TECHNICAL MEMORANDUM

Date: May 29, 2022

To: Michelle Brown, PE
Chief, Bureau of Watershed Management & Modeling, SJRWMD

Andrew Sutherland, PhD
Coordinator, Environmental Resource Program, SJRWMD

Fatih Gordu, PE
Chief Water Resource Engineer, SJRWMD

Olkeba Leta, PhD
Engineer Scientist, SJRWMD

From: Jeffrey N. King, PhD PE
Principal Engineer, Applied Technolcgy and Management

Subject: Johns Lake Minimum Flows and Levels Peer Review
Task B4: Final Peer-Review Technical Memorandum

Executive Summary

The St. Johns River Water Management District simulated Johns Lake levels in Orange County and Lake County, Florida, from 1948 to 2018. Simulated Johns Lake levels match measured levels well, during a validation period from 1995 to 2004 and during a calibration period from 2005 to 2018. The simulation informs the district's purpose: to protect Johns Lake from significant harm due to groundwater or surface water withdrawals.

The district may wish to refine the simulation and associated documents, prior to using the simulation to inform determination of a minimum lake level, in satisfaction of State of Florida Water Resource Implementation Rule 62.40.

Specifically, the district may wish to revise the simulation to incorporate additional technical information; calibrate the simulation to measured levels in several lakes near Johns Lake; revise the report that describes the simulation to reference or better reference source information and measurements on which the simulation is based; revise the report to further explain selected findings; and revise the report to explain the district's strategy to determine, quantify, document, and manage minimum lake levels during a period in which global and regional climates are changing.

Introduction

St. Johns River Water Management District (SJRWMD) published the following introduction and background statement in work order 3:

> The SJRWMD's minimum flows and levels (MFL) program, mandated by state water policy, is a district-wide effort to establish MFLs for priority lakes, streams and rivers, wetlands, springs, and groundwater aquifers. MFLs designate the minimum hydrologic conditions that must be maintained in these water resources to prevent significant harm resulting from permitted water withdrawals.

SJRWMD has identified Johns Lake as a priority water body. Johns Lake is located approximately 5 miles southeast of the City of Clermont and approximately 2 miles southwest of the City of Winter Garden on the border of Lake and Orange counties, Florida.

This lake receives water from direct precipitation, surface runoff, and baseflow, and loses water primarily through evaporation and seepage to the Upper Floridan Aquifer.

The purpose of establishing minimum lake levels for Johns Lake is to protect this lake from significant harm due to groundwater or surface water withdrawals. SJRWMD developed a continuous simulation hydrological 2D model of Johns Lake using an interconnected channel and pond routing (ICPR4) model. The model was completed in November of 2021. Review of this ICPR4 model will occur as part of the comprehensive Central Florida Water Initiative peer review process.

This technical memorandum constitutes task B4 of SJRWMD engineering and environmental services contract 32929, work order 3: an independent technical peer review of SJRWMD's numerical simulation of MFLs in Johns Lake, Orange County and Lake County, Florida (fig. 1).

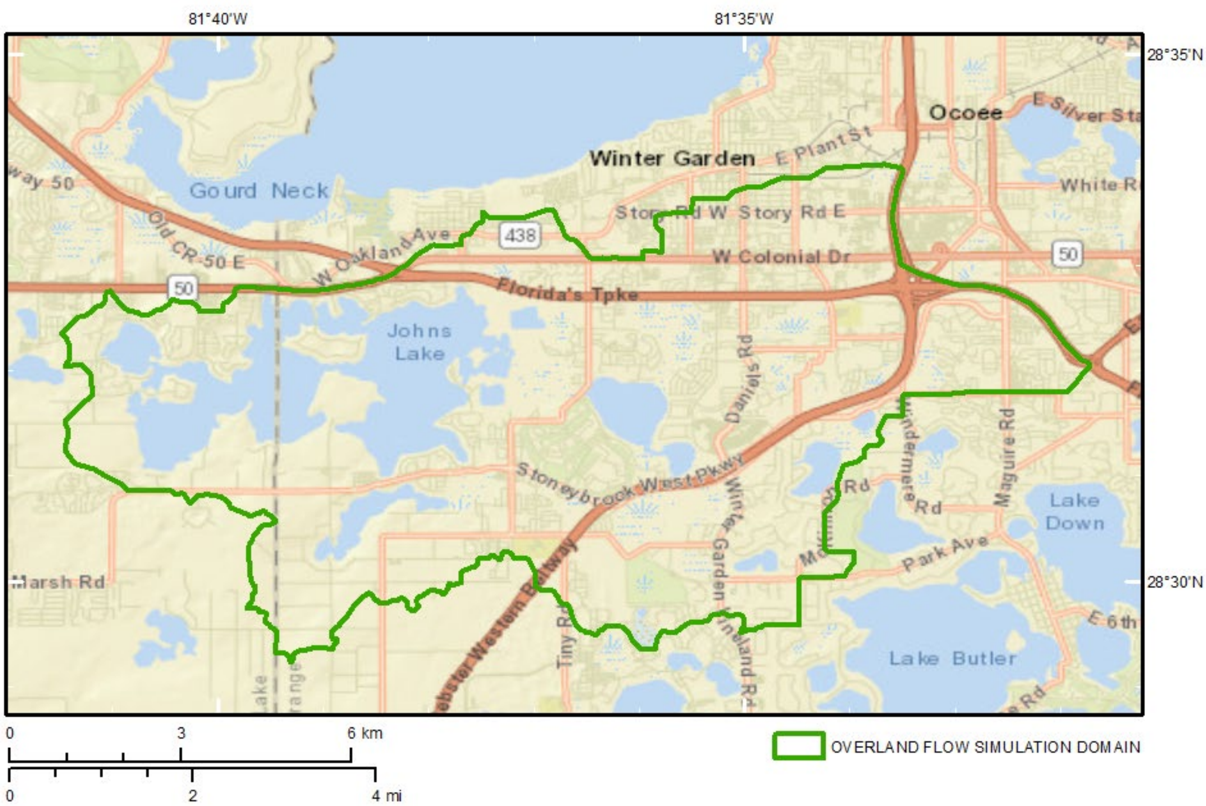

Figure 1. Johns Lake overland flow simulation domain, Orange County and Lake County, Florida.

In January 2022, SJRWMD identified Dr. Jeffrey King, PhD PE, Principle Engineer, Applied Technology & Management (ATM), a Geosyntec Company, as the independent peer reviewer for the Johns Lake ICPR4 long-term simulation of the hydrologic cycle and lake levels (fig. 2).

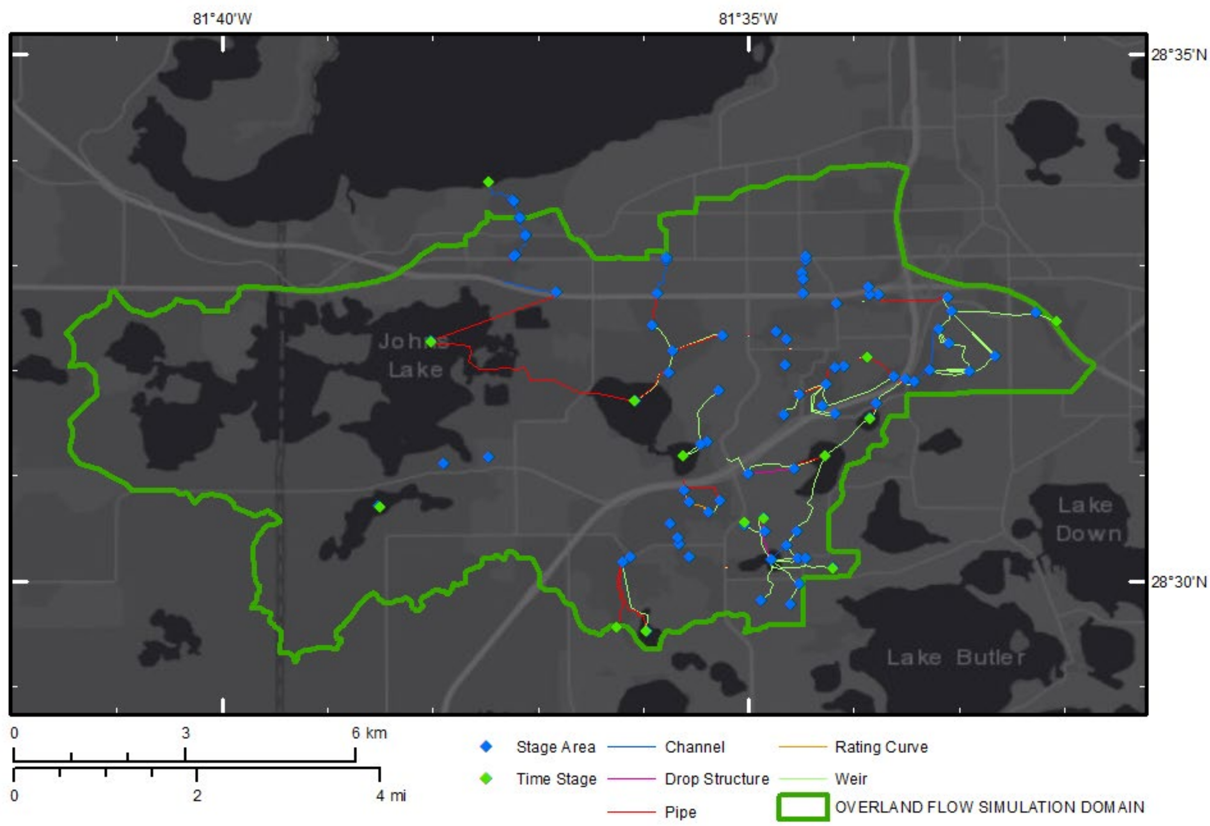

Figure 2. Johns Lake overland flow simulation domain, stage-area nodes, time-stage nodes, channel links, drop structure links, pipe links, rating curve links, and weir links, for simulation of the hydrologic cycle and lake level in Johns Lake from 1948 to 2018.

SJRWMD and Dr. King visited Johns Lake and the Johns Lake overland flow simulation domain on March 3, 2022, as task A of work order 3 (appendix). The district invited the general public and stakeholders to attend the visit. The district and Dr. King were accompanied by one interested party. Dr. King described task A in a March 9 memorandum.

SJRWMD conducted a public teleconference on April 6, 2022, as task B1 of work order 3. Prior to this teleconference, Dr. King conducted an initial, cursory review of the ICPR4 simulation and supporting documents. During this initial teleconference, Dr. King presented initial comments related to his cursory review. The general public and stakeholders presented technical information, asked questions, and shared concerns in the April 6 teleconference. Dr. King described the task B1 teleconference in an April 18 memorandum.

Subsequent to the April 6 teleconference, Dr. King substantially completed an independent technical peer review. Dr. King described the review in a task B2, draft technical memorandum, dated April 27, 2022.

SJRWMD and Dr. King presented the independent draft, technical peer-review memorandum to the general public and stakeholders in a public teleconference on May 12, 2022, as task B3 of work order 3. Dr. King described the task B3 teleconference in a May 19 memorandum.

Subsequent to the task B3 public teleconference, Dr. King revised and refined the task B2 draft technical memorandum. Dr. King publishes the present final technical memorandum as task B4 of work order 3. Publication of this final technical memorandum constitutes the conclusion of this independent technical peer review—under work order 3—of SJRWMD's numerical simulation of MFLs in Johns Lake, in Orange County and Lake County, Florida.

State of Florida promulgates in Water Resource Implementation Rule 62.40.473 that in determining an MFL, "consideration shall be given to natural seasonal fluctuations in water flows or levels, non-consumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology, including" the following ten water-resource values:

(a) Recreation in and on the water

(b) Fish and wildlife habitats and the passage of fish

(c) Estuarine resources

(d) Transfer of detrital material

(e) Maintenance of freshwater storage and supply

(f) Aesthetic and scenic attributes

(g) Filtration and absorption of nutrients and other pollutants

(h) Sediment loads

(i) Water quality

(j) Navigation

SJRWMD's consideration of these values to determine an MFL for Johns Lake will be informed by SJRWMD's numerical simulation of Johns Lake levels.

Task B4 Scope

The following scope governs task B4:

> B.4 Final Peer Review Technical Memorandum (TM): Consultant shall prepare a final TM that summarizes their findings and recommendations regarding the Johns Lake ICPR4 model and report and submit to the District's Project Manager.

This technical memorandum is structured to describe data and simulation elements, as stipulated in work order 3. Each review element is subdivided into review items. I enumerate comments across review items, such that each comment in this peer review has a unique number.

Data

This data element of the independent technical peer review addresses the following review items: (A) whether SJRWMD used best-available information to develop, calibrate, and verify the simulation; (B) whether necessary information was not available to SJRWMD to develop, calibrate, and verify the simulation; (C) whether SJRWMD discarded relevant information without appropriate justification; and (D) whether discarded information will change results.

A. Best-Available Information

In general, SJRWMD used best available information to develop the numerical simulation; however, SJRWMD may wish to revise the simulation to use additional relevant data, and the report that describes the simulation to better document the simulation. Specifically:

1. SJRWMD used best available lake level measurements in Johns Lake and Lake Avalon to calibrate and verify the simulation; however, SJRWMD possesses additional lake level measurements that, if used for calibration or verification, may improve predictions of future lake levels forced by Floridan aquifer system pumping scenarios and forced by global or regional climate change. SJRWMD may wish to revise the simulation to use additional lake level measurements for calibration or verification.

2. SJRWMD built the numerical simulation from geospatial data, hydro-meteorological data, and a U.S. Environmental Protection Agency Stormwater Management Model (SWMM) by Collective Water Resources (2019). SJRWMD worked with Streamline Technologies (2021) to refine the Collective simulation. SJRWMD broadly adopted the Streamline refinement of the Collective simulation. SJRWMD may wish to document the primary source of information used to populate structural dimensions and elevations in the Collective simulation. For example, if Collective relied on a specific survey of structural elevations to populate SWMM, SJRWMD may wish to review the primary survey documents and explicitly reference these documents in the report that describes the SJRWMD ICPR4 simulation.

3. In February 2021, Orange County Stormwater Management Division published a study by CDM Smith of the Johns Lake outfall and a conceptual design for the outfall. The study included new data, a permit review, new survey, and an ICPR4 simulation of extreme flood events. CDM (2021) assessed flood hazards by simulating the Johns Lake hydrologic system, forced by specific episodic events, such as a precipitation event with a one-percent chance of being exceeded in any given year (the so-called 100-year storm). The study also updates and references several previous studies and simulations of Johns Lake. SJRWMD may wish to itemize water-control structures, such as culverts, that exist in the CDM simulation, the Collective Water Resources (2019) simulation, and the SJRWMD ICPR4 simulation. SJRWMD may wish to include structural dimensions and elevations in this itemization, to ensure that SJRWMD details all relevant structures and that control elevations and dimensions in the SJRWMD simulation conform to elevations from other simulations. Where differences exist between control elevations and dimensions in the SJRWMD simulation and other simulations, SJRWMD may wish to document and justify these differences.

4. Streamline Technologies (2021) refined a preliminary SJRWMD ICPR4 simulation to generalize several water-control structures, for use in continuous simulation of the hydrologic cycle in Johns Lake. Itemization of water-control structures in the CDM, Collective, Streamline, and SJRWMD simulations will also appropriately document and relate generalized dimensions and elevations with the relevant structure, in the actual physical system.

5. CDM (2021) included a permit review. SJRWMD may wish to ensure that the simulation details changes to the hydrologic and overland flow system that may have occurred since the Collective Water Resources (2019) simulation. For example, a residential development is presently being constructed near West Orange Trail (appendix photograph 17). New water control structures (photograph 14, photograph 15, and photograph 16) may have been constructed, to drain stormwater from this new development into the Johns Lake overland flow domain. SJRWMD may wish to review CDM (2021) and other documents to ensure that new water control structures are incorporated, as appropriate, into the SJRWMD ICPR4 simulation. If new water control structures do not appreciably affect Johns Lake levels, SJRWMD may wish to justify this in a report that describes the simulation.

B. Information Deficiencies

6. SJRWMD used available bathymetric lake-bed elevations for Johns Lake and Lake Avalon. SJRWMD did not use bathymetric lake-bed elevations for other lakes, perhaps because these elevations are not available.

   SJRWMD used bathymetric elevations of the Johns Lake bed to best represent the relationship between level and volume in Johns Lake. The major objective of this ICPR4 simulation is to quantify the elevation of a minimum lake level in Johns Lake, necessary to satisfy rule 62.40. Accurate lake-bed elevations in Johns Lake are necessary to best simulate the role of hydrologic, hydrogeologic, and atmospheric forcing on lake level. SJRWMD's use of bathymetric elevations for the Johns Lake bed is critical to this simulation of a minimum Johns Lake levels. This understanding of the change in lake volume as a function of lake level is critical, particularly at relatively low lake levels above, near, and below a proposed minimum lake level.

   SJRWMD used bathymetric elevations of the Lake Avalon bed to best represent the stage-volume relationship in Lake Avalon. Although the major objective of this ICPR4 simulation is to quantify a minimum Johns Lake level, necessary to satisfy rule 62.40, the importance of benthic discharge flux to Johns Lake and benthic recharge flux from Johns Lake on lake level requires accurate representation of the hydraulic gradient from Johns Lake to the surficial aquifer, the Floridan aquifer system, and to adjacent lakes. Accurate lake-bed elevation in Lake Avalon is necessary to best simulate the role of hydrologic, hydrogeologic, and atmospheric forcing on lake level in Lake Avalon, and the role of Lake Avalon level on the hydraulic gradient between Johns Lake and Lake Avalon. SJRWMD's use of bathymetric elevations of the Lake Avalon bed is critical to this simulation of a minimum Johns Lake level. This understanding of the change in Lake Avalon volume as a function of lake level is also critical.

   SJRWMD did not use bathymetric elevations for Beulah Lake, Black Lake, Luntz Lake, Roberts Lake, Tilden Lake, and Yarbo Lake. Although the major objective of this ICPR4 simulation is to quantify a minimum Johns Lake level, necessary to satisfy rule 62.40, the importance of benthic discharge flux to Johns Lake and benthic recharge flux from Johns Lake on lake level requires accurate representation of the hydraulic gradient from Johns Lake to these other lakes. Lake level in Lake Luntz (fig. 8), Lake Roberts (fig. 9), and Lake Tilden (fig. 10) is not simulated below a minimum elevation for each lake, which is greater than measured lake levels on these lakes. This failure to simulate minimum levels in these lakes is likely due to an absence of stage-volume information below a lake level in the digital elevation model.

SJRWMD may wish to revise the simulation to incorporate lake-bed elevations for other lakes. SJRWMD may choose to measure lake-bed elevation; or SJRWMD may make reasonable assumptions about lake-bed elevations from an assumed maximum lake depth and an assumed lake bed geometry, and to document these reasonable assumptions in the report that describes the simulation. Simulations are abstract representations of more complex systems. Although crude, some hydrologists will accept an assumed maximum lake depth and assumed lake bed geometry as an acceptable, abstract representation.

7. John Schmidt, President, Johns Lake Association, asked in the April 6 teleconference whether SJRWMD simulated the water control structure near West Colonial Drive (photograph 7, photograph 8, photograph 9), and the influence of this water-control structure on flow from the Johns Lake watershed to Lake Apopka. Leta and others (2021) state that "larger discrepancy between the long-term observed and simulated stages is noticed before 1993, a period when significant urbanization had not occurred or considered as a pre-development period. The decrease in model performance during this period could be due to additional uncertainties attributed by … significant land use/land cover developments of the watershed." SJRWMD simulated contemporary land use. SJRWMD also simulated structure elevations and structure geometry for a water control structure near West Colonial Drive (photograph 7, photograph 8, photograph 9), which controls the flow of water from Johns Lake to Lake Apopka; and channel roughness near this water control structure (photograph 8, photograph 12, and photograph 19).

   SJRWMD may choose to revise the simulation to incorporate transient land use based on available historical aerial photographs. The University of Florida manages an archive of aerial photographs that detail Johns Lake and surrounding areas, with photographic mosaics from 1941, 1947, 1954, 1958, and 1974. SJRWMD maintain GIS shapefiles for land use in 1973, 1984, 1990, 1994, 1999, 2004, 2009, and 2014.

   To improve the match between measured and simulated lake level by simulating transient hydraulic conditions, SJRWMD may also choose to perform additional research into changes in elevations and geometry for the West Colonial Drive water control structure, changes in channel roughness, and changes in water control structure operation.

8. Assumptions: A simulation is an abstract representation of a more complex system. Simulations typically require assumptions that result in tractable solutions, but introduce abstractions. To simulate Johns Lake levels, SJRWMD made several assumptions. For example, SJRWMD assumed piecewise homogeneity in a groundwater simulation that defines the Floridan aquifer system boundary condition. Leta and others (2021) did not systematically identify or justify assumptions. Because assumptions are not systematically identified and justified, reviewers of this simulation and the supporting document are challenged to

methodically consider each assumption. SJRWMD may wish to revise the document that describes the simulation to systematically identify each assumption, and to explicitly justify each assumption.

9. John Schmidt, President, Johns Lake Association, asked in the April 6 teleconference whether SJRWMD considered changes in benthic sediments in Johns Lake and Lake Avalon. Leta and others (2021) stated that "the relationship between [Johns Lake] and [groundwater] stages might have changed over time." Leta and others (2021) also stated that "sediment and nutrients loadings to the lake might have increased and caused [bed] compaction during the post-development period. This could have altered the leakance value of the lake between the pre- and post-development conditions. Since we assumed constant leakance value, which we derived based on the post-development conditions, it is possible that the pre-development leakance value would be higher than the calibrated leakance value." Leta and others (2021) evaluated a relatively greater leakance for the pre-development period prior to about 1993. Specifically, Leta and others (2021) stated "we further increased the calibrated leakance value of Johns Lake by 50%, a value proposed by [Streamline Technologies] (2021), and evaluated its effects on simulated stages of Johns [Lake]. We found that the effect of increased leakance values on pre-development simulated stages is relatively low as compared to the effects of [land use and land cover] change and adjusted groundwater stages." Leta and others (2021) acknowledge transience in land use and leakance, between the period before about 1993 and the period after 1993. If SJRWMD choose to simulate the physical system that existed prior to 1993, SJRWMD may wish to simulate transient leakance and transient land use (as suggested in comment 7). Note that this recommendation and the recommendation in comment 26 are mutually exclusive, such that SJRWMD may choose to follow either this recommendation or the recommendation in comment 26, recognizing that it will not be possible to conform to both recommendations.

C. Discarded Information

10. SJRWMD include measured lake levels in the ICPR4 simulation as time-stage nodes for the following lakes (fig. 3): Lake Avalon (fig. 4), Lake Beulah (fig. 5), Black Lake (fig. 6), Johns Lake (fig. 7), Lake Luntz (fig. 8), Lake Roberts (fig. 9), and Lake Tilden (fig. 10). SJRWMD used measured lake levels in Johns Lake for calibration and validation, and described this calibration in the associated report (Leta and others, 2021). SJRWMD also used measured lake levels in Lake Avalon (appendix 2 of Leta and others, 2021). Leta and others (2021) calculate calibration statistics for both Johns Lake and Lake Avalon (Leta and others, 2021 and appendix 2 of Leta and others, 2021). Leta and others (2021) did not describe calibration using measured lake levels for Lake Beulah, Black Lake, Lake Luntz, Lake Roberts, or Lake Tilden. Leta and others (2021) did not calculate calibration statistics for these other lakes. SJRWMD may wish to describe calibration or validation of the simulation to these other measured lake levels, including calculation of calibration statistics. Although calibration and validation of the simulation to these other lake levels may not ultimately result in significant changes to the probability distribution of simulated Johns Lake levels, the only genuine method to prove this may be to calibrate the simulation to measured levels in these other lakes and calculate calibration statistics for these other lakes.

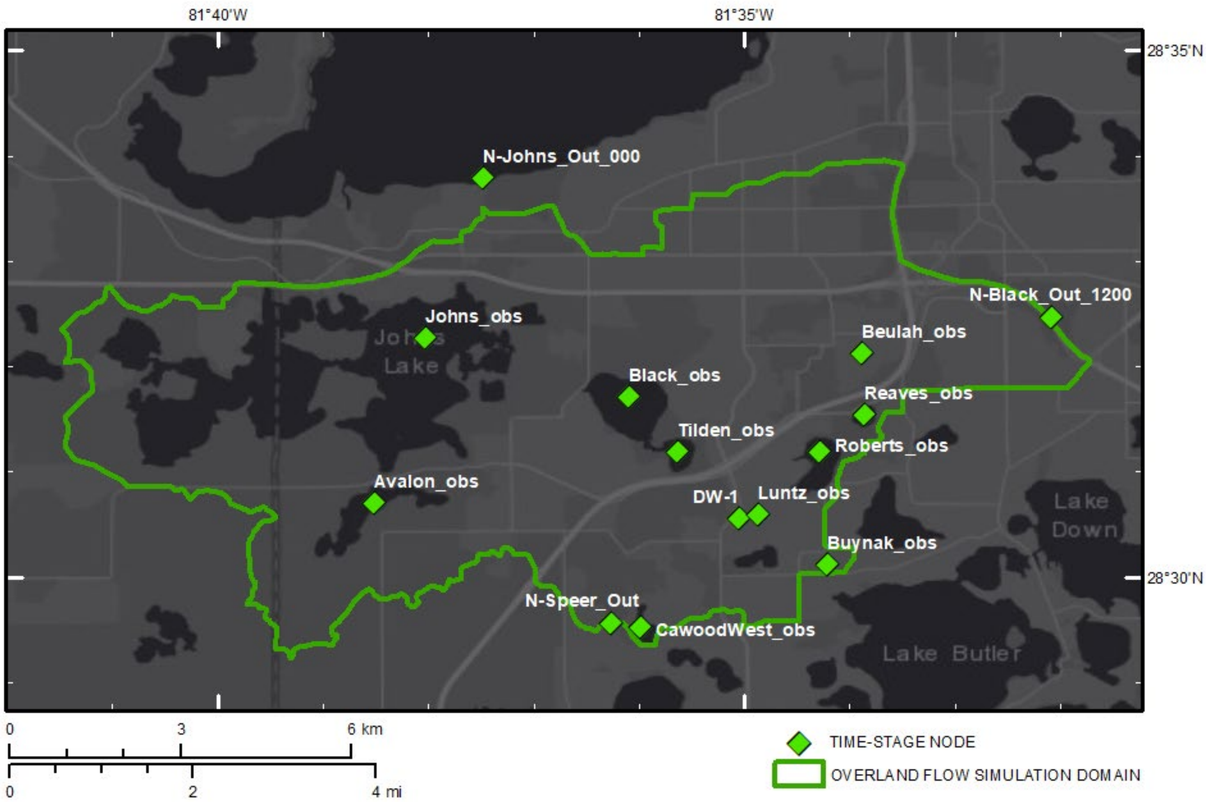

Figure 3. Johns Lake overland flow simulation domain and simulation nodes with measured stage time series.

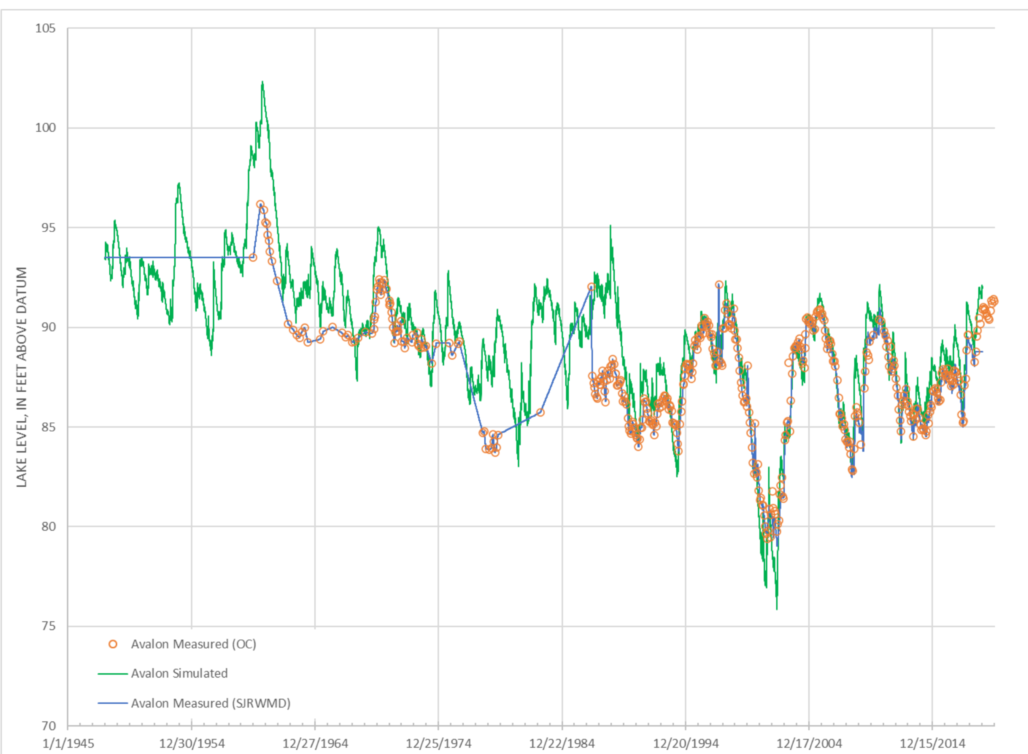

Figure 4. Simulated time series for Lake Avalon level in feet above the model datum; and measured Lake Avalon level in feet above the North American Vertical Datum of 1988, as reported by Liquid Solutions Group for Orange County (OC) Stormwater Management Division; and measured Lake Avalon level in feet above the model datum, as tabulated by the St. Johns River Water Management District (SJRWMD) as a time-stage node in the simulation.

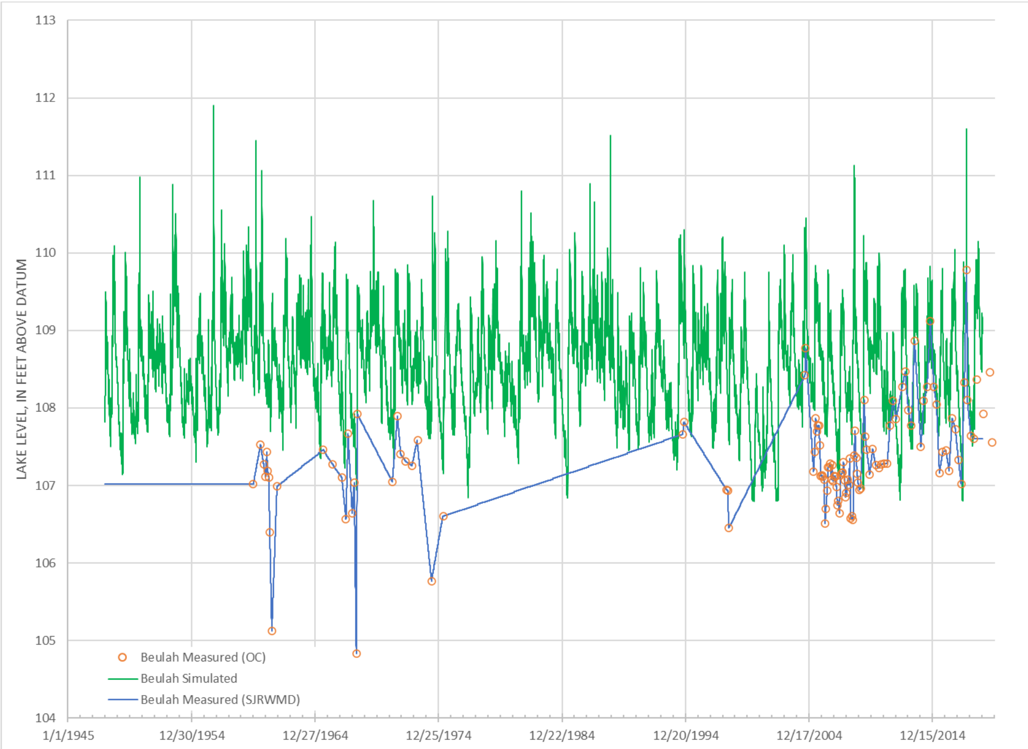

Figure 5. Simulated time series for Lake Beulah level in feet above the model datum; and measured Lake Beulah level in feet above the North American Vertical Datum of 1988, as reported by Liquid Solutions Group for Orange County (OC) Stormwater Management Division; and measured Lake Beulah level in feet above the model datum, as tabulated by the St. Johns River Water Management District (SJRWMD) as a time-stage node in the simulation.

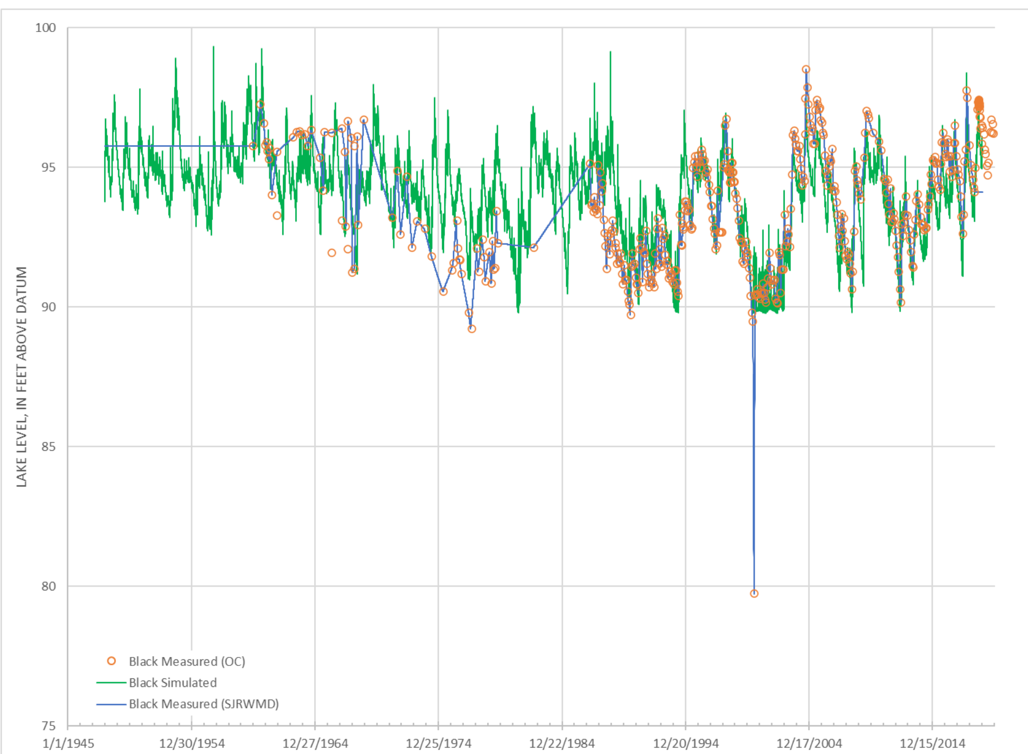

Figure 6. Simulated time series for Black Lake level in feet above the model datum; and measured Black Lake level in feet above the North American Vertical Datum of 1988, as reported by Liquid Solutions Group for Orange County (OC) Stormwater Management Division; and measured Black Lake level in feet above the model datum, as tabulated by the St. Johns River Water Management District (SJRWMD) as a time-stage node in the simulation.

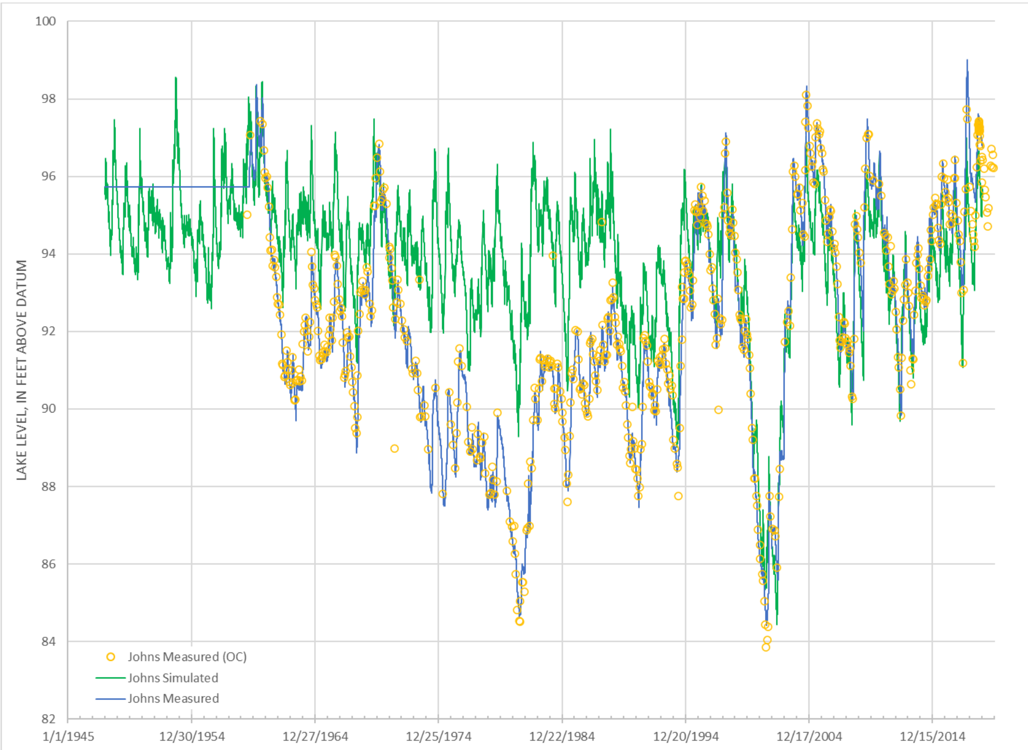

Figure 7. Simulated time series for Johns Lake level in feet above the model datum; and measured Johns Lake level in feet above the North American Vertical Datum of 1988, as reported by Liquid Solutions Group for Orange County (OC) Stormwater Management Division; and measured Johns Lake level in feet above the model datum, as tabulated by the St. Johns River Water Management District (SJRWMD) as a time-stage node in the simulation.

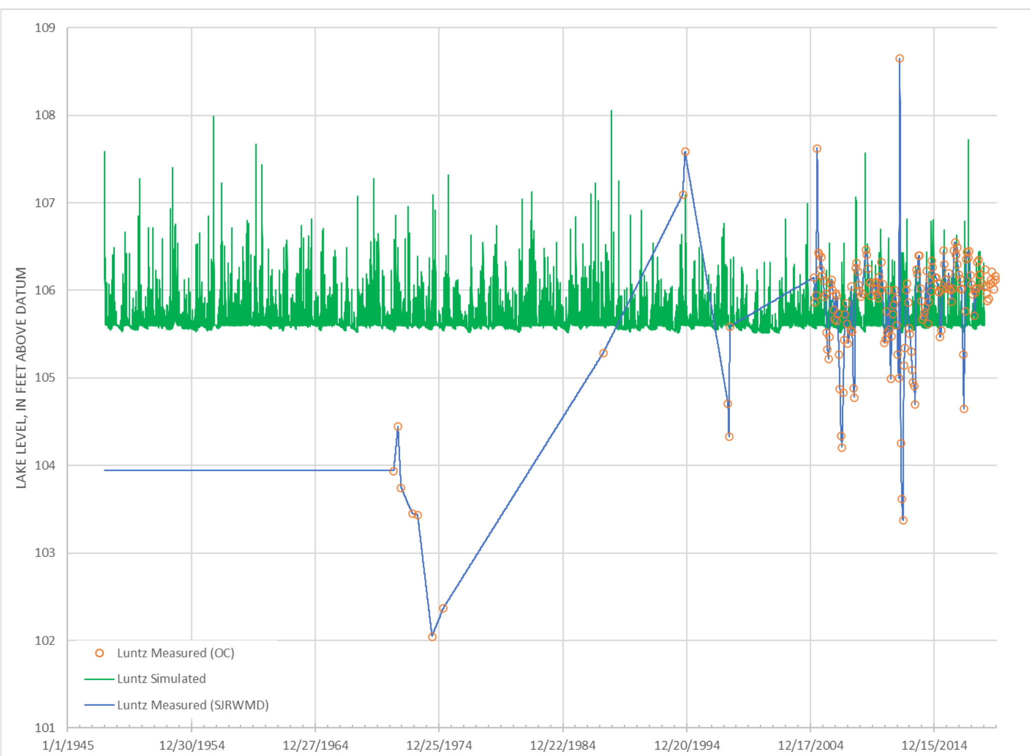

Figure 8. Simulated time series for Lake Luntz level in feet above the model datum; and measured Lake Luntz level in feet above the North American Vertical Datum of 1988, as reported by Liquid Solutions Group for Orange County (OC) Stormwater Management Division; and measured Lake Luntz level in feet above the model datum, as tabulated by the St. Johns River Water Management District (SJRWMD) as a time-stage node in the simulation.

Figure 9. Simulated time series for Lake Roberts level in feet above the model datum; and measured Lake Roberts level in feet above the North American Vertical Datum of 1988, as reported by Liquid Solutions Group for Orange County (OC) Stormwater Management Division; and measured Lake Roberts level in feet above the model datum, as tabulated by the St. Johns River Water Management District (SJRWMD) as a time-stage node in the simulation.

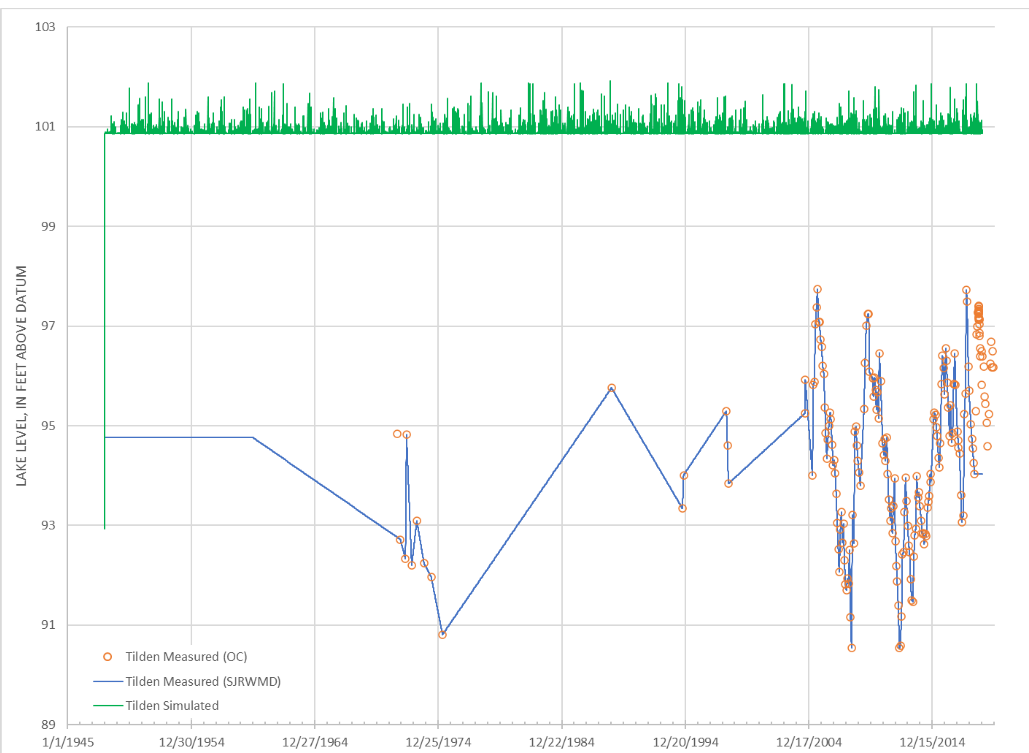

Figure 10. Simulated time series for Lake Tilden level in feet above the model datum; and measured Lake Tilden level in feet above the North American Vertical Datum of 1988, as reported by Liquid Solutions Group for Orange County (OC) Stormwater Management Division; and measured Lake Tilden level in feet above the model datum, as tabulated by the St. Johns River Water Management District (SJRWMD) as a time-stage node in the simulation.

11. SJRWMD included measured lake levels in the ICPR4 simulation as time-stage nodes (plotted on Figure 4 through Figure 10 as blue polylines). Liquid Solutions Group—as consultants to Orange County Stormwater Management Division—provided SJRWMD with measured lake levels following the April 6, 2022, public teleconference (also plotted on Figure 4 through Figure 10, as orange points). SJRWMD time-stage lake levels appear to match Liquid Solutions Group lake levels for all lakes, except Lake Roberts. SJRWMD may wish to determine which set of Lake Roberts levels are correct.

12. When calculating calibration statistics, SJRWMD should include differences between simulated lake level and measured lake level at coincident times. SJRWMD should either not include differences between simulated lake level and interpolated lake level at intermediate times between measured lake levels; or SJRWMD should discuss and explicitly justify use of differences between simulated lake level and interpolated lake level at intermediate times between measured lake levels, in calibration statistics.

D. Effect of Discarded Information on Results

13. Calibration and validation of the simulation to measured lake levels on Lake Avalon, Lake Beulah, Black Lake, Lake Luntz, Lake Roberts, and Lake Tilden (comment 10) will improve the reliability of the simulation. Simulated lake levels do not match measured lake levels on Lake Beulah (fig. 5), Lake Luntz (fig. 8), Lake Roberts (fig. 9), or Lake Tilden (fig. 10). The simulation will be more reliable if simulated lake levels match measured lake levels on these lakes. The simulation will also be a more reliable predictor of the effect of Floridan aquifer system pumping and climate change on lake level if the simulation is capable of matching measured lake levels on these lakes. Although calibration and validation of the simulation to these other lake levels may not ultimately result in significant changes to the probability distribution of simulated Johns Lake levels, the only genuine method to prove this may be to calibrate the simulation to measured levels in these other lakes and calculate calibration statistics for these other lakes.

14. Leakance is the quotient of hydraulic conductivity and hydrogeologic unit thickness. Leakance parameterizes the flow of water between a lake and an underlying hydrogeologic unit or aquifer system. More water flows through a hydrogeologic unit with a relatively greater leakance than through a unit with a relatively lesser leakance, forced by the same hydraulic gradient. Leta and others (2021) assert that Johns Lake level is most sensitive to leakance between Johns Lake and the Floridan aquifer system than other parameters: Leta and others (2021) stated that leakance is the "most important parameter" in the simulation. Leta and others (2021) also assert that Johns Lake level is sensitive to hydraulic conductivity of the surficial aquifer system. Hydraulic conductivity is the ratio of groundwater flow to the hydraulic gradient that forces the flow. The hydraulic gradient between Johns Lake and surrounding lakes forces groundwater flow to or from Johns Lake. Given the sensitivity of Johns Lake level to groundwater flow to and from the lake, SJRWMD may wish to accurately simulate hydraulic gradients to and from Johns Lake (comment 10 and comment 11), which are both a function of Floridan aquifer system potentiometric-surface elevation and lake level in lakes near Johns Lake. SJRWMD may wish to improve the accuracy of hydraulic

gradient simulation by refining the simulation to decrease the difference between simulated and measured lake level in Lake Beulah, Lake Luntz, Lake Roberts, and Lake Tilden. Although calibration and validation of the simulation to these other lake levels may not ultimately result in significant changes to the probability distribution of simulated Johns Lake levels, the only genuine method to prove this may be to calibrate the simulation to measured levels in these other lakes and calculate calibration statistics for these other lakes.

Simulation

This simulation element of the independent technical peer review addresses the validity, defensibility, and appropriateness of the following review items: (E) model development, (F) calibration, and (G) validation.

E. Development

I independently executed each simulation. My execution of these simulations did not result in model warnings, continuity errors, convergence errors, or other errors. Simulated volumes are reasonable. Each simulation ran to completion.

Johns Lake has a transmissive connection to the Floridan aquifer system. Johns Lake may be vulnerable to aquifer pumping. ICPR4 was used to simulate surface-water elevations and flows in the overland flow simulation domain, and water-table elevations and flows in the surficial aquifer system. SJRWMD used Upper Floridan aquifer potentiometric-surface elevations from the East Central Florida transient expanded model (ECFTx) as the bottom boundary condition for ICPR4 simulation of groundwater flow and water-table elevation in the surficial aquifer system. The Johns Lake ICPR4 simulation was not dynamically linked to ECFTx. The ICPR4 simulation used one-dimensional mapped basins in the upland parts of the overland flow simulation domain, and two-dimensional overland flow features in lakes, topographically depressed areas, and wetlands along lake margins. The simulation is based on 2014 land use, revised in 2019; SSURGO soils; and three Upper Floridan aquifer wells. One primary objective of the simulation is to understand the influence of aquifer pumping on lake levels.

15. Datum: Leta and others (2021) reference the North American Vertical Datum of 1988 (NAVD88) eight times. Although all elevations input into the simulation appear to be relative to NAVD88, SJRWMD does not explicitly state a datum reference for all elevation citations. SJRWMD may improve simulation input files and simulation documents by explicitly citing NAVD88 throughout input files and documents; or by explicitly citing a different datum, if relevant.
16. SRWMD may wish to document surveyor, survey dates, publication dates, survey methods, survey owner, resolution, and other relevant metadata for specific, important simulation inputs, including but not limited to the NRCS soils survey, the digital elevation model, bathymetric elevations, and structural dimensions and elevations of water control structures, such as culverts and drop structures.
17. Simulation parameters: SRWMD used ICPR4 weir cross sections to define weir length and weir geometry by extracting weir station and weir elevation from a digital elevation model, along a defined cross section. The following weir cross sections may not extended a sufficient width to fully enclose the water surface: C-Black_800, C-Black_510B, C-Yarbo_020B, C-Clarice_000, and C-Luntz-000C. This list of weirs is not an exhaustive list of all the weirs where this may occur. This list

details a few examples where this may occur. SJRWMD may wish to ensure that all weir cross sections fully enclose the water surface during weir flow. SJRWMD may wish to extend cross sections that do not fully enclose weir flow. This comment relates to weir geometry. I did not determine whether these weirs flow or do not flow, or whether correction of weir length will change simulation results.

A simulation is an abstract representation of a more complex system. Streamline Technologies (2021) abstractly represented some pipes as weirs, to accelerate run time during the continuous simulation of the hydrologic cycle. This is a useful strategy. In the present comment, I refer to traditional, broad-crested weirs, in which water flows over a landform defined by a topographic ridge, where incipient weir flow occurs at the minimum topographic elevation across the ridge. In the present comment, I do not refer the abstract representation of water control structures—such as culverts—as weirs, in which the weir geometry does not conform to a landform defined by a topographic ridge, but conforms to a structural geometry, such as a circular cross-section, through which water begins to flow at some governing, invert elevation.

18. Simulation parameters: SRWMD used ICPR4 weir cross sections to define weir length and weir geometry. Weir elevations along the defined weir alignment may have been automatically sampled from the DEM by ICPR4. If the weir alignment is not along the crest of the weir, but along an offset alignment parallel to the crest, weir elevations and weir geometry may not accurately reflect the crest, and the weir may transmit water at an incorrect, lower elevation. Mis-aligned weir cross sections may exist at the following weir cross sections: C-Black_800, C-Black_1130E, C-Yarboi_020B, C-Black_140B, C-Clarice_000, C-Luntz_000C. This list of weirs is not an exhaustive list of all the weirs where this may occur. This list details a few examples where this may occur. This comment relates to weir geometry. I did not determine whether these weirs transmit flow or whether correction of possible alignment deficiencies will change simulation results; SJRWMD may wish to systematically make this determination with respect to all weir cross sections.

    For example, the western side of weir C-Black_800 may sample a raster cell along the basin boundary that is lower than the physical weir divide. The governing weir section may conform to a ridge that is a few feet southeast of the basin boundary. Mis-aligned weir cross sections that sample lower elevations can result in simulated weir flow when weir flow will not occur in the physical system, because the DEM is not sampled along the true ridge. SJRWMD may wish to re-orient weir cross-section geometry to conform to the ridge, paying attention to relatively small spatial scales that may exist between two pixels, or at a near-pixel scale. Conformance of basin boundary delineation to weir-cross section delineation is not generally necessary, because simulation components that rely on basin boundaries may not be critically sensitive to near-pixel-scale alignment.

    Streamline Technologies (2021) abstractly represented some pipes as weirs, to accelerate run time during the continuous simulation of the hydrologic cycle. In the present comment, I refer to traditional, broad-crested weirs, in which water flows over a landform defined by a topographic ridge, where incipient weir flow occurs at the minimum topographic elevation across the ridge. In the present comment, I do not refer the abstract representation of water control structures—

such as culverts—as weirs, in which the weir geometry does not conform to a landform defined by a topographic ridge, but conforms to a structural geometry, such as a circular cross-section, through which water begins to flow at some governing, invert elevation.

19. Simulation parameters: SJRWMD used a uniform Manning's n friction parameter for channel cross section C-Johns_Out_210. Typically, Manning's n friction parameter is less in the channel than in the overbank. SJRWMD may wish to justify a uniform Manning's n friction parameter for channel cross section C-Johns_Out_210 and for other channel cross sections where friction is simulated as uniform; or simulate channel friction with zones that reflect non-uniform frictional resistance across each channel, based on field measurements and observation.
20. Simulation parameters: SJRWMD used a uniform channel cross section for channels C-Black_920 and C-Black_930, such that the upstream channel cross section is identical to the downstream channel cross section. Inspection of the DEM shows that these channel cross sections may not be uniform, along the channel. SJRWMD may wish to revise channel cross section designations throughout the simulation domain to ensure that channels C-Black_920 and C-Black_930, and other channels that exhibit variation in cross section, along the channel, are not simulated by a uniform cross section, along the channel.
21. Simulation parameters: SJRWMD do not use exit loss or entrance loss coefficients for some channels. SJRWMD may wish to use exit loss and entrance loss coefficients for channels, where appropriate. For example, where a channel discharges into a lake, exit head loss may occur as flow in the channel decelerates into the lake.
22. Simulation parameters: Collective Water Resources (2019) parameterized water as 100% impervious. SJRWMD changed land cover impervious designations for water from 100% impervious to 0% impervious. SJRWMD may wish to explain whether land cover impervious designations should be 100% impervious or 0% impervious, whether land cover imperviousness can be 100% impervious at some locations and 0% impervious at other locations, and to document the consequences of this change.
23. Leta and others (2021) stated that "the ICPR4 model showed reasonable simulations of surface water – groundwater interaction processes and stages of Johns Lake, indicating the model can be used for MFLs modeling and scenarios analysis." Leta and others (2021) did not discuss specific scenarios. Florida's water management districts may wish to simulate future conditions precipitation, evaporation, evapotranspiration, potentiometric-surface elevation in the Floridan aquifer system, and other hydrologic fluxes and processes in the development of MFLs, particularly with respect to changes that are occurring in global and regional climate systems, and the influence of these changes on the development of MFLs.
24. ICPR4 is a closed source model. The source code for ICPR4 is not available for inspection by the general public. The publishers of ICPR4 require that users pay a fee to use ICPR4. Florida's water management districts may wish to consider whether MFLs should be developed with open-source models, to improve transparency and accessibility for the general public.

F. Calibration

25. Leta and others (2021) stated that "larger discrepancy between the long-term observed and simulated stages is noticed before 1993 … The decrease in model performance during this period could be due to additional uncertainties attributed by lack of long-term observed groundwater and rainfall data within the watershed …" Leta and others (2021) explicitly acknowledge that long-term measured groundwater levels and rainfall depths in the overland flow simulation domain are deficient. SJRWMD attempted to mitigate deficient groundwater levels near Johns Lake by correlating a time series for groundwater level near the lake with a longer-duration time series for groundwater level about ten miles east of the lake; and using this correlation to extend the duration of the groundwater time series near Johns Lake. However, Leta and others (2021) also stated that "additional bias was introduced into the extended data before 1993". SJRWMD may wish to identify the Johns Lake system prior to 1993 as sufficiently different than the contemporary Johns Lake system, such that simulated lake levels prior to 1993 are characterized as not informative of a contemporary water resource valuation. SJRWMD may wish to consider characterizing the Johns Lake simulation, from 1993 to 2018, as sufficient to inform contemporary MFL development, and to justify exclusion of simulation prior to 1993 as not informative of contemporary MFL development. This characterization may require additional analysis, investigation, and justification, beyond the argument that I present here.
26. SJRWMD may wish to use the 1993 to 2018 simulation of the contemporary Johns Lake hydrologic and hydrogeologic system, to develop a longer-term simulation of the contemporary system, forced by historic precipitation, evapotranspiration, and potentiometric-surface elevations prior to 1993. This simulation of the contemporary system should be parameterized to reflect the contemporary system. SJRWMD may wish to characterize a longer-term simulation as hypothetical, and to use this hypothetical simulation as a representative long-term, contemporary-system simulation for developing a contemporary MFL. SJRWMD may wish to avoid comparing this hypothetical simulation to measured lake levels prior to 1993, since the simulated hydrologic and hydrogeologic system does not represent the system that may have existed over this longer term, prior to 1993.

Comments 1, 10, and 13 also address calibration.

G. Validation

Comments 1, 10, 13, 25, and 26 address validation, either directly or indirectly.

H. Results

Black Lake is the dominant water-balance inflow; vertical seepage to the Upper Floridan aquifer is the dominant water-balance outflow. Leta and others (2021) assert that leakance is the most sensitive simulation parameter, and that the simulation is relatively less sensitive to horizontal and vertical hydraulic conductivity.

27. Long-term simulation results: Leta and others (2021) compared measured and simulated Johns Lake level from 1948 to 2018. Leta and others (2021) calculated simulation statistics that compare the fit between measured and simulated Johns Lake levels and compare the fit between measured and simulated Lake Avalon

levels. Leta and others (2021) also possessed lake levels for the following lakes:, Lake Beulah, Black Lake, Lake Luntz, Lake Roberts, and Lake Tilden. SJRWMD may wish to compare measured and simulated lake level for these other lakes with plots and calibration statistics.

28. Long-term lake levels: Measured and simulated Johns Lake levels deviate over the 70-year record, such that differences between measured and simulated levels during a contemporary period—from the late 1990s to 2018—are generally less than differences between measured and simulated levels during an historical period—from 1948 to the late 1990s. SJRWMD provide reasonable explanations as to why the contemporary match is better than the historical match, including transient land use, transient leakance, transient channel conditions, changes in the geometry and operation of the control structure near West Colonial Drive, and poor measurements.

    A plot of simulated levels versus annual exceedance probability does not compare well with a plot of measured levels versus annual exceedance probability, over an undisclosed period of record. The slope is positive of a linear regression of measured Johns Lake levels from 1980 to 2018. The slope is zero of both a linear regression of simulated Johns Lake levels from 1980 to 2018 and a linear regression of measured Upper Floridan aquifer potentiometric-surface elevations from 1980 to 2018. Does this failure to match slopes of regressions of simulated and measured lake level, together with the match between the slopes of simulated lake level and measured Floridan aquifer system potentiometric-surface elevation, suggest that the SJRWMD ICPR4 simulation is not sufficient to investigate lake level change forced by groundwater pumping? Will incorporation of additional lake level measurements from lakes in the southeastern part of the Johns Lake overland flow simulation domain improve matches between measured and simulated lake level, and improve the ability of the simulation to predict lake level changes forced by groundwater pumping?

29. Instabilities: The initial condition in the following links results in relatively greater rates of change for flow than during other periods of the flow time series: C_Johns_000C, C-Black_600, C-Reaves_000 (fig. 11B), C-Johns_Out_140, and C-Johns_Out_170A (fig. 11A). SJRWMD may wish to build a hot start initial condition that does not result in relatively greater rates of change for flow than during other periods of the flow time series, for all links in the simulation. Ideally, a time series for flow should change gradually from an initial condition, for all links in the simulation. SJRWMD may wish to avoid abrupt changes in flow immediately after the simulation commences, throughout the simulation.

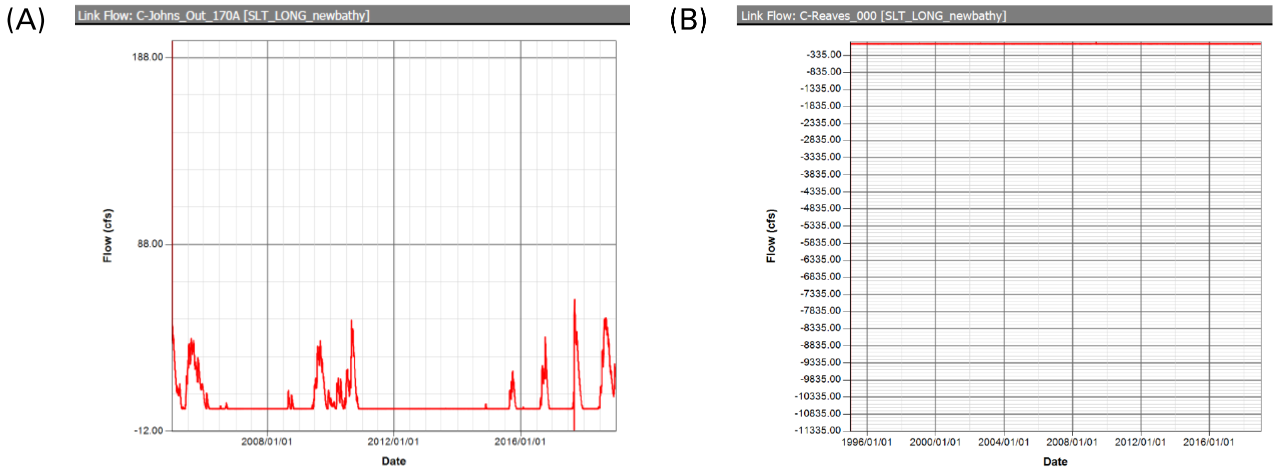

Figure 11. Examples of simulation links with initial conditions that result in relatively greater rates of change for flow than during other periods in the flow time series at (A) link C-Johns_Out_170A and (B) link C_Reaves_000.

30. Instabilities: The initial condition for stage at the following nodes results in a relatively greater rate of water-surface elevation change than during other periods of the stage time series: N-Johns_000_A, N-Tilden_100 (fig. 12). SJRWMD may wish to build a hot start initial condition that does not result in relatively greater rates of water-surface elevation change than during other periods of the flow time series, for all nodes in the simulation. Ideally, the time series for water-surface elevation should change gradually from an initial condition, at all nodes in the simulation. SJRWMD may wish to avoid abrupt changes in water-surface elevation immediately after the simulation commences, throughout the simulation.

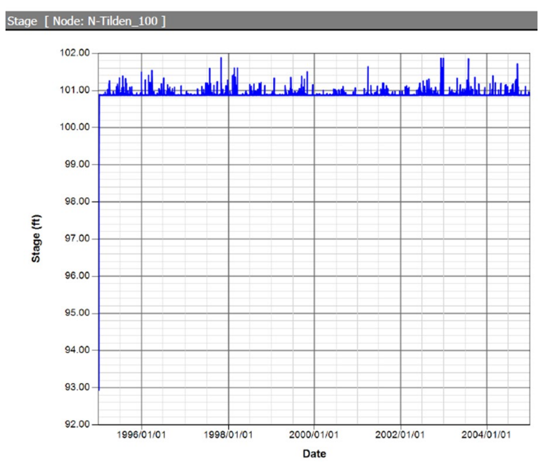

Figure 12. Examples of simulation node (N-Tilden_100) with initial conditions that result in relatively greater rates of water-surface elevation change than during other periods of the flow time series.

31. Instabilities: The following links exhibit relatively greater rates of change for flow than during other periods of flow time series; or possibly oscillation, in which flow rate changes rapidly and repeatedly from positive to negative over a relatively short duration: C_Black_020B_C, C_Black_120C (fig. 13), C_Black_710B, C-Black_600, and C-Black_200. SJRWMD may wish to physically justify these changes in flow or oscillatory behavior, or use simulation strategies, such as damping, to diminish these rates of flow change.

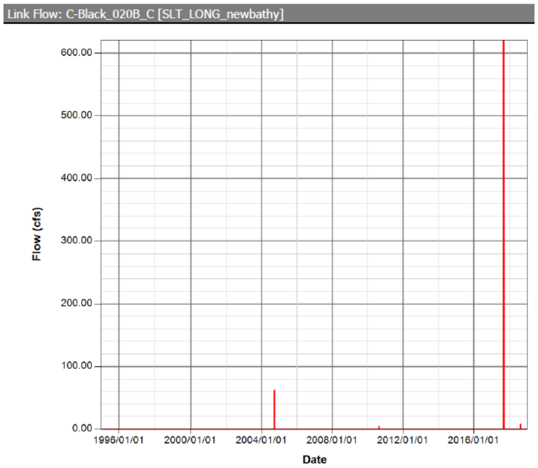

Figure 13. Example of simulation link (C-Black_020B_C) with a relatively greater rate of change for flow in late 2017 than during other periods of flow time series.

32. Assumptions and Sensitivity: SJRWMD parameterized several processes that govern the hydrologic cycle. SJRWMD systematically analyzed the sensitivity of the following five key parameters: initial abstraction, crop coefficient, vertical saturated hydraulic conductivity, horizontal saturated hydraulic conductivity, and leakance. SJRWMD assumed parameters, based on standards of practice, literature, other simulations, and similar applications in Florida. SJRWMD systematically investigated the reasonableness of parameter assumptions by analyzing parameter sensitivity. SJRWMD's sensitivity analyses are generally reasonable. SJRWMD tested sensitivity of selected parameters by increasing or decreasing each parameter with a pre-determined coefficient (table 1). SJRWMD determined that leakance is the most sensitive parameter; however, SJRWMD's determination was not based on a uniform sensitivity change coefficient, for all tested parameters. SJRWMD multiplied leakance by 3, but only increased initial abstraction by 20 percent (equivalent of multiplying initial abstraction by 1.2). Does a sensitivity change coefficient of 3 for leakance perturb the simulation in a manner that is equivalent to a sensitivity change coefficient of 1.2 for initial abstraction? SJRWMD's sensitivity analyses may not be as determinative of relative sensitivity as analyses based on differential representations of the change in an objective function with respect to the change in estimable parameters (Doherty, 2010). SJRWMD may wish to revise the report that describes the simulation to acknowledge limitations in sensitivity analyses and limitations in statements related to relative sensitivity of individual parameters.

Table 1. Sensitivity parameter and sensitivity change coefficient.

Parameter	Sensitivity change coefficient			
Initial abstraction	0.8	0.9	1.1	1.2
Crop coefficient	0.8	0.9	1.1	1.2
Vertical hydraulic conductivity	0.3	0.5	2.0	3.0
Horizontal hydraulic conductivity	0.3	0.5	2.0	3.0
Leakance	0.3	0.5	2.0	3.0

Notes: Decreased by 20% is equivalent to multiplied by 0.8
Decreased by 10% is equivalent to multiplied by 0.9
Increased by 10% is equivalent to multiplied by 1.1
Increased by 20% is equivalent to multiplied by 1.2
Divided by 3 is equivalent to multiplied by 0.3
Divided by 2 is equivalent to multiplied by 0.5

Water Balance

In the simulation, 47% of the water fluxing into the Johns Lake system is from basin inflow, which includes rain; 53% of water into the system is by benthic groundwater discharge flux from the Floridan aquifer system to the Johns Lake system. Benthic groundwater discharge flux is referred to as baseflow in some publications.

In the simulation, 50% of the water fluxing out of the Johns Lake system is to basin outflow, which includes evaporation to the atmosphere, evapotranspiration to the atmosphere, and infiltration to the surficial aquifer; 42% of the water fluxing out of the system is benthic groundwater recharge flux from the Johns Lake system to the Floridan aquifer system; and 8% of the water fluxing out of the Johns Lake system is surface-water flow from the Johns Lake overland flow simulation domain to other watersheds, in which the primary surface-water conveyance out of the Johns Lake overland flow simulation domain is a ditch that drains to Lake Apopka. Benthic groundwater recharge flux is referred to as seepage in some publications.

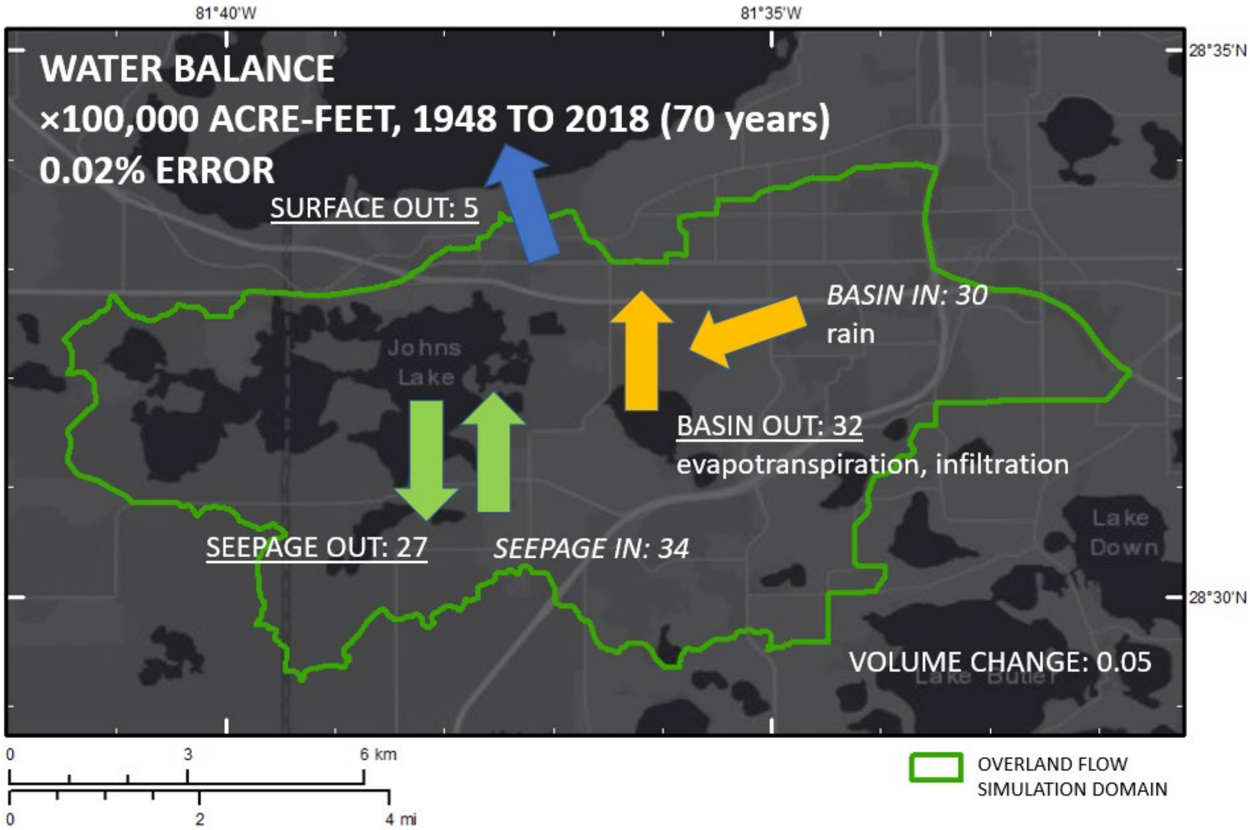

Figure 14. Simulated water balance in acre feet, to or from the Johns Lake overland flow simulation domain, from 1948 to 2018.

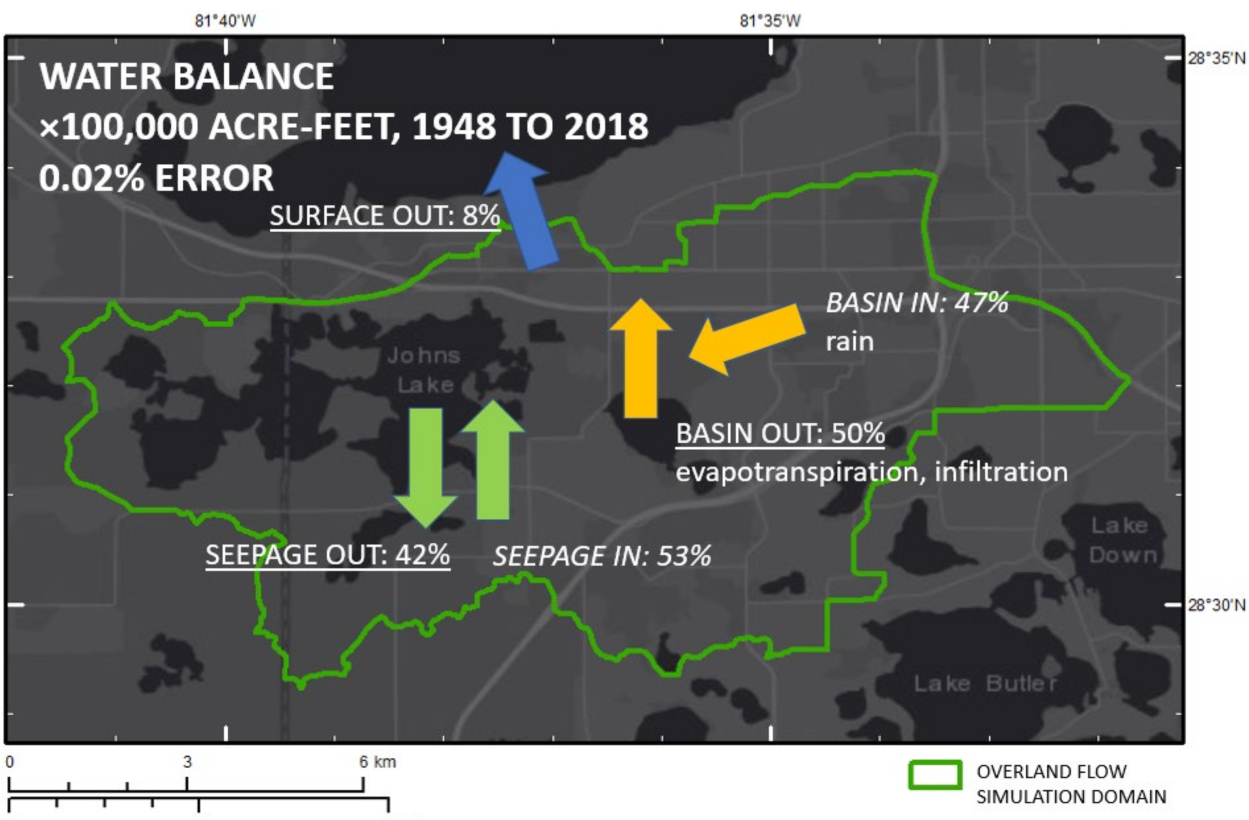

Figure 15. Simulated water balance as a percent of total inflow or total outflow, to or from the Johns Lake overland flow simulation domain, from 1948 to 2018.

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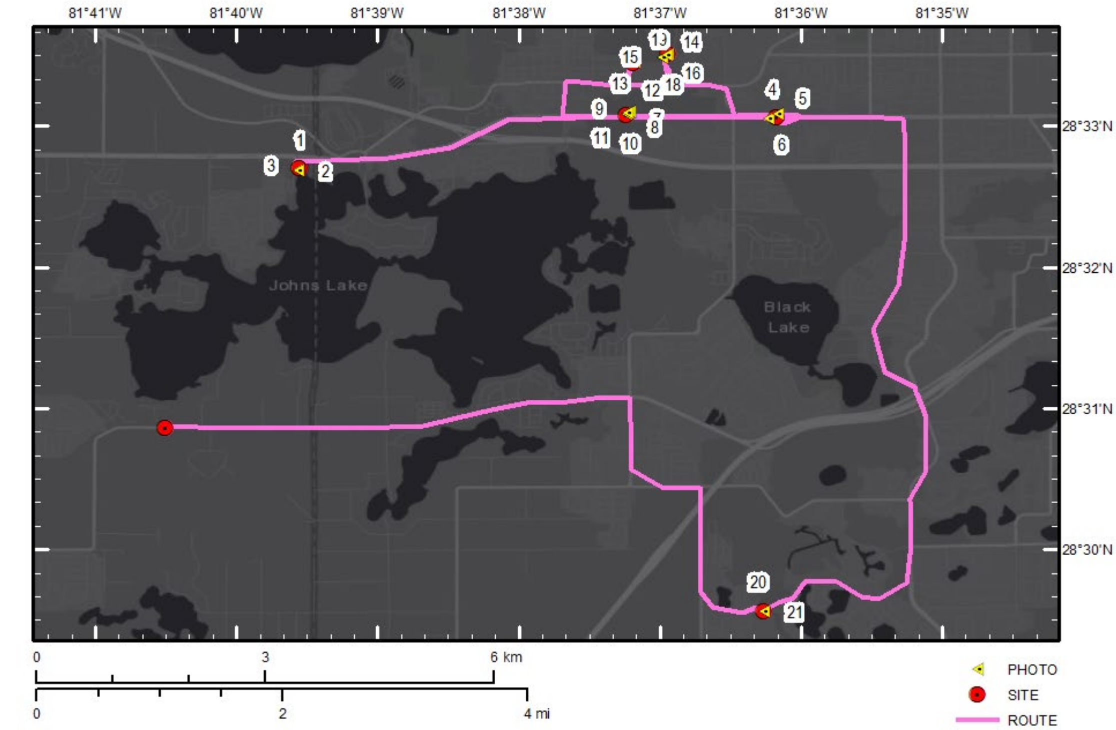
Appendix

(A)



(B)

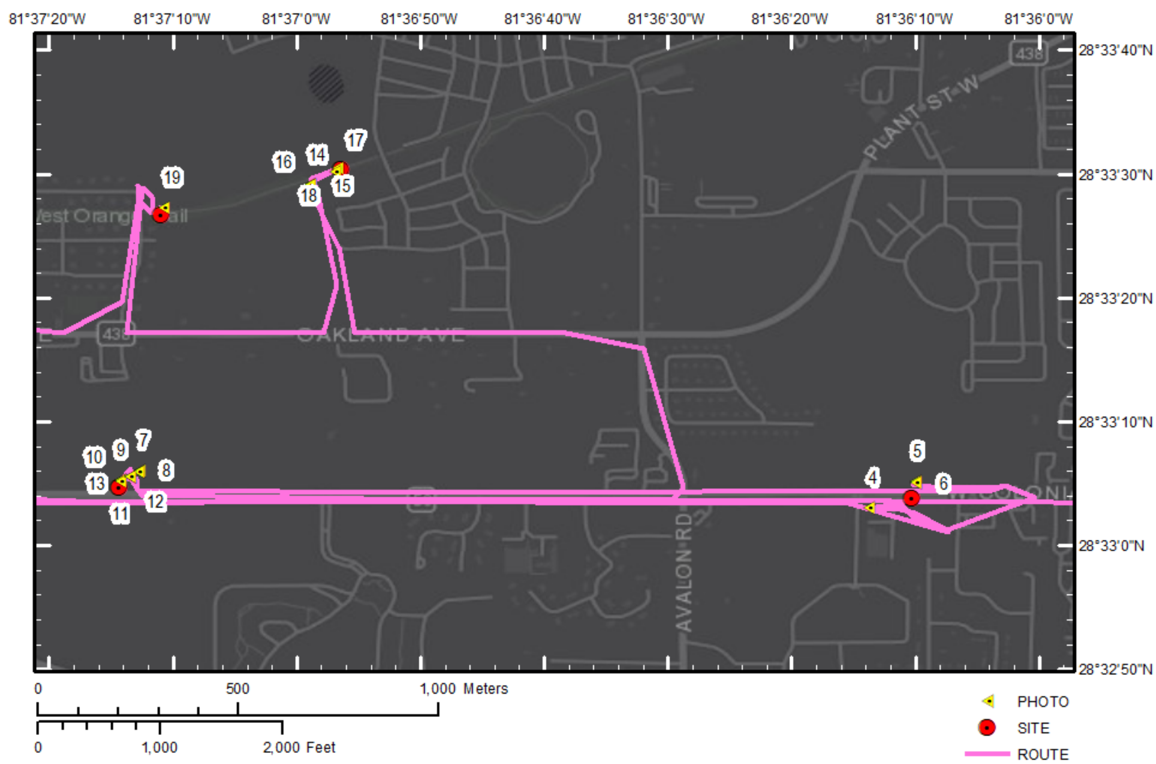
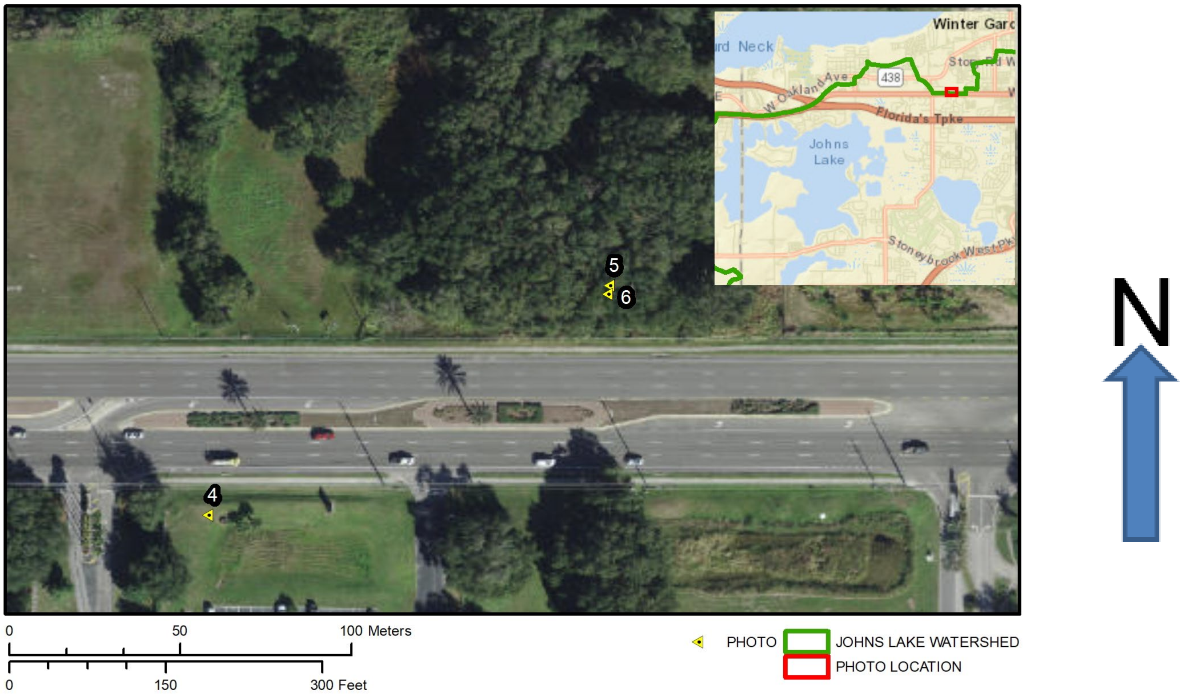


Figure A 1. Site visits, tour route, and associated photograph locations for (A) a March 3, 2022, tour, and (B) a part of the March 3 tour along West Colonial Drive (photographs 4 through 13) and along the West Orange Trail (photographs 14 through 19).

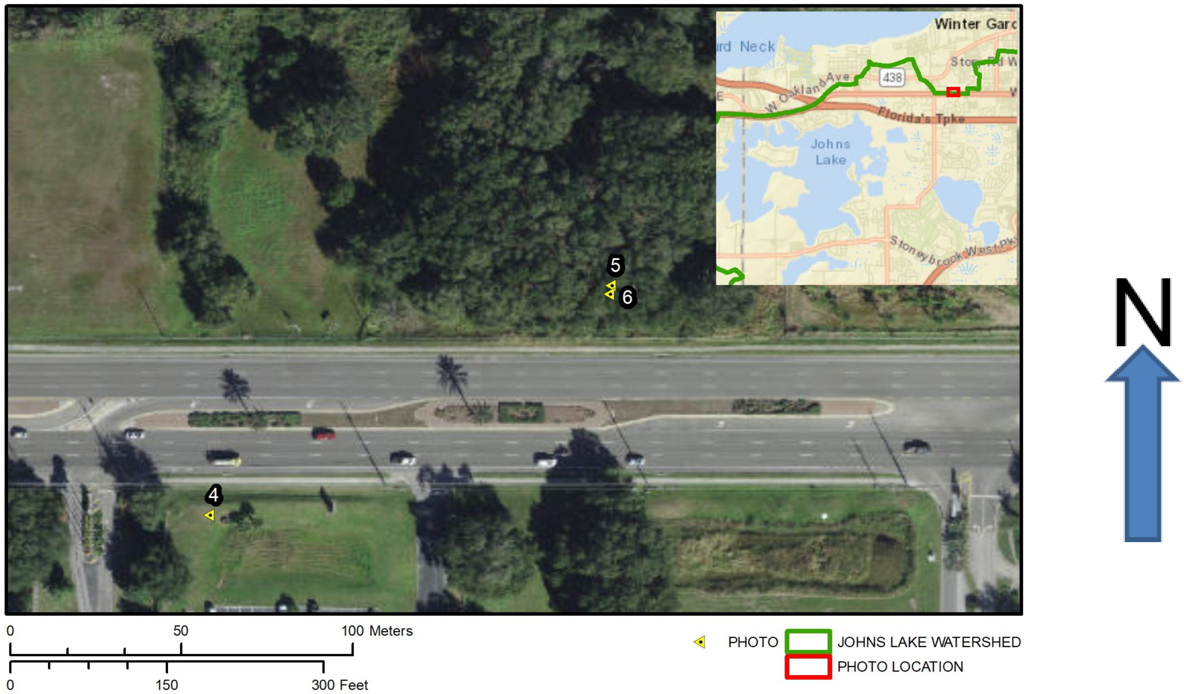
Photograph 1. Johns Lake at the Johns Lake boat ramp from 28° 32′ 41.3″ N 81° 39′ 33.8″ W, looking south on March 3, 2022.

Photograph 2. Johns Lake at the Johns Lake boat ramp from 28° 32' 41.1" N 81° 39' 33.7" W, looking southeast on March 3, 2022.

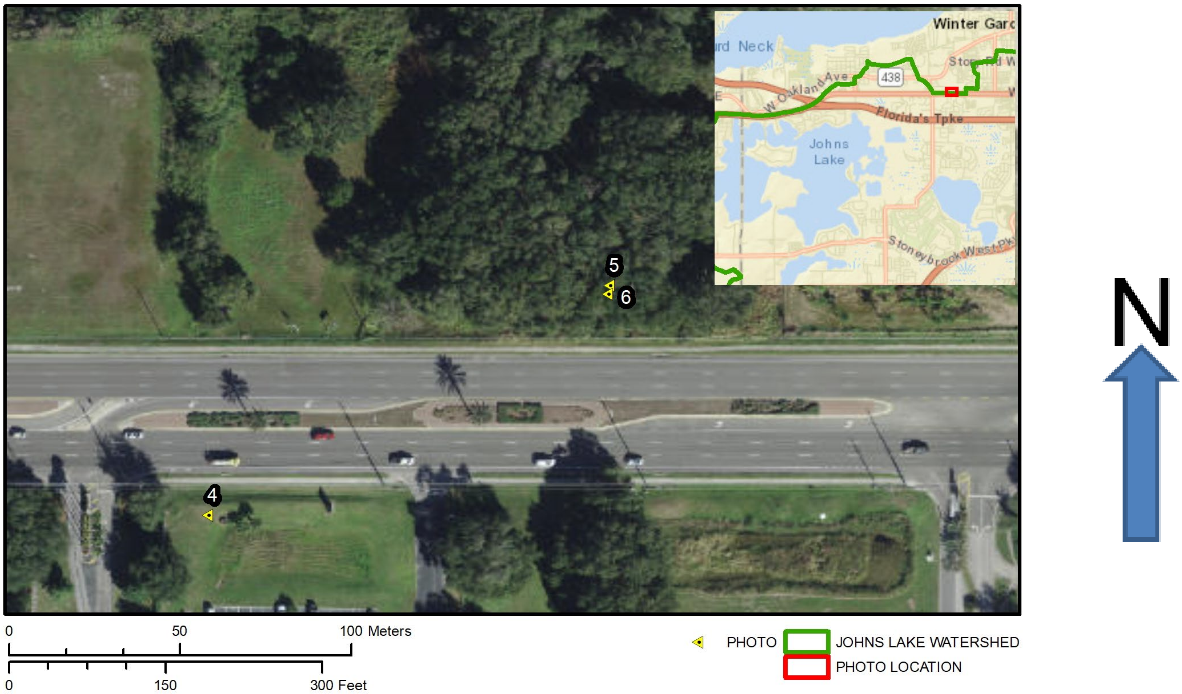
Photograph 3. Johns Lake at the Johns Lake boat ramp from 28° 32′ 41.0″ N 81° 39′ 33.5″ W, looking east on March 3, 2022.



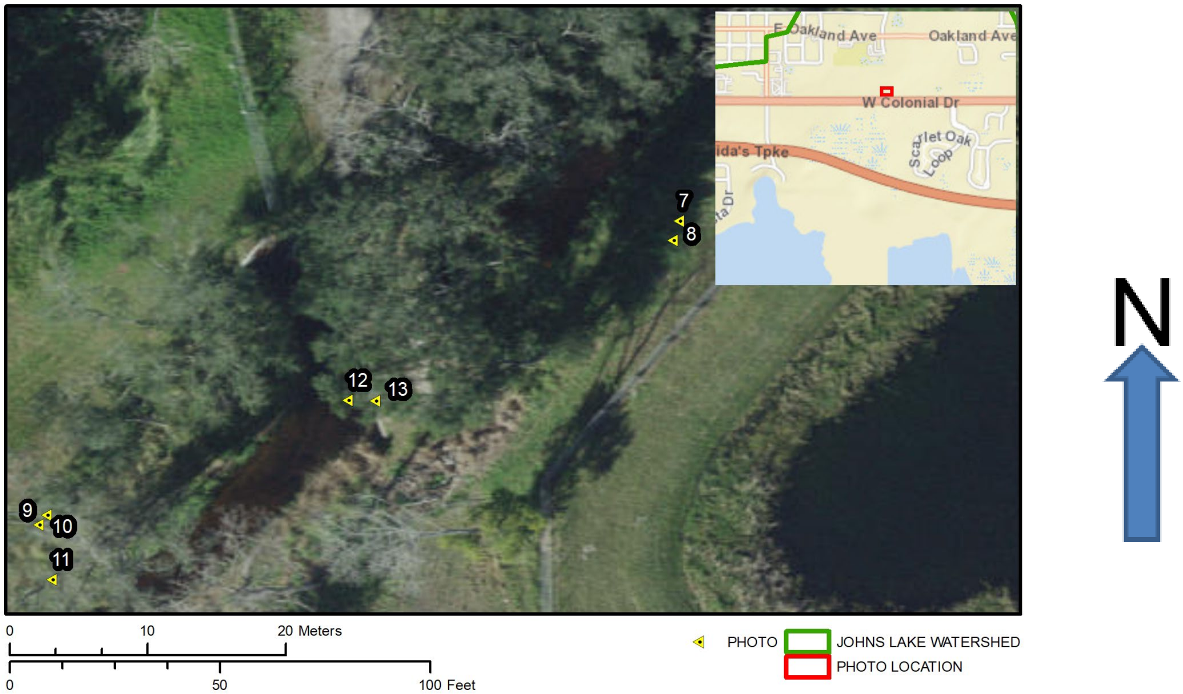
Photograph 4. A drop structure in dry detention pond from 28° 33′ 2.9″ N 81° 36′ 13.8″ W, looking east along West Colonial Drive on March 3, 2022.



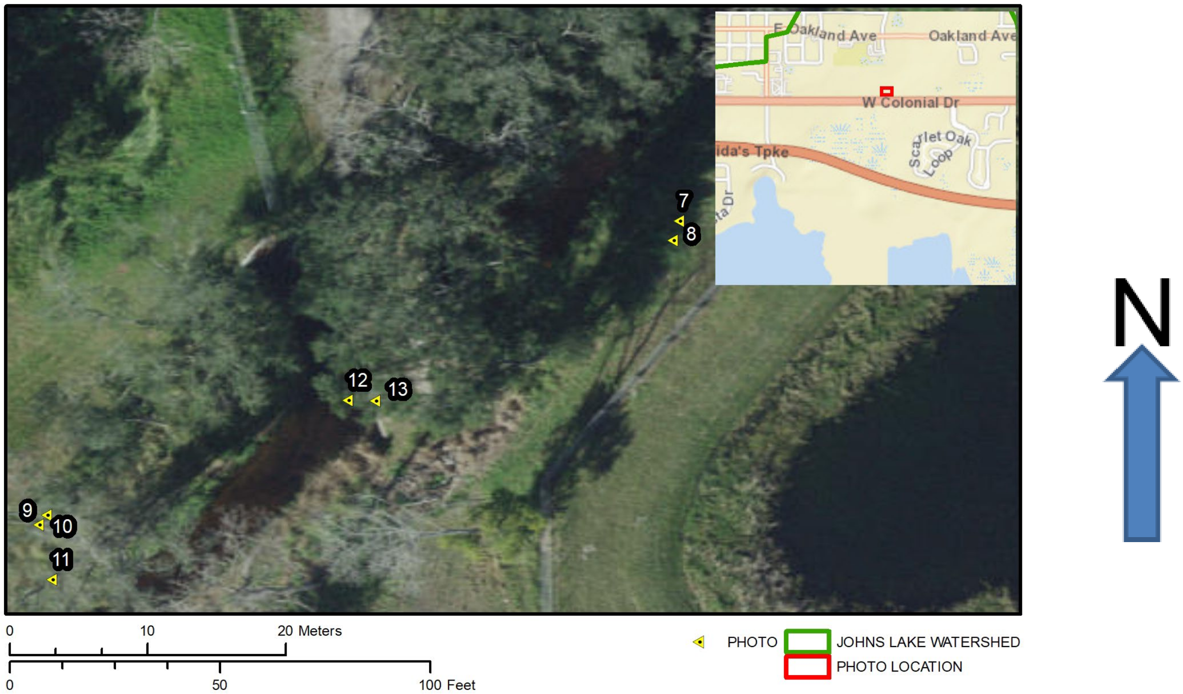
Photograph 5. A ditch north of West Colonial Drive on the sidewalk at the terminus of the ditch, from 28° 33′ 5.1″ N 81° 36′ 10.0″ W, looking north, away from West Colonial Drive on March 3, 2022.



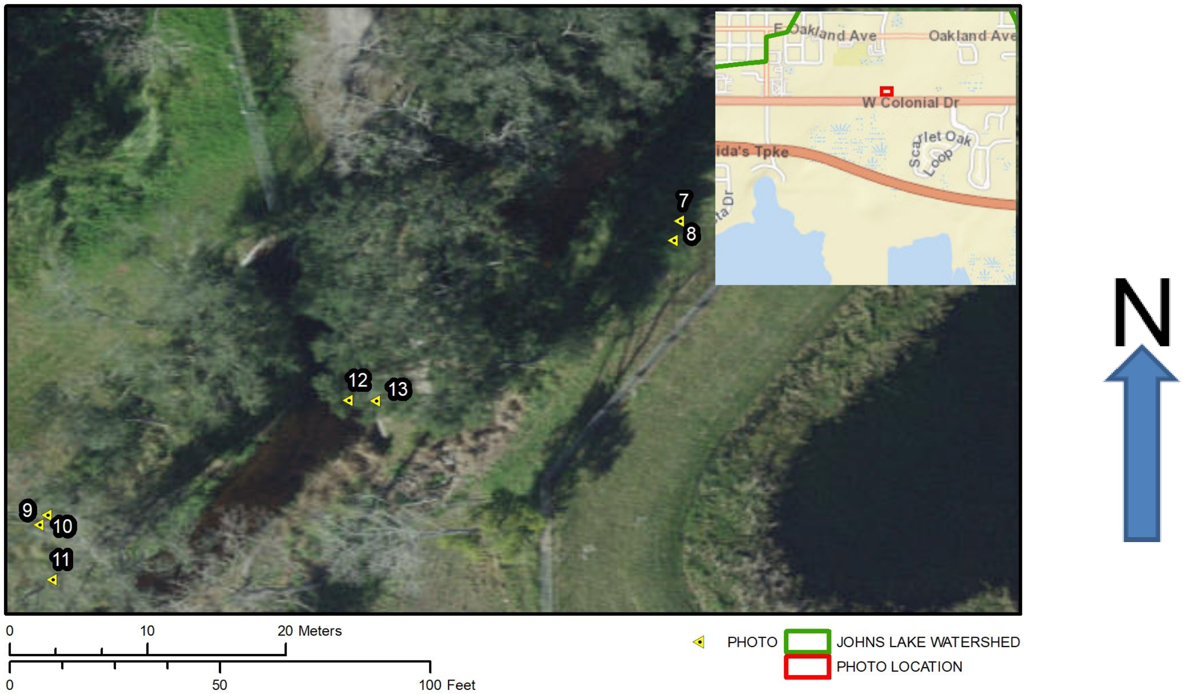
Photograph 6. A ditch terminus at West Colonial Drive, on the eastern bank of the ditch from 28° 33′ 5.0″ N 81° 36′ 10.0″ W, looking south toward West Colonial Drive on March 3, 2022.



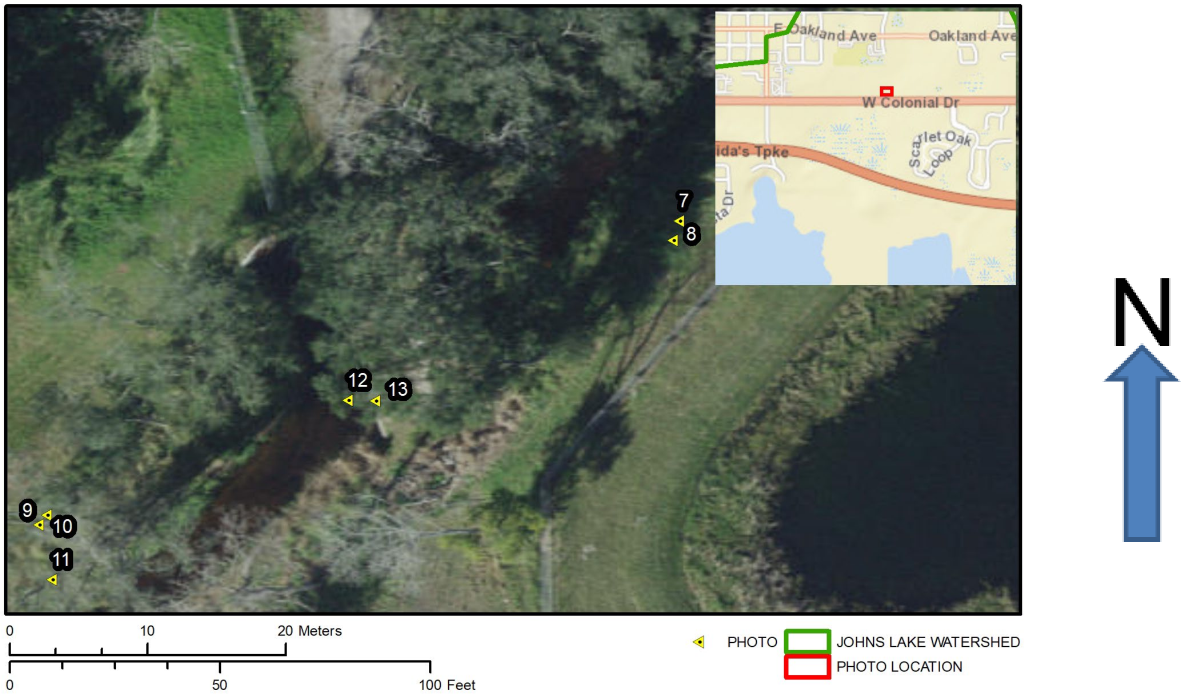
Photograph 7. The downstream side of a water control structure that once regulated the flow of water from the Johns Lake watershed to a ditch that drains to Lake Apopka, on the southeastern bank from 28° 33′ 5.9″ N 81° 37′ 12.8″ W, looking southwest toward West Colonial Drive on March 3, 2022.



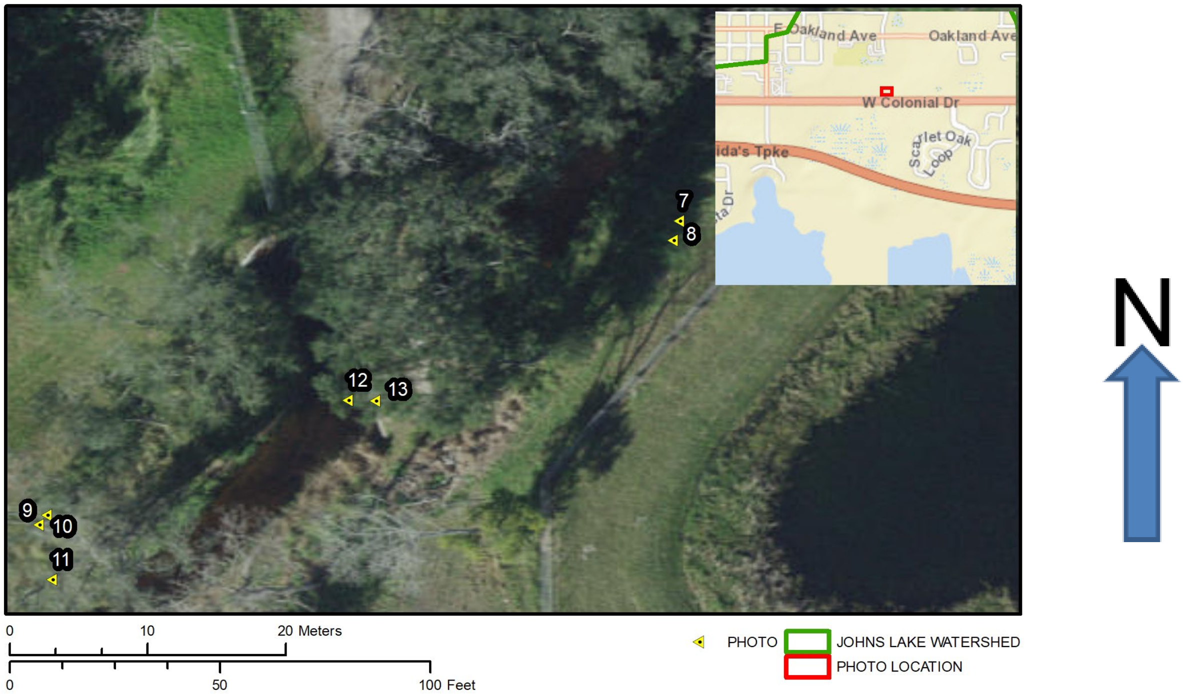
Photograph 8. The ditch downstream of a water control structure (photograph 7), on the southeastern bank from 28° 33′ 5.9″ N 81° 37′ 12.8″ W, looking northeast toward Lake Apopka on March 3, 2022.



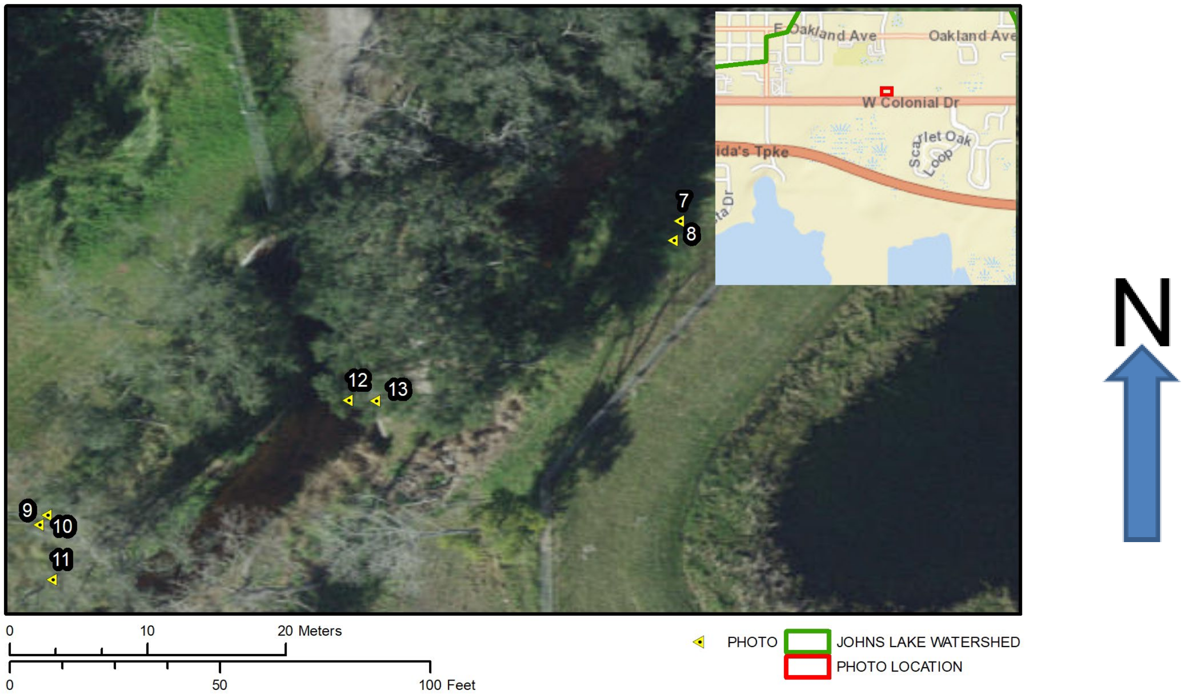
Photograph 9. The upstream side of a water control structure (photograph 7) from 28° 33′ 5.3″ N 81° 37′ 14.3″ W, looking northeast, away from West Colonial Drive and toward Lake Apopka on March 3, 2022. The water control structure once regulated the flow of water from the Johns Lake watershed to a ditch that drains to Lake Apopka.



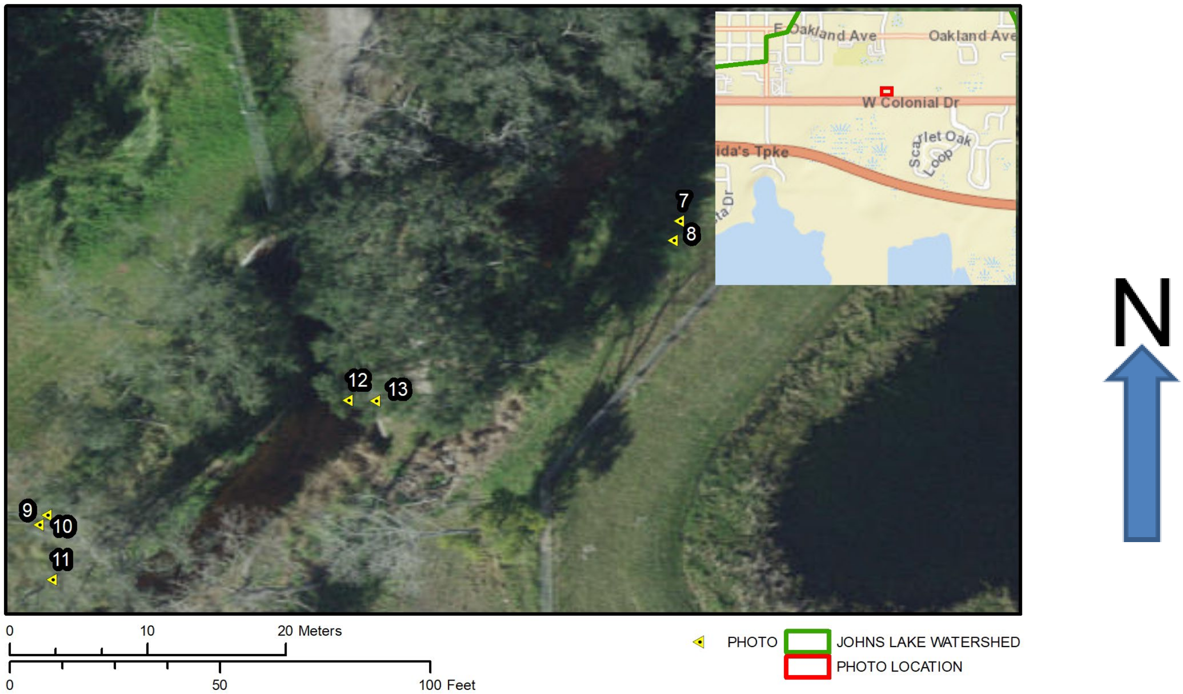
Photograph 10. The downstream side of a box culvert under West Colonial Drive from 28° 33′ 5.2″ N 81° 37′ 14.3″ W, looking southwest from the northeastern edge of a concrete erosion-control apron (photograph 11) that functions as a weir, controlling the flow of water from the Johns Lake watershed, toward a former water control structure (photograph 9), to a ditch that drains to Lake Apopka (photograph 8) on March 3, 2022.



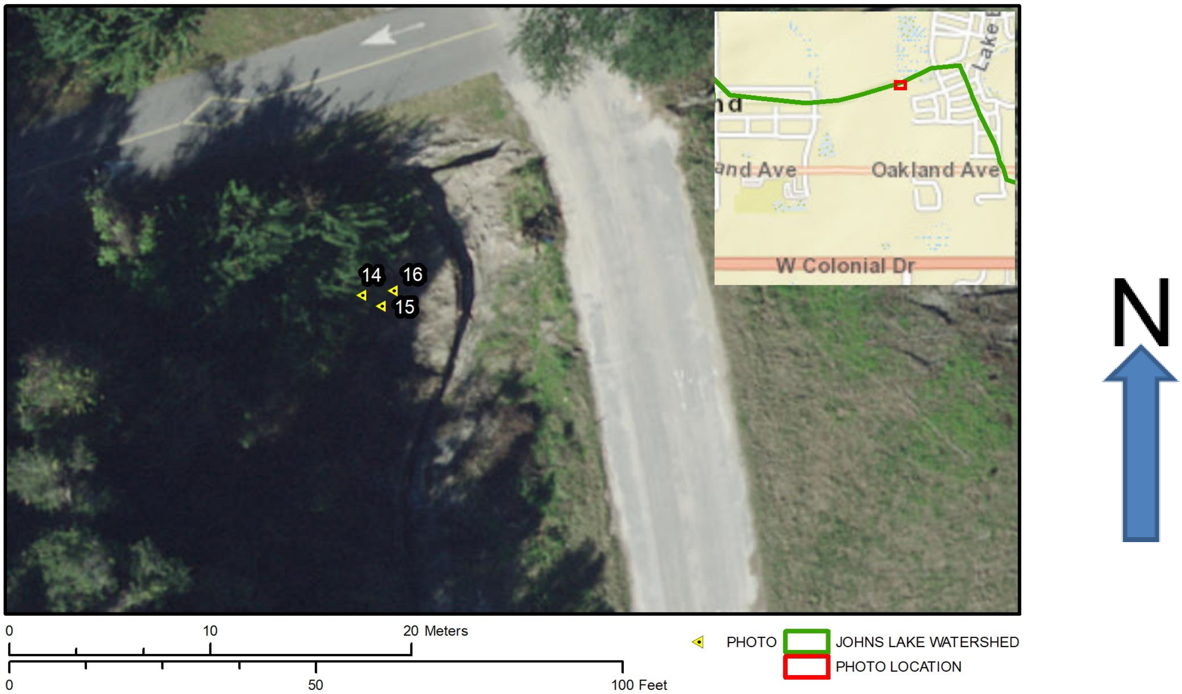
Photograph 11. A concrete erosion-control apron (photograph 11) from 28° 33′ 5.1″ N 81° 37′ 14.2″ W, looking southeast from the northern side of the ditch across the apron on March 3, 2022. The apron functions as a weir, controlling the flow of water from the Johns Lake watershed, toward a former water control structure (photograph 9) to a ditch that drains to Lake Apopka (photograph 8).



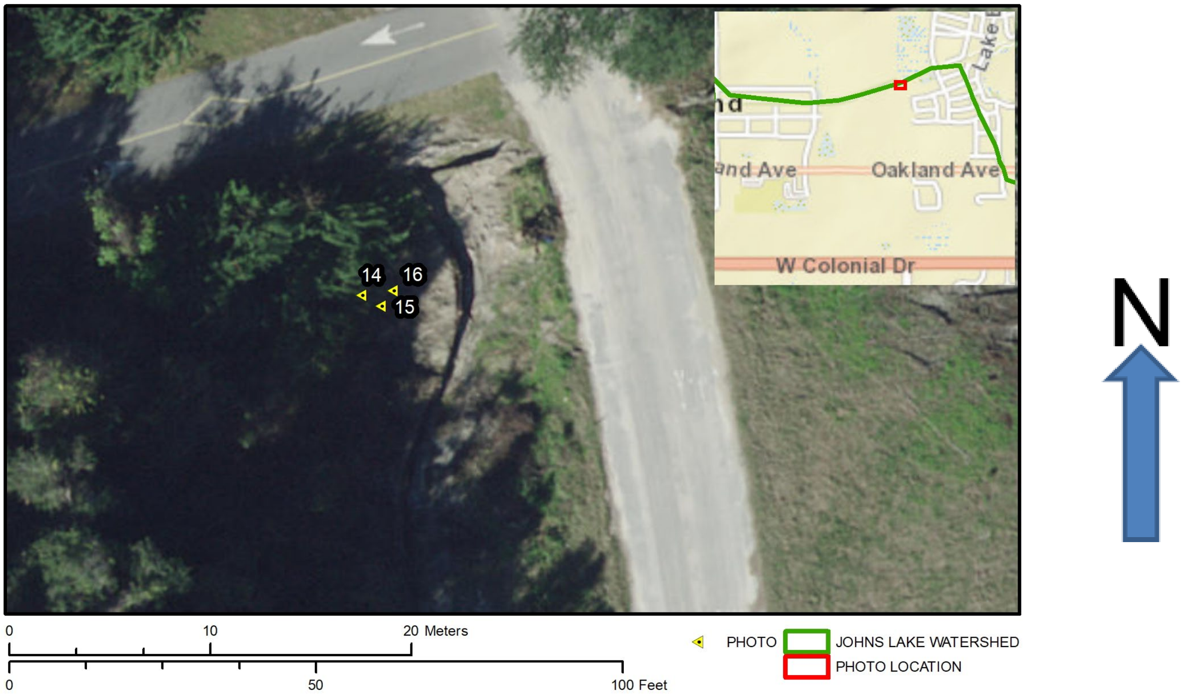
Photograph 12. A ditch and concrete apron—which functions like a weir—downstream of a twin box culvert under West Colonial Drive (photograph 10), at a water control structure (photograph 7) from 28° 33′ 5.5″ N 81° 37′ 13.5″ W, looking southwest toward West Colonial Drive and Johns Lake on March 3, 2022. The water-control structure once regulated the flow of water from the Johns Lake watershed to a ditch that drains to Lake Apopka.



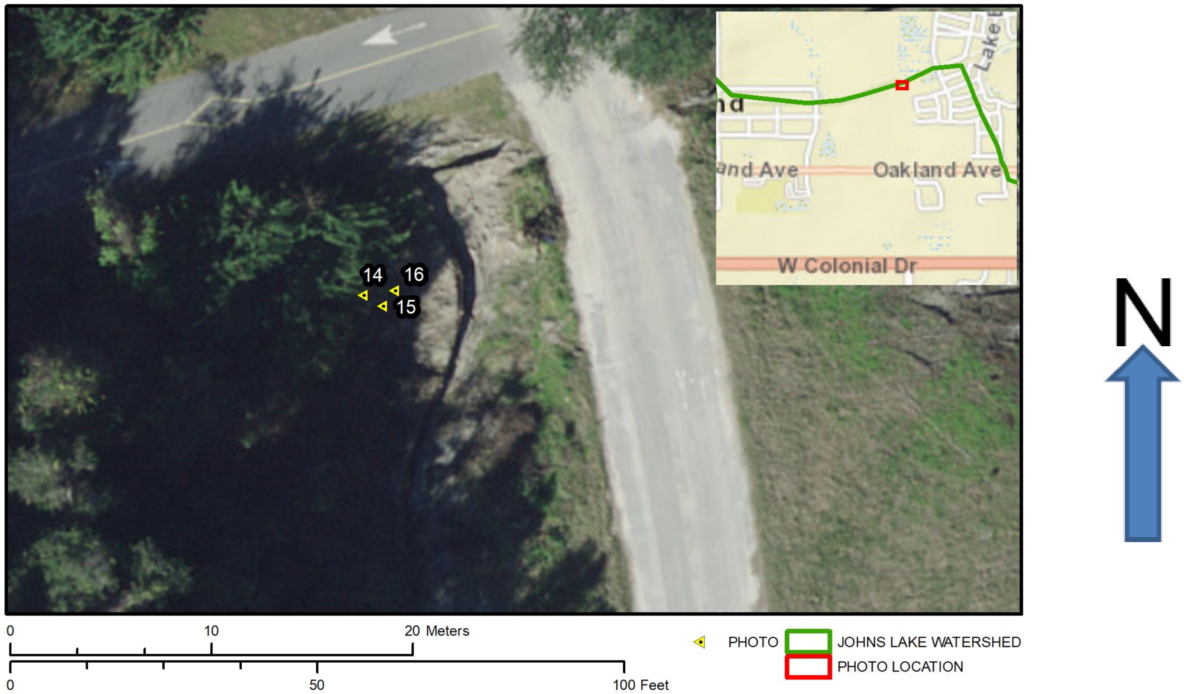
Photograph 13. Two culverts, at a water control structure (photograph 7) from 28° 33′ 5.5″ N 81° 37′ 13.5″ W, looking northwest along the southern face of the water control structure on March 3, 2022. The water control structure once regulated the flow of water from the Johns Lake watershed to a ditch that drains to Lake Apopka.



Photograph 14. The downstream side of a culvert and the top of a velocity damper inside a water-control structure, looking down and east from 28° 33′ 29.1″ N 81° 36′ 59.0″ W on March 3, 2022. The culvert may drain a relatively new residential development (photograph 17) north of and outside the delineated Johns Lake overland flow simulation domain, into the domain.



Photograph 15. A velocity damper inside a water control structure downstream of a culvert (photograph 14) from 28° 33′ 29.1″ N 81° 36′ 59.0″ W, looking down on March 3, 2022. The culvert may drain a relatively new residential development north of and outside the delineated Johns Lake overland flow simulation domain, into the domain.

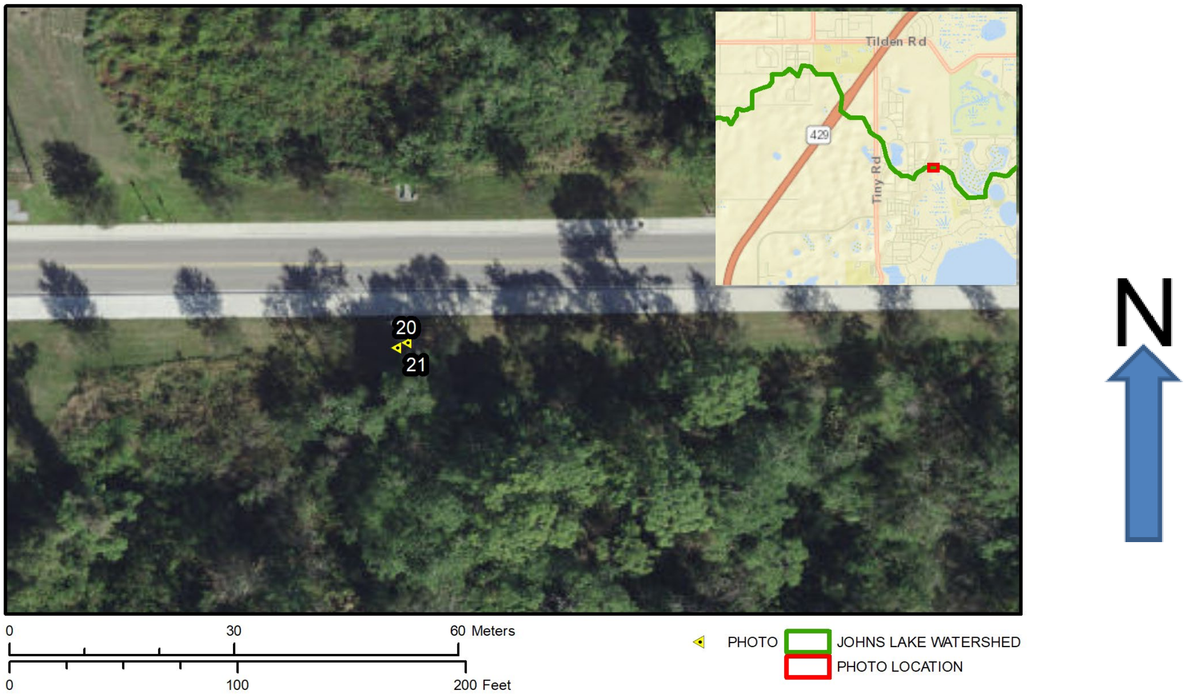


Photograph 16. A weir at the end of a water control structure downstream of a culvert (photograph 14), from 28° 33′ 29.1″ N 81° 36′ 59.0″ W, looking southwest on March 3, 2022. The culvert may drain a relatively new residential development north of and outside the delineated Johns Lake overland flow simulation domain, into the domain.

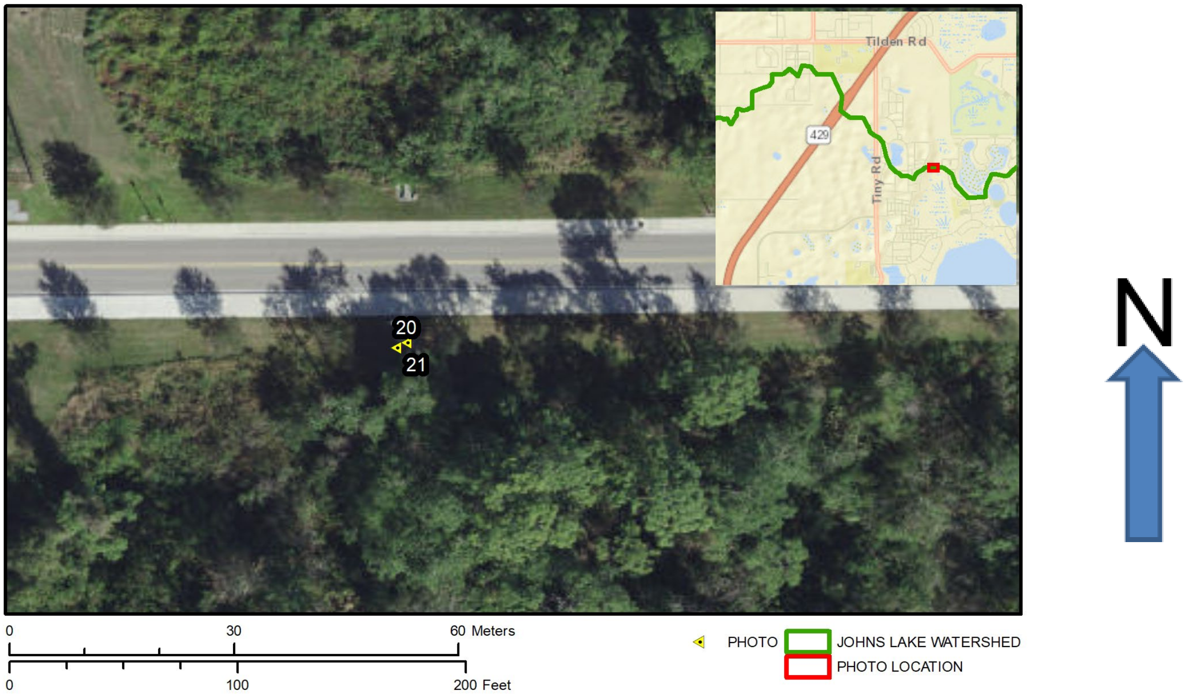
Photograph 17. A culvert north of the West Orange Trail, from 28° 33′ 30.4″ N 81° 36′ 56.7″ W, looking north on March 3, 2022. The culvert may drain a relatively new residential development north of and outside the delineated Johns Lake overland flow simulation domain, into the domain.

Photograph 18. The upstream end of a culvert south of the West Orange Trail, from 28° 33′ 30.1752″ N 81° 36′ 56.9124″ W, looking southwest on March 3, 2022. This culvert is likely connected to the water control structure shown in photograph 14, photograph 15, and photograph 16. The culvert may drain a relatively new residential development north of and outside the delineated Johns Lake overland flow simulation domain, into the domain.

Photograph 19. The downstream side of a culvert under West Orange Trail, from 28° 33′ 27.3″ N 81° 37′ 10.7″ W, looking south on March 3, 2022. The St. Johns River Water Management District employee in the background is standing on West Orange Trail. The district employee in the foreground is standing near the channel bank. The channel is deeply entrenched, but not visible at this location.



Photograph 20. Two culverts on the south side of Orchard Hills Boulevard, from 28° 29′ 33.4176″ N 81° 36′ 15.7104″ W, looking northeast on March 3, 2022.



Photograph 21. Two culverts on the south side of Orchard Hills Boulevard, from 28° 29′ 33.4428″ N 81° 36′ 15.6672″ W, looking east on March 3, 2022.