TECHNICAL MEMORANDUM

SULPHUR SPRINGS AUGMENTATION FEASIBILITY STUDY PROJECT

APRIL 2023

Prepared for:

Prepared by:

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PROFESSIONAL CERTIFICATION

The hydrogeologic interpretations and analyses for groundwater modeling for the Sulphur Springs Feasibility project have been done in accordance with accepted professional hydrogeologic practices. This work was prepared specifically at the request of the City of Tampa.

I hereby certify that these analyses were conducted by me or under my direct supervision.

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6th Day of April 2023

SECTION I - INTRODUCTION

1.1 Project Objectives

The Sulphur Springs Augmentation Feasibility Study Project is a cooperative funding project between the City of Tampa (COT) and the Southwest Florida Water Management District (District). HSW Consulting, LLC (HSW) and its subconsultants (HSW Project Team) were selected to conduct this feasibility study of investigating mechanisms to reduce salinity and improve freshwater/groundwater flow to Sulphur Springs.

The Project Objectives are:

1. Determine the feasibility and benefit of providing additional freshwater flows to reduce salinity increases in Sulphur Springs.
2. Determine the benefit to Sulphur Springs of eliminating Sulphur Springs as a Lower Hillsborough River minimum flow recovery source.
3. Evaluate the potential for reduction or elimination of flooding at Ewanowski Springs.
4. Improve stormwater quality, which will also help to improve Sulphur Springs water quality.

The project scope of work was designed to be conducted in two phases. The initial phase will refine the existing SEAWAT groundwater model to evaluate the potential changes in long-term Sulphur Springs water quality with the addition of stormwater and/or changes in COT withdrawals. If the results of the modeling indicate positive outcomes for Objectives 1 and 2, then the remaining tasks will be completed as a second phase of the Project.

This Memorandum provides a summary of the scope of work and results from Task 1 of the Project.

1.2 Background

In June 2018, HSW completed development of a SEAWAT variable-density groundwater model as part of the feasibility analysis of the Tampa Augmentation Project (TAP). The groundwater model's development, calibration, and application were documented in a report to the COT (HSW and Carollo, 2018). The Phase I Feasibility Study evaluated managed aquifer recharge using reclaimed water within the Upper Floridan Aquifer (UFA). The recovered water would be directed to the Hillsborough River Reservoir (HRR) or to the David L. Tippin Water Treatment Facility (DLTWTF). The TAP SEAWAT Model was used to evaluate the potential changes in water levels and water quality resulting from two proposed TAP recharge and recovery scenarios.

In November 2020, HSW completed TAP Phase II modifications to the TAP Phase I SEAWAT model developed, in response to questions from third party reviewers. These modifications included expanding the model boundaries further north to include Tampa Bay Water's Northwest Hillsborough Regional Wellfield (NWHRWF) and Carrollwood Wells. These modifications also included improvements of the model calibration in the Tampa Bypass Canal (TBC) and Harney Canal area. These changes are documented in a separate report to the COT (HSW and Carollo, 2020).

Sulphur Springs is currently a public supply source that is limited by spring discharge water quality. Results of the TAP SEAWAT Phase I model scenarios suggested that recharge from several TAP recharge wells could have some beneficial impact on the water quality from discharge at Sulphur Springs. Observed total dissolved solids (TDS) concentrations of spring discharge were about 700 milligrams per liter (mg/L) in the 1970's and 1980's and have increased over time to exceed 3,000 mg/L in recent years.

The potential for enhancing Sulphur Springs discharge water quality was explored in TAP SEAWAT Phase I by moving one of the simulated TAP-recharge wells closer to Sulphur Springs within the springshed. Improving water quality discharging from Sulphur Springs may allow greater withdrawals from the spring.

The aquifer and springshed water quality and sources of water to the spring were investigated in a study by Scharping et al. (2018). The study concluded that over the last 30 years the salinity in the spring has increased rapidly due to a number of reasons, including pumping the spring water, changing groundwater levels, correlating recharge rates, and the blockage of karstic conduits connected to the spring**.**

Deeper, more saline UFA water upwells beneath the Hillsborough River corridor, which has lower topographic elevations than the surrounding areas. Groundwater flow near Sulfur Springs is generally horizontal in the deeper recharge zone until it reaches the Hillsborough River corridor. Upon reaching the Hillsborough River corridor, this horizontal flow becomes upward flow. This upward head gradient results in upconing of more saline water and groundwater discharge to the river and springs.

Scharping et al. (2018) mapped a cave system north of the spring that connects a series of swallets, sinkholes, and Curiosity Creek. The cave system, located at a depth of about 100 feet below ground surface, is a preferential flow path providing fresh water supply to the spring. It is reported that direct connections between some of these features have been blocked since the 1980's. Divers identified several vents on the cave bottom that "are most likely the sources of seawater intrusion to Sulphur Springs Cave" Scharping et al. (2018).

The results of Phase I TAP groundwater modeling suggested that recharge water from the TAP program could have the potential to beneficially impact water quality at Sulphur Springs. The expanded modeling presented in this report include additional modifications to the model developed to explore the feasibility of improving the discharge and water quality in Sulphur Springs.

SECTION 2 - SULPHUR SPRINGS EXPANDED SEAWAT MODEL

To evaluate potential improvements to Sulphur Springs, the previous Phase II TAP SEAWAT model was revised. The modifications to the model included expanding the model boundaries further north, modifications to the conceptual model of the springshed, and the aquifer parameters used to simulate its conduit system and springshed.

2.1 Northern Boundary Extension

The Sulphur Springs SEAWAT model was extended by the addition of twenty-two 1,000-foot square rows to the north. This extension expanded the model boundary 22,000 feet north to encompass all of the springshed boundary provided by the District (**Figure 1)**. In addition, a focus area of finer grid (200 feet square) was incorporated around the spring and its conduit system extending north to the Blue Sink complex (**Figure 2).**

Topography for the extended portion of the grid is from the National Elevation Dataset in NAVD88. Layer elevations for the bottoms of the Surficial Aquifer System, Intermediate Confining Unit (ICU), Suwannee and Ocala limestones, Avon Park Formation, Middle Confining Unit, and the lower Floridan Aquifer were taken from the District's DWRM3 and the ECFTX models (ESI, 2014; CFWI, 2014). The additional layers within these hydrologic units in the northern extension of the SEAWAT model were divided based on the vertical discretization of the previous SEAWAT model.

The average of May (dry season) and September (wet season) District 2010 contour maps of the UFA potentiometric surface was used to determine the constant head boundaries in layers for the freshwater portions of the aquifer. The vertical profile of water quality for the expanded portion of the western boundary and the western portion of the expanded northern boundary was based on data from seven water quality monitoring wells located just outside the western boundary and used to monitor for saline intrusion for the NWHRWF (**Figure 3)**. The water quality for the expanded eastern boundary and the eastern portions of the expanded northern boundary were estimated and assumed to be less than 1,000 mg/L for TDS down to an elevation of -950 feet NAVD88 (depth of 975 feet). Water quality in the Lower Floridan Aquifer was assumed to approach the TDS concentration of seawater.

Similarly, aquifer parameters for the expanded portion of the model were derived primarily from the DWRM3 model. The initial horizontal hydraulic conductivities and specific storage of the units described above were calculated from the transmissivities and storativities of the DWRM3 model and divided among the individual layers based upon the layer thicknesses. Initial vertical permeabilities were estimated from leakance values from the DWRM3 model. Pumping rates for wells in the expanded portion of the SEAWAT model were taken from the DWRM3 model and assigned layer designations based on casing and borehole elevations. Initial river cells, drain cells, recharge rates, and evapotranspiration rates for the extended grid area are from the DWRM3 model. These parameters were subsequently modified during revision and calibration of the conceptual model of the spring conduit system described below.

2.2 Sulphur Springs Springshed and Conduit System

Karst Environmental Services, Inc. (KARST) is part of the HSW Project team. KARST divers were part of the previous explorations of the Sulphur Springs cave conduit system and were able to provide valuable insight into the physical cave system. Scharping et al. (2018) mapped a cave system north of the spring connecting a series of swallets and sinkholes and Curiosity Creek. The cave system, located at a depth of about 100 feet below ground surface, is a preferential flow path providing fresh water to the spring (**Figure 4**). Dye tracing studies conducted by the COT have shown direct connections of the conduit system to Alaska Sink, Jasmine Sink, Orchid Sink, Hondaland Sink, and Blue Sink (Environmental Engineering Consultants, 1992). The documented former connection of Sulphur Springs with Blue Sink reportedly collapsed in 1987 (Environmental Engineering Consultants, 1992). Additional sinkholes, previously classified as “likely connected to the conduit system”, have been filled in over the last few decades due to commercial and residential development. A large portion of the springshed is located in an urban area and potential recharge to the aquifer has likely declined over the years due to urban development and stormwater runoff management.

In the previous TAP Phase I and Phase II SEAWAT models, the source of Sulphur Springs discharge was simulated using a series of drain cells in the top layer of the UFA following the estimated karst conduit from the spring and extending north to Blue Sink complex. The simulated Sulphur Springs discharge quantities and TDS concentrations from the drain cells were calibrated to current conditions with constant pumping rates and recharge stresses.

Sulphur Springs is a dynamic groundwater flow system. The USGS reported spring flows between 1917 to 1959 ranging from 12.9 to 110 cubic feet per second (cfs) with the average being 57.2 cfs. The average flow in the 1980’s reportedly reduced to about 39 cfs (Environmental Engineering Consultants, 1992). The period 2016 through 2022 has seen relatively stable average annual spring pool discharges of 20.38 cfs and this period was chosen as the Current Conditions Baseline for scenario comparisons (**Figure 5**). The COT began diverting water from the spring pool in 1964 to replenish the Hillsborough River Reservoir during droughts (Scharping et al., 2018). In 2002 the pumping system was modified to allow extracted spring water to be diverted to the base of the reservoir dam to augment the Lower Hillsborough River (Scharping et al., 2018). The COT also now has the option of routing portions of the diversion to the Sulphur Springs run. The COT spring pool diversions described above have continued to the present with the 2016-2022 average annual diversion rate of 9.23 cfs. During the dry season, the seasonal maximum COT diversion rate is frequently high enough to completely stop the natural flow from the spring pool. The combined total of average annual spring pool discharges plus the average annual COT diversions is 29.61 cfs and represents the average annual total output of the spring.

Historically, TDS concentrations for the spring discharge were fresh at about 500 mg/L up until the 1960s (**Figure 6**). The spring discharge lowers the piezometric head in the UFA, and the spring is in close proximity to the lower Hillsborough River which also lowers the head in the UFA. The lowering of head in the UFA by the spring and the river causes upward vertical movement of deeper, more saline groundwater.

There is considerable seasonal variation in spring discharge and TDS concentration. During 2008, spring discharge ranged from 8 to 40 cfs and TDS concentrations ranged from 1,350 to 4,164 mg/L. Although there is some correlation between spring discharge and water quality, there are large spikes in TDS concentration occurring during seasonal declines in TDS concentrations (**Figure 7**). TDS concentrations from the spring pool currently range between 2,500 and 3,000 mg/L (**Figure 6**). Nearby TDS concentrations ranging from 10,600 to 11,500 mg/L have been measured in the Tourist Club monitor well, located 425 feet southeast of the spring pool (**Figure 8**). This monitoring well measures TDS at a depth of 250-350 feet below ground surface at the bottom of the Suwannee limestone formation.

The water quality in Sulphur Springs appears to be a delicate seasonal balance between the heads and fresh water sourced more locally from the Suwannee limestone via secondary porosity conduits and deeper saline waters in the Avon Park Formation, where heads are influenced by more distant or regional recharge events**.** Seasonal reductions in the head in the Suwannee limestone may result in increased upconing of saline groundwater from the Avon Park Formation via the observed salt vents in the cave system (**Figure 9**) **(**Scharping et al., 2018). The primary conduit system of Sulphur Springs is known to lay in the uppermost 100 feet of the upper Floridan aquifer in the Tampa-Suwannee limestone interface. Divers have reportedly identified a greater degree of vertical planes and fracturing in the shape of the Sulphur Springs cave tunnel which is contrary to most karst cave systems in Florida where the orientation of the conduit planes is more horizontal. Divers have reportedly identified several saline water vents on the cave bottom that "are most likely the sources of seawater intrusion to Sulphur Springs Cave" **(**Scharping et al, 2018**).**

The conceptual model of the spring represents that upconing of saline water has filled the secondary porosity underlying the spring areas with more saline water. Higher regional UFA water levels during the wet season may be pressurizing the system, resulting in the upward movement through the salt vents of the more saline water stored in the secondary porosity (**Figure 9**). As a result, increases in discharge TDS can be observed during both spring pumping periods and wet season non-pumping periods.

The SEAWAT model was refined with this conceptual model of the spring and springshed to better evaluate the potential benefits of additional stormwater recharge and elimination of spring withdrawals by the COT. Simulation of seasonal fluctuations in discharge and water quality are beyond the scope of work for this feasibility-level study. As a result, calibration periods selected for historical and current conditions baseline simulations were chosen based on average annual discharges and average annual TDS concentrations.

2.3 Estimated Available Stormwater for Augmentation

The HSW Team's analysis for developing an estimate of available stormwater for augmentation included estimating wet season and dry season flows for Curiosity Creek that may be available for diversion and measuring the salinity in total dissolved solids (TDS). The detailed discussion of estimates is provided as **Appendix A**.

The 1,595-acre Curiosity Creek basin receives 57 inches of rainfall per year. A portion of that rainfall infiltrates, a portion is lost to evapotranspiration, and the remaining balance runs off into the creek. Groundwater flow from Ewanowski Spring also contributes to the Curiosity Creek flow. The wet season estimate is a four-month period between June and September, when 62 % of the rainfall occurs. The wet season flow is estimated to be 7.38 million gallons per day (mgd). The dry season estimate is an eight-month period from October through May, with an estimated flow is 1.94 mgd. The average annual available flow for diversion is estimated to be 3.75 mgd.

Water quality was sampled at the following three locations:

- 122nd Street
- Blue Sink
- F-100C Pond

Specific Conductance measurements of 209 to 213 microSiemens per centimeter were recorded, which converts to a TDS of approximately 135 mg/L using a conversion factor of 0.64 (University of California, Division of Agriculture and Natural Resources).

2.4 SEAWAT Model Refinement for Sulphur Springs

The multiple drain cells extending to the north representing the spring conduit in the previous model were replaced with a single drain cell at the spring vent in layer 3, representing the top of the Suwannee limestone. The bottom of layer 3 was reset to coincide with the known maximum depth of the cave system. Layer 4, immediately beneath the layer containing the spring conduit, was subdivided into two layers of equal thickness to improve the vertical discretization beneath the Hillsborough River and the spring where the fresh water/saline interface is known to occur at shallow depths. In the current conditions simulation and corresponding scenarios, the drain cell in the spring node was replaced by a well pumping at a rate of the average spring run discharge. An additional well was added to the spring node to simulate COT diversion pumping from the spring. The total simulated spring discharge is the sum of these two wells in the spring node.

Generally, karstic aquifers can be successfully modeled in MODFLOW by assuming an aquifer permeability that is some average value of the less permeable limestone matrix and the highly permeable conduits, large and small, that occur in the karst area. In this area, a substantial portion of the actual conduit has been physically mapped by divers and a larger area of the conduits has been inferred from dye studies and hydraulic connections based on water level changes in sinkholes observed during induced changes in the spring pool during pumping by the COT.

In addition to the springshed having a higher horizontal and vertical permeability than the surrounding aquifer, a single line of model cells in layer 3 with very high permeabilities, extending northward along the known and inferred route of the cave system, was added to the model. The highest hydraulic conductivity of 130,000 feet/day extends from the spring pool to Alaska Sink. A hydraulic conductivity of 90,000 feet/day was used in the conduit from Alaska Sink to Orchid Sink, and 25,000 feet/day was used from Orchid Sink to the end of the conduit at the Blue Sink complex.

A series of historical SEAWAT simulations were conducted to establish initial head and water quality conditions for the current conditions model. The current conditions model is based on the period between 2016 and 2022. The historical models were run to develop a model where head and TDS concentrations have stabilized with regards to aquifer parameter and boundary conditions. The historical models were run in temporal series with boundary condition changes to account for the damming of the Hillsborough River, the construction of the TBC, and changes in well withdrawals to provide a set of initial heads, initial TDS concentrations, and spring discharges, consistent with the current conditions model using 2019 pumping rates from the DWRM3 model.

Simulated water levels were compared to observed water levels in the springshed. There is limited data for head and water quality at deeper depths in the UFA. The primary focus of the water level and water quality calibration was in the center of the model where deep core water levels and water quality were available **(Figure 10).** A secondary focus of water level and water quality calibration was in the springshed itself. Most of the available water levels are from shallow UFA wells. Simulated surficial aquifer and UFA target errors for the current conditions model are shown in **Figure 11** and **Figure 12**, respectively. Some of these shallow UFA wells had single data points for water quality with TDS concentrations less than 500 mg/L. These water quality data were used for a qualitative check on the simulated TDS concentrations at the top of the UFA.

The Tourist Club well is located 425 feet southeast of the spring pool and is open to the entire depth of the Suwannee limestone. Water levels from the Tourist Club well were available for the period of 1960 to 1991 and specific conductance is available from 1991 to the present (**Figure 8**).

Deep cores collecting lithology, water levels, and water quality vertically from the Suwannee limestone down to the bottom of the Avon Park Formation were installed during TAP Phase 1 (**Figure 13**). The NWHWRAP-2D monitor well in the Rome Avenue area has specific conductance data down to the bottom of the Avon Park Formation (**Figure 14**). Vertical profiles of simulated TDS concentrations compared to observed monitor well data at Sulphur Springs and the nearby Tourist Club well are shown in (**Figure 15**). The Sulphur Springs pool is monitored for discharge and water quality, (**Figure 5** and **Figure 6**).

The target for simulated Sulphur Springs discharge for the Current Conditions 2016-2022 model (29.61 cfs) is composed of the sum of observed average annual spring discharges (20.38 cfs) plus the observed average annual spring withdrawals diverted (9.23 cfs) to the base of the Hillsborough River Reservoir Dam or the spring run by the COT. In order to compare future scenarios of the Current Conditions model to future No Diversion scenarios, an estimate of Sulphur Springs discharge without any COT diversions needed to be created since any annual average of observed spring discharges has some COT diversions in it since 1964.

ROMP 66 is a District monitor well pair (surficial aquifer and Suwannee limestone) near Sulphur Springs with water levels and limited water quality data. Water levels at ROMP 66 Suwannee have been shown to correlate well with Sulphur Springs discharges (**Figure 16**) (Scharping et al, 2018)**.** Based on the good correlation between ROMP 66 Suwannee water levels and Sulphur Springs discharges, the rate that the Sulphur Springs pool discharge would be without COT diversion during periods of observed COT diversions was estimated using ROMP 66 water levels as a surrogate for discharges. Using this method, the 2016-2022 average annual spring pool discharge without COT diversions was estimated to be 26.38 cfs (**Table 1**).

2.5 SEAWAT Model Scenarios

Future scenario conditions were simulated for 20 years representing the period 2023-2043. The 2016-2022 Current Conditions model was established as the initial condition for all future scenarios and was extended through 2043 for a baseline to compare to other scenarios. The following boundary conditions were held constant within the scenario simulations:

- Net annual recharge to the aquifer system with no seasonal changes
- Regional groundwater pumpage from other users
- Average annual spring discharge rate
- Average annual COT diversion rate
- Stormwater augmentation

Average annual excess stormwater available for augmentation is 3.75 mgd (5.81 cfs) at a concentration of 135 mg/L TDS (**Appendix A**). The augmentation of stormwater was simulated as an injection well in the conduit at the location of Jasmine Sink. Jasmine Sink was chosen for the location of the application by the COT because it is close to stormwater infrastructure capable of delivering, with some modification, a large amount of stormwater to the location. Phase II of this feasibility study will determine more refined quantities and the method of delivery of excess stormwater to the spring.

Four scenarios described in the scope of work were simulated and are described in (**Table 1**).

Table 1. Sulphur Springs Simulated Scenarios Average Annual Discharges and Augmentations 2016-2022.

Future Scenario Descriptions for Period 2023-2043	Sulphur Springs Run Discharge, cfs*	COT Diversions, cfs	Total Sulphur Springs Discharge, cfs	Excess Stormwater Recharge, cfs	Reclaimed Water Recharge, cfs
Scenario 1. Baseline condition scenario – continue to use Sulphur Springs as a Lower Hillsborough River minimum flow recovery source for the next 20 years.	20.38	9.23	29.61	0	0
Scenario 2. No COT Diversions	26.38	0	26.38	0	0
Scenario 3. Current Conditions + Stormwater Recharge	20.38	9.23	29.61	5.81	0
Scenario 4. No Diversions + Stormwater Recharge	26.38	0	26.38	5.81	0

* cfs, cubic feet per second

The COT requested two additional scenarios, not in the scope of work, to investigate the additional benefit of adding 10 mgd (15.47 cfs) of reclaimed water as managed aquifer recharge with and without current COT diversion flow rates (**Table 2**). The reclaimed water quality was simulated with 750 mg/L of TDS. Simulated excess stormwater and reclaimed water were added to the Sulphur Springs conduit system by an injection well at the location of Jasmine sink.

Table 2. Sulphur Springs Additional Simulated Average Annual Discharges and Augmentations 2016-2022.

Future Scenario Descriptions for Period 2023-2043	Sulphur Springs Run Discharge, cfs*	COT Diversions, cfs	Total Sulphur Springs Discharge, cfs	Excess Stormwater Recharge, cfs	Reclaim Recharge, cfs
Scenario 5. Current Conditions + Stormwater + Reclaimed water	20.38	9.23	29.61	5.81	15.47
Scenario 6. No Diversions + Stormwater + Reclaimed water	26.38	0	26.38	5.81	15.47

* cfs, cubic feet per second

SECTION 3 - MODEL USE

The Sulphur Springs SEAWAT model focuses on an area where the hydrogeology is complex and groundwater development and long-term aquifer monitoring have been minimal. Tampa Bay to the south allows for the presence of saline water at relatively shallow depths along the Hillsborough River corridor. The existence of several springs, which are indicative of karstic features also adds to this complexity. The study for which the SEAWAT model is being developed is a “feasibility study”. The users of the model, or of the model’s resultant predictions, need to be aware of the capabilities of the SEAWAT model, and the quantity and quality of the hydrologic data on which the model is based.

3.1 SEAWAT Model Assumptions

Sulphur Springs is a dynamic groundwater flow system located in a complex coastal hydrologic environment. Spring discharge, groundwater levels and water quality are the result of both natural and anthropogenic influences. Historical hydrologic data, especially water quality data, prior to 2000 are limited. When developing models of complex areas, it is necessary to make simplifying assumptions to the model structure and input parameters. This model holds some parameters constant although they are known to vary with time (e.g., recharge).

Apart from assumptions made in model structure and the input parameters, there are limitations in the SEAWAT code that are a combination of the limitations of MODFLOW, MT3D and SEAWAT (Guo and Langevin, 2002). Groundwater flow near fractures or karst features is represented by an equivalent porous media. Equations used in the MT3D code assume a fully miscible liquid phase of very small compressibility. The SEAWAT 2000 model is a density-dependent flow model. Density is dependent on the concentration of total dissolved solids. Although density varies with temperature, that parameter is not included in the simulation. It is assumed that the difference in temperature at the depths simulated in the study area will not significantly change the density of the water.

3.2 SEAWAT Calibration Reliability

Successful calibration of the Sulphur Springs SEAWAT model for the COT has been demonstrated by adequately matching simulated and observed water levels and water quality over time and at various depths throughout the study area. The accuracy and reliability of any model’s calibration depends upon the quality and quantity of available hydrologic data representing water levels, flows and water quality. The detailed vertical distribution of hydraulic conductivity and water quality within the UFA is only known at well NWHWRAP-2D and the core hole test locations completed as part of an earlier investigation. The reliability of the calibration may, in some areas, depend on the discretization of the grid and the location of the calibration data. Although a finer grid discretization around the spring or wells may be desirable to improve calibration and evaluate the magnitude and lateral extent of upconing, the current Sulphur Springs SEAWAT model is deemed to be appropriate at the feasibility-level model as described in the Project Objectives.

3.3 Predictive Uncertainties

The benefit of developing and calibrating a numerical groundwater model is that it can be used to predict changes in groundwater levels, flows, and water quality due to changes in environmental stresses. Field testing including drilling coreholes to the bottom of the Avon Park Formation and aquifer performance testing at Woodland Terrace recharge and recovery wells were completed in TAP Phase I. Test well drilling and review of water quality responses to aquifer storage and retrieval operations at the COT's Rome Avenue Complex were completed in TAP Phase II. TAP Phase I and II data were combined with limited historic discharge and water quality data for Sulphur Springs to show that the calibrated Sulphur Springs SEAWAT model has demonstrated reliable comparisons to these known hydrologic stresses. Estimates of groundwater baseflow and the effects of tidal influences on baseflow are unknown. Model boundary inflows and outflows are also subject to uncertainties. However, the use of numerical models in determining differences between two scenarios generally is believed to reduce these uncertainties.

3.4 Appropriate Model Use

As with any tool, a hydrologic simulation model performs best when used for the purposes for which it was designed. It is impracticable to document within this report everything learned about the performance characteristics of the model. Preceding project reports detail the analysis of available historical data that support the conceptualization and subsequent development and calibration of the Sulphur Springs SEAWAT model for the COT. This report details the updated Sulphur Springs model calibration based on historical data and results of prior field testing conducted in the study area. The model has been designed to simulate the discharge and water quality characteristics of Sulphur Springs and its springshed to assist users in determining whether the project is feasible, in other words, *"possible or reasonable"*.

Calibration of the Sulphur Springs SEAWAT model suggests that water quality is sensitive to: (1) vertical variations of the TDS concentrations within the UFA; (2) the vertical hydraulic parameters controlling the vertical migration of water; and (3) the quantity of water recharged or withdrawn at any given location. Where observed historical water quality data were available for calibration, the confidence in the model calibration is greater. As more aquifer and water quality data become available in the springshed, increased confidence will be possible in model predictions.

Future scenarios described in this report were designed to answer specific questions. The current conditions baseline model assumes no change in recharge (climate), groundwater withdrawals (regional pumping), or springshed (aquifer and conduit). The scenario results should only be used for the objectives of this study with these limitations in mind.

SECTION 4 - SEAWAT MODEL SCENARIO RESULTS

The results of our analysis indicate benefits to water quality in all of the three originally scoped scenarios and two supplemental scenarios when compared to the current baseline conditions of Scenario 1 (**Figure 17**). The model exhibits that routing excess stormwater to the Sulphur Springs conduit system increases flow and reduces salinity at Sulphur Springs.

- Stopping all COT diversions (Scenario 2) results in a reduction of TDS concentrations by about 213 mg/L over time (**Figure 18**).
- The results of the simulated scenarios indicate continuing current COT diversions and adding 3.75 mgd of excess stormwater (Scenario 3) to the conduit system results in a reduction of TDS concentrations by about 492 mg/L (**Figure 19**).
- Stopping all COT diversions and adding 3.75 mgd of excess stormwater (Scenario 4) to the conduit system results in a reduction of TDS concentrations by about 719 mg/L (**Figure 20**).
- Continuing current COT diversions and adding 3.75 mgd of excess stormwater plus 10 mgd of reclaimed water to the conduit system results in a reduction of TDS concentrations by about 1,094 mg/L (**Figure 21**).
- Ceasing current COT diversions and adding 3.75 mgd of excess stormwater plus 10 mgd reclaimed water to the conduit system results in a reduction of TDS concentrations by about 1,271 mg/L (**Figure 22**).

The benefits of ceasing an average annual COT diversion of 9.23 cfs would likely achieve a seasonal reduction of about 500-600 mg/L due to the higher actual dry season diversion rate of about 28 cfs. The addition of excess stormwater would likely have additional seasonal benefits as well, due to the availability of higher (7.38 mgd) wet season rates than the average annual 3.75 mgd rate simulated.

Over time, repeated diversions during the dry season have likely filled secondary porosity in the bottom of the Suwannee limestone with saline water that historically would have been fresh. Stopping COT diversions will begin to reverse or mitigate the diversion’s effects on saltwater upconing beneath the spring caused by lowered UFA heads in the dry season (**Figure 9**) and the quantity of saline water accumulated in the secondary porosity below the spring area may decrease. Adding excess stormwater will increase the spring flow and reduce the salinity of the spring discharge.

In conclusion, the outcomes of the various scenarios developed during this first Task activity of the project show that Project Objectives 1 and 2 are met. The further refinement of these objectives, as well as addressing Project Objectives 3 and 4 would be assessed as part of Tasks 2 through 4 in the second Phase of this project.

SECTION 5 - REFERENCES

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FIGURE 1. SULPHUR SPRINGS SEAWAT MODEL BOUNDARIES.

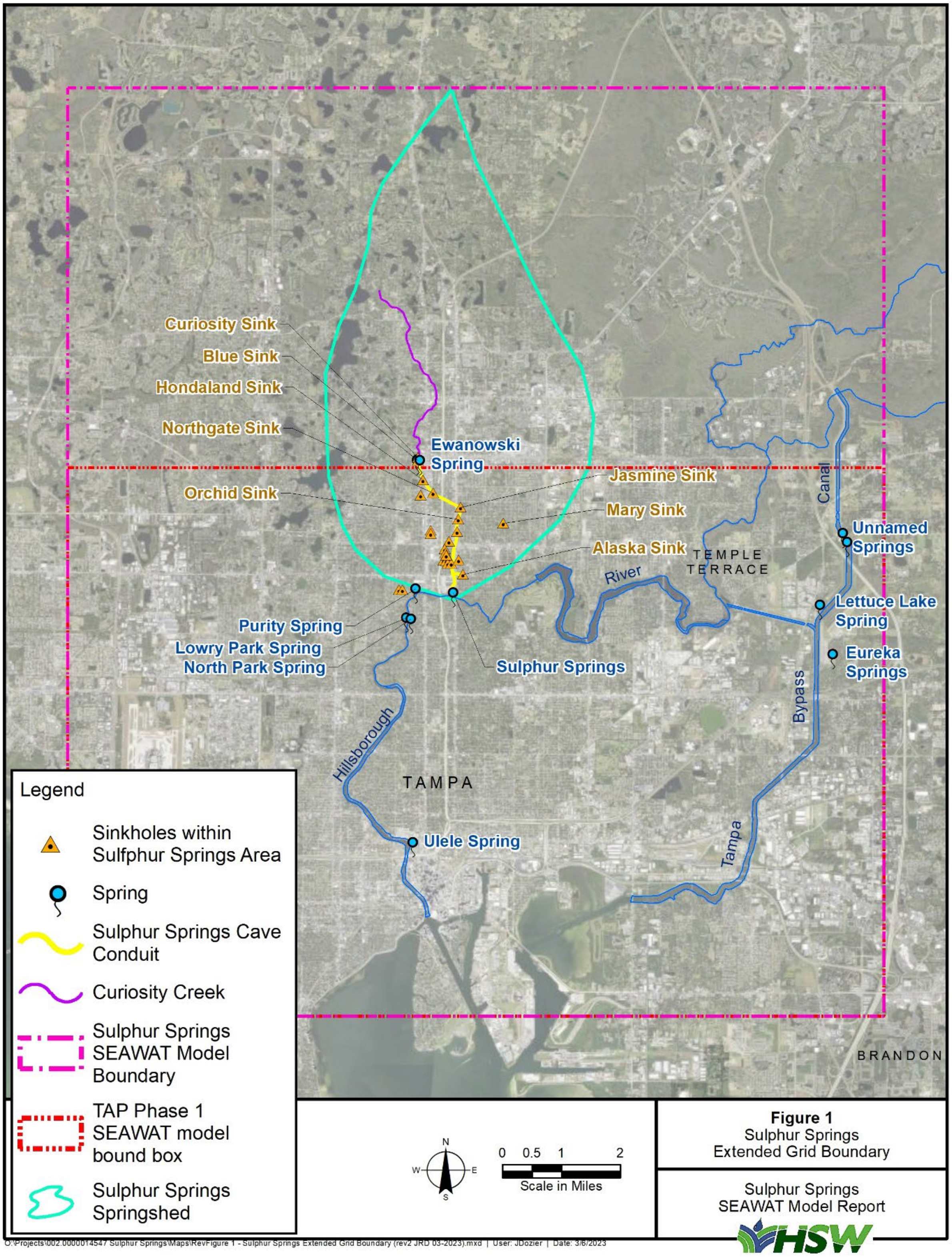


FIGURE 2. FOCUS AREA SULPHUR SPRINGS SEAWAT MODEL GRID.

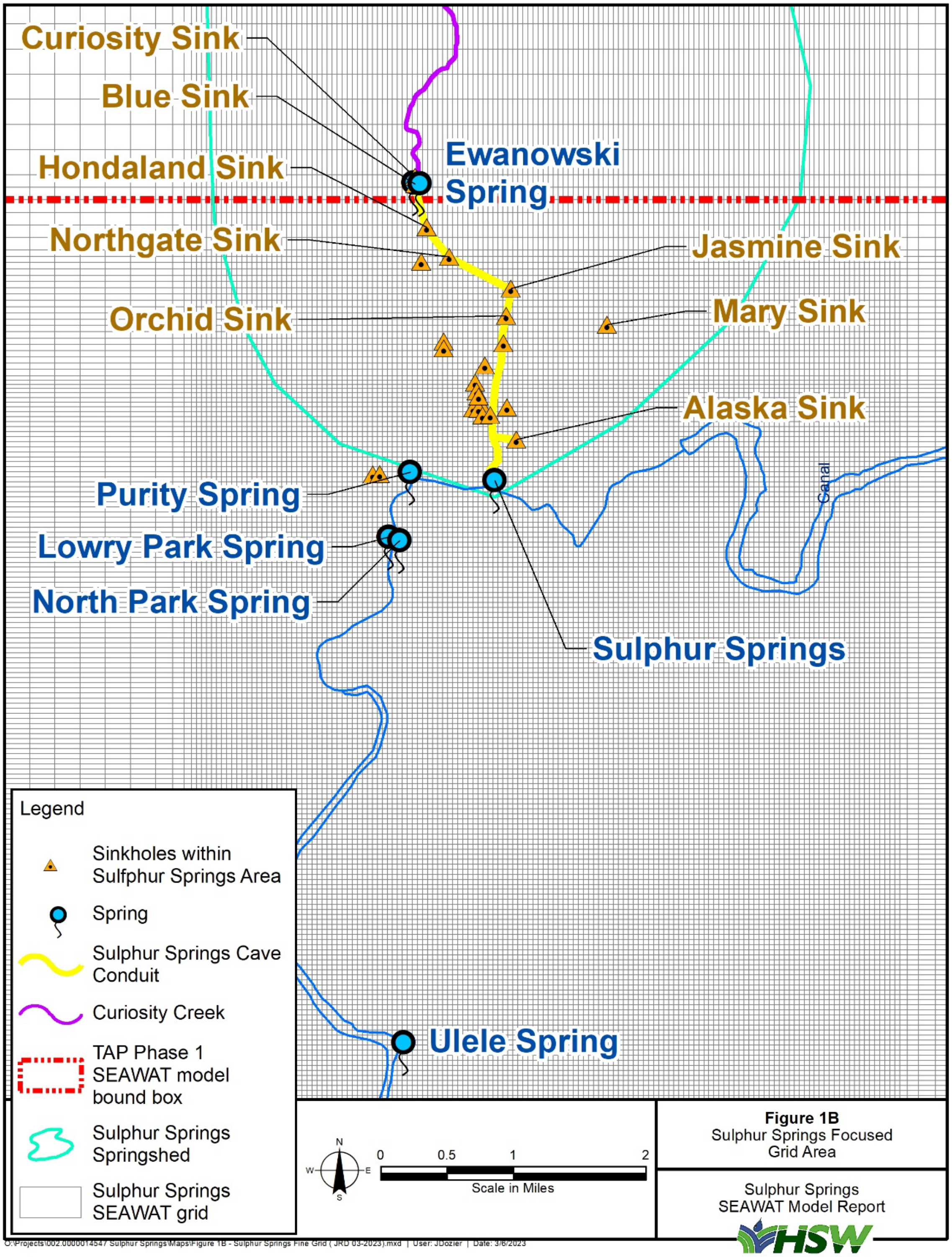


FIGURE 3. NWHRWF MONITOR WELLS USED FOR WESTERN MODEL BOUNDARY CONDITIONS.

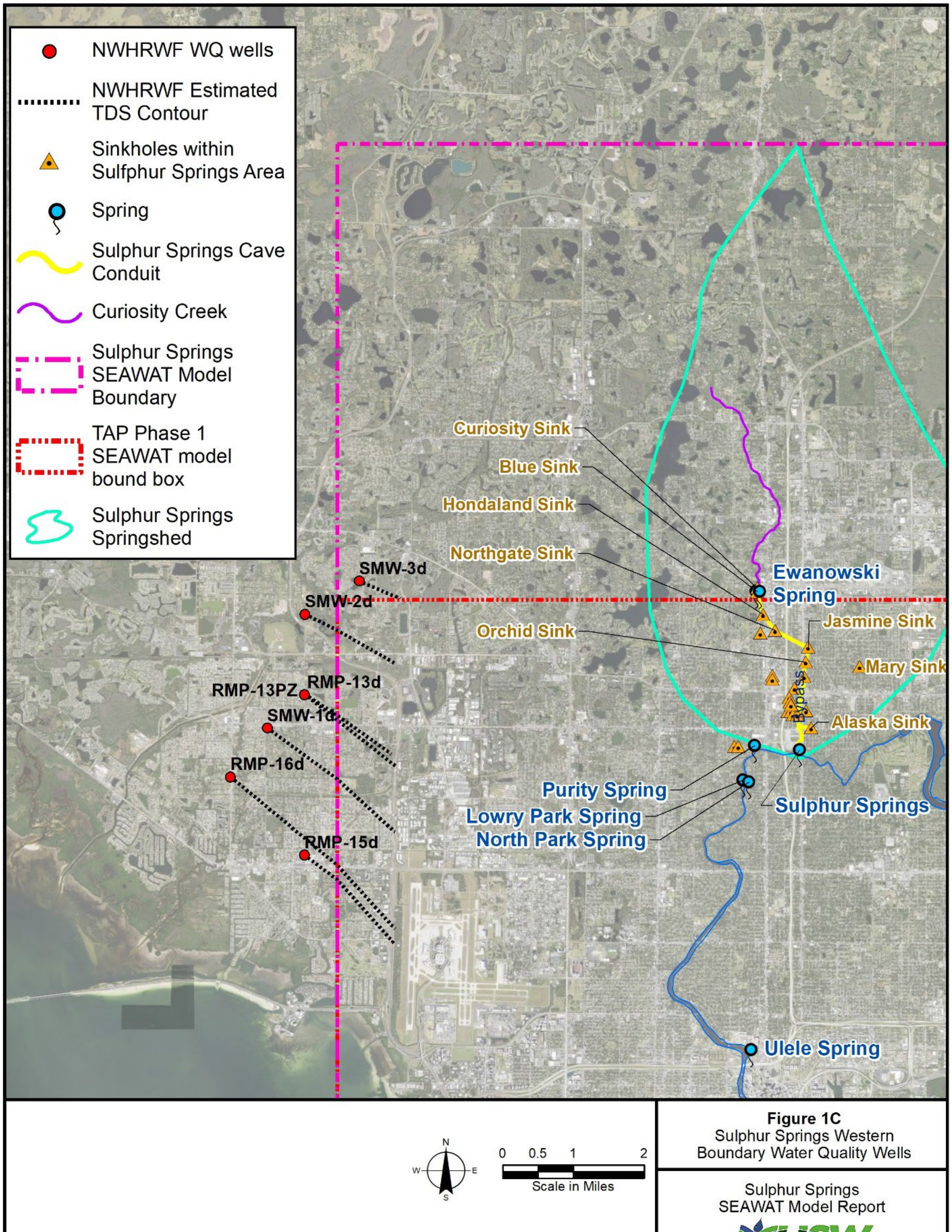


FIGURE 4. LOCATION OF SULPHUR SPRINGS AND MAPPED CAVE PASSAGE (SCHARPING ET AL., 2018).

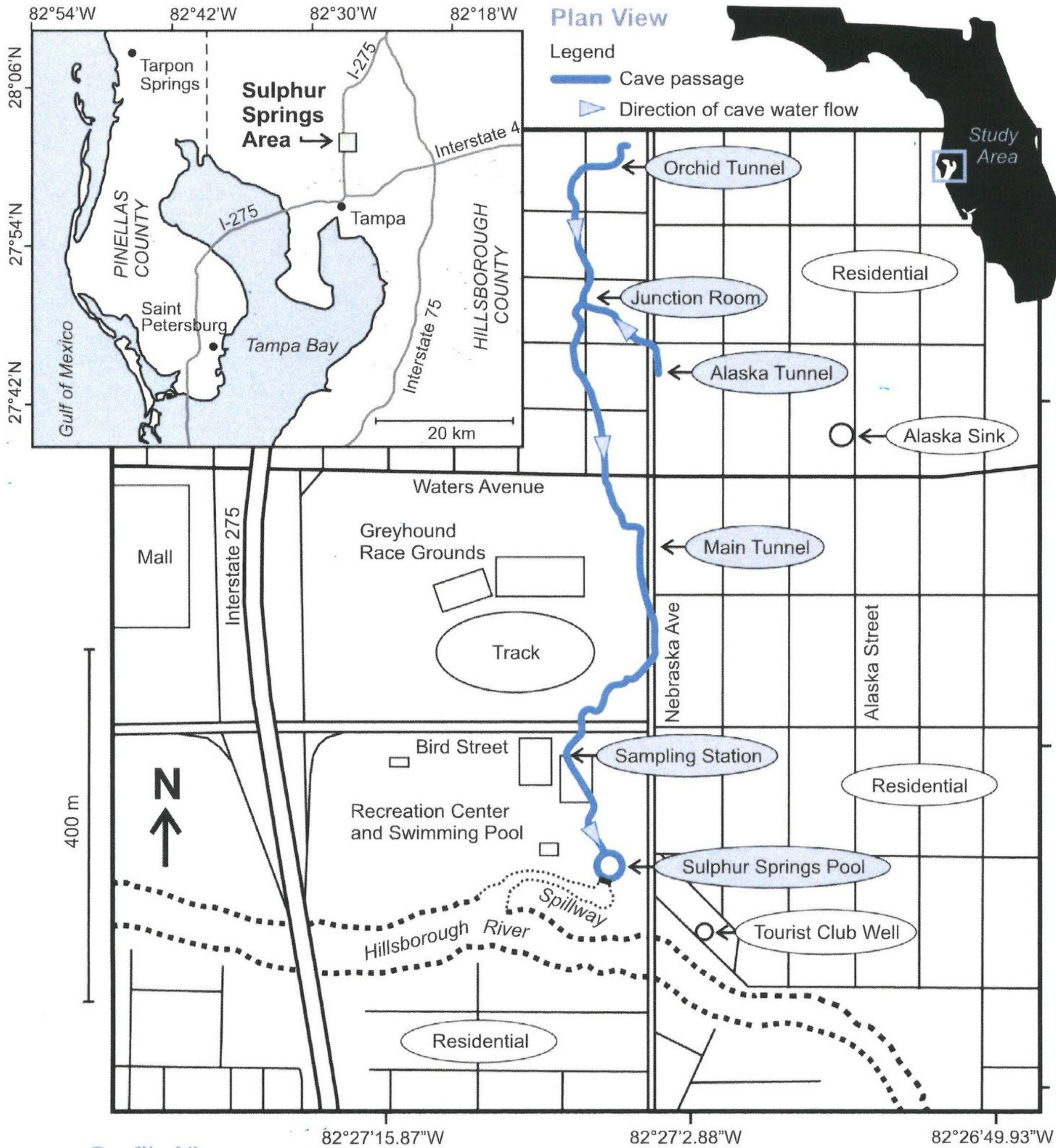


FIGURE 5. PERIOD OF RECORD SULPHUR SPRINGS AVERAGE ANNUAL DISCHARGE.

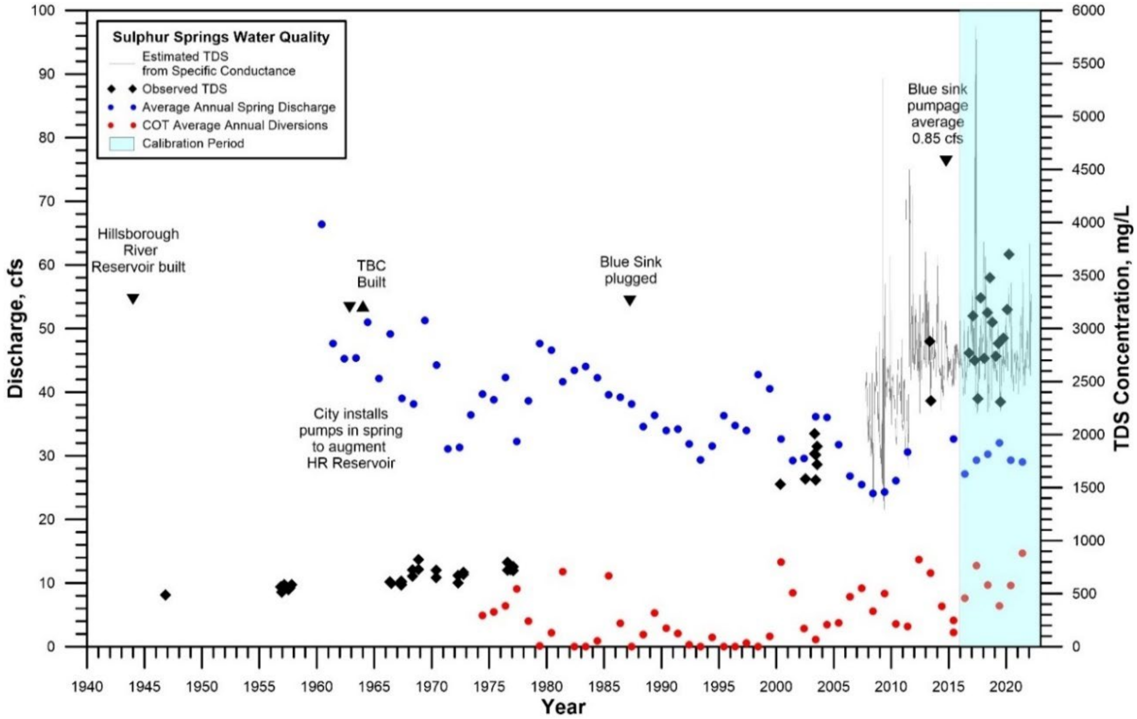


FIGURE 6. PERIOD OF RECORD WATER QUALITY AT SULPHUR SPRINGS.

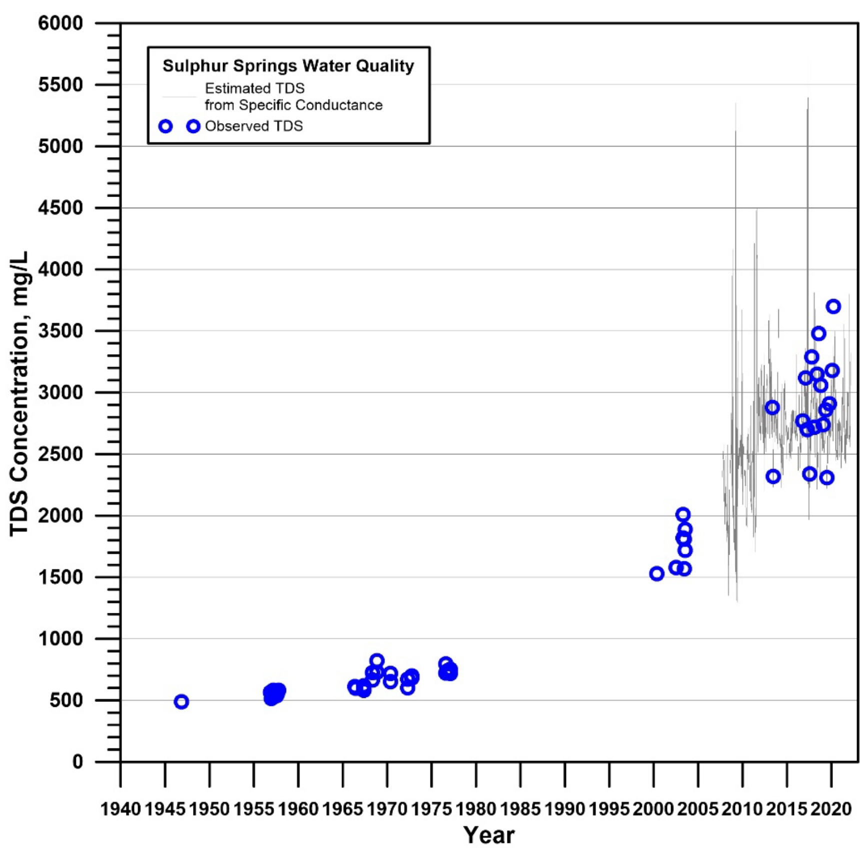


FIGURE 7. SULPHUR SPRINGS DAILY DISCHARGE AND WATER QUALITY.

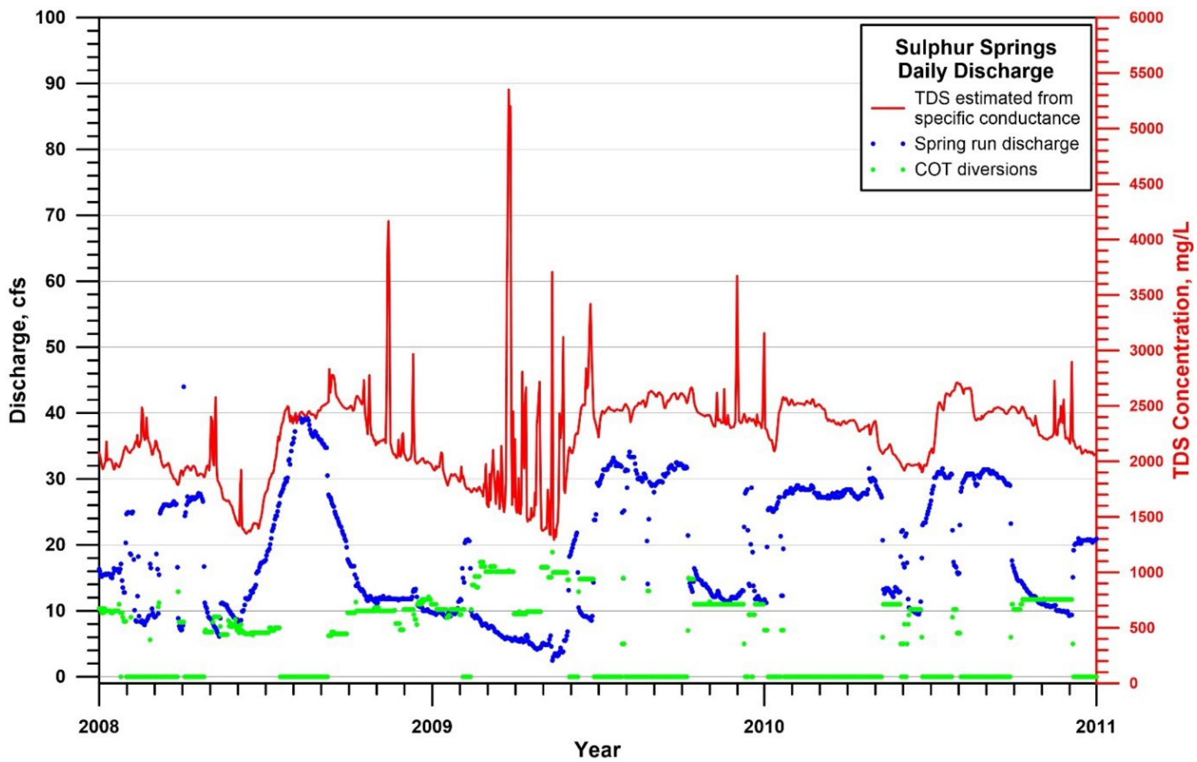


FIGURE 8. TOURIST CLUB WELL WATER LEVELS AND WATER QUALITY.

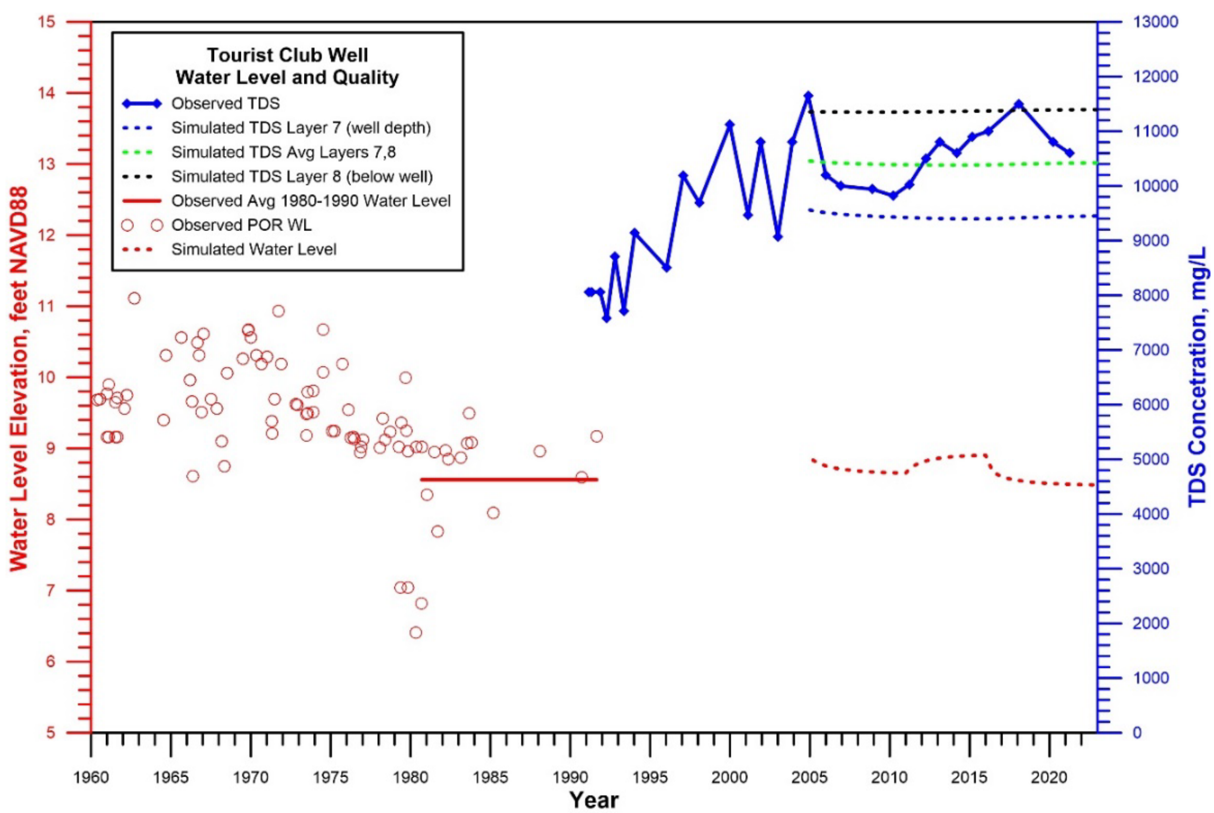


FIGURE 9. CONCEPTUAL MODEL OF THE SULPHUR SPRINGS RELATIONSHIP BETWEEN RECHARGE AND WATER QUALITY (SHARPING ET AL, 2018).

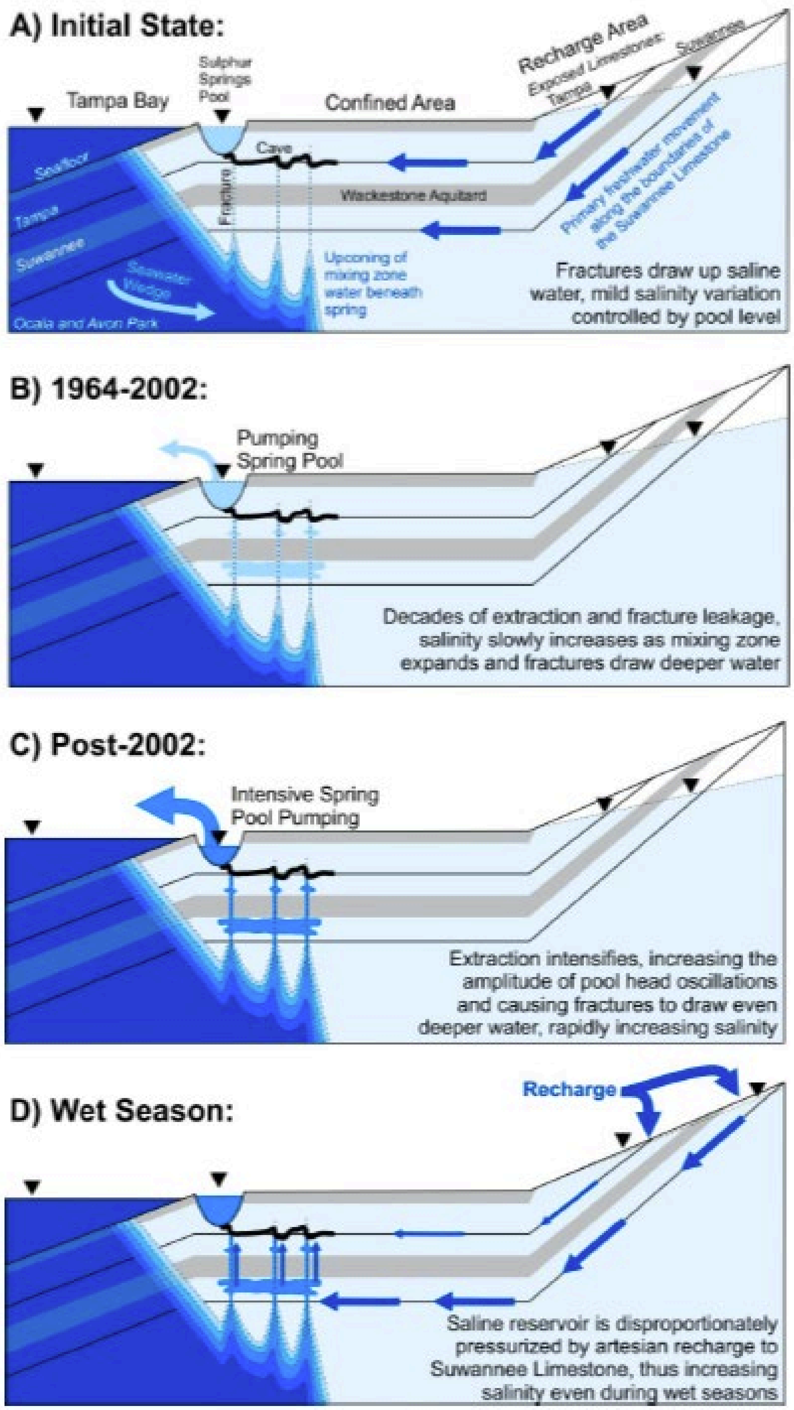


Figure 16. Model of Sulphur Springs Cave seawater intrusion. The upper and lower bedding planes of the Suwannee Limestone are the most permeable units of this portion of the aquifer. Confining units/aquitards are indicated by gray bars.

FIGURE 10. LOCATION OF SULPHUR SPRINGS SEAWAT MODEL PRIMARY CALIBRATION POINTS.

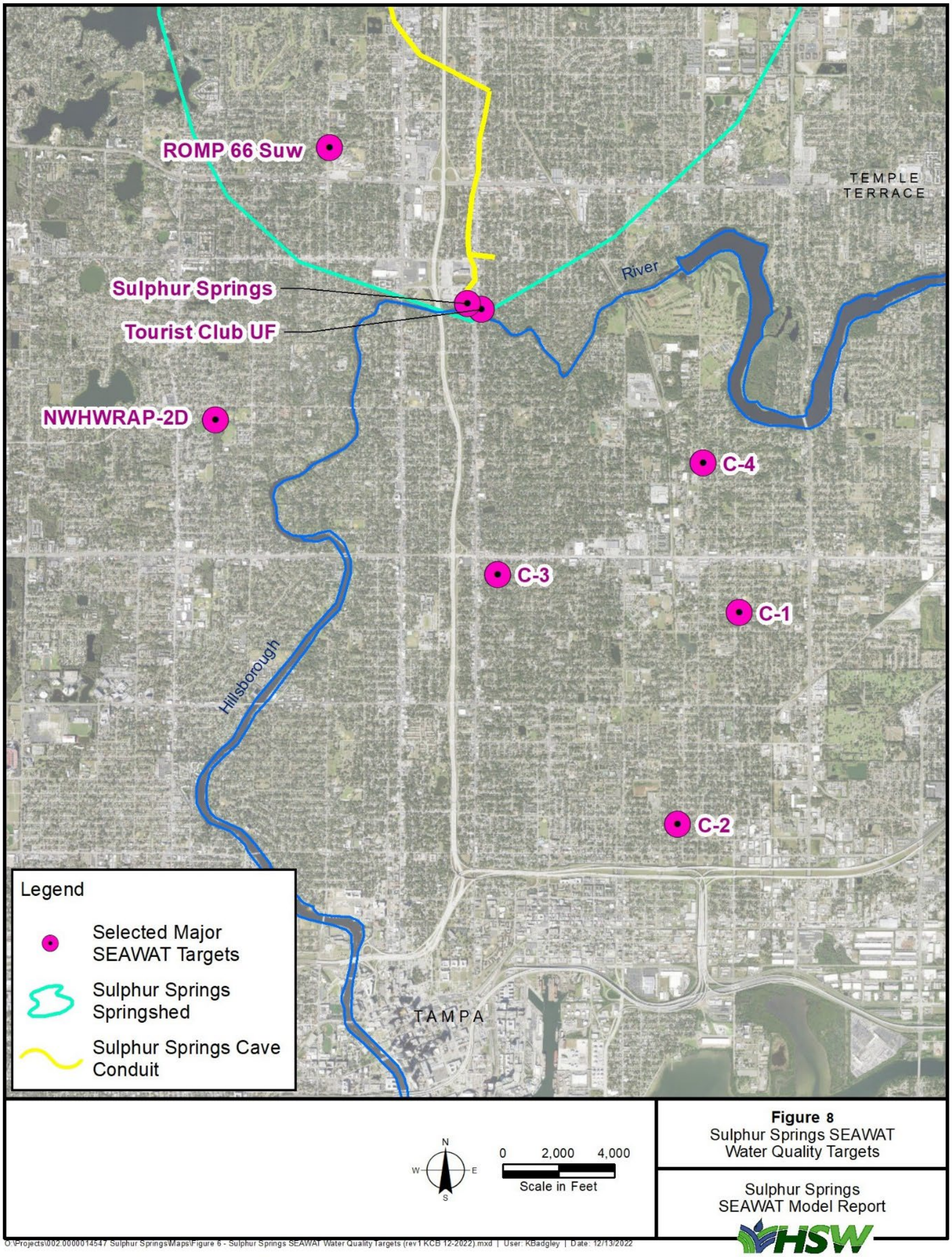


FIGURE 11. SURFICIAL AQUIFER WATER LEVEL TARGET ERRORS.

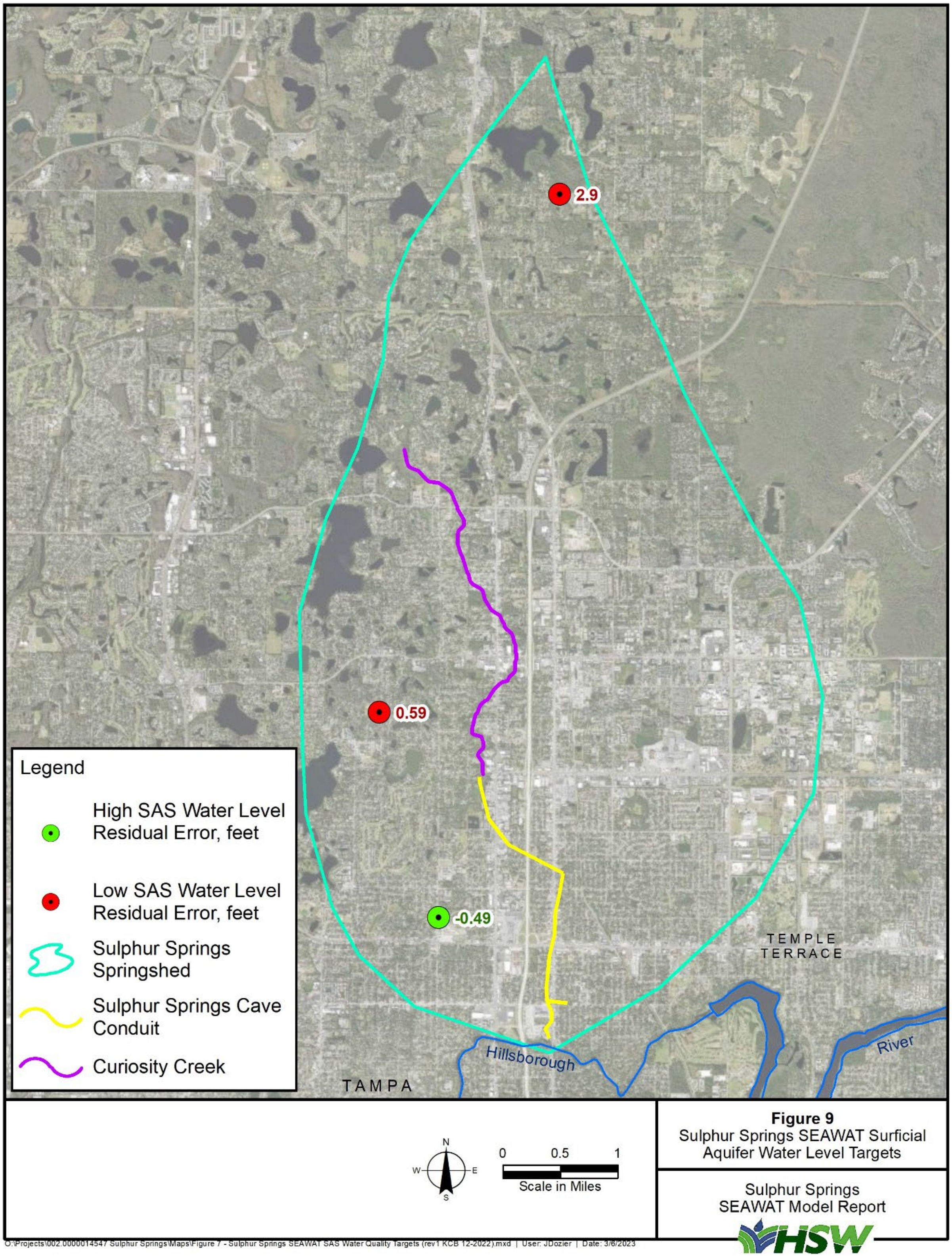


FIGURE 12. UPPER FLORIDAN AQUIFER WATER LEVEL TARGET ERRORS.

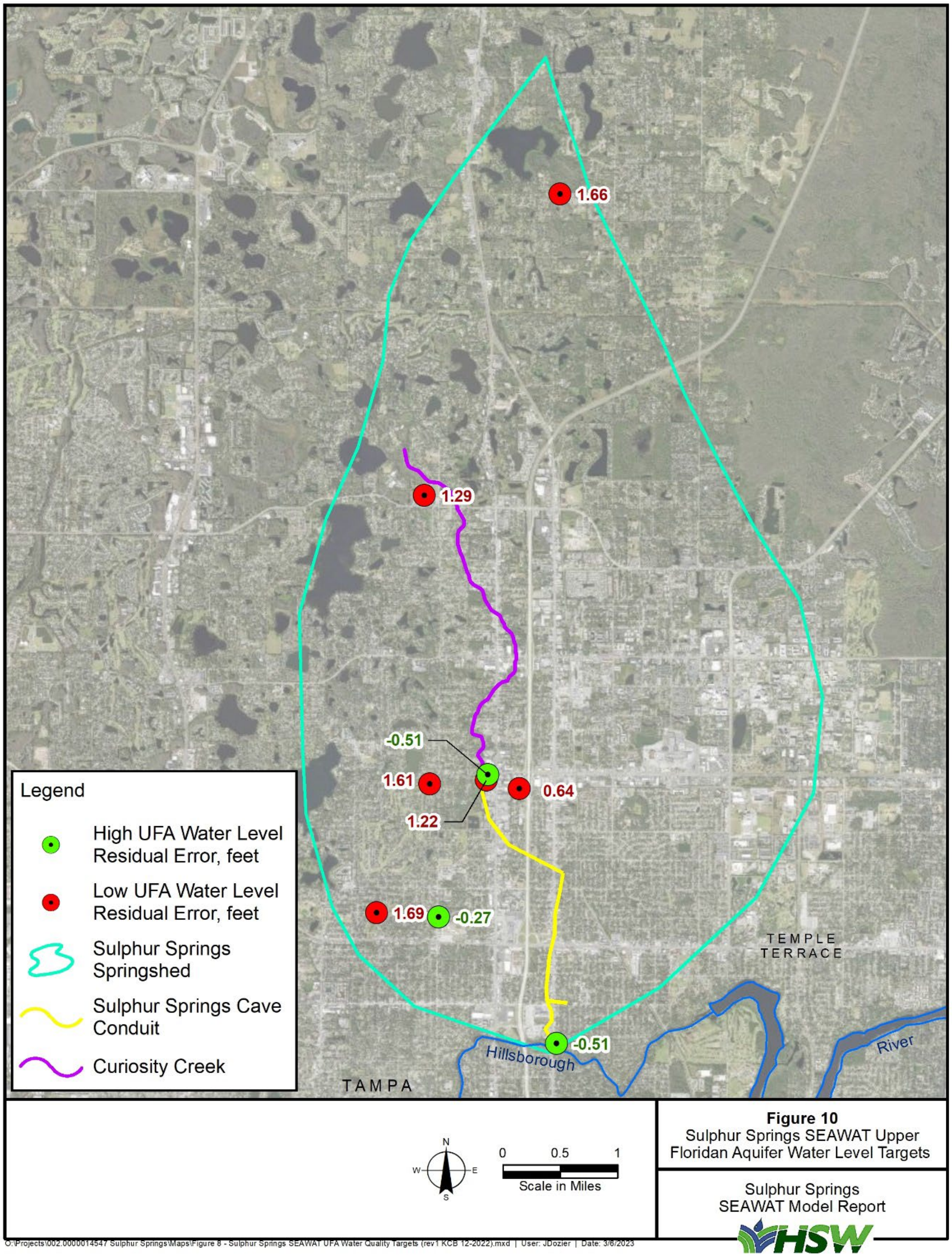


FIGURE 13. SIMULATED AND OBSERVED WATER QUALITY WITH DEPTH AT TAP PHASE I CORES.

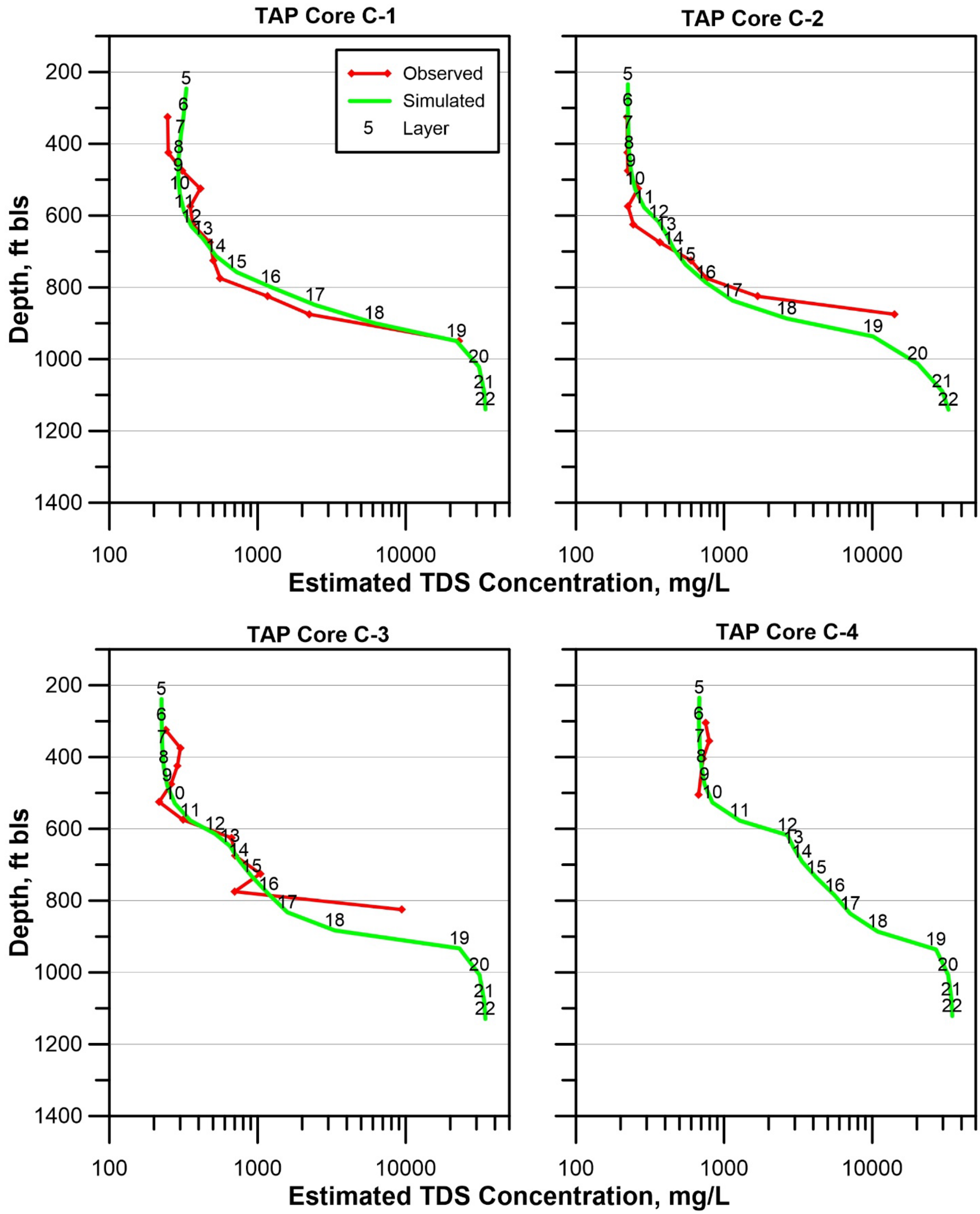


FIGURE 14. SIMULATED AND OBSERVED WATER QUALITY WITH DEPTH AT NWHWRAP-2D.

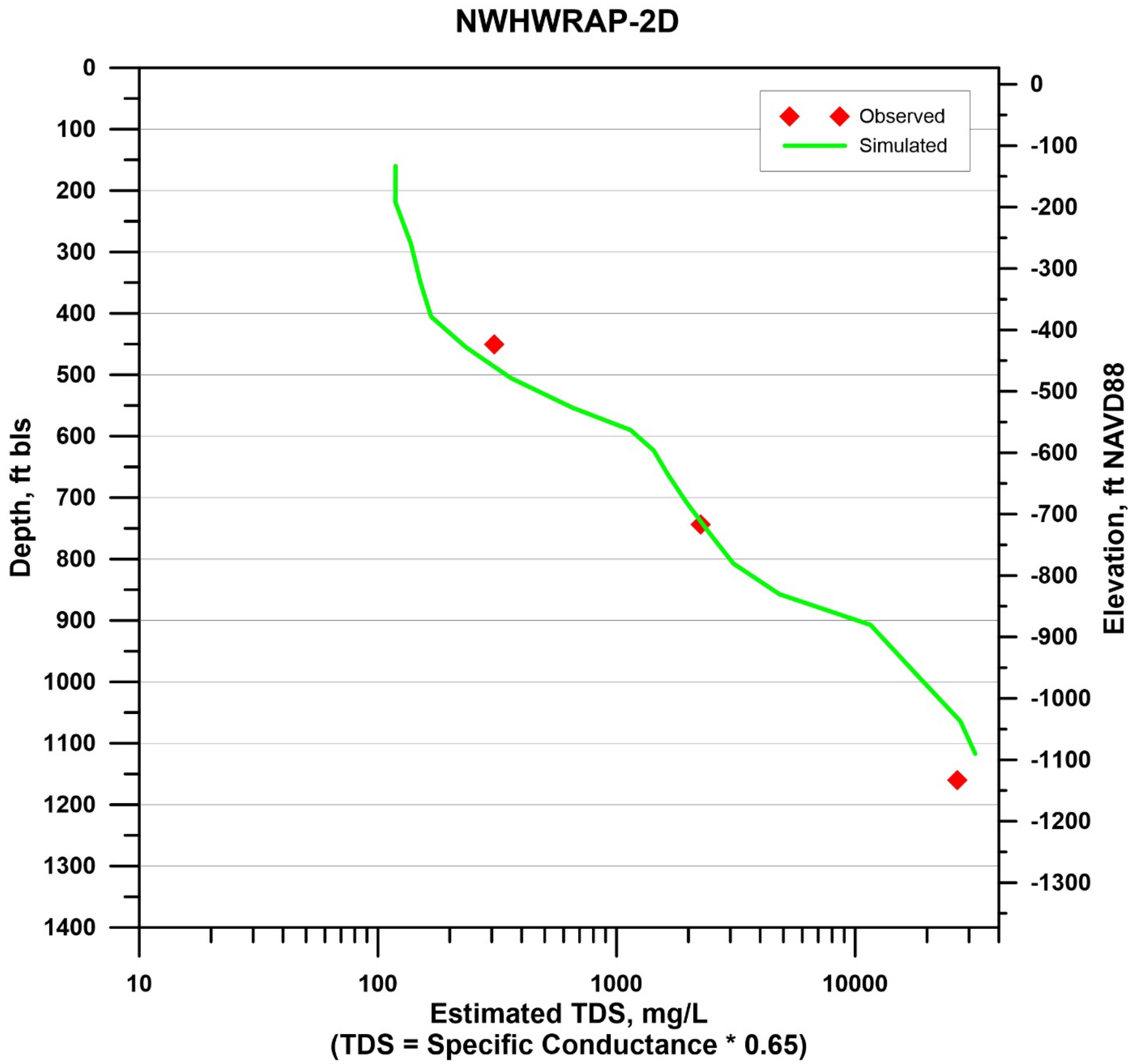


FIGURE 15. SIMULATED AND OBSERVED WATER QUALITY WITH DEPTH AT SULPHUR SPRINGS AND TOURIST CLUB WELL.

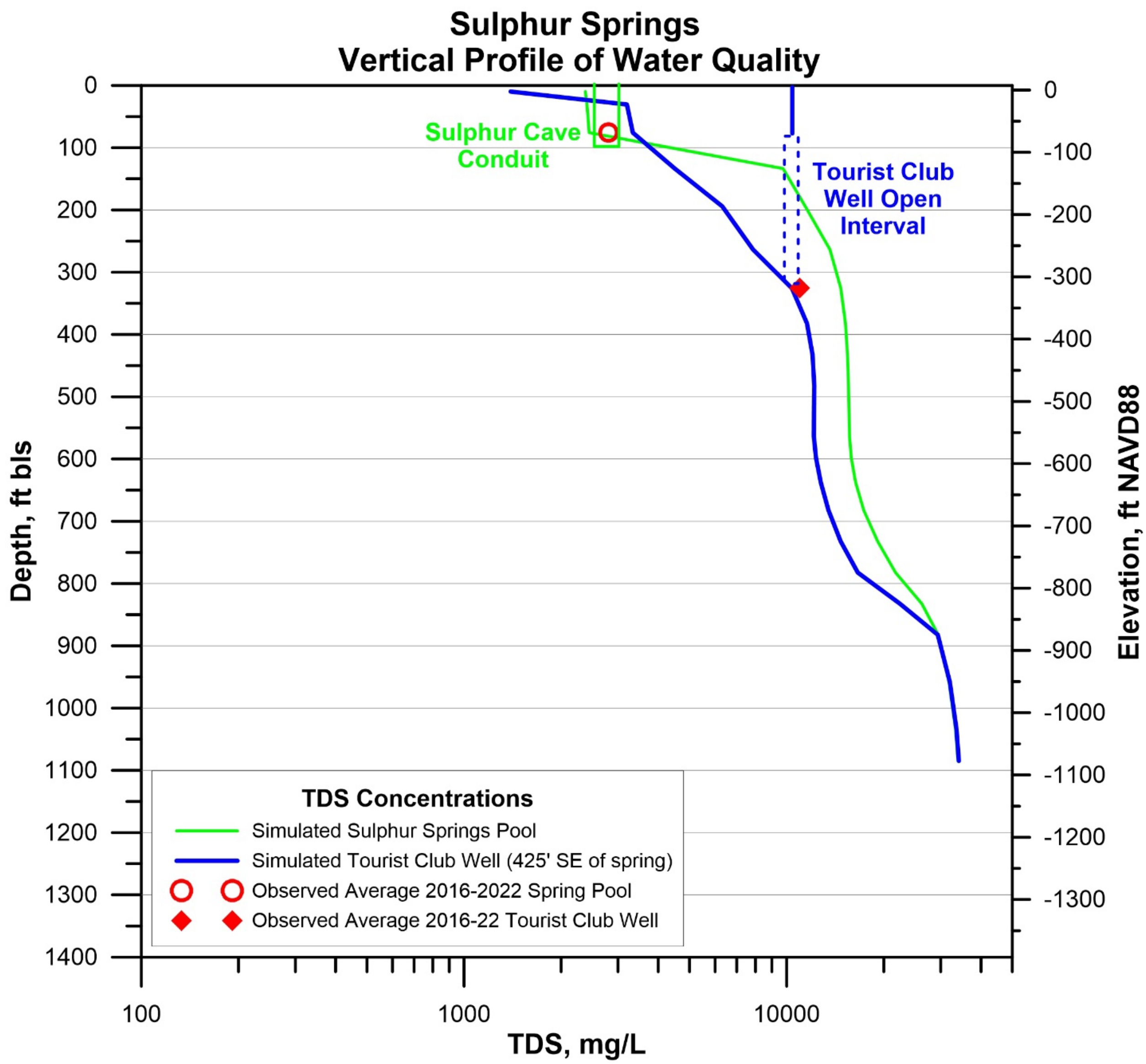


FIGURE 16. COMPARISON OF SULPHUR SPRINGS DISCHARGE AND ROMP 66 UFA WATER LEVELS.

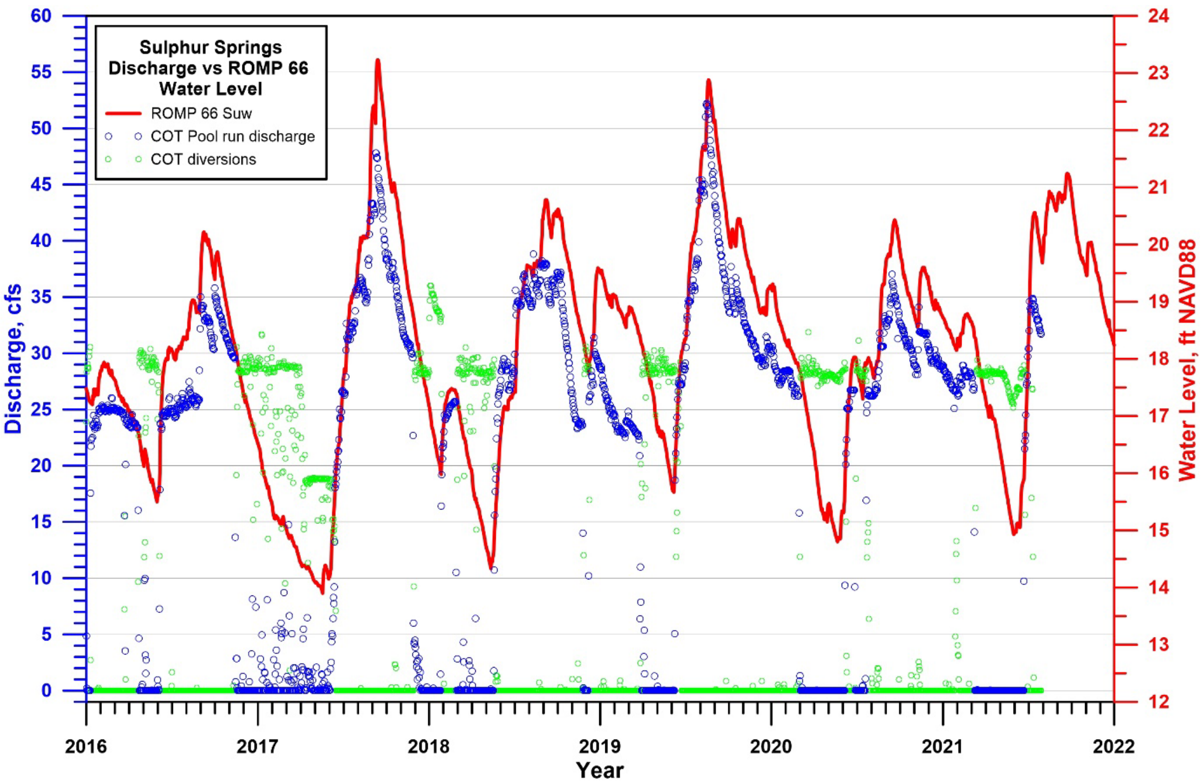


FIGURE 17. SCENARIO 1 BASELINE: SIMULATED 2023-2043 WATER QUALITY WITH CONTINUED CURRENT CONDITIONS.

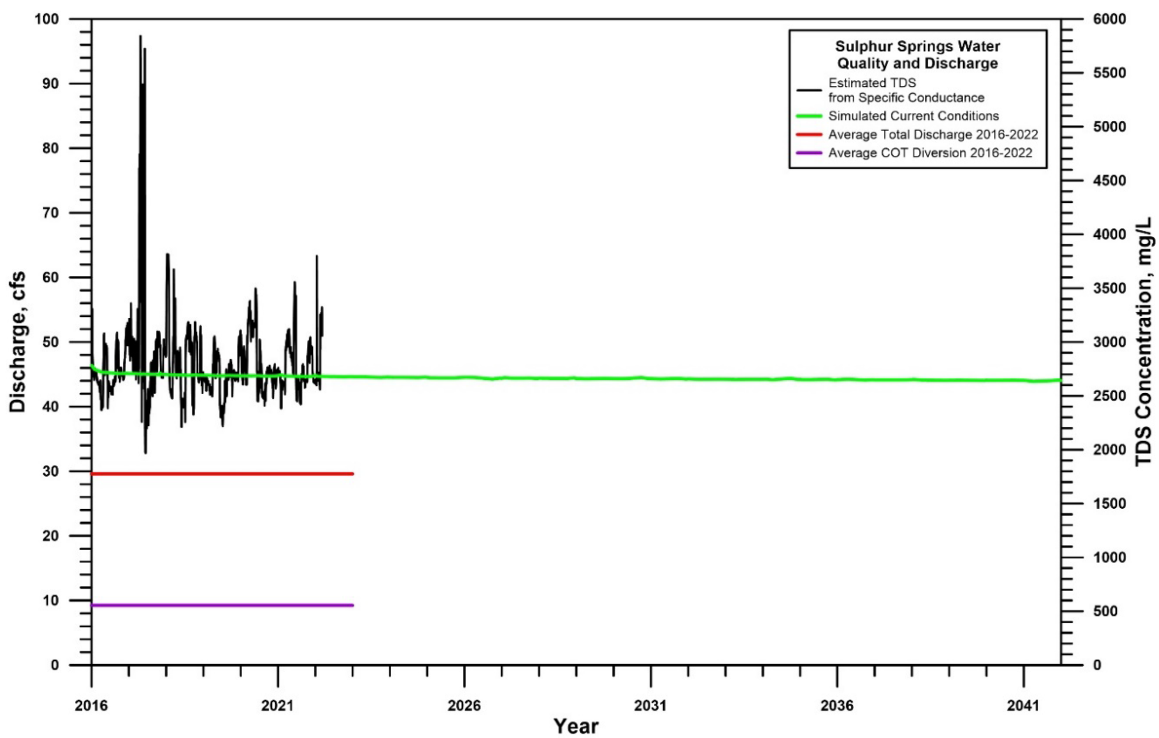


FIGURE 18. SCENARIO 2: SIMULATED 2023-2043 WATER QUALITY WITH NO COT DIVERSIONS.

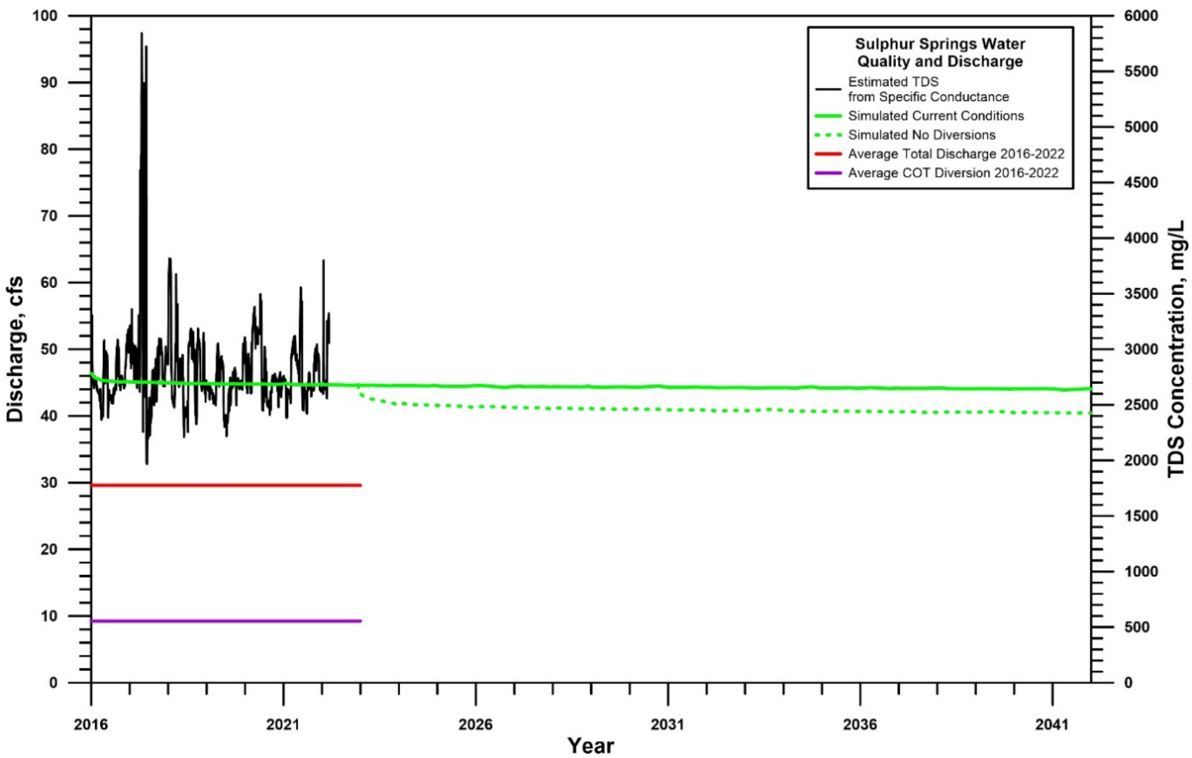


FIGURE 19. SCENARIO 3: SIMULATED 2023-2043 WATER QUALITY WITH CONTINUED CURRENT CONDITIONS PLUS STORMWATER RECHARGE.

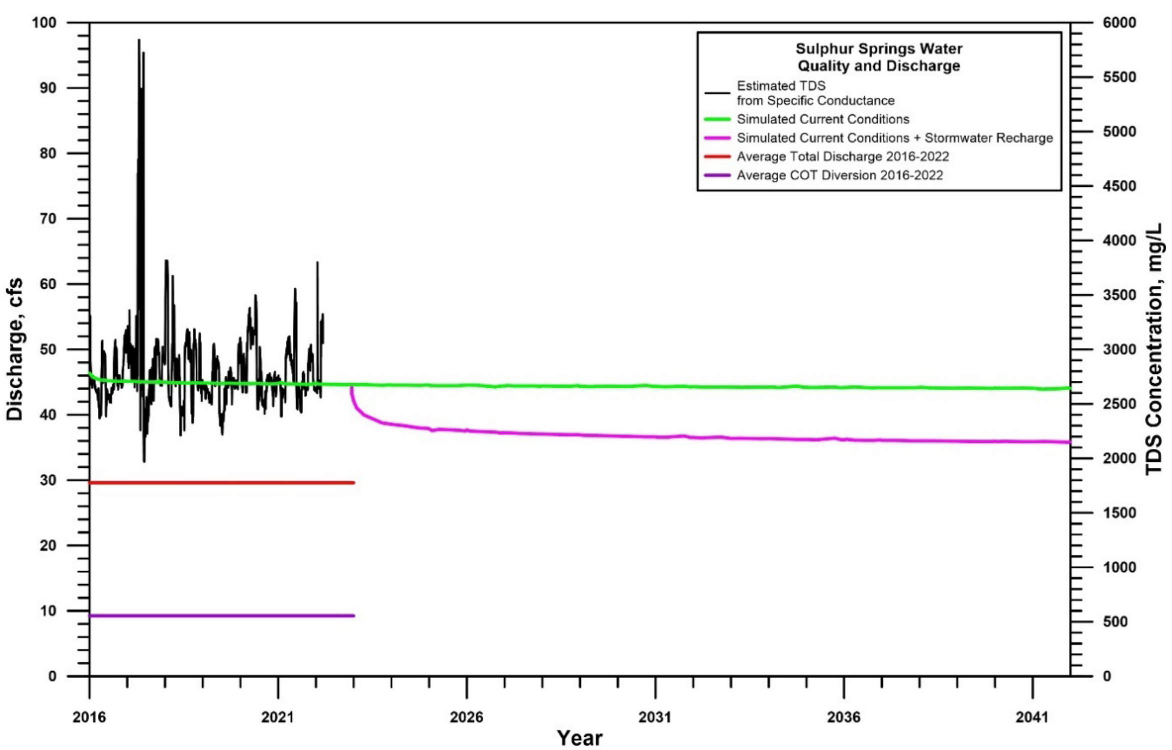


FIGURE 20. SCENARIO 4: SIMULATED 2023-2043 WATER QUALITY WITH NO COT DIVERSIONS PLUS STORMWATER RECHARGE.

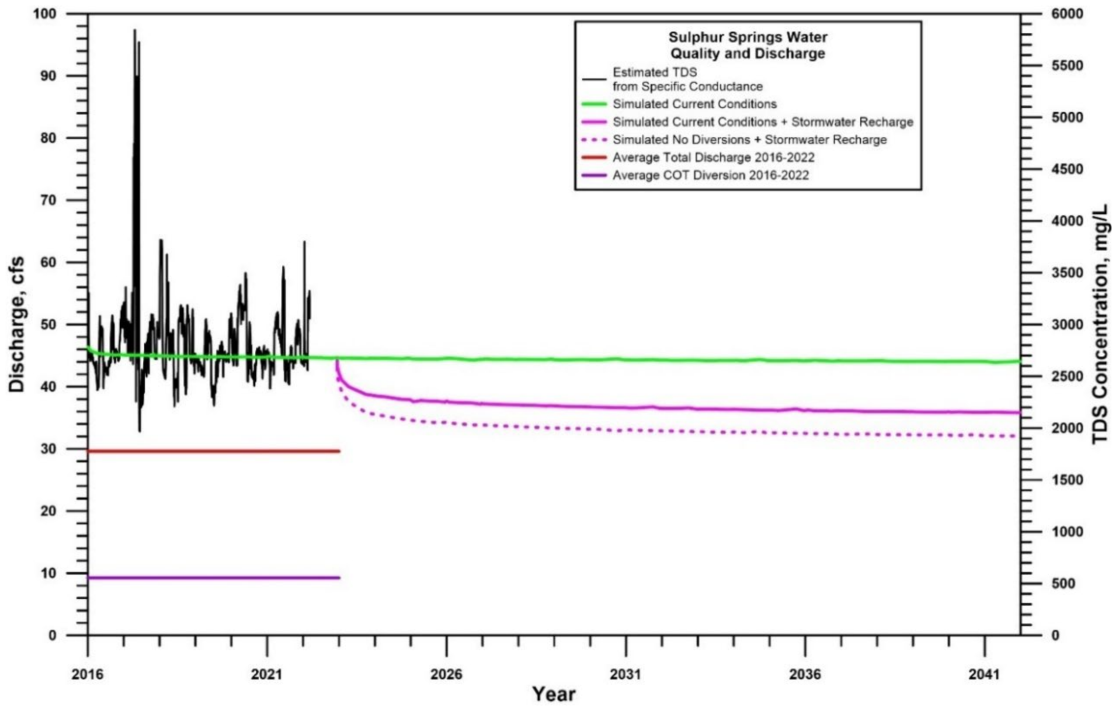


FIGURE 21. SCENARIO 5: SIMULATED 2023-2043 WATER QUALITY WITH CONTINUED CURRENT CONDITIONS PLUS STORMWATER RECHARGE PLUS RECLAIMED RECHARGE.

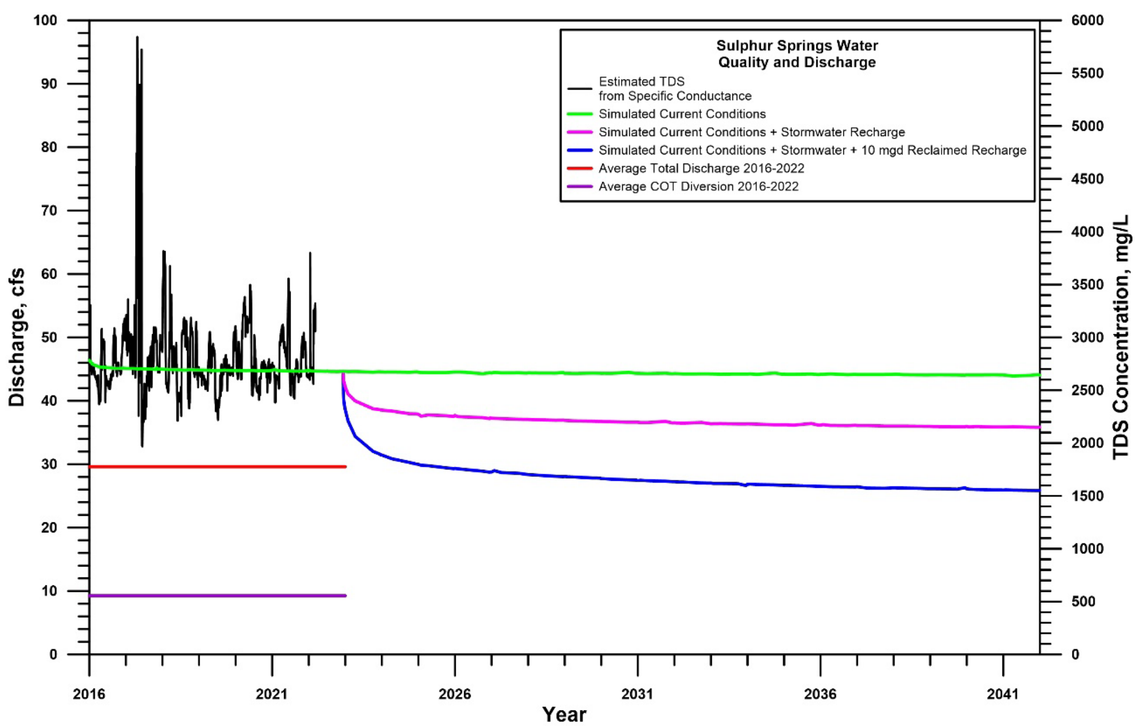
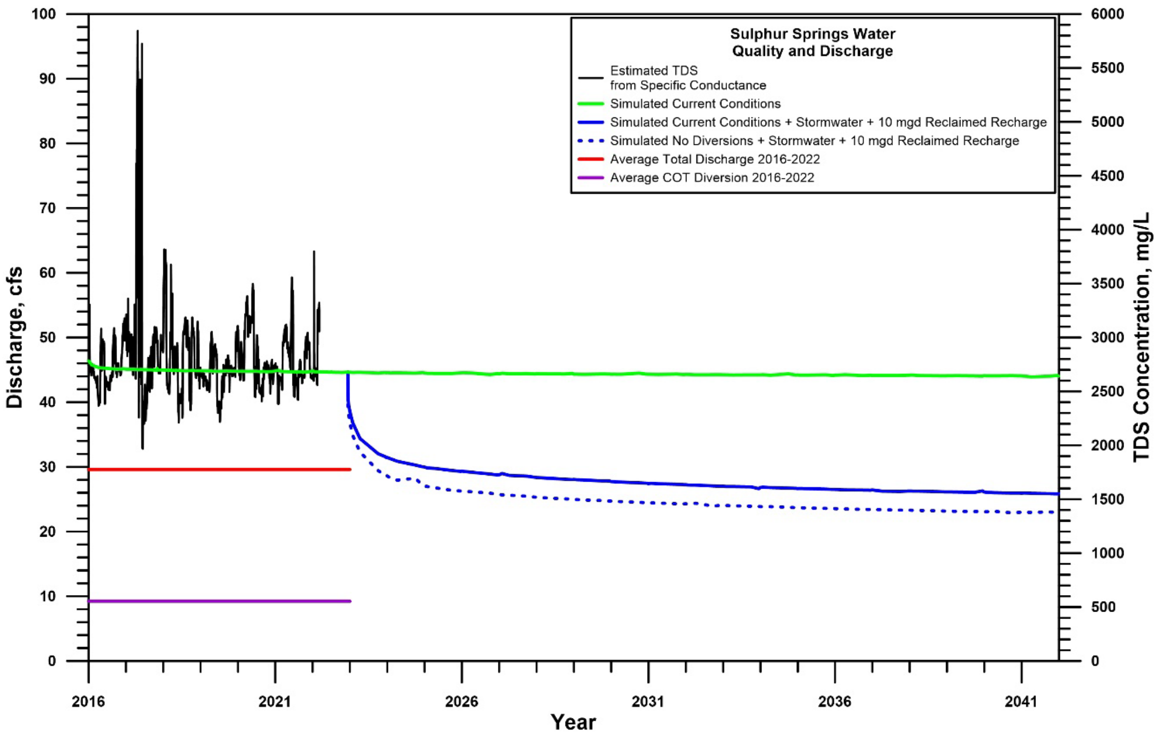


FIGURE 22. SCENARIO 6: SIMULATED 2023-2043 WATER QUALITY WITH NO COT DIVERSIONS PLUS STORMWATER RECHARGE PLUS RECLAIMED RECHARGE.



APPENDIX A

DATE: June 9, 2022

TO: Cathleen Jonas, PG (HSW)
Jim Dozier, PG (HSW)

FROM: Matthew Goolsby, PE, CFM

SUBJECT: Summary of Surface Water Volume Seasonal Estimates
City of Tampa Sulphur Springs Flow Augmentation Study

Applied Sciences Consulting, Inc. (Applied Sciences) is pleased to submit the following Task Memorandum (Memo) to HSW Consulting, LLC. (HSW), dba Verdantas, which summarizes the surface water volume estimates performed under Task 1, Model Refinement, for the City of Tampa (Owner) Sulphur Springs Flow Augmentation Study (Study). Please note that the findings presented in this Memo are preliminary estimates commensurate with the level of effort requested by the Owner for this effort. These findings and methods will be further refined and validated in future tasks.

I. Project Location and General Description

The purpose of this Study is to investigate the feasibility of routing excess surface water from Curiosity Creek during high surface water flow events, options to store and treat these flows, and mechanisms to reduce salinity and increase flows to Sulphur Springs. Secondary assessments include the potential for reducing flooding at Ewanowski Springs and the improvement of stormwater quality. Ultimately, this Study's findings will be used to assess the resource benefit in relation to the Owner's Purify Usable Resources for the Environment (PURE) project. The general location of the Project is shown on the attached map (Figure 1).

In summary, the intent of the Project would be to:

1. Provide additional freshwater flows to mitigate salinity increases in Sulphur Springs;
2. Eliminate Sulphur Springs as a Lower Hillsborough River minimum flow recovery source;
3. Reduce flooding at Ewanowski Springs;
4. Improve surface water quality, including the Sulphur Springs water quality.

II. Task Summary

Task 1 Model Refinement called for a limited analysis regarding the surface water characteristics and volume available from Curiosity Creek to augment Sulphur Springs. This task requires the SEAWAT model to be updated and modified to allow for better resolution around the Sulphur Springs area and to perform specific scenarios involving surface water augmentation. To perform these scenarios, HSW requested three specific estimated values from Applied Sciences to perform an initial evaluation of project feasibility. The SEAWAT model requires seasonal estimates of surface water volume. These volumes are requested in the wet and dry season average daily flow (ADF). Additionally, the SEAWAT model requires salinity values in total dissolved solids (TDS).

Data Collection and Review

As part of the data collection effort, Applied Sciences acquired the Hillsborough County 2020 Curiosity Creek Watershed Model, which was updated to incorporate the latest LiDAR (2018) and areas of new development. This watershed model is developed for event-based rainfall events ranging in duration from 1-day to 5-day. Applied Sciences also collected the latest North Tampa Closed Basins (NTCB) model, which is adjacent to the Curiosity Creek Watershed and includes sinks that have historical sub-surface connections to Sulphur Springs.

In future study phases this model will be integrated with the North Tampa Closed Basins (NTCB) model and modified to allow for continuous simulation to evaluate annual and seasonal surface water availability and feasibility of various alternatives.

Other relevant data collection tasks included collecting surface water and groundwater gages around the Curiosity Creek and Blue Sink area, and reviewing past studies for pertinent information regarding surface water volumes, flows, and water quality characteristics. The September 2009 Blue Sink Pumping Test No. 2 Report, performed by the South West Florida Water Management District (SWFWMD) provided water quality characteristics at Blue Sink. United States Geological Survey (USGS) gage number 280311082274200 (Ewanowski Spring) provided some understanding of base stream flow through the downstream end of Curiosity Creek. Rainfall data from Station 19436: Hillsborough River at Sulphur Springs provides historical annual rainfall patterns. USGS evapotranspiration (ET) data was collected between 2000 and 2017 to understand typical Reference and actual ET patterns.

Surface Water Volume Analysis

In order to estimate wet season and dry season ADF without developing a continuous simulation model, applied sciences first looked to the Curiosity Creek watershed model to obtain the drainage area to the Blue Sink and F-100C Pond. To accomplish this effort, Applied Sciences selected the model catchments that had direct contributing flows to the Curiosity Creek system during the mean annual (2.33-year recurrence) event. The mean annual event corresponds to 4.5 inches of rainfall over a 24-hour period. This means any portions of the watershed that are closed basins during a mean annual event, or are located downstream of the F-100C Pond were excluded from the watershed area. Exhibit 1 shows the catchments that are excluded (colored grey) or included (clear with black border). The mean annual event was also used as a reference for upper limit expected flows to F-100C Pond. The mean annual event produces a peak flow rate of 89 MGD and an average flow of 25.2 MGD over the entire model simulation (58 hours). Using trend fitting, the 1-year recurrence interval (3.1 inch 24-hour event) has an average MGD of 19.8 MGD.

Based on the drainage area selection approach listed above the drainage area to F-100C Pond is 1,595 acres. Using the rainfall data from station 19436, the average annual rainfall is 57 inches. According to SWFWMD 62 percent of the rainfall occurs in the wet season, which occurs between June and September.

Regarding hydrologic conditions, much of the contributing area is hydrologic group A, well drained, soils. This means that much of the rainfall has the propensity to infiltrate rather than continue as surface runoff. With that said, much of the contributing area is developed, which decreases the ability for infiltration and increases the runoff excess amount into Curiosity Creek. The Curiosity Creek watershed hydrologic approach was the TR-55 Curve Number (CN) method. This method produces reasonable results for single events, but is not considered reliable for continuous simulation. Additionally, some of the rainfall that infiltrates will eventually contribute to Curiosity Creek flow through groundwater transport. Also, when accounting for ET losses, a portion of the water loss is from soil moisture and shallow water tables. Therefore, for the purposes of this analysis infiltration is assumed to be accounted for within ET values as to be conservative and not double count water losses. Based on measured ET data from the USGS a reasonable estimate for wet season ET is 4.5 millimeters per day, whereas dry season ET is approximately 1.75 millimeters per day. The annual total comes out to about 973 millimeters, or 38 inches, which is typical for west-central Florida.

Additionally, there is some consideration to base flow from areas along Curiosity Creek, such as Ewanowski Spring. Using the stream flow data from USGS and some approximations, it is estimated that the average baseflow during the wet season is approximately 2.5 cfs, whereas the dry season average is closer to 1 cfs.

By applying these variables, the estimated wet season average daily surface water volume available is 7.38 MGD and the estimated average daily dry season surface water volume available is 1.94 MGD. Curve fitting the Curiosity Creek Model results to the wet season highest month produces an average flow of approximately 8.5 MGD, so these estimates are in line with the existing model. The average daily event produces 3.75 MGD, which is in line with the average annual daily flow estimate of 3.56 MGD.

It should be made aware that these estimates do not take into account hydrogeological conditions at Blue Sink, where water could be lost and/or recharged as discussed in the 2009 SWFWMD Blue Sink Pumping Study. A more detailed water budgeting approach will take place in future phases to verify these results. This evaluation only considered flows directly connected to the Blue Sink Area and F-100C Pond. Consideration to supplementing volume from other areas into the F-100C Pond could also be evaluated, but would require pumping and complex operations.

Surface Water Quality Analysis

In addition to the wet season and dry season average daily surface water volume available, the SEAWAT model requires a TDS value. This value is critical to determining if the surface water will be a beneficial resource for the Sulphur Springs augmentation. The 2009 SWFWMD study indicated that Blue Sink had a conductivity value of 330-400 microSiemens per centimeter, which approximately converts to a TDS of 250 ppm and indicates highly fresh water. There are additional laboratory analysis results for various constituents at Blue Sink that will assist with feasibility of alternatives, should consideration to permittability during the alternatives analysis be required. These include nutrients (nitrogen and phosphorus), total suspended solids, volatile suspended solids, color, and turbidity.

Field measurements were collected on April 14, 2022 at three locations (Exhibit 3). The sampling reports are included on Exhibits 4-6. These parameters included pH, specific conductance, temperature, Dissolved Oxygen, and turbidity. Notes covering conditions, observations, and other details were collected in addition to field photographs. The specific conductance at all three locations were within 209 to 213 microSiemens per centimeter, which converts to a TDS of approximately 135 ppm. There have not been enough measurements to estimate seasonality with the salinity, but it is expected that the TDS would not fluctuate significantly enough to impact the feasibility study.

III. Future Phases

The second task of this Project will be to expand the Curiosity Creek watershed model to integrate with the NTCB model and modify the model to perform continuous simulations in order to better estimate surface water availability. This model will then be applied to run alternative scenarios to evaluate feasibility of surface water augmentation and verification of no adverse impacts. The model will also be applied to provide pump sizing to handle peak flows. Additional work involving water quality, feasibility, and cost -effectiveness will be performed.

EXHIBITS

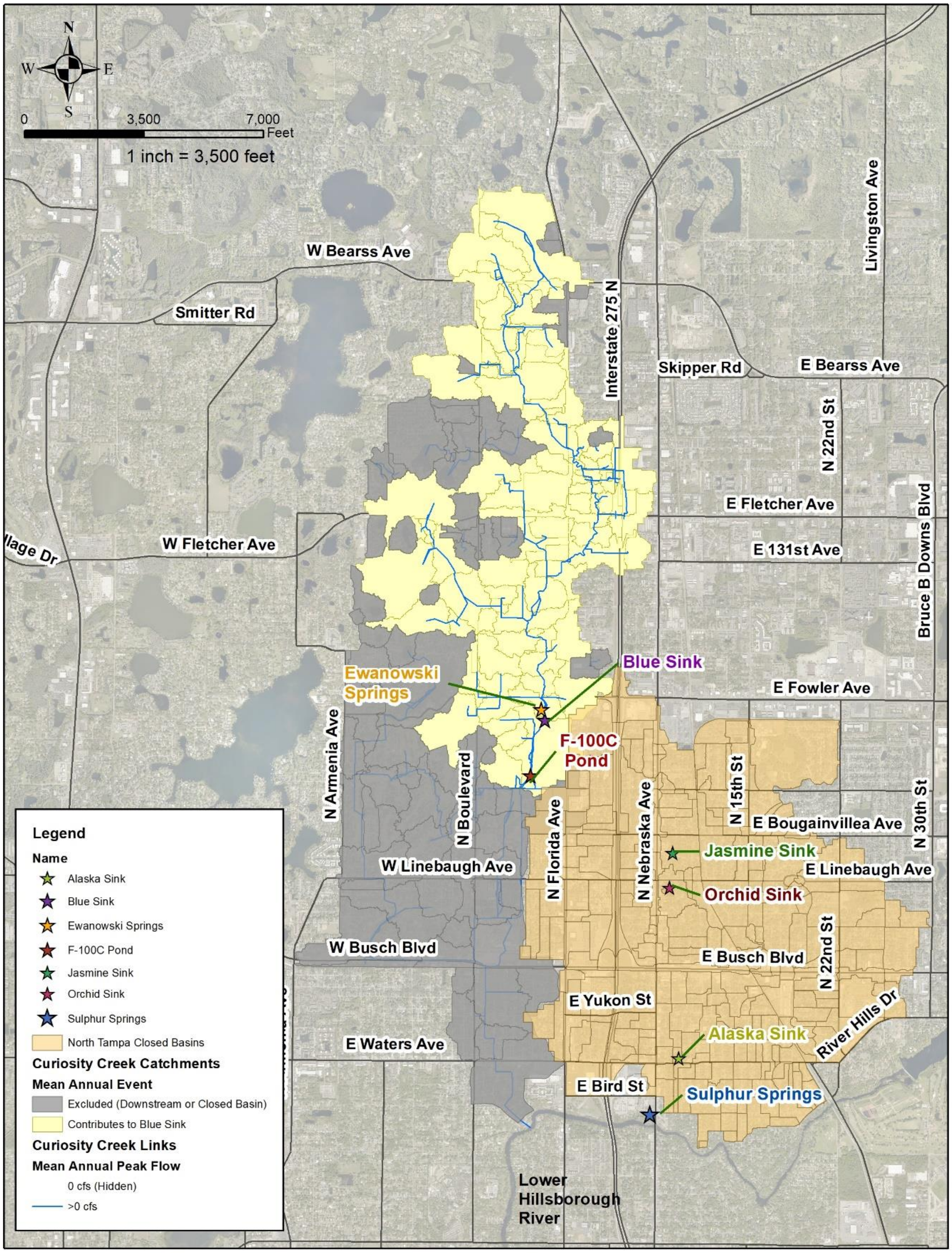


Exhibit 1 Curiosity Creek Watershed with Mean Annual Flows

Watershed Stats	Total	unit	comment
Annual Rainfall	57	inches	Avg. Rainfall POR Station 19436: Hillsborough River at Sulphur Springs
Watershed Area	1,595	acres	Curiosity Creek Model (Catchments w/ Flow to Sink during MA event)
Wet Season			
Duration	4	months	June-September
Rainfall	35.34	inches	SWFWMD: 62% of rainfall occurs in Wet Season
Water Loss (ET and Infiltration)	19.16	inches	Estimates 4 mm/day ET in the wet season
Runoff Volume	2151.0	ac-ft	Runoff depth minus ET across watershed
Base Flow (Springs)	1.62	MGD	Assume 2.5 CFS
Wet Season ADF	**7.38**	**MGD**	
Dry Season Rainfall			
Duration	8	months	October-May
Rainfall	21.66	inches	SWFWMD: 38% of rainfall occurs in Dry Season
Water Loss (ET and Infiltration)	14.37	inches	Estimates 1.5 mm/day ET in the dry season
Runoff Volume	969.1	ac-ft	
Base Flow (Springs)	0.65	MGD	Assume 1 CFS
Dry Season ADF	**1.94**	**MGD**	
Average Annual Daily Flow	3.75	MGD	

Exhibit 2 Curiosity Creek Watershed Surface Water Availability Estimates

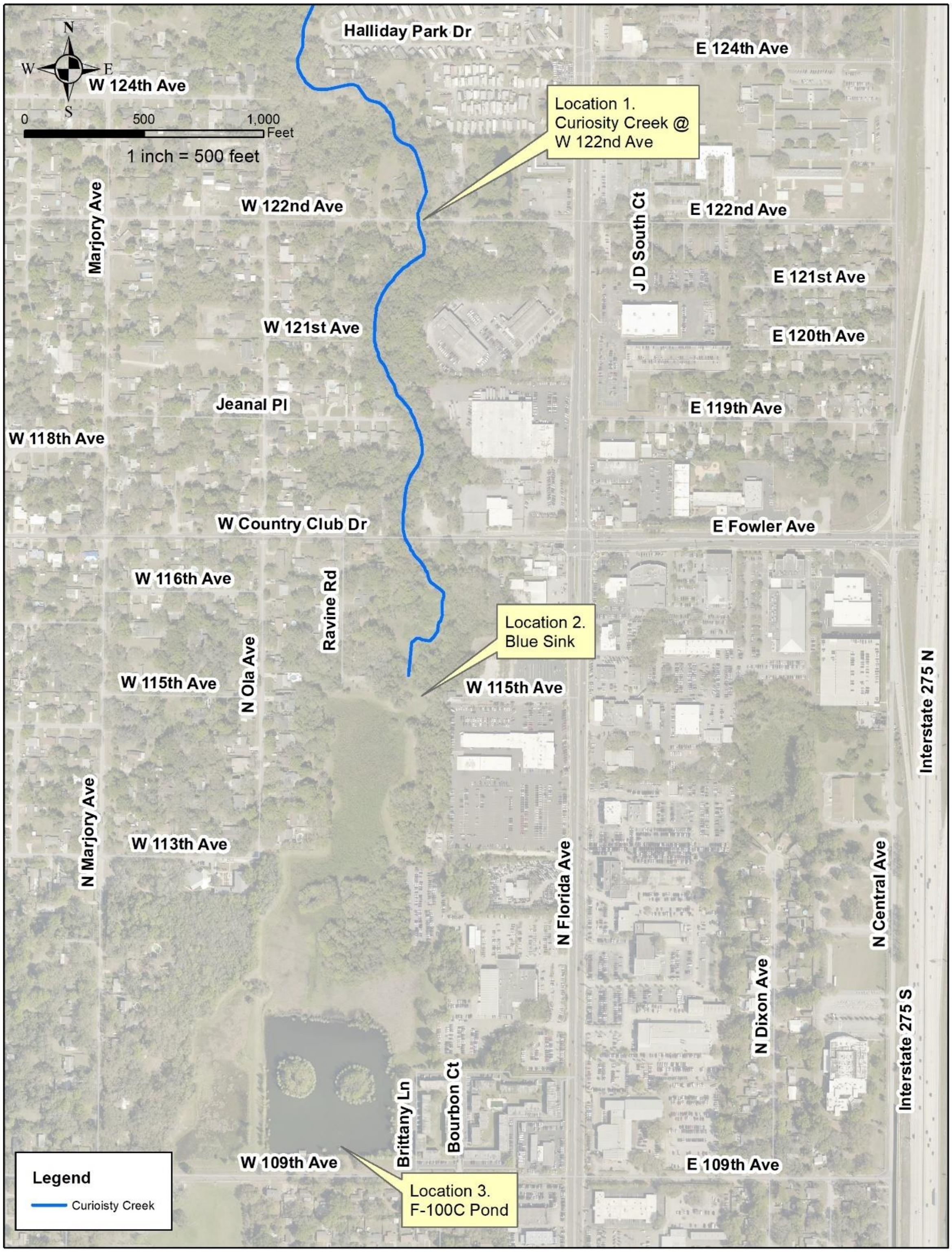


Exhibit 3 Sampling Locations

SAMPLE EVENT FIELD FORM

Site No.: 1	Event Date / Time: 4/14/22 0800
Stream / Location: Curiosity Creek @ 122ND St	Weather Conditions: Overcast Air Temp.: 72 °F / °C
ASCI Personnel: Hunter	Stream Depth: 0.5'
Sample Method (Dip, Van Dorn, Other):	Sample Depth:

Observations: Clear, tannic

Physical Characteristics

Field Parameters (Units)	Result / Comments
pH (SU)	7.35
Specific Conductance (uS/cm)	213
Temperature (ºC)	21.86
Dissolved Oxygen (mg/L)	6.36
D.O Saturation (%)	72.6%
Turbidity (NTU)	0.56
Observed Flow	Low → Moderate

Maintenance Issues

(Note: Erosion, Overgrowth, Trash / Debris, Sedimentation, Structural Cracking or Failure, etc.)

Additional Comments (Wildlife Observed, Human Activities, etc.):

Alligator Snapping Turtle nearby

Revised 08/2020

APPLIED SCIENCES

Exhibit 4 Sampling Form for Location 1

SAMPLE EVENT FIELD FORM	
Site No.: 2	Event Date / Time: 4/14/22 0700
Stream / Location: Blue Sink	Weather Conditions: Overcast Air Temp.: 70 °F/ °C
ASCI Personnel: H Center	Stream Depth: 1.5' (>150 see staff gage photo)
Sample Method (Dip, Van Dorn, Other):	Sample Depth:
Observations: Batteries in YSI died, went to Curiosity Creek and returned at 900 AM	

Physical Characteristics

Field Parameters (Units)	Result / Comments
pH (SU)	7.27
Specific Conductance (uS/cm)	709
Temperature (°C)	21.77
Dissolved Oxygen (mg/L)	3.18
D.O Saturation (%)	36.3%
Turbidity (NTU)	0.54
Observed Flow	N/A

Maintenance Issues

(Note: Erosion, Overgrowth, Trash / Debris, Sedimentation, Structural Cracking or Failure, etc.)

Water surface covered w/ Lemna/Duckweed

Additional Comments (Wildlife Observed, Human Activities, etc.):

Revised 08/2020

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Exhibit 5 Sampling Form for Location 2

SAMPLE EVENT FIELD FORM	
Site No.: 3	Event Date / Time: 4/14/22 0940
Stream / Location: F100-C Pond @ 109th St	Weather Conditions: Overcast Air Temp.: 75 °F / °C
ASCI Personnel: Hunter	Stream Depth: 1.5
Sample Method (Dip, Van Dorn, Other):	Sample Depth:
Observations: slightly turb, tannic	

Physical Characteristics	
Field Parameters (Units)	**Result / Comments**
pH (SU)	7.54
Specific Conductance (uS/cm)	211
Temperature (°C)	23.77
Dissolved Oxygen (mg/L)	5.27
D.O Saturation (%)	62.3%
Turbidity (NTU)	1.64
Observed Flow	N/A

Maintenance Issues

(Note: Erosion, Overgrowth, Trash / Debris, Sedimentation, Structural Cracking or Failure, etc.)

Trash at outfall

Additional Comments (Wildlife Observed, Human Activities, etc.):

Revised 08/2020

APPLIED SCIENCES

Exhibit 6 Sampling Form for Location 3

PHOTOGRAPHS
SAMPLING APRIL 14, 2022

Location 1. Curiosity Creek @ W 122nd Avenue

Location 1. Curiosity Creek @ W 122nd Avenue

Location 1. Curiosity Creek @ W 122nd Avenue

Location 1. Curiosity Creek @ W 122nd Avenue

Location 2. Blue Sink Area

Location 2. Blue Sink Area

Location 2. Blue Sink Area

Location 2. Blue Sink Area

Location 3. F-100C Pond

Location 3. F-100C Pond

Location 3. F-100C Pond

Location 3. F-100C Pond

Location 3. F-100C Pond