPF model has been developed for Sylvan Lake and its tributary area. Updates have included tributary area, land use distribution, rainfall and PET time series, and initial establishment of lake and pervious land area recharge to the Floridan aquifer that are consistent with the most recent District recharge mapping.

Please call me at (904) 527-6706, or e-mail me at wagnerra@cdmsmith.com if you have any questions, comments, or require further information.

Sincerely,

Richard A. Wagner

Richard Wagner, P.E., D.WRE
Principal Water Resources Engineer
CDM Smith Inc.

cc: File
Shayne Wood, CDM Smith
Joanne Chamberlain, SJRWMD
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Appendix C

Task C Letter Report

8381 Dix Ellis Trail, Suite 400
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August 1, 2017 (updated September 30, 2017)

Dr. Xiaoqing Huang
St. Johns River Water Management District
PO Box 1429
4049 Reid St.
Palatka, FL 32178

Subject: Sylvan Lake MFL Evaluation – Task C: Model Calibration

Dear Dr. Huang:

This letter summarizes the work completed by CDM Smith Inc. in Task C of the Sylvan Lake Minimum Flows and Levels (MFL) Evaluation, under Work Order #17 of contract #27776. Task C involves the calibration of the Sylvan Lake HSPF model for the current MFL analysis. This work builds upon our two previous letter reports on data and model refinement.

Model Calibration Period

CDM Smith recommends the period of 2008 through 2016 as the most appropriate calibration period for the HSPF model. This period features the following:

- **Best calibration data.** This period includes rainfall data collected at a USGS gage in the Sylvan Lake Park, which should provide the best representation of rainfall in the lake tributary area. In addition, the data used for Floridan well levels is primarily measured levels, as opposed to synthesized levels prior to July 2009.

- **Variety of meteorological conditions**. The calibration period includes 9 years of simulation, which includes years of dry, average, and wet conditions. The wettest year is 2008 (65.7 inches) and the driest year is 2015 (38.1 inches). The overall mean for these years is 49.1 inches.

- **More recent period that is considered consistent with current land use and lake seepage conditions.** District staff pointed out that some of the development in the lake tributary area was occurring in the late 1990s and early 2000s. Consequently, the model (based on 2009 land use data) is most representative of conditions in the tributary area after the early 2000s.

For the calibration period of 2008 through 2016, the average annual rainfall of 49.1 inches is somewhat less than the long-term average of 51.6 inches for the years 1948 through 2016. The average annual PET during the period is 51.8 inches per year, slightly less than the long-term annual average of 53.0 inches per year. **Table 1** summarizes annual rainfall and PET statistics for the calibration period, validation period, and period of record.

Table 1. Annual Totals and Statistics for Rainfall and Potential Evapotranspiration

Time Period	Annual Rainfall (in)			Annual PET (in)		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Calibration Period (2008-2016)	38.1	49.1	65.7	50.4	51.8	54.2
Validation Period (1997-2007)	32.8	51.9	66.2	49.8	52.4	55.1
Period of Record (1948-2016)	32.8	51.6	74.1	49.5	53.0	56.3

Model Modifications during Calibration

The Task B letter report identified five areas that may be contributing flow to Sylvan Lake. The manner in which these areas were simulated has been modified based in part on model calibration, and in part on water table elevation data acquired from the Floridan Aquifer Vulnerability Assessment (FAVA) conducted by the Florida Department of Environmental Protection (FDEP) and Florida Geological Survey (FGS).

Figure 1 illustrates the unconfined surficial aquifer system (SAS) water table elevations mapped by FDEP and FGS as part of the FAVA program. Review of the water table elevation map suggests that the groundwater from the Land-Locked Lakes area south of Markham Road, and the Land-Locked Lakes area north of Markham Road and east of Merlot Drive, is unlikely to flow toward Sylvan Lake. These areas are also characterized as “high” Floridan recharge areas. Consequently, the model is not including any inflows from surface or groundwater from the Land-Locked Lakes area to Sylvan Lake.

The Limited Discharge Basin – East is a relatively small area that is connected to Sylvan Lake by a culvert estimated to be 12 inches in diameter based on the field visit by District and CDM Smith staff. Initially, this area was modeled as pervious and impervious area discharging to a storage area south of South Sylvan Lake Road, with discharge through the culvert characterized in the storage area FTABLE based on inlet control calculations for the 12-inch culvert. However, initial calibration modeling indicated that during wet conditions when there may be runoff and groundwater flow to the storage area, the Sylvan Lake water levels tended to be significantly higher than in the storage south of the road, suggesting that it is more likely that the lake will actually flow back through the culvert into the area south of the road. Consequently, the Limited Discharge Basin – East was added to the Sylvan Lakes direct tributary area, and the Sylvan lake FTABLE was modified to include the storage south of the road.

The Limited Discharge Basin - West was modeled as pervious and impervious area discharging to a storage area south of South Sylvan Lake Road. The storage area allowed for surface discharge over the road if the water elevation in the storage area was high enough (which did not occur during the calibration or validation periods). The modeled seepage from the storage area was considered to discharge to Sylvan Lake as groundwater flow.

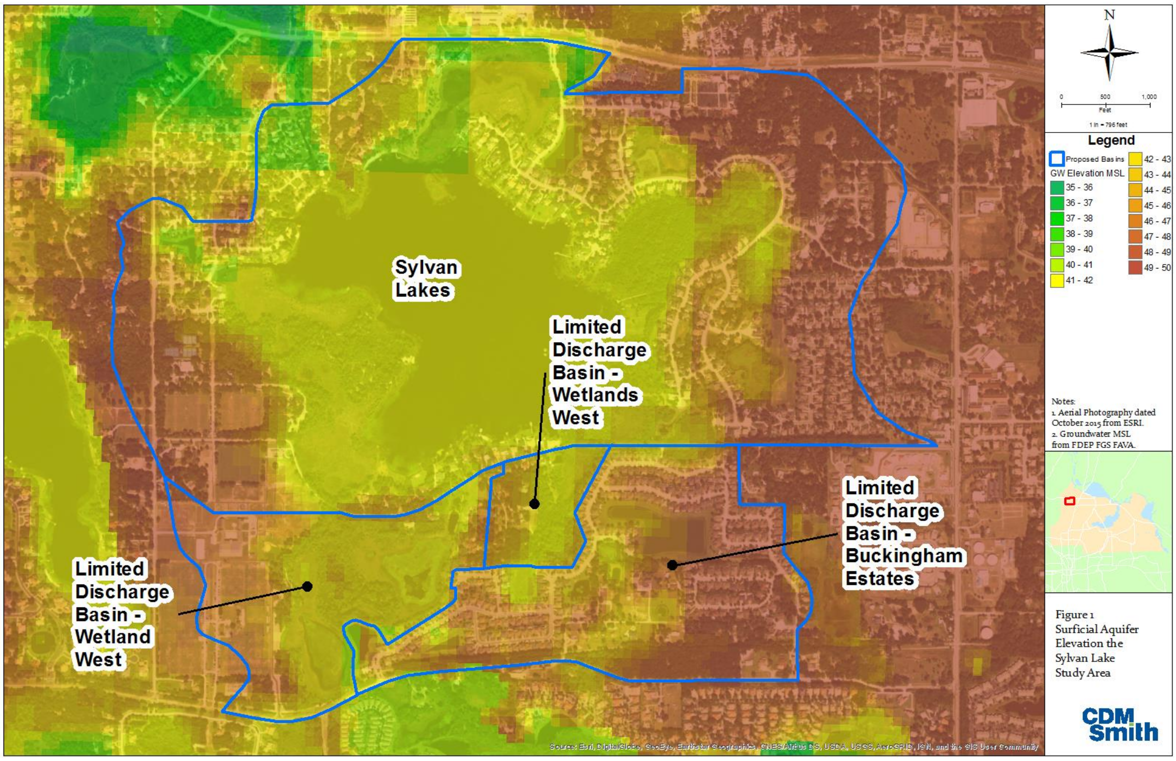

Figure 1. Surficial Aquifer in the Sylvan Lake Study Area

The Buckingham Estates area was modeled as described in the Task B letter report, directing the groundwater discharge from the pervious land area to Sylvan Lake.

Model Calibration Process

The results of the model for the calibration period were compared to observed lake stages, according to the criteria established in the scope by the District. Goals of the calibration included:

- Maximizing the number of simulated lake stages that are within +/- 0.5 foot of observed values (achieving at least 85 percent within the target)
- Nash-Sutcliff score of at least 0.90

The model results presented here did achieve the Nash-Sutcliff score, and the goal of 85 percent of values within +/- 0.5 foot was almost achieved. Reasons for this are discussed later in the letter report.

Model Hydrologic Parameter Values

Table 2 lists the major hydrologic model input by land use category. Based on a review of the modeled response in lake stages to the large storm events, the values of parameters such as LZSN and UZSN were set at the middle of the range of values suggested in the *BASINS Technical Note 6: Estimating Hydrology and Hydraulic Parameters of HSPF* (EPA, 2000).

Table 2. Hydrologic Parameter Input Values in Sylvan Lake HSPF Model

Land Use Type	LZSN (inches)	INFILT (in./hr.)	CEPSC (inches)	UZSN (inches)	LZETP	DEEPFR
Low Density Residential	5.0	0.50	0.05	0.70	0.60	0.78
Medium Density Residential	5.0	0.50	0.05	0.70	0.60	0.78
Industrial and Commercial	5.0	0.50	0.05	0.70	0.60	0.78
Open and barren land	5.7	0.68	0.03	0.70	0.60	0.78
Pasture	5.7	0.68	0.08	0.70	0.60	0.78
Agriculture general	6.3	0.80	0.08	0.80	0.70	0.78
Forest	7.5	1.00	0.12	1.00	0.80	0.78
Wetlands	3.0	0.40	0.12	0.40	0.90	0.00

Lake Bathymetry and Seepage Outflow

Figure 2 shows the relationship between depth, surface area and total volume for Sylvan Lake. A depth of zero corresponds to an elevation of 24.6 feet NAVD 88. The District provided data up to an elevation of 38.6 feet NAVD 88 (depth of 14.0 feet) and a higher surface area and volume was established based on the 1-foot contour data from Seminole County.

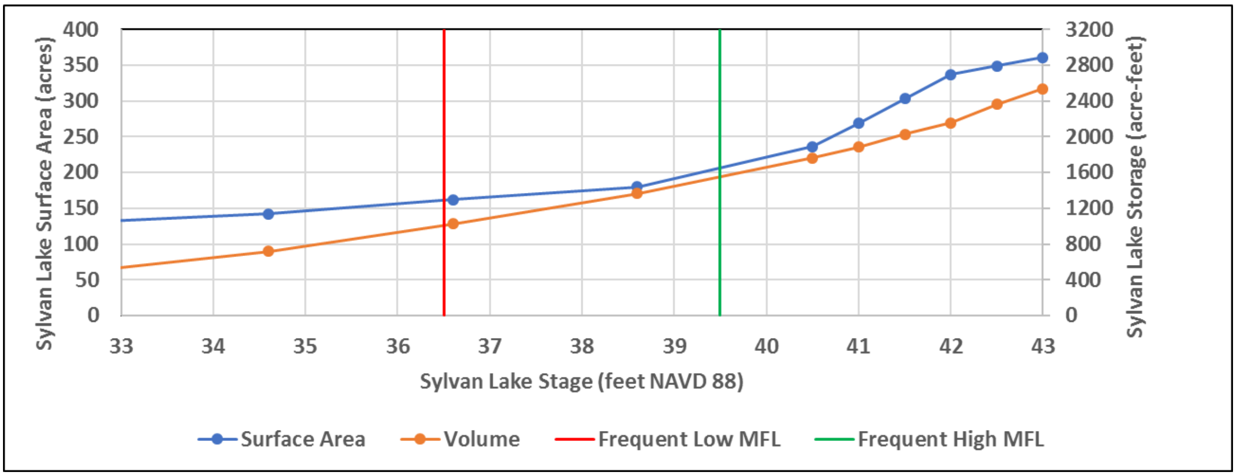

Figure 2. Sylvan Lake Depth/Surface Area/Volume Relationship

Lake seepage in the model is calculated as a function of the lake surface area and the head differential between the lake stage and the well elevation. The equation used in the Special Action is:

(1) OUTDGT 1 = KVALUE * (ALLSTG – GWSTAG) * RCA1,

where

OUTDGT 1 = lake seepage outflow (cfs),

KVALUE = seepage coefficient (ft^2/sec/acre),

RCA1 = lake surface area (acres)

In the model calibration, a constant value of 0.00081 was used for KVALUE in the equation, which corresponds to a seepage rate of 25 inches per year, which is somewhat higher than the value from the latest District recharge map (which shows "medium" [5–10 inches per year] to "high" [10–15 inches per year]) in the lake tributary area.

Model Results

Figures 3 and 4 present the observed and modeled stage time series and frequency-exceedance relationship for Sylvan Lake during the years 2008 through 2016. The results indicate that the model is doing a very good job of simulating lake stages and replicating high and low lake stages during the simulation period.

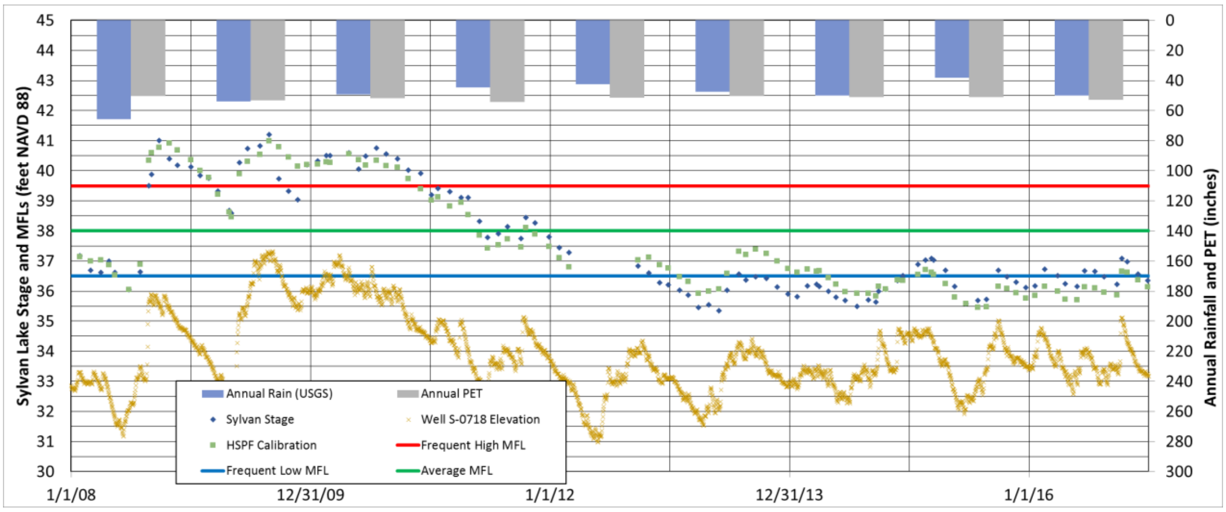

Figure 3. Comparison of Observed and Modeled Stage Time Series in Sylvan Lake for Calibration Period

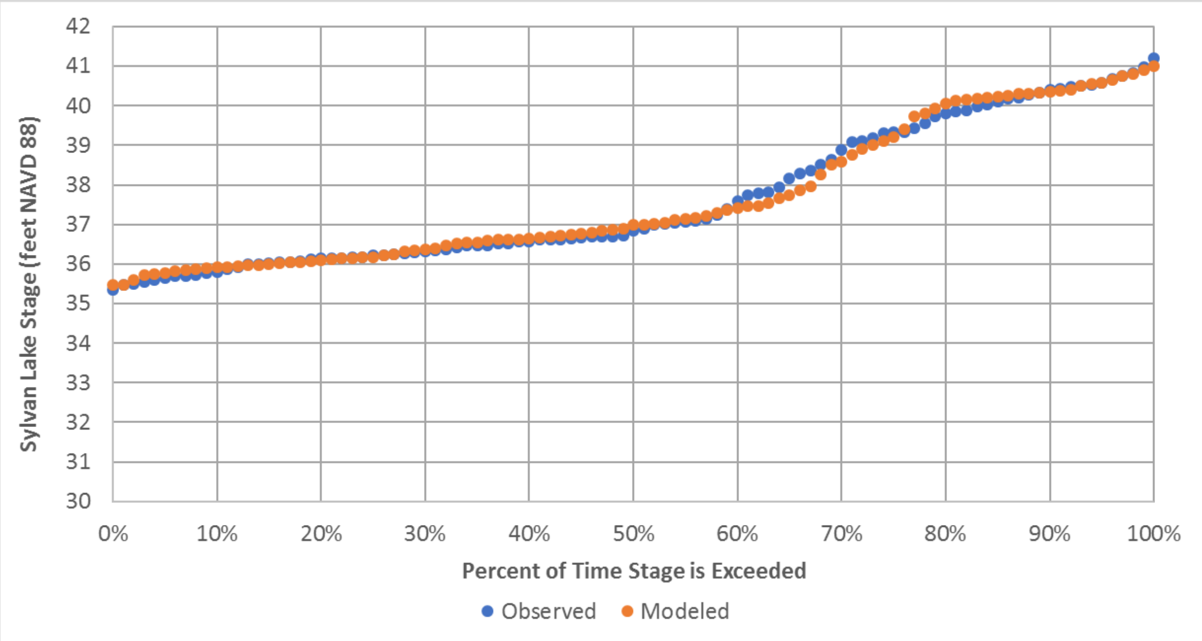

Figure 4. Comparison of Observed and Modeled Stage Frequency-Exceedance in Sylvan Lake for Calibration Period

Calculations were performed to determine the Nash-Sutcliffe score for the simulation period. The calculation uses the following equation:

(2) $NS = 1 - [\sum (S_o - S_m)^2 / \sum (S_o - S_{bar})^2]$,

where

S_o = observed lake stage (feet NAVD 88),

S_m = modeled lake stage (feet NAVD 88), and

S_{bar} = average observed lake stage (feet NAVD 88).

Based on differences between the observed lake stages and mean observed lake stage during the calibration period (37.64 feet NAVD 88), and differences between the observed and modeled lake stages, the calculated Nash-Sutcliffe score is 0.93, and achieves the goal of 0.90 or higher.

The differences between the observed and modeled lake stages were also evaluated to determine the percentage of time that the absolute difference between the observed and modeled stages was 0.50 foot or less. The results indicated that 72 percent of the paired data were within 0.5 foot, which is less than the 85 percent goal, and that 85 percent of the paired data show a difference of 0.56 foot or less.

The model results were also evaluated for the average annual lake water budget, and for comparison of average annual modeled deep recharge with the latest District recharge map. For the area discharging directly to the lake, the overall average annual deep recharge (which includes the lake recharge discussed earlier, plus recharge for pervious land areas) was 10.5 inches per year, which is at the within the ranges of the District recharge map showing this area as a combination of "moderate" (5-10 inches per year) and "high" (10 to 15 inches per year) recharge. For the limited discharge area (groundwater flow only), the average annual deep recharge was 7.8 inches per year.

The average annual water budget for Sylvan Lake is presented in **Table 3**. The table indicates that direct rainfall accounts for 63 percent of the total lake inflow, and lake surface evaporation accounts for 66 percent of the total lake outflow. Inflow from the limited discharge area south of the lake accounts for 6 percent of the total inflow to the lake.

Table 3. Average Annual Sylvan Lake Water Budget for Calibration Period

LAKE INFLOWS	Average Annual Volume (acre-feet)	Average Annual Value (inches over lake surface)	Percent of Inflows or Outflows
Direct Rainfall	734	48.9	63%
Pervious Inflow – Direct Tributary Area	225	15.0	19%
Impervious Inflow – Direct Tributary Area	130	8.7	11%
Baseflow Inflow – Indirect Tributary Area	74	4.9	6%
TOTAL	1,163	77.5	100%
LAKE OUTFLOWS			**Percent of Outflows**
Evaporation	773	51.5	66%
Lake Seepage to Floridan Aquifer	399	26.6	34%
Lake Surface Discharge	0	0.0	0%
TOTAL	1,172	78.1	100%

Values in inches based on average lake surface area during calibration period (180 acres)

Model Validation Period

The calibrated model was applied for the years 1997 through 2007 as a validation period. The comparison between observed and modeled stages was not expected to be as good as for the calibration for several reasons:

- This period does not have rainfall at the nearby USGS gage. For this period, the Sanford gage (which is still reasonable proximate to Sylvan Lake) is used.
- As mentioned earlier, development was occurring in the direct tributary area during this period.

Figures 5 and 6 present the observed and modeled stage time series and frequency-exceedance relationship for Sylvan Lake during the years 1997 through 2007. The results indicate that the model is still doing a good job of simulating lake stages and replicating high and low lake stages during the simulation period. The shortcoming of the calibration period is the minimum rainfall during the simulation period (Table 1). The validation period addresses this issue and indicates the calibrated model can confidently simulate years with low rainfall.

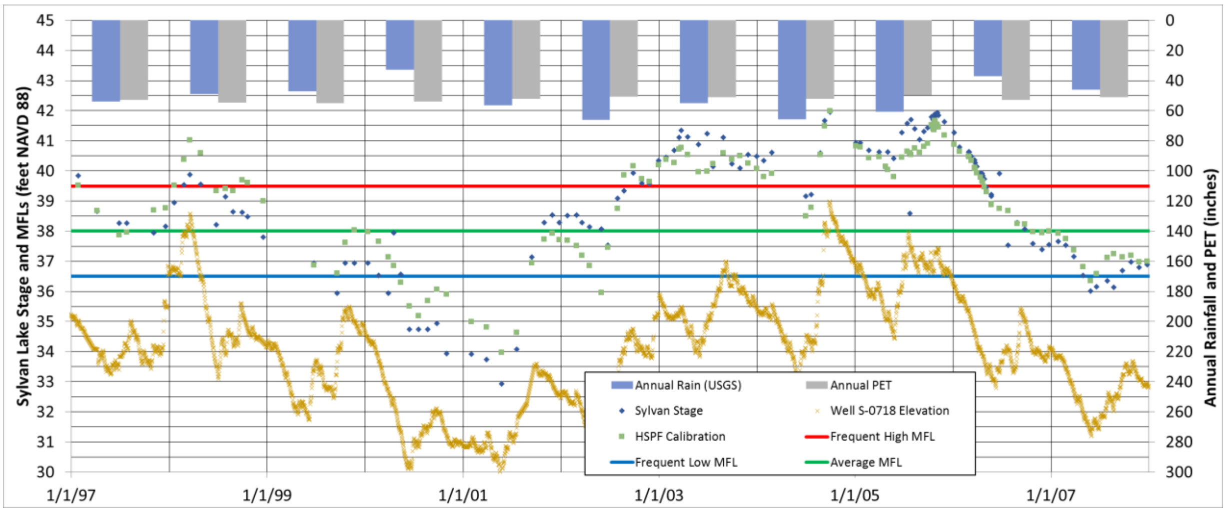

Figure 5. Comparison of Observed and Modeled Stage Time Series in Sylvan Lake for Validation Period

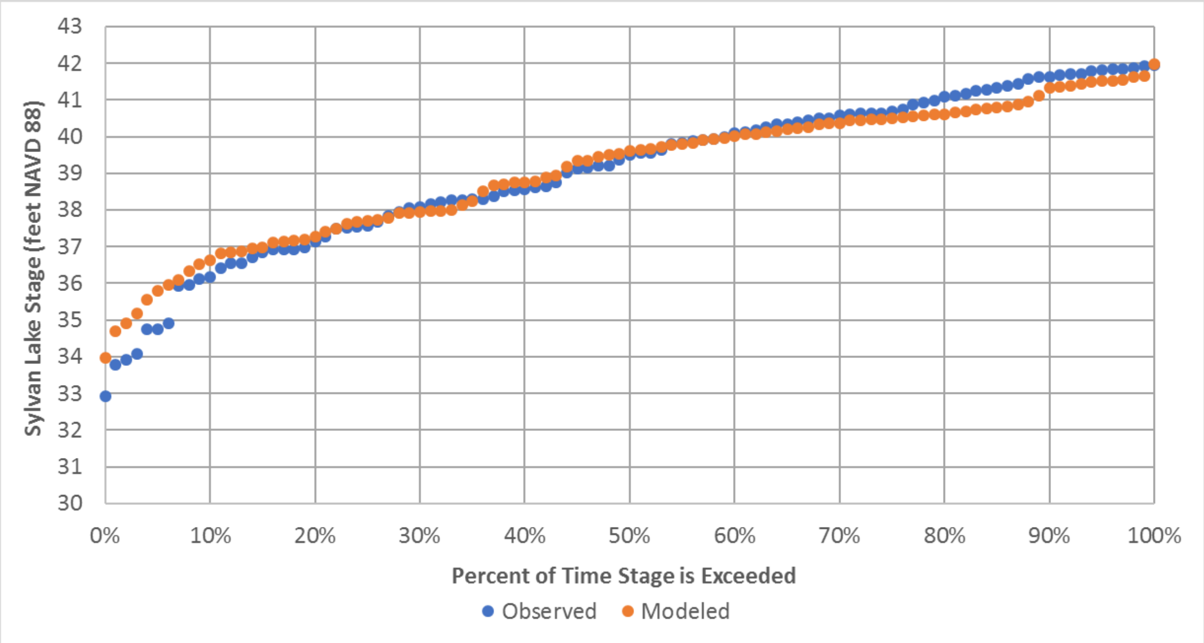

Figure 6. Comparison of Observed and Modeled Stage Frequency-Exceedance in Sylvan Lake for Validation Period

Based on differences between the observed lake stages and mean observed lake stage during the validation period (39.06 feet NAVD 88), and differences between the observed and modeled lake stages, the calculated Nash-Sutcliffe score is 0.90, which achieves the calibration goal of 0.90 or higher.

The differences between the observed and modeled lake stages were also evaluated to determine the percentage of time that the absolute difference between the observed and modeled stages was 0.50 foot or less. The results indicated that 57 percent of the paired data were within 0.5 foot, which is less than the 85 percent calibration goal, and that 85 percent of the paired data show a difference of 1.08 feet or less.

The average annual water budget for Sylvan Lake during the historical low and high lake stages are presented in **Tables 4** and **5,** respectively. Table 4 indicates that direct rainfall accounts for 56 percent of the total lake inflow and lake surface evaporation accounts for 64 percent of the total lake outflow during the historic low period (2000-2001). Table 5 indicates that direct rainfall accounts for 66 percent of the total lake inflow, and lake surface evaporation accounts for 58 percent of the total lake outflow during historic high period (2005).

Table 4. Average Annual Sylvan Lake Water Budget for Historic Low (2000-2001) during Validation Period

LAKE INFLOWS	Average Annual Inflow (acre-feet)	Percent of Inflows
Direct Rainfall	562	56%
Pervious Inflow – Direct Tributary Area	246	25%
Impervious Inflow – Direct Tributary Area	115	11%
Baseflow Inflow – Indirect Tributary Area	79	8%
TOTAL	1,002	100%
LAKE OUTFLOWS	**Average Annual Outflow (acre-feet)**	**Percent of Outflows**
Evaporation	679	64%
Lake Seepage to Floridan Aquifer	382	36%
Lake Surface Discharge	0	0%
TOTAL	1060	100%

Discussion of Model Results

For the calibration, the model does a very good job of following the trends of increasing and decreasing lake stages, and range of lake stages over the calibration period. In effect, both metrics (modeled stage within 0.5 foot of measured stage at least 85 percent of the time and Nash-Sutcliffe of 0.90 or greater) are essentially met. Results for the validation period are still quite good, though not as good as the calibration results in matching observed lake stages.

Table 5. Average Annual Sylvan Lake Water Budget for Historic High (2005) during Validation Period

LAKE INFLOWS	Average Annual Inflow (acre-feet)	Percent of Inflows
Direct Rainfall	1296	66%
Pervious Inflow – Direct Tributary Area	380	19%
Impervious Inflow – Direct Tributary Area	157	8%
Baseflow Inflow – Indirect Tributary Area	142	7%
TOTAL	1,975	100%
LAKE OUTFLOWS	**Average Annual Outflow (acre-feet)**	**Percent of Outflows**
Evaporation	1,058	58%
Lake Seepage to Floridan Aquifer	677	37%
Lake Surface Discharge	89	5%
TOTAL	1823	100%

Summary

CDM Smith developed a calibration model for Sylvan Lake, evaluating the years 2008 through 2016. Model calibration considered comparison of measured and modeled stages using graphical and statistical methods, which indicated that the model did a very good job of replicating increasing and decreasing trends in lake stage, and the range of lake stage values measured during the calibration period. Applying the same hydrological parameters to a separate validation period also resulted in very good agreement with observed lake stages during the validation period.

Please call me at (904) 527-6706, or e-mail me at wagnerra@cdmsmith.com if you have any questions or require further information.

Sincerely,

Richard A. Wagner

Richard Wagner, P.E., D.WRE
Principal Water Resources Engineer
CDM Smith Inc.

cc: File
Shayne Wood, CDM Smith
Joanne Chamberlain, SJRWMD
Andrew Sutherland, SJRWMD

Appendix D

INTERA Peer Review Comments and Associated Actions for Revised Sylvan Lake Model

Comment	Page	Peer Review Statement	Action
1	2	"Using hourly rainfall will make the model better able to replicate high intensity event responses."	District provided rainfall data time series at an hourly time step for the model update.
2	3	"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."	Revised model includes pervious land elements (PERLNDs) that reflect the 13 land use categories established in previous District analyses.
3	4	"The DCIA values at these ratios are fairly rare and usually get routed through some stormwater storage element."	Revised model includes imperviousness values for urban land use categories that have been used previously by the District and were used in the 2015 and 2016 MFL studies at the request of the District.
4	4	"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."	Lower imperviousness values are already being used (see previous comment/response) and can be lowered if model results suggest that is required (also refer to comment/response 9).
5	5	"The high rainfall intensity associated with convective activity makes it impossible to accurately represent these storms with long numerical time steps."	Addressed in response to comment 1
6	5	"In the Sylvan Lake model, the basin was found to have small errors estimated at about a 3% error."	Revised model has boundaries established by available basin delineations combined with field visit verification by District and CDM Smith.
7	6	"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."	District has provided PET time series for the model revision, and it has been checked to avoid any such anomalies.
8	8	"The changing area in the reach should be offset with changes in the associated basin area."	Revised model included Special Actions to adjust the contribution of wetlands to reflect changing lake surface area calculated for the lake reach.

Comment	Page	Peer Review Statement	Action
9	9	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."	The model was able to achieve a very good match between modeled and observed lake stages for both the calibration and validation periods, without making adjustments to the RETSC parameter values. This may be due in part to the lower DCIA values (see response to comments 3 and 4).
10	11	"If future re-evaluations are called for Sylvan Lake then following recommendations are offered as possible action items:	Items 1, 2, and 3 have been addressed in previous comments/responses. Collection of additional calibration data (4), sensitivity analysis (5), and evaluation of statistical approach (6) are beyond the scope of the study.
		1. Utilize Special Actions to correct for mass balance inconsistencies	
		2. Further study DCIA percentages or specifically account for retention ponds	
		3. Carefully delineate basin and determine area that truly contribute to Sylvan Lake	
		4. Collect some calibration data to constrain model calibration (observe Sylvan Lake outflows, observe major inflow locations)	
		5. Conduct sensitivity analysis of key parameters (e.g., DCIA)	
		6. Evaluate a statistical approach relating lake stage to aquifer levels."	