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Memo

To: Joanne Chamberlain, P.E., PMP, Bureau Chief, SJRWMD

From: Silong Lu, Ph.D., P.E., D.WRE, Dynamic Solutions, LLC

Date: 12/31/2018

Re: **INDEPENDENT TECHNCIAL PEER REVIEW SERVICES**
REVIEW OF HSPF AND HEC-RAS MODELS DEVELOPMENT AND DOCUMENTATION FOR WEKIVA BASIN, FLORIDA

Introduction

The Wekiva River Watershed is a part of the Middle St. Johns River Basin, and is located in Lake, Seminole, Orange and Marion counties. The watershed drains an area of approximately 376 square miles to the St. Johns River and is comprised of four principal watercourses: the Wekiva River, the Little Wekvia River, and Black Water Creek and Rock Springs Run. Many relatively small springs also exist in the watershed. Discharges from the springs contribute to a significant portion of flow in the Wekiva River.

Four waterbodies within the Wekiva River Watershed, that is, Wekiva River at SR 46, Little Wekiva River, Wekiva Springs and Rock Springs, are on the SJRWMD's minimum surface water flows and levels (MFLs) priority list. MFLs for the Wekiva River at SR 46 were adopted in 1992, and are currently under re-evaluation. All four systems are scheduled for adoption by 2019. The goal of the re-evaluation (for the Wekiva River at SR 46) and determination (for other systems in the watershed) is to ensure that adopted MFLs are based on the most up-to-date criteria, hydrological data, and models available.

The previously-developed Hydrological Simulation Program-FORTRAN (HSPF) model was updated in 2018 by the St. Johns River Water Management District (SJRWMD) to simulate the hydrology of the Wekiva River Watershed. The existing steady-state, one-dimensional river hydraulics HEC-RAS model was updated and extended in 2018 by the SJRWMD to include the Little Wekiva River and Rock Springs Run, as well as the Wekiva River Watershed to simulate the water surface profiles of the system. In addition, dynamic HEC-RAS model simulation was also conducted. With the HSPF simulated flows applied as boundary conditions, the HEC-RAS model is used to simulate the stages at various transect locations. Results from the two models will be used to determined and evaluate the MFLs.

The HSPF and HEC-RAS models of the Wekiva River Watershed were reviewed by Dynamic Solutions, LLC (DSLLC), with an emphasis on available data, model conceptualization, model assumptions, and model calibration. Overall, the model development generally followed standard engineering practice, utilizes the best available data, and made reasonable assumptions. However, providing additional documentation and discussion, as detailed below, may enhance the quality of the work.

This technical memorandum summarizes DSLLC's review of the Wekvia River Watershed HSPF and HEC-RAS models and associated model files [three (3) HSPF models and two (2) HEC-RAS models] including the following documentation:

- *Wekiva River Hydrology and Hydraulic Modeling for Minimum Flow and Level Evaluations (Seong and Wester, SJRWMD, 2018).*

Review Questions

The review questions below were provided by the District. To assess each question, model input files and model documentation were reviewed by DSLLC. DSLLC responses to the review questions are provided below.

1) Assess the adequacy and appropriateness of the data used in model development and calibration

Data used for hydrology and hydraulic model development and calibration for this study shall include:

1. Land Use and Land Cover data;
2. Soil Data;
3. Topographical Data;
4. Rainfall and Potential Evapotranspiration Data;
5. Spring Discharge;
6. Point Source Discharge;
7. Stream/River Cross Sectional Data;
8. Hydraulic Structure Data; and
9. Observed Flow and Stage Data.

These data and other information provided were reviewed to determine if the best available data were utilized for the models, and ultimately for MFL development. The following datasets were provided and reviewed for adequacy and appropriateness:

- Watershed Delineation
- Land Use and Land Cover

- Meteorological Data – Rainfall and Potential Evapotranspiration
- Spring Discharge
- Point Source Discharge
- Stream/River Cross Sectional Data
- Hydraulic Structure Data
- Observed Flow and Stage Data

Watershed Delineation

Watershed delineation and the watershed boundary of the Wekiva River Watershed were presented in Figure 2 (SJRWMD, 2018). The watershed was sub-divided into 44 sub-watersheds and the sub-watershed boundaries were defined using elevation and terrain models developed by SJRWMD. It appears that the delineation took into account the topographic elevation contours and other features such as roads. Several sub-watersheds (sub-watersheds 39-44 as shown in Figure 2 of the report) are treated as closed drainage areas and do not contribute surface runoff to downstream areas but recharge groundwater and are assumed to occur through the nearly springs, thus, not simulated directly in the HSPF model. Watershed delineation and the sub-division into sub-watersheds appear to be adequate and appropriate for the purpose of this study.

However, it would be very helpful to the reader if a color-shaded topographic map of the watershed is provided in the report.

Land Use and Land Cover

Land use and land cover presented in Figure 3 of the report was taken from the SJRWMD 2009 coverage for this study. There are over 100 different land use classes within the watershed based on the Florida Land Use and Classification Code System (FLUCCS). These land use classes, as grouped into 13 major land uses (note: 17 land use categories were used in the models) based on similarities in their hydrologic properties, are appropriate. Forested lands (24.3%) and wetland areas (18.5% riparian wetland and 5.6% non-riparian wetland) each account for about a quarter of the watershed area as shown in Figure 3 (SJRWMD, 2018). Developed area including medium and high density residential and industrial and commercial land use accounts for 20.3% of the watershed.

Since the simulation period of the watershed model is from 2003 to 20016, selection of the 2009 land use and land cover data appears to be an appropriate choice and adequate for the purpose of the study, although more recent 2014 land use and land cover became available post model calibration. It should be noted that comparison of the 2009 land use and land cover data to the 2014 data revealed that very minor changes in the land use and land cover occurred during that time window.

The 2009 land use and land coverages were also used to delineate riparian and non-riparian wetlands as shown in Figure 4 (SJRWMD, 2018) to better represent the impact of wetlands on the drainage pattern in the watershed.

Land use data were used to develop model parameters including interception storage capacity, pervious and impervious land use areas, lower and upper zone nominal storages, Manning's n value, and lower zone ET parameter, etc.

Meteorological Data – Rainfall and Potential Evapotranspiration

Daily rainfall data at four weather stations (Deland 1 SSE FL US, Lisbon FL US, Orlando International Airport, and Sanford FL US) were downloaded from NOAA and were filled for missing data with NEXRAD rainfall available from SJRWMD. Daily rainfall total were disaggregated into hourly time series using WDMUtil (the watershed data management tool for HSPF) based on an hourly NEXRAD rainfall hourly time series. Hourly precipitation data for each station were stored in the WDM file - RainModel_2017.wdm. Each sub-watershed was assigned to the rainfall station co-located in the same Thiessen polygon as shown in Figure 5 (SJRWMD, 2018). Hourly precipitation data were used by the HSPF model to generate watershed surface runoff and to calculate direct rainfall on the waterbodies in the watershed.

Potential evapotranspiration (PET) rates were estimated using the Hargreaves method with a monthly correction factor scaled to the Priestly-Taylor estimated evaporation. This approach has been used by SJRWMD to estimate PET when observed data are not available, which appears to be appropriate for Florida. Hourly PET data for each station were stored in the WDM file - RainModel_2017.wdm. Each sub-watershed was assigned to the weather station co-located in the same Thiessen polygon as shown in Figure 5 (SJRWMD, 2018). Hourly PET data were used to calculate evapotranspiration loss from pervious and impervious land segments and waterbody surface direct loss.

Both the hourly rainfall and PET datasets used for the model simulation are adequate and appropriate for the purpose of the study.

Spring Discharge

Spring discharge in the watershed accounts for a substantial portion of the flow in the Wekiva River, especially in periods of low flow. These springs discharge treated as external flow sources in the hydrological models can significantly impact overall water budget of the watershed; therefore, it is critical to develop a procedure that is technically sound and defensible using the best available data to fill and extend the spring discharge data when observed data are missing.

Among the thirty-five (35) spring discharges included in the hydrological HSPF models, only six (6) of them have a relatively long record of flow data that cover the model calibration period of 2003 to 2016 and long-term simulation period of 50 to 60 years. Data gap-filling and extension of spring discharge data were based on the available observed data for the springs. A procedure presented in Appendix A of the report (SJRWMD, 2018) was developed for data gap-filling and extension of springs flow for: 1) the springs with a relatively long period of record; 2) the springs with short period of record; and 3) the springs with very few observation data.

For the springs with a relatively long period of record data, the flows of these springs were correlated using the Line of Organic Correction (LOC) method with the closest Upper Floridan Aquifer (UFA) levels at Orlo Vista (OR-0047 Well) which has a long-term observed groundwater level record data. The derived correlation equation for each spring was then used for the gap-filling and extension of flow data. Good correlations were found for four (4) of the six springs with a coefficient of determination (R^2) greater than 0.5.

For the three (3) springs with short periods of record, the flow data of these springs were filled in and extended using a simple linear regression (SLR) with nearby larger magnitude springs in the basin. Good correlations were obtained for two (2) of the three springs with a coefficient of determination (R^2) greater than 0.5 and the third one with a coefficient of determination (R^2) of 0.40.

For the other fifteen (15) springs with very few observation data, their flows were estimated using the ratio of mean flows of observation data with the corresponding mean flows of nearby springs.

Because of concerns relating to the availability of spring flow data and some low correlation (R^2) values, it may be tempting to consider using a groundwater model, or coupled groundwater and surface water model, to simulate spring flow data for the missing periods. However, the groundwater model or coupled groundwater and surface water model would be calibrated only to the available spring flow data and there is no guarantee that the calibrated groundwater model will produce better spring flow data than those estimated with the methods discussed above.

Due to availability of the spring flow data and the reasoning discussed above, using different methods for data gap-filling and extension appear to be appropriate and defensible. For model simulations, using the daily spring flows stored in the WDM file –Wekivadata_2017.wdm for model simulation is adequate.

It should be pointed out that a total of thirty-five (35) springs were modeled in the hydrological models (UCI files). However, thirty-four (34) springs were mentioned in the text of the report, twenty-seven (27) were reported in Table 5 and twenty-four (24) in Table A-1 of the report (SJRWMD, 2018). For consistency, the same number of springs should be discussed throughout the report, as well as in the hydrological models, or some explanations are needed if different numbers are used in the different parts of the report and the models.

Please note, in Table 5 of the report, the average discharge of Wekiva Falls for 1995-2007 and 2007-2016 should be equal to 18.58524 and 13.1852 cfs, respectively.

Point Source Discharge

Sixty (60) permitted point source discharge sites in the Wekiva River watershed (SJRWMD, 2018) were identified by Florida Department of Environmental Protection (FDEP). However, only two wastewater treatment dischargers (Wekiva Hunt Club and Altamonte Springs/Swofford wastewater treatment facilities) were included in the hydrological models. Annual average effluent discharges of the two dischargers were stored in the WDM file –Wekivadata_2017.wdm. However, it was found that annual average effluent data (in MGD) in the WDM file do not match those in Table 8 (SJRWMD, 2018).

The report shall clearly state the reason why the other fifty-eight (58) permitted point source dischargers were not included in the hydrological models and discuss the impact of exclusion of those dischargers on the model results.

Stream/River Cross Sectional Data

The details regarding the timing and use of cross-section data are well documented in the report.

The spacing of cross-sections (XS) throughout the reach is generally adequate for the stated purpose, with the exception of:

- The reach of the Little Wekiva above the “MFL_Sabol” cross-section. The model is adequate to compute the elevation at the surveyed cross-sections in this reach, but great caution should be used when extrapolating water levels between the surveyed cross-sections.
- The reach of ROK from “ROK3” to “ROK7” cross-sections. The model is adequate to compute the elevation at the surveyed cross-sections in this reach, but great caution should be used when extrapolating water levels between the surveyed cross-sections.

There are some questions and inconsistencies regarding cross-section elevations:

- There is no mention of Digital Elevation Model (DEM) information in the report; however, a DEM seems to be utilized in model development. If the DEM was in fact utilized, the report should state the source, datum, and resolution.
- The cross-sections lines shown in the HEC-RAS model (both the “Geometric Data” and “RAS Mapper” windows) do not show the full, true extent of the cross-sections. The XS lines shown are shorter than the width shown on the station-elevation plots for the XS. This makes it difficult to evaluate the model geometry, as we do not have a reference for the true location of the station-elevation data for each cross-section. This is particularly relevant near the confluence of the Wekiva – Little Wekiva junction, where the XS ends from each branch should end on a common “match line.”
- On the Little Wekiva River reach, XS 245.69 downstream to XS 30.5 are unbounded at high flows. It is possible this is okay on “river left,” as they will match with the Wekiva River XSs, but “river right” should be bounded by topography.
- On the Wekiva River, Wekiva_riv_down reach, XS 405.9 (MFL_RailRoadGage), XS 319.75 (MFL_SR46E), and XS 318.81 (MFL_SR46B) are unbounded. It is likely the

vertical wall approximation of being unbounded is justified here, but it is unknown. It is better to add station-elevation points to each side to bound the section.

- On the Wekiva River, Wekiva_riv_down reach, XS 0 to 76.89 (XS1), the XSs are unbounded. The steady state flow profile indicates there is energy loss (slope) through these XSs, so the width does indeed influence conveyance. A test where the lower three cross-sections were widened by 400 feet showed a 0.5-foot difference at XS1 decreasing 0.05-ft at SR46E for the PF13. (Note: We realize that these sections exist within the floodplain of the Saint Johns River so the cross-sections may be truly unbounded. However, the best approximation of the width of the active flow should be utilized.)

Hydraulic Structure Data

The report states that data for the SR46 Bridge was taken from the 2016 SJRWMD work. The original source or survey information should be given for completeness of this report.

Observed Flow and Stage Data

Seven (7) gaged flow datasets were used for the hydrological model calibrations. Among the seven (7) gages, three of them are located on the Wekiva River and two of them are located on both the Black Water Creek and the Little Water Creek. Daily observed flow data collected by USGS or SJRWMD at each gage stored in the WDM file – Wekivadata_2017.wdm were used to compare to the model simulated flows for visual comparison and statistical calculation. Although there exist data gaps in the two flow datasets (one on the Little Wekiva River and one on the Wekiva River), the seven observed daily flow data sets, in general, are adequate and appropriate for calibration of the hydrological models.

The seven (7) gaged stage data sets were compared to the model-simulated stages of the calibrated transient hydraulic model. Eight (8) water level gaging stations were used to compare to the model-simulated stages using thirteen (13) steady-state hydraulic model simulations. The stage data sets were generally adequate and appropriate for calibration of the hydraulic models.

a. Was "best information available" utilized to develop and calibrate the models?

The best information available was used to develop and calibrate the hydrological HSPF models with the exception of hydrological soil group data. Hydrological soil group data from the SJRWMD 2008 coverage should be utilized in development of the hydrological models as the basis in estimating soil infiltration rate for each sub-watershed although the current infiltration rates used in the calibrated models appear to be within the acceptable range.

The best information available was also used to develop and calibrate the HEC-RAS models.

b. Are there any deficiencies regarding data availability?

Based on adequacy of the data discussed above, there are no deficiencies regarding data availability for both the hydrological and hydraulic models. All the data used in the models were available in sufficient spatial and temporal resolutions.

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

Based on the data presented in the documentation and knowledge of additional data sources, it appears that fifty-eight (58) permitted point source dischargers mentioned in the report were not included in the hydrological models without appropriate justification. In the report, it should clearly state the reason why those dischargers were not included in the models and discuss the impact of exclusion of those dischargers on the model results.

As those point sources are general small, or are known to not directly discharge to surface waters, use of those point sources in the hydrological models would not significantly affect the model results.

2) Assess the validity, defensibility and appropriateness of the model development and calibration.

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

The watershed HSPF models used:

- seventeen (17) land use categories regrouped from the SJRWMD's 2009 land use data set used in the models;
- the SJRWMD-developed watershed and sub-watershed boundaries;
- hourly precipitation data disaggregated from daily rainfall data using an hourly NEXRAD rainfall time series and filled using NEXRAD rainfall if missing at stations Deland, Lisbon, Sanford, and Orlando International Airport; and
- calculated PET based on temperature records at stations Deland, Lisbon, Sanford, and Orlando International Airport.

However, hydrological soil group data were not used to estimate the infiltration rates for each sub-watershed in the hydrological models although the infiltration rates used in the calibrated models appear to be within the acceptable range.

Wetland land use category was broken into riparian and non-riparian wetlands for better simulating the impact of wetlands on the drainage pattern in the watershed as nearly a quarter of the land use (24.1%) in the watershed is wetland.

"Special Actions" options in HSPF were used to account for variable PERLND and RCHRES surface areas to eliminate some double-counting of rainfall and evaporation when water levels are high and some under-counting when water levels are low for accurate model simulations.

The model was calibrated with the automatic parameter estimation tool PEST with acceptable range of possible parameter values including key parameters of LZSN, INFILT, DEEPFR and UZSN in the hydrological models although a summary table showing these key parameter values were not provided and discussed in the report.

Model results for the 14-year simulation period (2003 to 2016) and the 10-year calibration period (2003 to 2012) that included dry years, average years, and wet years were evaluated both graphically and statistically. Extension of the model simulation period is believed to be sufficient for purpose of conducting the hydrological model calibration. A time series plot, a 45-degree line plot, and frequency-exceedance curve plot of the observed flows versus HSPF simulated flows were provided for visual comparison and evaluation.

Statistical comparison of the observed and modeled flows included the root mean square error (RMSE), the coefficient of determination R^2, and Nash-Sutcliffe coefficient. Overall, the HSPF models simulated flows reasonably well except for the Wekiva River near Apopka site, which may be attributable to the rainfall dataset and urban development activities in the area.

The report and models did not provide any water budgets for land use category, the basin, and/or subbasin. However, our water budget analysis [see below, in 2) d] showed that the ratio of the total annual tributary surface runoff to the total annual rainfall flow budget is reasonable and consistent with our experience in Central Florida given the types of soil and land use in the tributary. The average annual accumulative total ET loss and total surface runoff for each land use category appears to be reasonable within typical ranges of the values found in central Florida. By land use category, the highest total ET loss was associated with the wetland land use and the highest surface runoff occurred in the urban areas (i.e., residential, commercial and institutional and services land uses), which was expected.

The hydraulic HEC-RAS models were developed with cross sectional data of the rivers/streams, stage data as downstream boundary, and observed flows and HSPF-simulated flow as upstream and internal flow boundaries. These are sufficient in spatial and temporal resolutions. Calibrated Manning's n values appear to be reasonable and modeled stages matched those observed reasonably well.

Overall, both the hydrological and hydraulic models are considered to be appropriate, defensible, and valid, given the District's MFLs approach, with some improvements discussed in the Summary section below.

b. Evaluate the validity and appropriateness of all assumptions used in the model development and calibration.

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

There are three key assumptions used in the hydrological HSPF model development including:

- The contributions from these closed sub-watersheds to the Wekiva River are assumed to occur through the nearby springs, thus, not simulated directly in the HSPF model;
- For non-riparian wetlands, the impact of non-riparian wetlands on baseflow runoffs are assumed to be negligible; consequently, the baseflow originating from the non-riparian wetland drainage areas is routed to receiving reach segment directly; and
- For gap-filling and extension of the spring flow data, springs flows are assumed to be either correlated with the UFA levels in the region or correlated with nearby spring flows in the basin; therefore, derived correlation equations were used to fill the data gap and extend the spring flows.

Closed drainage areas/sub-watersheds do not contribute surface runoff to downstream areas. The outflows from these closed drainage areas act to recharge groundwater; therefore, it is reasonable to assume that the contribution from these closed drainage areas to the Wekiva River occurs through the nearby springs.

The non-riparian wetlands modeled by surface FTABLEs in HPSF to represent the high water table and storage effects in non-riparian wetlands appear to be appropriate and reasonable.

Given the availability of the spring flow data, using those good correlation relationships between the spring flows and the UFA levels in the region and good correlation relationships between the springs and nearby springs in the basin for data gap-filling and extension appears to be reasonable.

In short, all the assumptions used in the hydrological models are reasonable and consistent given the best information available.

For the hydraulic HEC-RAS models, an additional assumption should be added stating the idea that water levels simulated by the model are most accurate at or near surveyed cross-sections, use caution for water levels further from surveyed cross-sections

Figure 30 in the report shows Manning’s n as a function of water level (Figure 30a) and flow (Figure 30b). The physical reasons for Manning’s n showing a “more consistent” relationship with flow should be discussed. We hypothesize that stage and flow data from all years were used to make these plots, so the reason the flow produces a cleaner relationship is because the base level changes from the gage are accounted for implicitly. If this is correct, this should be addressed in the report.

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

To our knowledge, there is no other information available that could have been used to eliminate any of the assumptions used in the hydrological HSPF models. Regarding Manning's n versus stage and flow relationships in Figure 30, it may be useful to recreate Figure 30a using only data from 2008 forward, when the gage datum is at the current base level. This may yield a "more consistent" relationship between water level and flow. Using the relationship of Manning's n versus stage may change results of the HEC-RAS models. However, we understand that functionally in HEC-RAS, varying Manning's n as a function of flow is much more efficient. However, as stated above, this discussion should be included in the report.

It is important to realize that assumptions are almost always needed to complete the modeling excise. Potentially, model assumptions may change results of the model simulations.

c. **Review model input and output data including but not limited to:**

- **Model elevations vs collected data to verify same datum used consistently;**

  Raw elevation data were not provided for review to verify that the same datum was used consistently.

- **Flow/stage plots to look for model instabilities;**

  By carefully examining the hydrological model-simulated instream flows at seven calibration locations, no model instabilities were observed in the hydrological HSPF models. It should be pointed out that the simulated reach stages are dependent on the bottom elevations of the reaches and negative stages do not mean there are any model errors and do not adversely impact the flow simulations.

  No significant instabilities were found in the hydraulic HEC-RAS models.

- **Output file for model warnings (full flow channels, flooded nodes, etc.);**

  There were two warnings that consistently appeared.

  (1) Warning that "cross-section end points had to be extended vertically." This issue was addressed in the "Stream/River Cross Sectional Data" section, when it was recommended that cross-sections be extended to bound all flows.

  (2) Warning about the "conveyance ratio" being too high or too low. This warning indicates that cross-section spacing may be too large. This warning should be

addressed by adding to the report the assumption that (as stated above): "water levels simulated by the model are most accurate at or near surveyed cross-sections, use caution for water levels further from surveyed cross-sections."

- **Continuity error and convergence data;**

  No continuity or convergence errors were found in the HEC-RAS models.

- **Water budget to check for reasonableness;**

  Water budget information was not provided in the report and model outputs.

  A table showing the water budget of the basin such as ET, rainfall, spring flows, surface runoff, interflow, and baseflow should be provided in the report.

- **Values assigned to model parameters to check for reasonableness;**

  As discussed in the previous section (Section 2), values of the key parameters of LZSN, INFILT, DEEPFR and UZSN used in the calibrated hydrological models are within the acceptable ranges for the Central Florida region. These values of the key parameters were determined with the automatic parameter estimation tool called PEST during model calibration.

  Manning's n values and other loss coefficients in the hydraulic HEC-RAS models are reasonable throughout the model and sufficiently documented. One addition that should be made was previously discussed with regard to Figure 30.

- **Appropriateness of boundary conditions including spring flows and river stages used in model inputs; and**

  As discussed in the previous section, it is appropriate that daily springs flows were treated as internal flow boundaries in the hydrological HSPF models.

  Using the river stage at the Lower Wekiva gage (located 0.9 mile from the Wekiva River mouth) as the downstream boundary condition in the hydraulic HEC-RAS models is appropriate.

- **Review of the methodologies used to**
  - **Develop boundary conditions including spring flows; and**
  - **Incorporate HSPF output in HEC-RAS models.**

  The methodologies used to fill and extend springs flows were reviewed. The review discussion is presented in the previous section. It was concluded that the methodologies used for the springs with a relatively long period of record, the springs with short period of record, and the springs with very few observation are all appropriate and defensible.

In the hydraulic HEC-RAS models, observed water level data at the Lower Wekiva gage (0.9 mile from the Wekiva River mouth) was used as the downstream stage boundary condition, while spring discharges at Rock Springs, Wekiva Springs and the Little Wekiva River at SR 434 gaging station were applied to upstream boundary conditions. HSPF model-simulated flows used as internal flow boundary conditions at flow-change locations where no observed flow data were available are appropriate.

d. Development of an independent water budget will be included in this subtask

Water budgets by land use category shown in Table 1 were developed by modifying the Wekiva River subwatershed HSPF model UCI file to output average annual flow in inch per acreage per year. The average annual total ET loss and total surface runoff for each land use category appears to be reasonable within typical ranges of the values found in Central Florida. By land use category, the highest total ET loss was associated with the wetland land use and the highest surface runoff occurred in the urban areas (i.e., residential, commercial and industrial land uses), which was expected.

Table 1 - Average Annual Flow (in inch/acre/year) by Major Land Use Category

Flow (in/ac/yr)	Forest	Wetland	Residential /Commercial /Industrial
Surface Runoff	3.1	0	35.4
Interflow	9.6	3.6	2.6
Baseflow	11.8	6.9	3.1
Rainfall	52.7	52.7	52.7
Total Simulated ET	28.2	42.1	11.6

Summary

In model development and calibration of the Wekiva River watershed, the best information/data available were utilized. No apparent deficiencies regarding data availability were found.

The methodology used to fill and extend the spring discharge data set when needed is appropriate and defensible given the best data available. Using the Special Actions options in HSPF to calculate variable areas of the wetlands and surface areas of water bodies is valid and appropriate.

The annual water budgets by land use category are considered to be reasonable for the area of the study. The assumptions used in the model development are reasonable and consistent given the best information/data available. Both the hydrological and hydraulic models are calibrated reasonably well.

In summary, the model is considered to be appropriate, defensible, and valid given the District's MFLs approach with the following improvements:

- Provide a summary table of key hydrological parameter values and discussion;
- Provide a water budget table of ET, rainfall, surface runoff, interflow, baseflow at minimum by land use category and discussion;
- Provide a general description how FTABLE was developed for each reach;
- Document the reason why the other fifty-eight (58) permitted point source dischargers were not included in the hydrological models and discuss the impact of exclusion of those dischargers on the model results;
- State assumptions in regard to the accuracy of the model between cross sections;
- Discuss the use (or not) of the DEM in the model;
- Discuss how the stream centerline was determined;
- Extend cross-sections so that all flows are bounded; and
- Provide full-extent, geo-referenced cross-sections.

Additionally, the following modifications are suggested in the report, for clarity.

- Use a consistent number for the springs in the watershed throughout the report and models;
- In Table 5 of the report, the average discharge of Wekiva Falls for 1995-2007 and 2007-2016 should be equal to 18.58524 and 13.1852 cfs, respectively.
- In Table 12 of the report, the last column is labeled "% flow at SR46." We believe this should be labeled as "non-exceedance probability"; and
- To be consistent with Figure 33, it is advised to that these values should be changed to "Exceedance Probabilities."

References

Seong, C.-H., and A. E. Wester, 2018. Wekiva River Hydrology and Hydraulic Modeling for Minimum Flow and Level Evaluations, SJRWMD Draft Report, Palatka, Florida

SJRWMD, 2012. The St. Johns River Water Supply Impact Study, Chapter 3: Watershed Hydrology. Appendix 3.B: HSPF Common Logic for the SJRWMD