MEMORANDUM

TO: Michelle Brown, Fatih Gordu

FROM: INTERA

DATE: October 11, 2019

RE: REVIEW OF LAKE WEIR HSPF MODEL

Introduction

Dynamic Solutions, LLC developed a surface water model of Lake Weir (Marion County) for the St. Johns Water Management District (SJRWMD), to support the assessment of the proposed minimum levels for this lake. The model was later updated by SJRWMD to simulate long-term water levels. The model will be used to assess the current status of the proposed minimum levels.

INTERA reviewed the Lake Weir HSPF model including long-term simulations with an emphasis on available data, model conceptualization, and model calibration. Overall, the model generally follows standard engineering practice and utilizes the best available data; however, several limitations were noted in the model conceptualization and calibration. Addressing these limitations will greatly improve the defensibility of the model and ultimately the Minimum Flow Level (MFL).

This technical memorandum summarizes INTERA's review of the Lake Weir HSPF model, long-term simulations and the associated model files including the following documentation:

- *Lake Weir HSPF Model Report, November 2016, Dynamic Solutions, LLC.*
- *Long Term Simulation HSPF Model of Lake Weir Draft Report, June 2019, District*

Review Questions

The District provided the review questions below. To assess each question, INTERA reviewed model input files and model documentation. INTERA responses to the review questions follow.

(1) Assess adequacy and appropriateness of the data used in model development, calibration, and long-term simulations.

Data used for model development include rainfall, area physical characteristics, lake stage, groundwater levels, lake bathymetry, lake discharges, and potential evapotranspiration (PET). The data were reviewed to determine if the best available data was utilized for the model development, calibration, and long-term simulations. The following datasets were reviewed for adequacy and appropriateness:

- Rainfall
- Historical groundwater levels
- Lake bathymetry and stage data
- Land use data
- Potential evapotranspiration (PET) data

Rainfall

Precipitation rates specified in .uci files for the calibration and the long-term simulations reference data set number 8102 (DSN 8102) from the Rainmodel_Weir.wdm provided by DSLLC (2016) and data set number 8104 (DSN 8104) in the Rainmodel_Weir.wdm file provided by the District (2019). The data sets are a composite of data collected from the NOAA station at Lisbon (1/1/1948 to 5/26/1988) and a SJRWMD station at Smith Lake at Belleview (5/27/1988 to 12/31/2015). According to DSLLC (2016), the record was a combination of the Lisbon Station (1948 to 1988), the Smith Lake Station (1988 to 2015) with remaining data gaps filled using the following stations: NOAA station Ocala and three SJRWMD stations Sunny Hill South #1, Sunny Hill C-D #5, and Blue House at Starkes Ferry. The time series were exported from their respective .wdm files and annual accumulations of rainfall were calculated, as shown in **Table 1** and **Figure 1**. These annual accumulations were compared to the DSLLC (2016) and SJRWMD (2019) reports. The annual totals were generally in agreement; however, the reevaluated mean and median were 0.1 inches above values reported in SJRWMD (2019). Additional details could be added to the documentation to address the development of the record and additional gap-filling techniques that were used.

Table 1. Annual Rainfall Accumulation (in/yr) of HSPF Period of Record

	Rainfall (DSLLC, 2016)	Rainfall (District, 2019)
Period of Record	2003 to 2014	1948 to 2017
Min	25.7	25.7
Max	59.2	82.0
Median	47.4	49.4
Mean	46.7	50.5

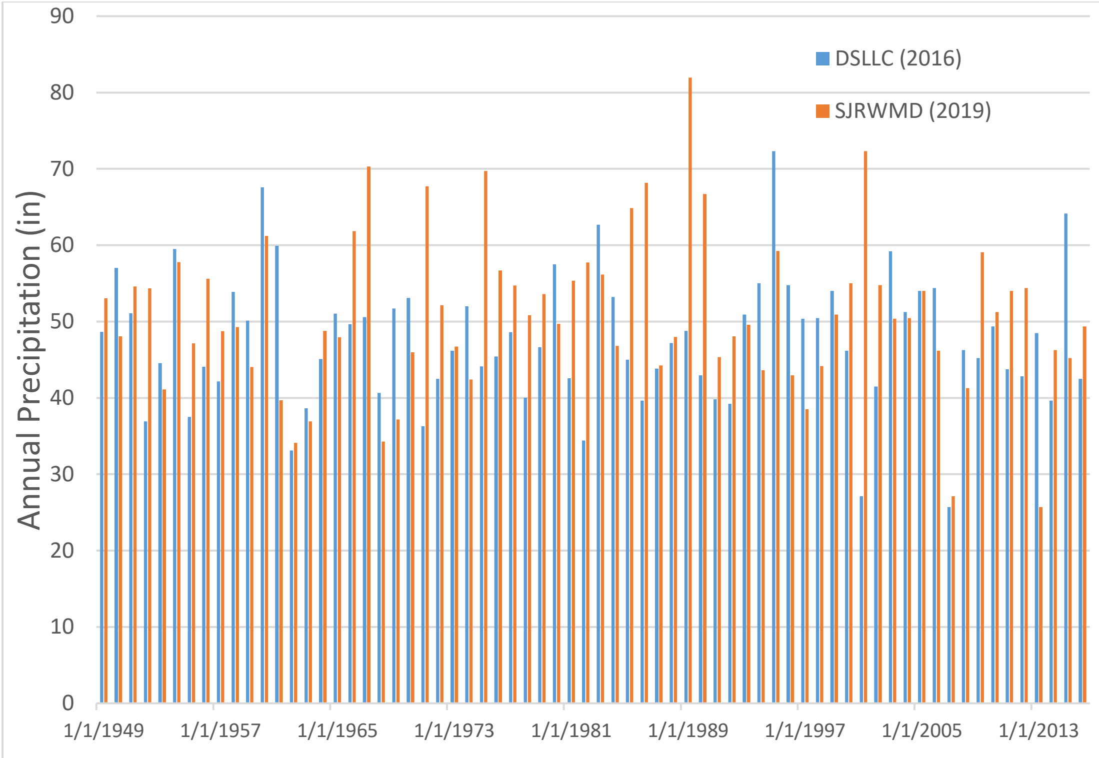

Figure 1. Annual Precipitation in DSLLC (2016) and SJRWMD (2019) .wdm Files

Historical Groundwater Levels

Historical groundwater levels were needed in order to estimate the potentiometric head beneath Lake Weir. Available water level data in the vicinity of Lake Weir was downloaded from the District's hydrologic data search tool. Several wells were available near Lake Weir, including Upper Floridan and surficial wells. The Lake Weir Middle School at Lady Lake (WL) FA (Station ID: 15912734) was the Floridan well in the closest vicinity to Lake Weir. The well record spanned from September 2001 to June 2016 (DSLLC, 2016). Data were recorded as a daily mean with good quality/good quality edited records. A comparison of the available data and time series for the well that was extracted from DSN 1812 of LakeWeir.wdm is shown in **Figure 2**. SJRWMD (2019) extended the Lady Lake data coverage from 3/15/1936 to 12/31/2017 using the station Blue House at Starkes Ferry, as shown in **Figure 3**. Data quality flags in the timeseries downloaded from the Starkes Ferry station indicate that data was "estimated based on correlation with neighboring station" until approximately January 2004, after which the data varied from good quality/good quality edited, and unverifiable due to equipment failure. The record was extended using the Line of Organic Correlation (LOC) $y = 1.085758x - 8.548992$. The extended record WDM 1814 of the LakeWeir.wdm provided by the District is shown in **Figure 4** with both observed well time series.

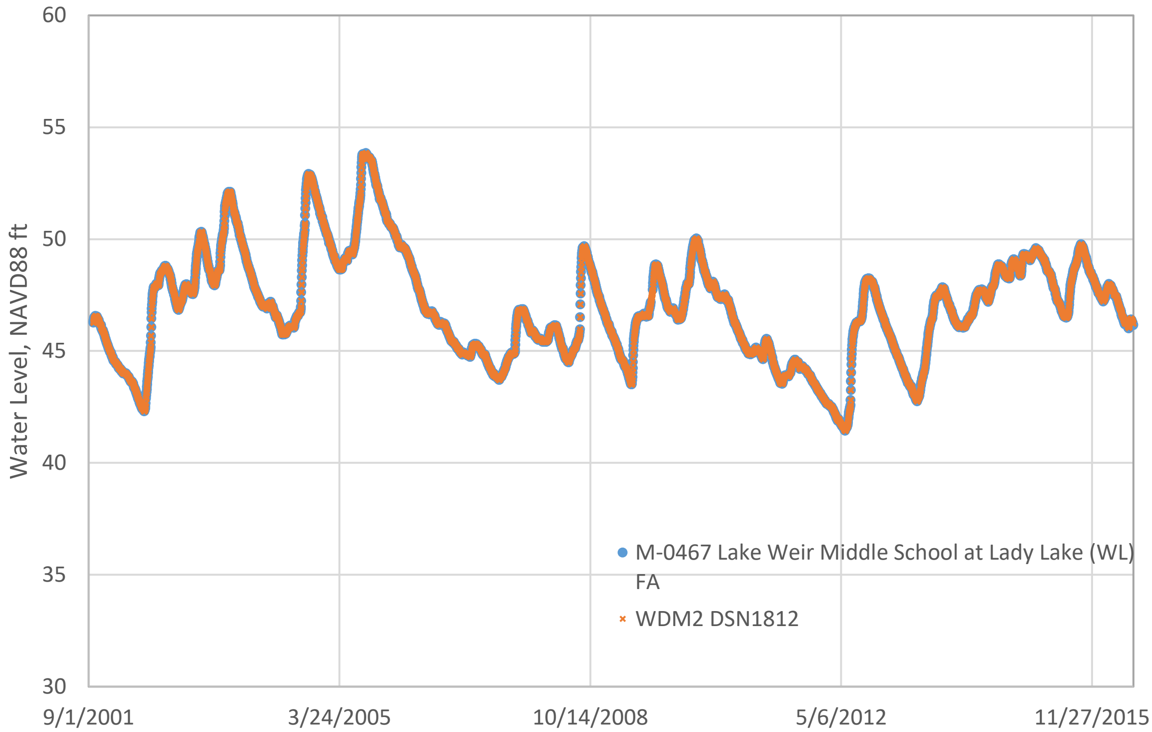

Figure 2. Comparison of Well M-0467 Lake Weir Middle School at Lady Lake Data (DSLLC, 2016)

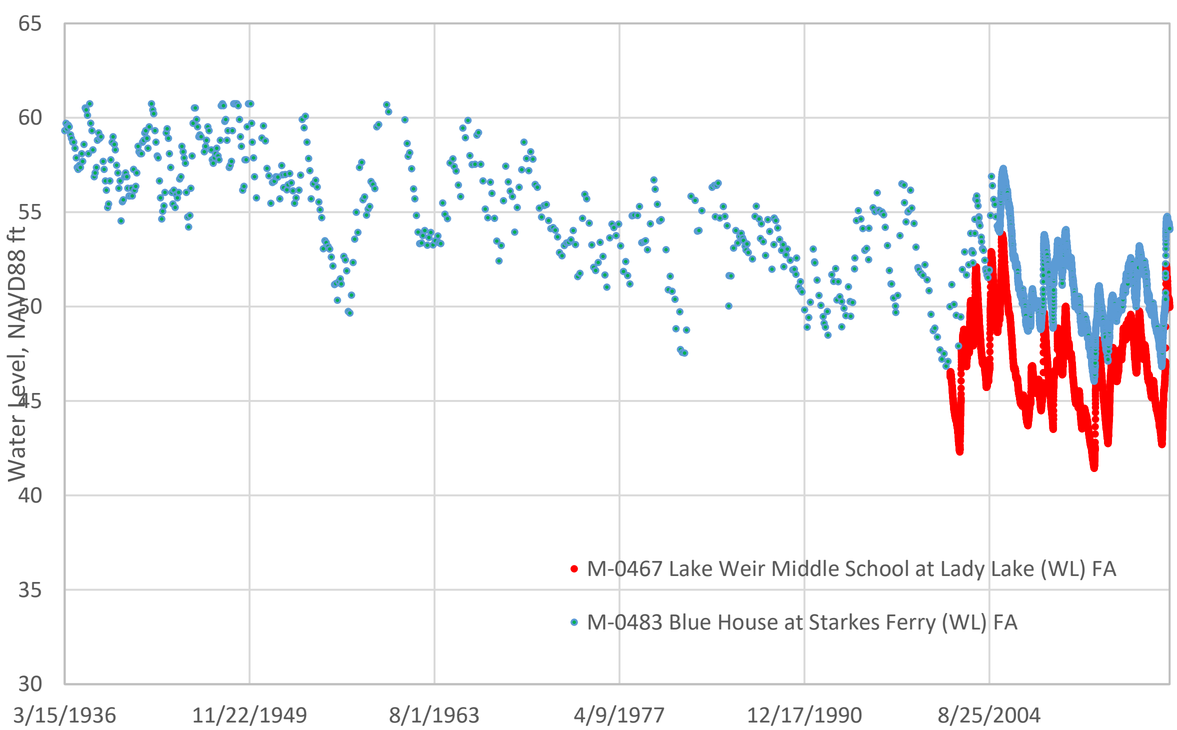

Figure 3. Comparison of Well M-0467 Lake Weir Middle School at Lady Lake Data and Well M-0483 Blue House at Starkes Ferry (District, 2019)

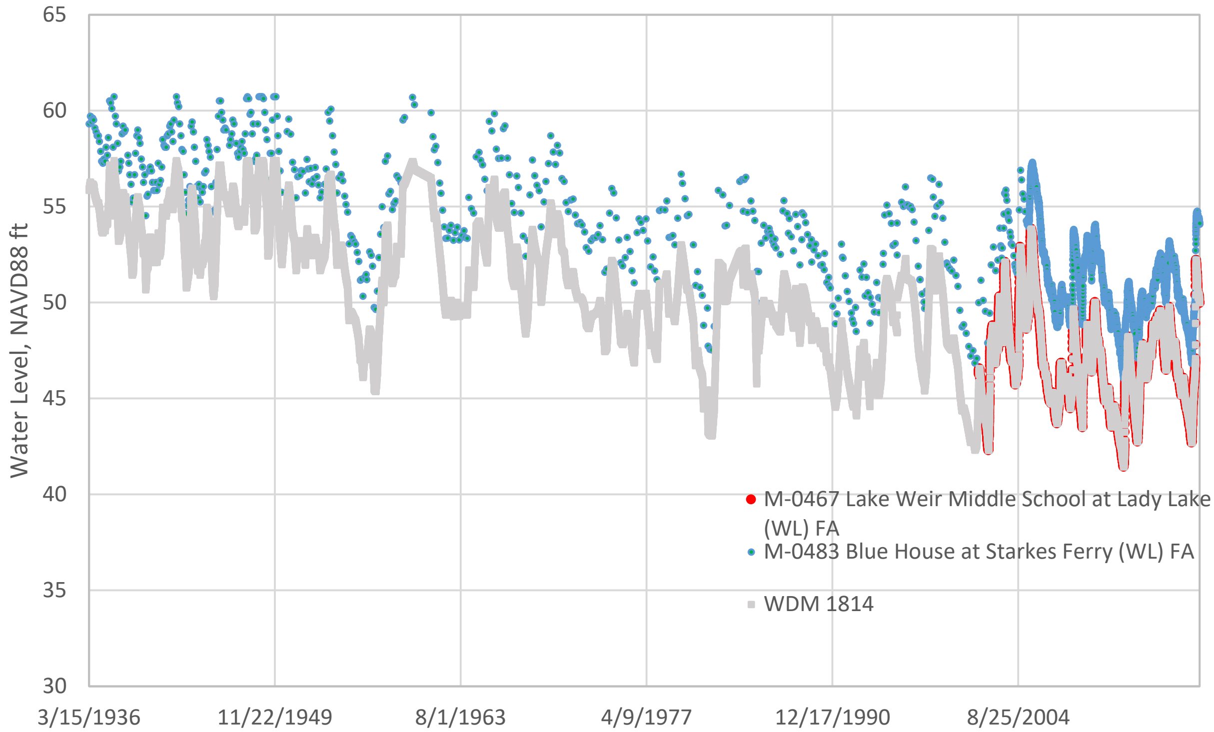

Figure 4. Comparison of Well M-0467 Lake Weir Middle School at Lady Lake Data, M-0483 Blue House at Starkes Ferry, and the extended Lady Lake well time series produced from Line of Organic Correlation (LOC) WDM 1814 (District, 2019)

Lake Bathymetry, Stage, and Outlet Discharge Data

Lake stage data was available online at the District's hydrologic data search tool. This data was used to develop an F-table for the RCHRES representing the lake in HSPF. DSLLC (2016) used the rating curve that was developed previously in Robison (2003), then adjusted to account for the NAVD88 datum shift, and is given as:

$$\mathbf{Q = 2.5*20* (\mathit{h}-56.4)^{1.5}}$$

where h is the stage (ft) and Q is the discharge (cfs). Examination of the rating curve and .uci files shows that the F-table matches the elevation-area-volume-outflow. Note that the author's name (Robison) is spelled incorrectly as Robinson and should be corrected in the text and reference section of the DSLLC documentation.

The stage-area-volume relationship was maintained from the Robison (2003) modeling effort. Bathymetry data was not discussed in the DSLLC (2016) documentation. In an effort to verify the stage-area relationship in the F-table, INTERA located Lake Weir bathymetry contours available on the District's website (**Figure 5**; [SJRWMD, 1990]). The contours were used to calculate the state-area relationship of the lake and compare it to the F-table in the calibration .uci file, as shown in **Figure 6**. As shown, there is a discrepancy between the F-table used in the .uci and the stage area relationship developed with bathymetry contours, particularly at high stages. This, in effect, builds error into the model that must be compensated for through model parameterization. For comparison, the average observed lake stage for each decade was calculated and the area difference for the average stage was calculated (**Table 2**). As shown, errors can be as high as 13.0%.

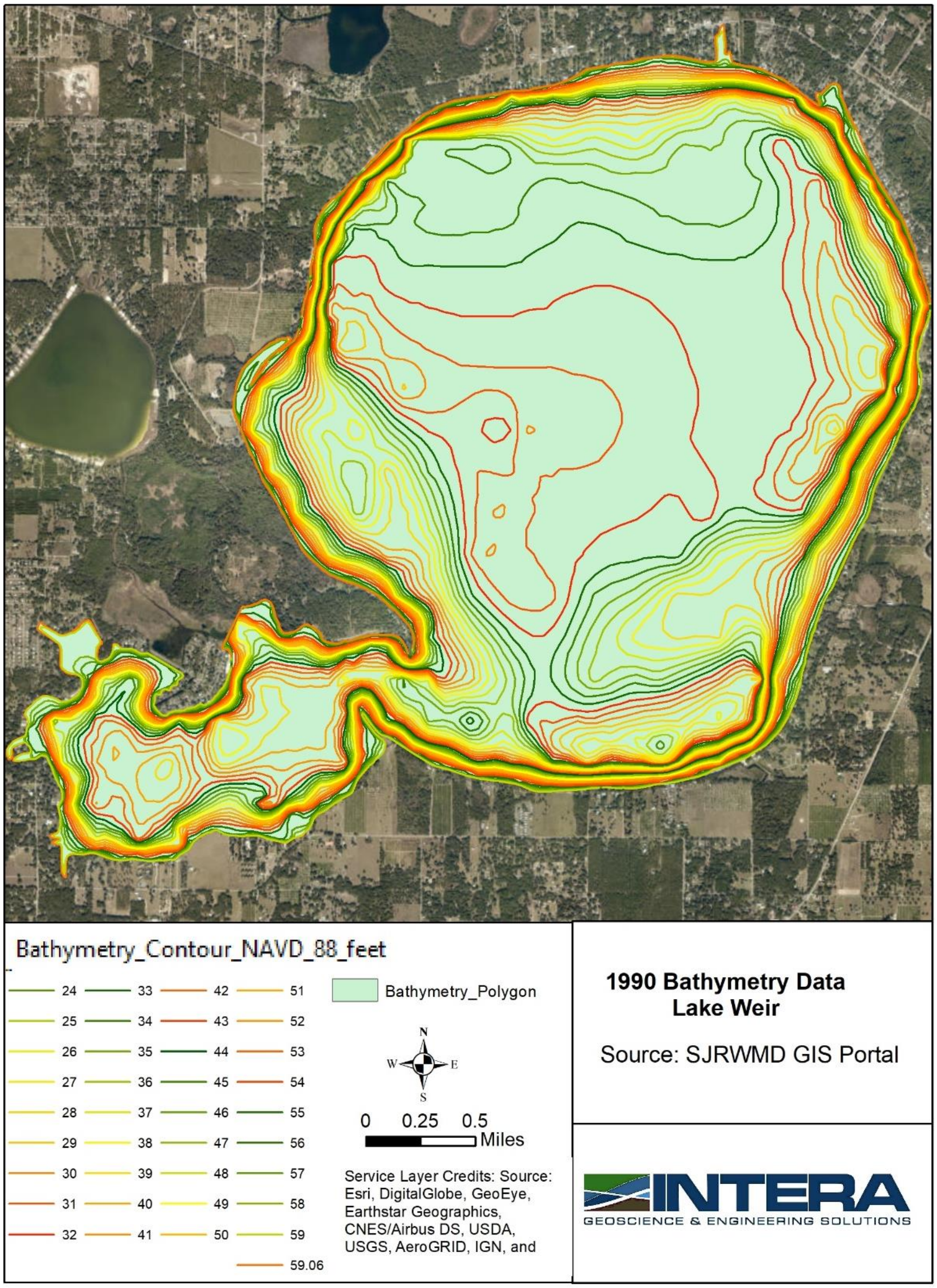

Figure 5. Lake Weir Bathymetry (SJRWMD, 1990)

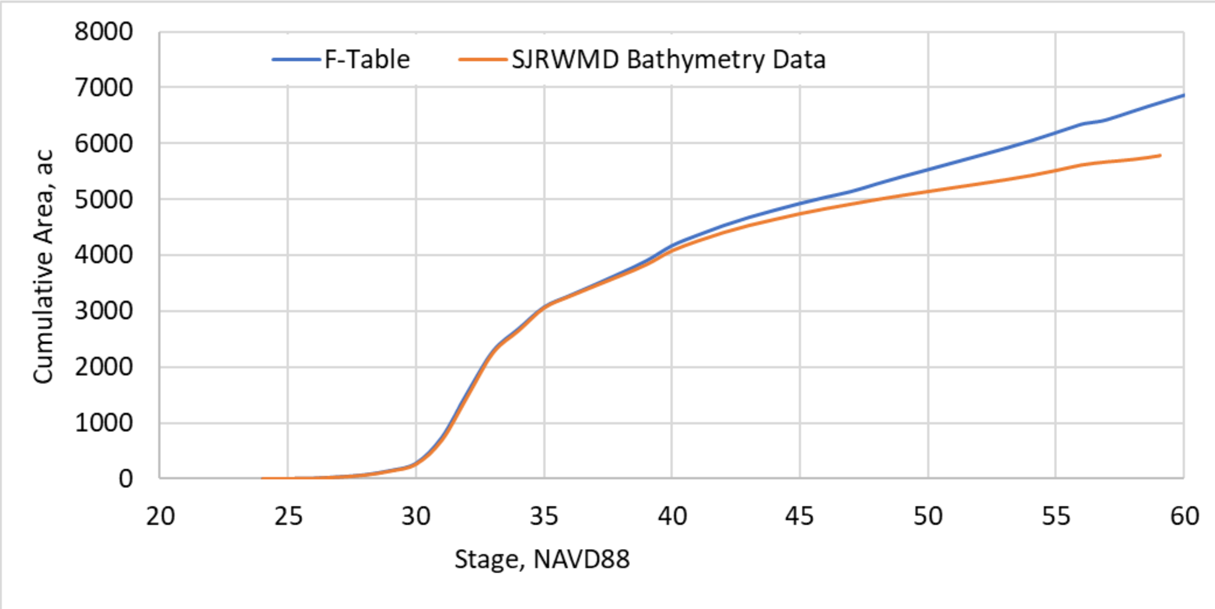

Figure 6. Stage-Area Comparison

Table 2. Area Comparison

Years	Average Observed Stage, feet NAVD88	Area Based on F-Table, acres	Area Based on Bathymetry, acres	Percent Difference between Bathymetry and F-Table areas
1942-1950	55.9	6,332.90	5,606.19	13.0%
1951-1960	55.4	6,267.12	5,562.40	12.7%
1961-1970	55.9	6,332.90	5,606.19	13.0%
1971-1980	56.0	6,350.13	5,617.66	13.0%
1981-1990	55.3	6,247.63	5,549.42	12.6%
1991-2000	53.5	5,984.32	5,388.60	11.1%
2001-2010	52.5	5,853.38	5,314.79	10.1%
2011-2017	50.7	5,628.06	5,190.91	8.4%

Land Use Data

Land use data was taken from the District's 2009 coverage, and the land uses were aggregated into 13 categories that were provided by the SJRWMD. Basin delineation was performed using the DEM elevation data. The DCIA percentage of urban land were specified as 5%, 15%, 35%, and 50% for Low Density Residential, Medium Density Residential, High Density Residential, and Commercial/Industrial, respectively. These values were used in the Lake Weir HSPF model and were based on the HSPF model for Lake Apopka and Upper Ocklawaha River (Huang and Smith, 2015).

When comparing the 2009 land use against the more recent aerial imagery, some discrepancies were noted due change in land use over time. Land use that were classified as "Forest" or "Groves" in 2009, has been developed since, and are now residential areas. Similarly, "Commercial/Industrial" areas listed in 2009, are open land in more recent aerials (**Figure 7**). It is important to note this for future studies. Updates to land use file will be needed in the future to be consistent with the physical condition of the watershed, and accurate model predictions.

Figure 7. 2009 Land Use Comparison and Aerial Provided by ESRI in the Basemap Layer

Potential Evapotranspiration (PET) Data

PET data were calculated using the Ocala station. Examination of the PET timeseries in DSN 3706 of the RainModel_Weir.wdm provided in DSLLC (2016) for the calibration model from 2003 – through 2014 and in DSN 3706 of the RainModel_Weir.wdm provided by SJRWMD (2019) for the long-term simulation model from 1948 through 2017 shows that the PET timeseries is hourly.

Annual PET statistics and totals, shown in **Table 3** for both calibration and long-term simulation models, appear reasonable, although slightly low for the adjusted PET rates used by the .uci once the scale factor of 0.8101 is applied in the External Sources block. There appears to be a slight downward trend in annual PET for 1948 to 2017 period (**Figure 8**). This may not be an issue for the overall model calibration and predictive simulation because the rates were fairly consistent between the calibration (2004 through 2012) and long-term simulation (1987 through 2012) periods.

Table 3. Annual PET Accumulation (in/yr) for time period used in HSPF

	Calibration Model		Long-term Simulation Model	
Period of Record	**2003 to 2014**		**1948 to 2017**	
	PET (DSLLC , 2016)	**PET Adj. (DSLLC , 2016)[1]**	**PET (District, 2019)**	**PET Adj. (District, 2019) [1]**
Min	58.91	47.72	57.95	46.95
Max	64.19	52.00	65.91	53.39
Median	60.72	49.19	61.59	49.89
Mean	61.16	49.55	61.60	49.91

1. A multiplier of 0.8101 was used to adjust the calculated evaporation values by the Hargreaves approach to match GOES PET estimates

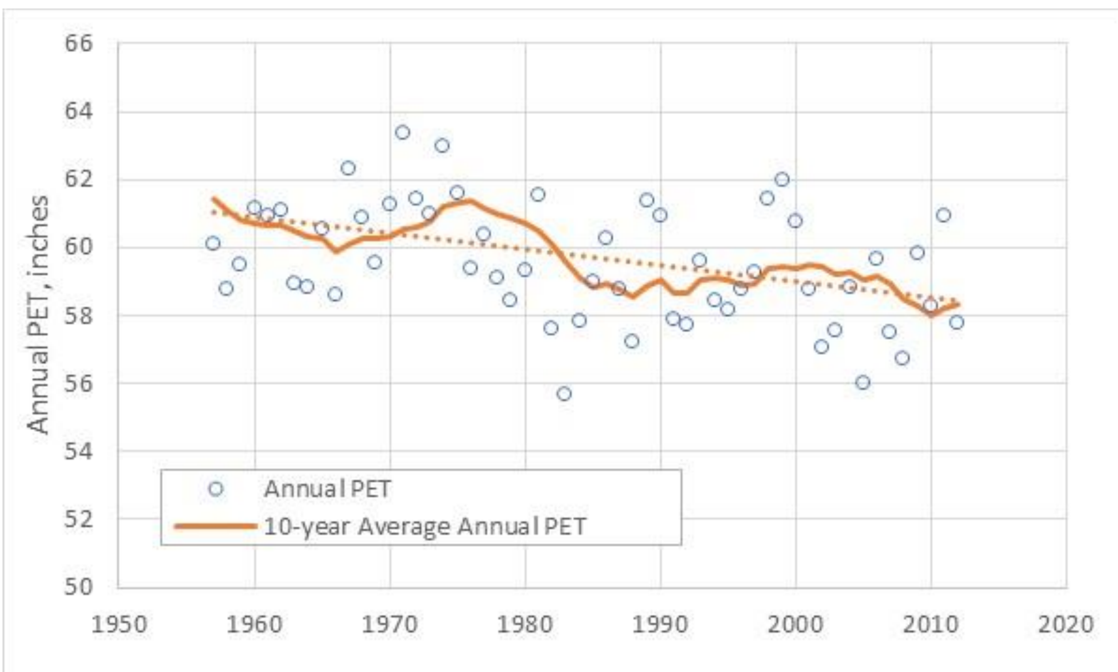

Figure 8. Non-Adjusted Annual PET Trend

a) Was "best information available" utilized to develop and calibrate the HSPF model?

In general, the best information available was used to develop and calibrate the HSPF model. Additional information should be added to the documentation to discuss gap-filling measures that were employed during model development. Additional discussion should be added to address why the available lake bathymetry data was not used for model development.

b) Are there any deficiencies regarding data availability?

All pertinent data needed to conceptualize and calibrate a surface water model of Lake Weir was available. There were no deficiencies regarding data availability.

c) Was relevant information available that was discarded without appropriate justification? Would use of discarded information significantly affect results?

Bathymetry data appears to have been available but was not used. The impact that of this data on the overall model results is not known at this time but it could be quantified by modifying the F-table in the calibration .uci file with the areas calculated using the available bathymetry data.

(2) Assess the validity, defensibility and appropriateness of the model development, calibration, and long-term simulations.

Based on the calibration results presented in the Calibration Report (Appendix C) (DSLLC, 2016), the daily and monthly observed and simulated stages were close to the calibration criteria of maximizing (at least 85%) the number of simulated lake stages within ±0.5 feet of measured. The second criteria of simulated Nash-Sutcliffe coefficient to be at least 0.85 was achieved for both monthly and daily temporal scale. **Table 4** shows the summary statistics as presented in Table 3 of the Appendix C (DSLLC, 2016)

Table 4 Summary Statistics for Daily and Monthly Stages of Lake Weir HSPF Model (Appendix C Table 3, DSLLC, 2016)

Stage	Sample size	Mean-Observed	Mean-Modeled	NSE	Percentage of modeled stages within ±0.5 feet of measured data
Daily	4,108	51.83	51.87	0.93	83.9%
Monthly	132	51.83	51.87	0.932	84.8%

a) Determine if the model is appropriate, defensible and valid given the District's MFLs approach.

Examination of Figure 4 in Appendix C of DSLLC (2016) shows a simulated hydrograph that appears reasonable when compared to the observed lake stage. The lake stage is due to all contributing water budget terms including water budget terms from the pervious and impervious land segments that are routed to it. In order to determine if the calibration is appropriate, it is imperative to examine individual components of the water budget. For the Lake Weir model, land segments were divided into 13 segment types based on land use. One of the largest water budget terms is actual evapotranspiration (AET). In HSPF, the output term for AET is TAET for PERLND segments, shown in **Table 5** for sub-basin 1. Wetland and water land segments should have the highest annual TAET rates, and residential and commercial/industrial land segments should have lower annual ET rates. As shown, wetland land segments had lower total ET rates than forested, range/shrub, and grove segments. Comparison to potential ET (PET) shows that wetland ET rates are much lower than PET. Wetland TAET rates should be close to PET since they are typically wet and water is not limited.

For the impervious land use, **Table 6** shows the SURO and RETS summary on an annual basis. It should be noted that initial RETS was zero and RETSC was very small. Impervious runoff (SURO) is very high, at times exceeding 50-inches per year.

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Table 5. TAET Sum by Year and Land Segment Type, inches

Year	Low Density Res.	Medium Density Res.	High Density Res.	Comm./ Indust.	Mining	Open	Pasture	Gen. Ag.	Groves	Range/ Shrub	Forest	Water	Wetland	PET	SUPY
	P:101	P:102	P:103	P:104	P:105	P:106	P:107	P:108	P:109	P:110	P:111	P:112	P:113		
2003	35.65	35.65	35.65	35.65	33.70	33.58	36.97	39.91	39.91	41.50	41.55	39.11	39.11	47.83	51.26
2004	33.06	33.06	33.06	33.06	30.82	30.72	34.20	37.26	37.26	38.69	39.02	38.99	38.99	49.12	54.00
2005	34.80	34.80	34.80	34.80	32.65	32.66	36.00	39.11	39.11	40.68	41.19	40.16	40.16	47.72	54.37
2006	21.71	21.71	21.71	21.71	19.95	20.50	22.94	24.63	24.63	25.20	26.29	21.89	21.89	51.19	25.69
2007	29.18	29.18	29.18	29.18	27.58	27.47	30.31	32.34	32.34	33.35	33.40	33.29	33.29	49.49	46.28
2008	30.67	30.67	30.67	30.67	28.32	28.67	31.71	34.76	34.76	35.86	37.02	38.74	38.74	48.84	45.23
2009	31.54	31.54	31.54	31.54	29.60	29.75	32.70	34.71	34.71	36.01	36.35	34.59	34.59	50.22	49.37
2010	32.49	32.49	32.49	32.49	29.90	30.20	33.05	35.41	35.41	37.00	37.52	33.54	33.54	50.03	43.73
2011	29.38	29.38	29.38	29.38	27.36	27.31	30.57	33.15	33.15	34.55	34.64	34.03	34.03	52.00	42.81
2012	33.56	33.56	33.56	33.56	30.99	31.18	34.05	36.36	36.36	37.83	38.11	35.40	35.40	50.12	48.50
2013	28.23	28.23	28.23	28.23	26.61	26.79	29.31	30.97	30.97	32.07	32.33	32.45	32.45	49.19	39.63
2014	36.42	36.42	36.42	36.42	34.33	34.22	37.42	40.48	40.48	42.12	42.16	43.00	43.00	48.82	64.13
Avg.	31.39	31.39	31.39	31.39	29.32	29.42	32.43	34.92	34.92	36.24	36.63	35.43	35.43	47.83	51.26

Table 6. SURO and RETS summary by Year for Impervious Land Use, inches

Year	I:101 SURO	I:101 RETS	I:102 SURO	I:102 RETS	I:103 SURO	I:103 RETS	I:104 SURO	I:104 RETS	I:201 SURO	I:201 RETS	I:203 SURO	I:203 RETS
2003	40.2	0.0	40.2	0.0	40.2	0.0	40.2	0.0	40.2	0.0	40.2	0.0
2004	43.7	0.0	43.7	0.0	43.7	0.0	43.7	0.0	43.7	0.0	43.7	0.0
2005	42.1	0.0	42.1	0.0	42.1	0.0	42.1	0.0	42.1	0.0	42.1	0.0
2006	18.5	0.0	18.5	0.0	18.5	0.0	18.5	0.0	18.5	0.0	18.5	0.0
2007	36.0	0.0	36.0	0.0	36.0	0.0	36.0	0.0	36.0	0.0	36.0	0.0
2008	35.4	0.0	35.4	0.0	35.4	0.0	35.4	0.0	35.4	0.0	35.4	0.0
2009	37.9	0.0	37.9	0.0	37.9	0.0	37.9	0.0	37.9	0.0	37.9	0.0
2010	34.7	0.0	34.7	0.0	34.7	0.0	34.7	0.0	34.7	0.0	34.7	0.0
2011	34.7	0.0	34.7	0.0	34.7	0.0	34.7	0.0	34.7	0.0	34.7	0.0
2012	38.4	0.0	38.4	0.0	38.4	0.0	38.4	0.0	38.4	0.0	38.4	0.0
2013	28.2	0.0	28.2	0.0	28.2	0.0	28.2	0.0	28.2	0.0	28.2	0.0
2014	51.9	0.0	51.9	0.0	51.9	0.0	51.9	0.0	51.9	0.0	51.9	0.0

b) **Evaluate the validity and appropriateness of all assumptions used in the model development, calibration, and long-term simulations.**

- **Are the assumptions reasonable and consistent given the "best information available"?**

The model is conceptualized using HSPF Special Actions to adjust the PERLND wetland segment based on the change in the RCHRES area of Lake Weir. This use of Special Actions for this adjustment allows for the overall conservation of basin area and, therefore, total mass entering and leaving the basin.

Special Actions are also used to represent lake leakage. The lake leakage term is a calibrated parameter. The reach contact area is held constant in Special Actions for the calculation of lake seepage although the reach area changes with lake stage. The effect of this assumption may be minimal since there is a small range of stages for the lake during the calibration period. The overall water balance for Lake Weir is shown in **Table 7**. The lake evaporation and direct rainfall fluxes are constrained. The change in storage (annual net flow) is also generally constrained because it is a reflection of the change in stage in the lake, which was used for calibration. Thus, the sum of pervious inflow, impervious inflow and seepage outflow comprise the remainder of the water balance. These fluxes are generally unconstrained, yet their sum is constrained as it should comprise the remainder of the water balance when rainfall, evaporation and change in storage are removed. Thus, if impervious inflow is too high, pervious inflow and/or seepage inflow may be too low. Although it is impossible to constrain these fluxes because they are generally not measurable, it is possible to examine the quantities for reasonableness given the overall pervious and impervious areas of the basin.

Warning/error messages involving continuity errors appear in the HSPF echo file when the model is executed. Although the effect of these warnings/errors may be insignificant, this should be explained in the model documentation.

In the Lake Weir model, sub-basins were individually calibrated and parameterized. This results in a parameterization that is slightly inconsistent across sub-basins. Comparison of the water balance summary for pervious land segments is shown in **Table 8**. Changing of INFILT by basin results in varying water balance by basin. The effect of this inconsistent parameterization is small as shown by a comparison of water balance quantities by similar land segment types. Impervious land segments are identically parameterized, as shown by the identical water balances shown in **Table 9**.

Table 7. Lake Weir Annual Water Balance (Source: Appendix C, Table 7, DSLLC (2016)

Year	ΔVolume	Rainfall	Runoff	ET	Overflow	Seepage
2004	5,600	26,700	8,590	24,300	0	5,390
2005	8,000	27,800	9,010	24,500	0	4,310
2006	-18,000	12,800	1,960	25,700	0	7,060
2007	-2,900	22,000	6,270	23,600	0	7,570
2008	200	21,600	8,190	23,400	0	6,190
2009	300	23,600	6,820	24,000	0	6,120
2010	-2,300	21,300	6,780	24,400	0	5,980
2011	-7,200	20,200	4,680	24,500	0	7,580
2012	0	22,400	7,090	23,200	0	6,290
2013	-4,700	17,900	4,360	22,400	0	4,560
2014	15,000	29,900	11,100	22,800	0	3,200
Average	-545	22,382	6,805	23,891	0	5,841

Note: Unit is acre-feet; sign – means that lake loses water.

Table 8. Water Balance Summary for Pervious Land Use, inches

Land use	SUPY	PET	TAET	SURO	IGWI	AGWI
P:101	47.08	49.55	31.39	0.84	8.38	6.72
P:102	47.08	49.55	31.39	0.84	8.38	6.72
P:103	47.08	49.55	31.39	0.84	8.38	6.72
P:104	47.08	49.55	31.39	0.84	8.38	6.72
P:105	47.08	49.55	29.32	0.48	9.76	7.82
P:106	47.08	49.55	29.42	0.41	9.78	7.84
P:107	47.08	49.55	32.44	0.28	8.25	6.62
P:108	47.08	49.55	34.92	0.10	7.10	5.69
P:109	47.08	49.55	34.92	0.09	7.10	5.70
P:110	47.08	49.55	36.24	0.22	6.22	4.99
P:111	47.08	49.55	36.63	0.02	6.23	4.99
P:112	47.08	49.55	35.43	0.00	8.50	6.82
P:113	47.08	49.55	35.43	0.00	8.50	6.82
P:201	47.08	49.55	31.22	0.81	8.51	6.82
P:203	47.08	49.55	31.22	0.81	8.51	6.82
P:206	47.08	49.55	29.22	0.40	9.92	7.95
P:207	47.08	49.55	32.28	0.28	8.36	6.71
P:208	47.08	49.55	34.81	0.10	7.18	5.76
P:209	47.08	49.55	34.81	0.09	7.18	5.76
P:210	47.08	49.55	36.14	0.21	6.29	5.04
P:211	47.08	49.55	36.54	0.02	6.28	5.04

Land use	SUPY	PET	TAET	SURO	IGWI	AGWI
P:212	47.08	49.55	35.31	0.00	8.62	6.91
P:213	47.08	49.55	35.31	0.00	8.62	6.91
P:301	47.08	49.55	31.30	0.84	8.44	6.77
P:302	47.08	49.55	31.30	0.84	8.44	6.77
P:303	47.08	49.55	31.30	0.84	8.44	6.77
P:304	47.08	49.55	31.30	0.84	8.44	6.77
P:306	47.08	49.55	29.32	0.42	9.84	7.89
P:307	47.08	49.55	32.36	0.29	8.30	6.66
P:308	47.08	49.55	34.86	0.10	7.14	5.72
P:309	47.08	49.55	34.86	0.10	7.14	5.73
P:310	47.08	49.55	36.19	0.22	6.25	5.01
P:311	47.08	49.55	36.58	0.02	6.25	5.01
P:312	47.08	49.55	35.36	0.00	8.57	6.87
P:313	47.08	49.55	35.36	0.00	8.57	6.87
P:401	47.08	49.55	31.14	0.77	8.58	6.88
P:402	47.08	49.55	31.14	0.77	8.58	6.88
P:404	47.08	49.55	31.14	0.77	8.58	6.88
P:406	47.08	49.55	29.13	0.37	9.99	8.01
P:407	47.08	49.55	32.21	0.26	8.42	6.75
P:408	47.08	49.55	34.75	0.09	7.22	5.79
P:409	47.08	49.55	34.75	0.09	7.22	5.79
P:410	47.08	49.55	36.10	0.19	6.33	5.08
P:411	47.08	49.55	36.49	0.02	6.31	5.06
P:412	47.08	49.55	35.25	0.00	8.68	6.96
P:413	47.08	49.55	35.25	0.00	8.68	6.96
P:501	47.08	49.55	31.06	0.72	8.66	6.95
P:502	47.08	49.55	31.06	0.72	8.66	6.95
P:503	47.08	49.55	31.06	0.72	8.66	6.95
P:504	47.08	49.55	31.06	0.72	8.66	6.95
P:506	47.08	49.55	29.04	0.34	10.07	8.07
P:507	47.08	49.55	32.14	0.23	8.48	6.80
P:508	47.08	49.55	34.69	0.08	7.26	5.82
P:509	47.08	49.55	34.69	0.07	7.26	5.82
P:510	47.08	49.55	36.06	0.18	6.37	5.11
P:511	47.08	49.55	36.45	0.02	6.34	5.08
P:512	47.08	49.55	35.18	0.00	8.74	7.00
P:513	47.08	49.55	35.18	0.00	8.74	7.00

Table 9. Water Balance Summary for Impervious Land Use, inches

Land use	SUPY	PET	SURO	IMPEV	RETS	SURS
I:101- I:104	47.08	49.55	36.80	10.29	0.00	0.00
I:201- I:203	47.08	49.55	36.80	10.29	0.00	0.00
I:301- I:304	47.08	49.55	36.80	10.29	0.00	0.00
I:401-I:404	47.08	49.55	36.80	10.29	0.00	0.00
I:501-I:504	47.08	49.55	36.80	10.29	0.00	0.00

- **Is there information available that could have been used to eliminate any of the assumptions? Would the use of this additional information substantially change the model results?**

  Assumptions regarding initial storages were made but not discussed in the model documentation. Although these will change model results, they will generally converge after several model time steps. If initial conditions are highly different from normal conditions, the equilibration could take many time steps, making the model results during those time steps unreliable.

  INTERA found no additional information that could have been used to eliminate any of the modeling assumptions, but aerial photography verification of the basin demonstrated that there are large areas that contain impervious areas that are not directly connected to Lake Weir. Thus, the division between pervious and impervious land segments may need to be modified, or retention storage capacity of the impervious land segments may need to be increased. The sensitivity of the model to various parameters is not known because a sensitivity analysis was not conducted.

Long Term Simulation

The long-term simulation of the Lake Weir model was conducted on the calibrated model by the District in 2019. The only change reported in the input was the rainfall data. A composite long-term rainfall data from NOAA station at Lynn and Smith Lake station was used for long term simulation model. A detailed review of rainfall, and PET has been presented in the review of calibration model.

Review of the model reflected overall good agreement between the observed and simulated flow, as shown in **Figure 9**. The period of 1994-1999 showed some discrepancies, rainfall could be a possible cause. Further investigation of the basis of this discrepancy and a sensitivity analysis of the model would be helpful.

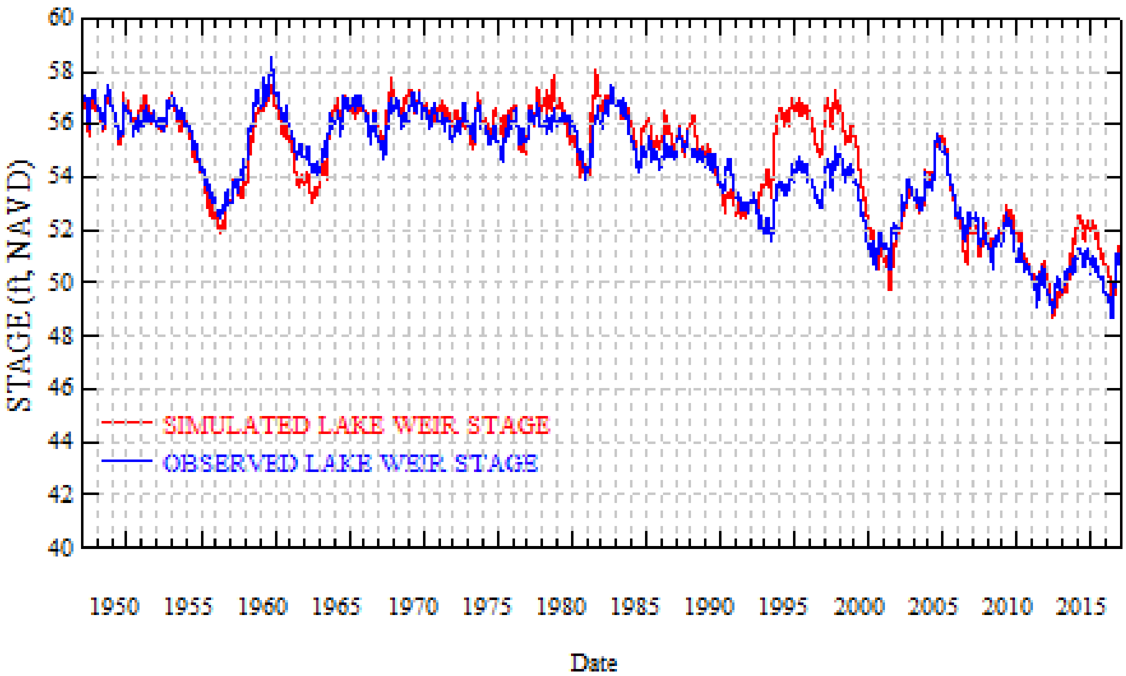

Figure 9 Comparison of Observed and Simulated Stages of Lake Weir (Source: Figure 11; District, 2019)

Typically, a long-term simulation model should have identical basin parameters as the calibrated model. When a comparison of the calibration and long-term uci files was performed, it was found that following parameters varied between the models:

- VLE
- MON-LZETPARM
- INFILT
- DEEPFR
- LZETP
- UZS
- LZS
- Special Actions – GENER 2

To further check the long-term simulation model, INTERA performed the long-term simulation on the calibrated model by changing the calibration .uci file for following inputs to match the District-provided long-term simulation model.

- Date (to extend model simulation time)
- External sources block (to extend model boundary conditions)
- Initial conditions

In general, the long-term .uci and the calibration .uci with long term boundary conditions resulted in similar simulated stages, as shown in **Figure 10.** This demonstrates that although the models are parameterized differently, the model is relatively insensitive to these differences.

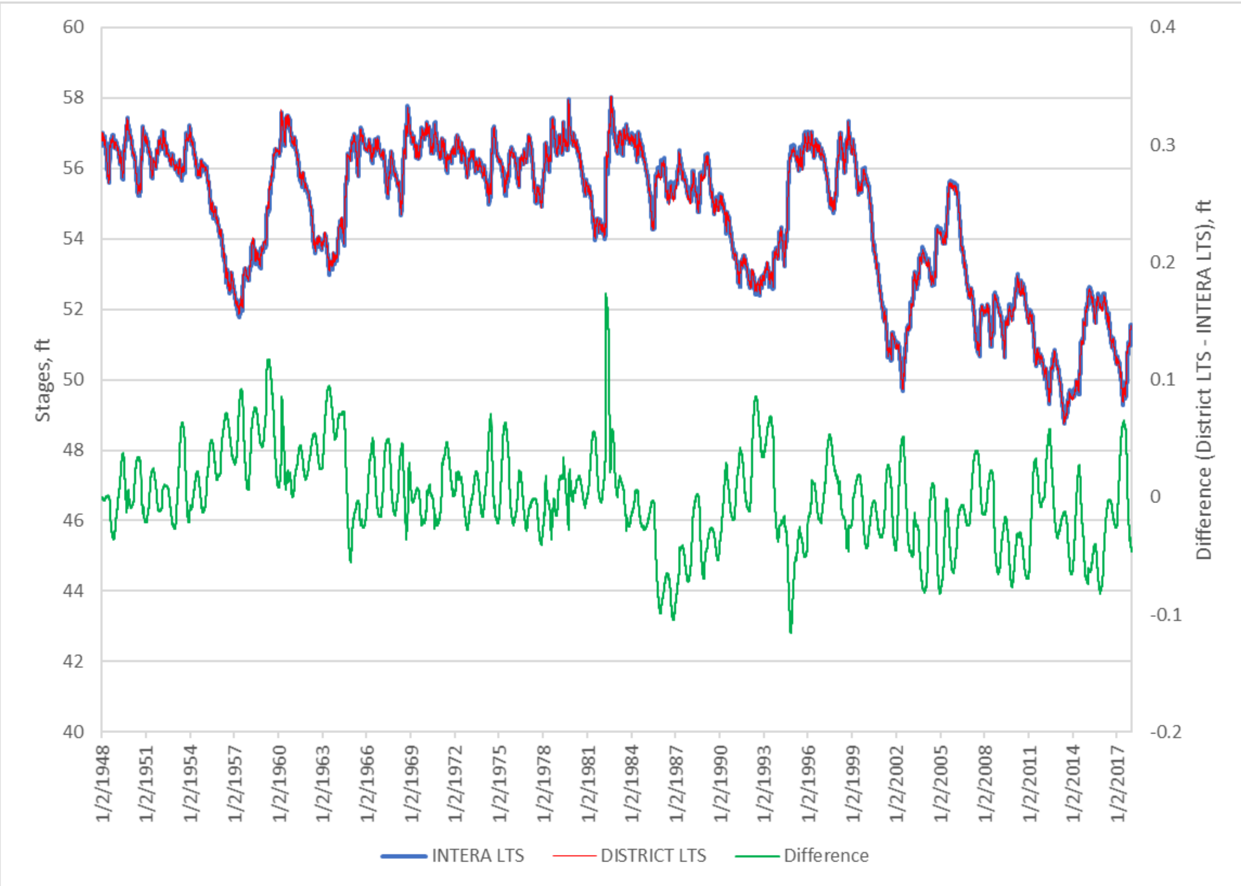

Figure 10. District-Provided Long-Term Simulation (DISTRICT LTS) and Long-Term Simulation Using Calibrated Model UCI file (INTERA LTS) and Difference between the Two Simulations.

Conclusions

In general, the model follows standard engineering practice and uses the best available data. Some improvements could be made to increase model defensibility. These include:

- Field verification of basin land use and stormwater features,
- Citation for bathymetry data that is currently available online, and justification for omittance of this data,
- Reconsideration of DCIA percentages because many areas are not directly connected to Lake Weir. No direct drainage features were found.
- Recalibration to ensure that wetland AET is higher than urban and forested segments. Wetland AET should be close to PET.
- Development of a sensitivity analysis to assess the sensitivity of lake stage to model parameterization,
- Modification of long-term .uci to match parameterization of calibration .uci, and
- Additional explanation for HSPF error messages within model documentation.

References

Dynamic Solutions, LLC (2016). *Lake Weir HSPF Model Report and Appendices*, Submitted to the St. Johns River Water Management District.

Huang, X. and Smith, D.R. (2015). *Draft Report of Lake Apopka and the Upper Ocklawaha River Minimum Flows and Levels Hydrological Assessment Method.* St. Johns Water Management District. Palatka, Florida

Robison, C.P. (2003). *Lake Weir Minimum Flows and Levels Hydrologic Method Report*, St. Johns River Water Management District. Palatka, Florida.

SJRWMD (1990). *Bathymetry Contour Polygon, Weir*. Available at https://data-floridaswater.opendata.arcgis.com/datasets/bathymetry-contour-polygon-weir-navd-88-feet-1990-sjrwmd?geometry=-82.274%2C28.962%2C-81.620%2C29.067.

SJRWMD (2019). *Long Term Simulation HSPF Model for Lake Weir in Marion County, FL.* Technical memorandum prepared by Awes Karama for the St. Johns River Water Management District.

Appendix – Error/Warnings

```
********************************************************************************
*                                                     *
*  ERROR/WARNING ID:   238   1                                  *
*                                                     *
*  The continuity error reported below is greater than 1 part in 1000 and is      *
*  therefore considered high.                                 *
*                                                     *
*  Did you specify any "special actions"?  If so, they could account for it.     *
*                                                     *
*  Relevant data are:                                   *
*  DATE/TIME: 2003/12/31 24: 0                                 *
*                                                     *
*  RCHRES :    1                                        *
*                                                     *
*     RELERR      STORS       STOR       MATIN      MATDIF                *
*  -3.355E-02  9.0087E+04  9.5453E+04  3.3042E+04  9496.6                  *
*                                                     *
*  Where:                                             *
*                                                     *
*  RELERR is the relative error (ERROR/REFVAL).                     *
*  ERROR  is (STOR-STORS) - MATDIF.                           *
*  REFVAL is the reference value (STORS+MATIN).                     *
*  STOR   is the storage of material in the processing unit (land-segment or      *
*         reach/reservior) at the end of the present interval.            *
*  STORS  is the storage of material in the pu at the start of the present       *
*         printout reporting period.                          *
*  MATIN  is the total inflow of material to the pu during the present printout    *
*         reporting period.                         *
```

* MATDIF is the net inflow (inflow-outflow) of material to the pu during the   *
*   present printout reporting period.   *
*   *
****

****
*   *
* ERROR/WARNING ID: 238   1   *
*   *
* The continuity error reported below is greater than 1 part in 1000 and is   *
* therefore considered high.   *
*   *
* Did you specify any "special actions"? If so, they could account for it.   *
*   *
* Relevant data are: *
* DATE/TIME: 2004/12/31 24: 0   *
*   *
* RCHRES :   1   *
*   *
*   RELERR   STORS   STOR   MATIN   MATDIF   *
*   -0.04499 9.5453E+04 1.0056E+05 3.5286E+04 1.0987E+04   *
*   *
* Where: *
*   *
* RELERR is the relative error (ERROR/REFVAL).   *
* ERROR is (STOR-STORS) - MATDIF.   *

```
*  REFVAL is the reference value (STORS+MATIN).                        *
*  STOR   is the storage of material in the processing unit (land-segment or      *
*          reach/reservior) at the end of the present interval.              *
*  STORS  is the storage of material in the pu at the start of the present        *
*          printout reporting period.                              *
*  MATIN  is the total inflow of material to the pu during the present printout    *
*          reporting period.                              *
*  MATDIF is the net inflow (inflow-outflow) of material to the pu during the      *
*          present printout reporting period.                          *
*                                                *
*********************************************************************************


*********************************************************************************
*                                                *
*  ERROR/WARNING ID:   238   1                               *
*                                                *
*  The continuity error reported below is greater than 1 part in 1000 and is      *
*  therefore considered high.                                  *
*                                                *
*  Did you specify any "special actions"?  If so, they could account for it.      *
*                                                *
*  Relevant data are:                                  *
*  DATE/TIME: 2005/12/31 24: 0                                 *
*                                                *
*  RCHRES :    1                                *
*                                                *
```

```
*    RELERR      STORS      STOR      MATIN     MATDIF                *
*  -3.233E-02  1.0056E+05  1.0850E+05  3.6848E+04  1.2380E+04                 *
*                                            *
*  Where:                                        *
*                                            *
*  RELERR is the relative error (ERROR/REFVAL).                        *
*  ERROR  is (STOR-STORS) - MATDIF.                              *
*  REFVAL is the reference value (STORS+MATIN).                          *
*  STOR   is the storage of material in the processing unit (land-segment or       *
*          reach/reservior) at the end of the present interval.               *
*  STORS  is the storage of material in the pu at the start of the present        *
*          printout reporting period.                              *
*  MATIN  is the total inflow of material to the pu during the present printout    *
*          reporting period.                                   *
*  MATDIF is the net inflow (inflow-outflow) of material to the pu during the      *
*          present printout reporting period.                          *
*                                            *
*************************************************************************************


*************************************************************************************
*                                            *
*  ERROR/WARNING ID:   238   1                             *
*                                            *
*  The continuity error reported below is greater than 1 part in 1000 and is       *
*  therefore considered high.                                  *
*                                            *
```

```
*  Did you specify any "special actions"?  If so, they could account for it.      *
*                                                   *
*  Relevant data are:                                        *
*  DATE/TIME: 2006/12/31 24: 0                                  *
*                                                   *
*  RCHRES :    1                                          *
*                                                   *
*     RELERR      STORS       STOR      MATIN     MATDIF                 *
*  -6.172E-02  1.0850E+05  8.9955E+04  1.4796E+04  -1.093E+04                 *
*                                                   *
*  Where:                                                *
*                                                   *
*  RELERR is the relative error (ERROR/REFVAL).                        *
*  ERROR  is (STOR-STORS) - MATDIF.                              *
*  REFVAL is the reference value (STORS+MATIN).                        *
*  STOR   is the storage of material in the processing unit (land-segment or       *
*          reach/reservior) at the end of the present interval.              *
*  STORS  is the storage of material in the pu at the start of the present        *
*          printout reporting period.                                 *
*  MATIN  is the total inflow of material to the pu during the present printout    *
*          reporting period.                                    *
*  MATDIF is the net inflow (inflow-outflow) of material to the pu during the      *
*          present printout reporting period.                          *
*                                                   *
*************************************************************************************
```

```
*********************************************************************************
*                                                  *
*  ERROR/WARNING ID:   238   1                                *
*                                                  *
*  The continuity error reported below is greater than 1 part in 1000 and is      *
*  therefore considered high.                                  *
*                                                  *
*  Did you specify any "special actions"?  If so, they could account for it.      *
*                                                  *
*  Relevant data are:                                   *
*  DATE/TIME: 2007/12/31 24: 0                               *
*                                                  *
*  RCHRES :    1                                  *
*                                                  *
*     RELERR      STORS       STOR       MATIN     MATDIF                *
*  -6.399E-02  8.9955E+04  8.7078E+04  2.8290E+04  4690.0                  *
*                                                  *
*  Where:                                          *
*                                                  *
*  RELERR is the relative error (ERROR/REFVAL).                     *
*  ERROR  is (STOR-STORS) - MATDIF.                          *
*  REFVAL is the reference value (STORS+MATIN).                      *
*  STOR   is the storage of material in the processing unit (land-segment or      *
*          reach/reservior) at the end of the present interval.             *
*  STORS  is the storage of material in the pu at the start of the present        *
*          printout reporting period.                            *
*  MATIN  is the total inflow of material to the pu during the present printout    *
*          reporting period.                                  *
```

* MATDIF is the net inflow (inflow-outflow) of material to the pu during the *

* present printout reporting period. *

* *

****

****

****

* *

* The count for the WARNING printed above has reached its maximum. *

* *

* If the condition is encountered again the message will not be repeated. *

* *

****

****