CITY OF HIGH SPRINGS INFILTRATIVE WETLAND PROJECT – COST-EFFECTIVE NUTRIENT REMOVAL FOR SMALLER UTILITIES

Chris Keller, P.E., Wetland Solutions, Inc., Scott Knight, Ph.D., P.E., Wetland Solutions, Inc., Tim Norman, P.E., Mittauer & Associates, Inc.

Introduction

With the availability of recent cost-share funding and legislative changes that will require advanced waste treatment standards (AWT), the City of High Springs has been expanding their wastewater collection system and planning for the necessary improvements and expansion of their wastewater treatment facility (WWTF). As a result, the City will need to expand their WWTF from its existing permitted capacity of 0.24 million gallons per day (MGD) to 0.48 MGD and bring the treatment level to AWT standards. Presently, the City's effluent (about 0.16 MGD) has an average total nitrogen (TN) concentration of about 12 milligrams per liter (mg/L) and is land-applied at a 27-acre spray irrigation site. The City's proximity to multiple springs of the Santa Fe River (Ginnie, Blue, and Poe being the most well-known) and the 2016 passing of Senate Bill 552 (Florida Springs and Aquifer Protection Act) requires substantial reductions in nitrogen loads reaching the aquifer.

In parallel with the plan and schedule to expand the WWTF, the City is currently in the design phase to convert the spray irrigation site to groundwater recharge wetlands as a cost-effective technology to achieve AWT standards, which both dramatically reduces TN loads and maximizes recharge of the surficial and Floridan aquifers. Groundwater recharge wetlands have been demonstrated to provide increased nitrogen removal as compared to other land application methods and return a larger fraction of the applied reclaimed water to the aquifer than spray irrigation. Multiple springs are located within approximately 5 miles of the spray field site. As regional groundwater flows to the northwest, some portion of the nutrient load and flow from the existing spray field site likely contributes to the discharge from one or more of these springs. Maximizing the water quality treatment and recharge volume by converting the spray field site to a recharge wetland system will benefit the region's springs. Implementation of a groundwater recharge wetland system also provides the City with the capability of achieving AWT quality effluent for future and permitted maximum flow rates for a fraction of the cost of alternative treatment methodologies.

Site Description

The location for the groundwater recharge wetland is at the WWTF and sprayfield site located south-southwest of downtown High Springs. The parcel is approximately 156 acres with about 50 acres of the parcel cleared for the access roads, WWTF, treated water storage, and sprayfield (Figure 1). The sprayfield sits in the middle of the parcel with forested buffers on the north, south, and west sides. The current sprayfield extents are set back approximately 500 feet or more from all property boundaries.

Figure 1. High Springs WWTF Property

Site soils have been classified as two types: Lake fine sand and Arredondo fine sand. Both site soils are classified as having slopes in the range of 0 to 5%. Lake fine sand is classified as excessively drained with low moisture-holding capacity, having deep groundwater tables, and with rapid permeability. Arredondo fine sands are also classified as well drained, but unlike Lake fine sands have a lower permeability layer in the subsoil typically below 48 inches deep. Generally, the western portion of the sprayfield is dominated by Lake fine sand and the eastern portion by Arredondo fine sand.

Topographic elevations on the High Springs WWTF parcel range between approximately 40 and 86 feet. The lowest topographic areas on the parcel are associated with sinkholes or other karst collapse features with four prevalent features located on the property. These features are indicative of the karst geology of this region with varying levels of confinement and a high incidence of sinkholes. All of the karst features onsite lie within the coniferous portions of the site with more consistent elevations across the sprayfield, ranging from 62 to 78 feet. Specifically, to the east and west of the cleared sprayfield area, within 100-200 feet, there are prominent karst features that are 16-24 feet deeper than surrounding topography. Geotechnical investigations were undertaken as part of this project to evaluate the potential for karst features within the wetland footprint. The site topography based on 2001 contours is shown in Figure 2.

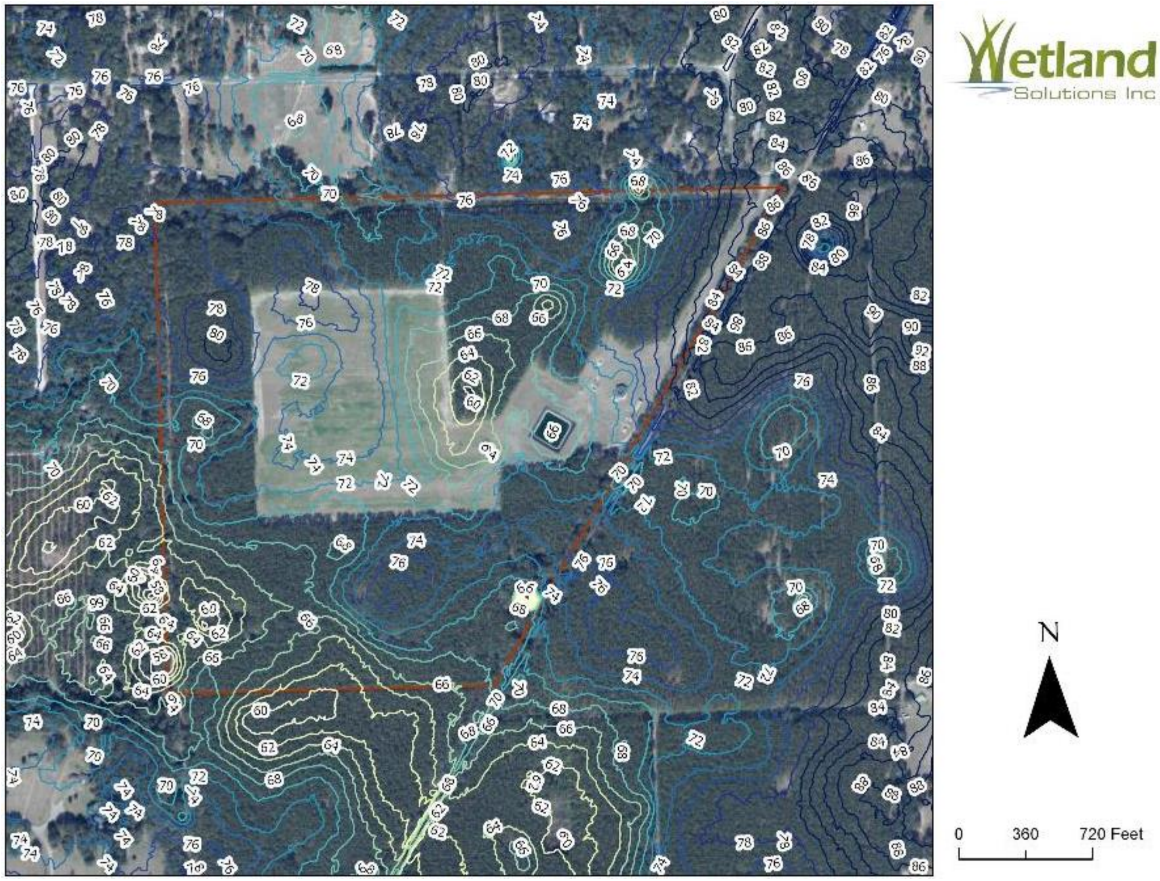

Figure 2. Site Topography

The High Springs parcel is located in an area that is known to have karst features. Because of this expectation, the project team was proactive in acquiring additional geophysical surveying to determine if any particularly problematic subsurface conditions existed on site. A ground-penetrating radar (GPR) geophysical survey was completed for the entire open field area (~20 ac) in late-August 2018 (UES 2018). GPR was used to provide a subsurface view of the project area and was evaluated for the presence of subsurface features that are indicative of sinkhole features. Settings used for the GPR provided information to an estimated depth of between 10 and 20 feet below the land surface. The survey data was evaluated for a variety of anomalies: downwarping, increase in penetration depth, or discontinuities that can be indicative of sinkhole activity (UES 2018). Despite the presence of any anomalies the report highlights that GPR data alone does not guarantee the presence of a sinkhole, or if a sinkhole is present that it is active. This survey identified a total of 71 anomalies that may be indicative of sinkhole activity (Figure 3). Based on regional conditions, it is anticipated that sinkhole activity may occur during project construction and operation. For this reason, a standard repair detail for sinkholes was included in the construction plans and in the operations and maintenance manual. It should be emphasized that the project objective is to recharge highly treated reclaimed water to the aquifer and the formation of sinkholes should be viewed as a temporary and repairable condition that will not impact long-term project function and water resource protection.

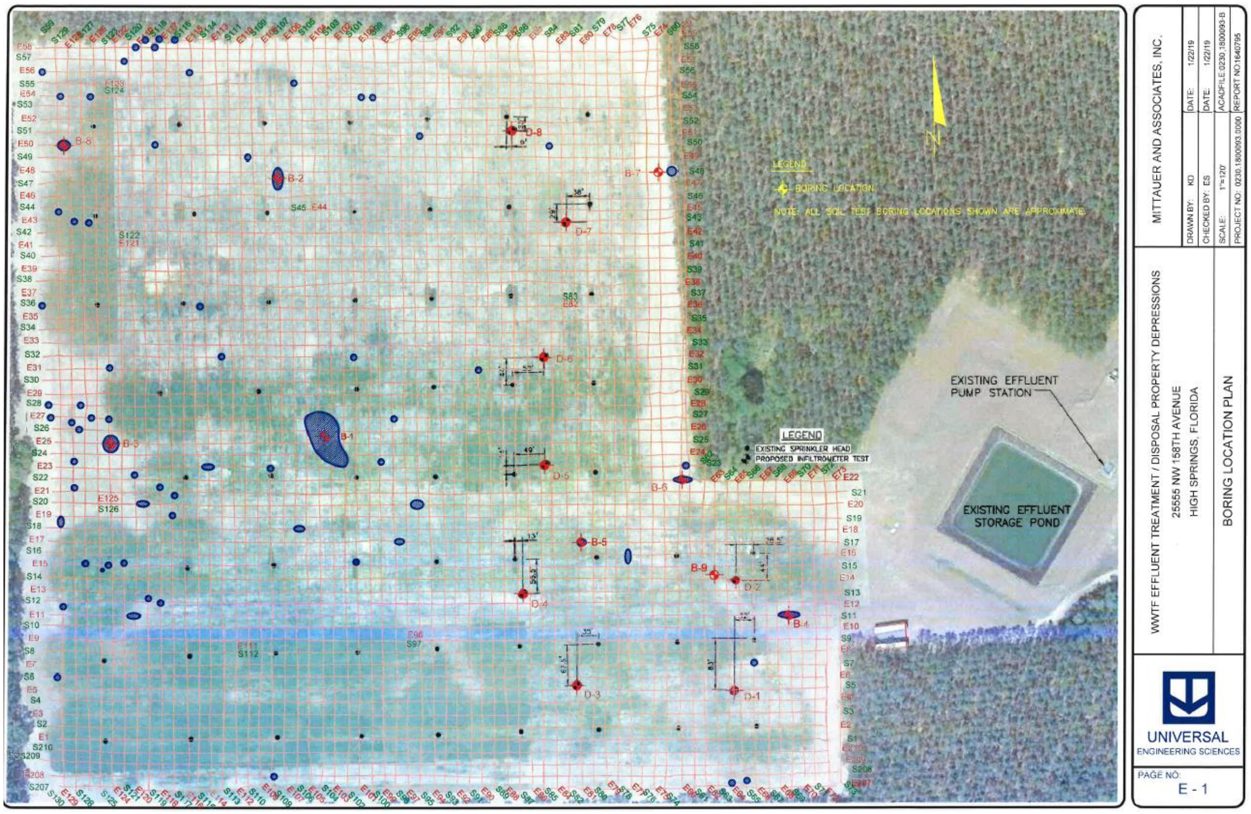

Figure 3. Ground-Penetrating Radar Identified Anomalies (UES 2018)

The groundwater potentiometric surface is a topographic map of estimated groundwater levels in the absence of confinement. This means that the potentiometric surface can exceed the ground surface in areas with confinement. In areas where the potentiometric surface is greater than the ground surface in the absence of a confining unit this groundwater pressure is often realized as artesian spring flow. Because this site is dominated by unconfined conditions the potentiometric surface is below the ground surface at this site but expresses at numerous springs and karst windows in the area (e.g. Blue Springs, Poe Springs, Ginnie Springs, etc.). The September 2016, potentiometric surface was estimated at 31-32 feet in the vicinity of the project site meaning that there are about 31-47 feet of occasionally saturated zone between the ground surface and the top of the Floridan aquifer. The potentiometric surface in this area is sloped towards the Santa Fe River and springs along the river. The potentiometric surface for September 2016 is shown in Figure 4.

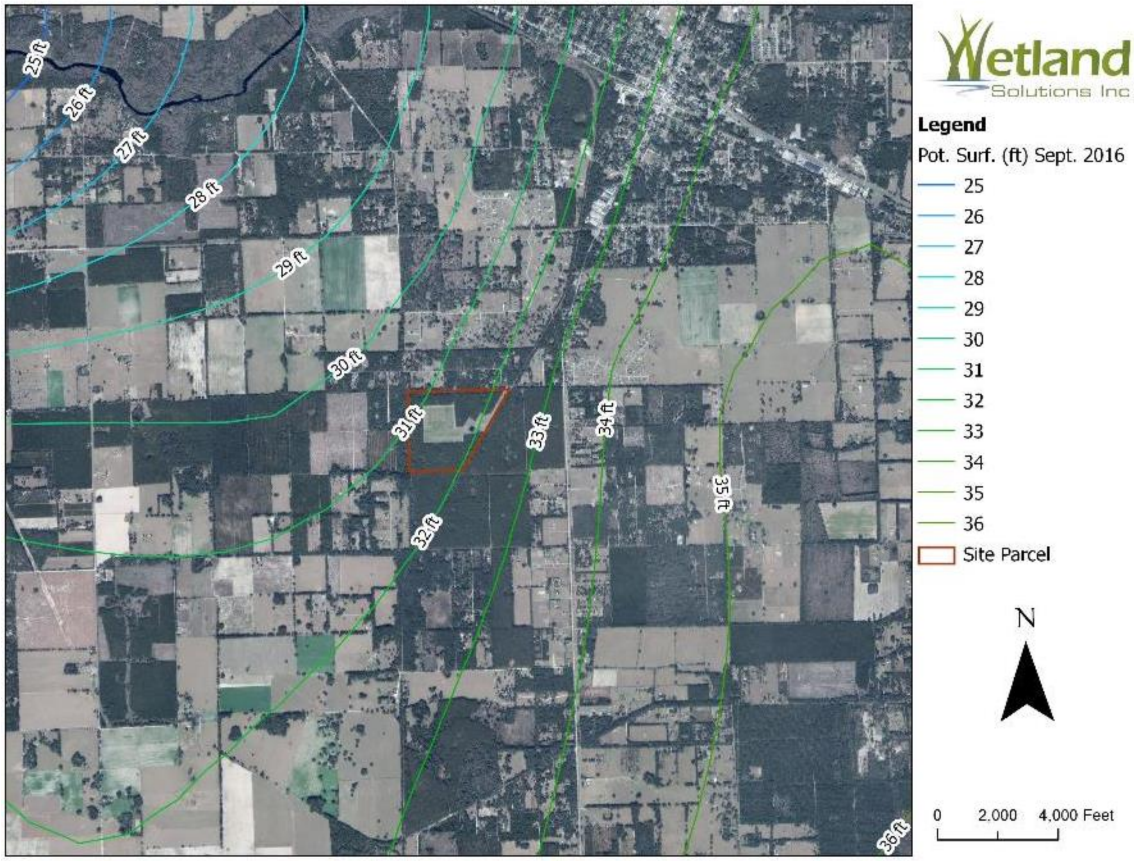

Figure 4. Upper Floridan Aquifer Potentiometric Surface – September 2016

Historical Performance

The High Springs WWTF currently discharges to a slow-rate land application site through a series of four zones of spray heads. Permitted flow for the facility is 0.240 MGD as an annual average daily flow. During the past year, monthly flows averaged 0.163 MGD. The time series of treated flows at the facility are shown in Figure 5 and ranged from approximately 0.13 to 0.18 MGD. Future flows are expected to increase as the wastewater treatment plant service area is expanded and the number of connections increase. A future phase of the treatment plant is expected to double treatment capacity with a commensurate increase in disposal capacity through a series of additional wetland cells.

Effluent is currently monitored only for total nitrogen, but prior to March 2013 was only monitored for nitrate. Monthly data are collected and submitted in the DMRs to FDEP. These data show that the total nitrogen varied between less than 5 to as much as 26 mg/L between April 2013 and August 2018, with an average of 7.2 mg/L during the past year (excluding two reported 0 values). Based on the nitrate data before March 2013 and an assumption of similar operations it appears that the effluent is nearly fully nitrified and most of the nitrogen is in the form of nitrate in the effluent. The time series of nitrogen is shown in Figure 6. This figure shows a generally decreasing trend in nitrogen during the past two years.

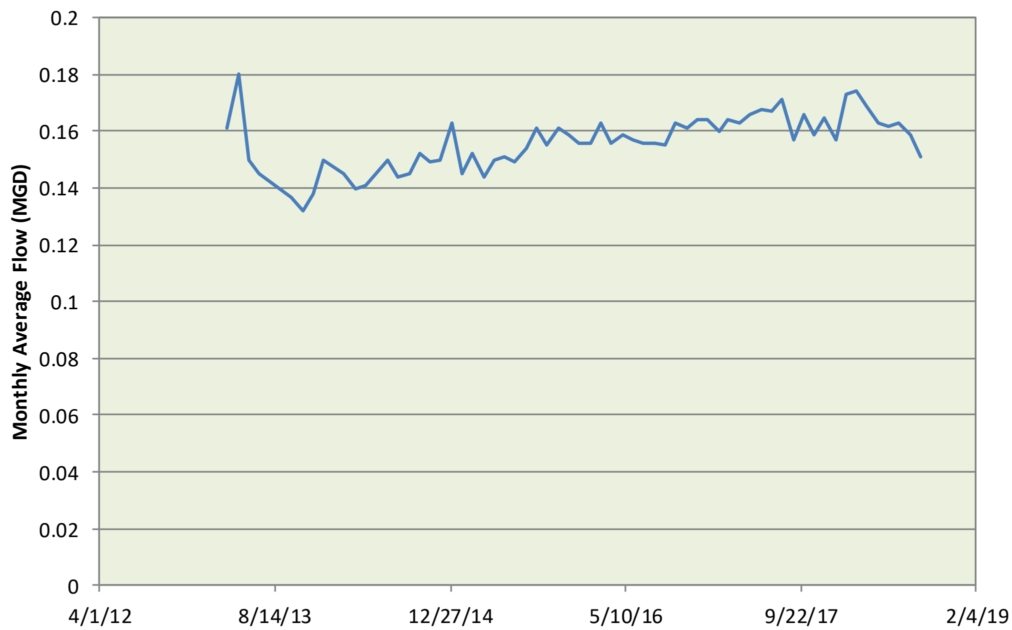

Figure 5. Wastewater Flows Delivered to the Sprayfield

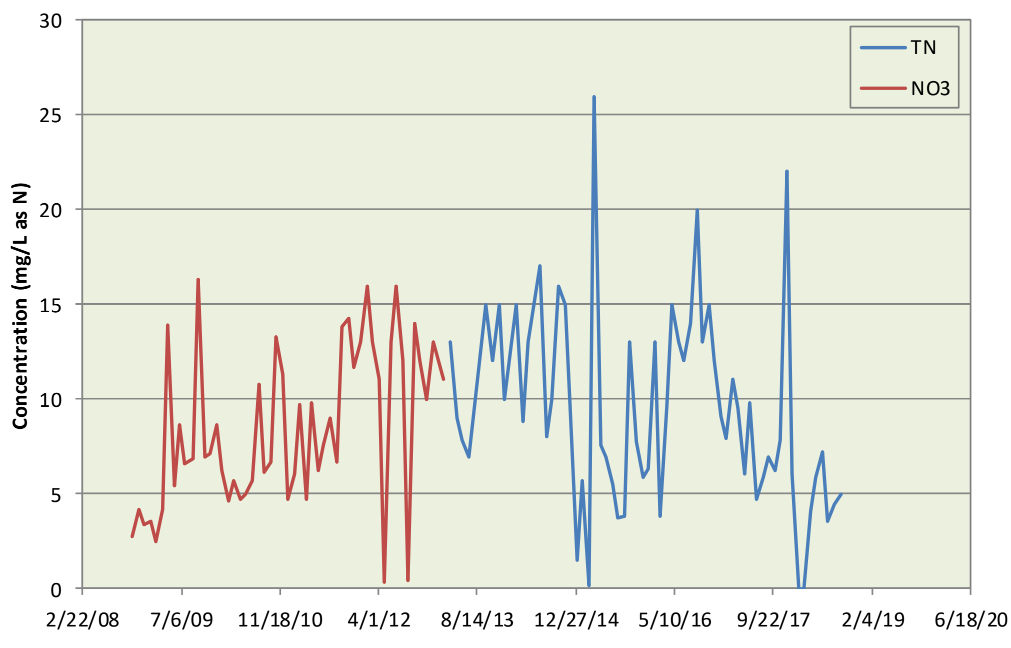

Figure 6. Nitrogen Concentrations in WWTF Effluent

Figure 7 shows monitoring well nitrate concentration data for the sprayfield site. Well MWI-2 is located near the center of the sprayfield and is completed into the top of the Floridan aquifer. Period-of-record average nitrate beneath the sprayfield was 3.65 mg/L with peak concentrations exceeding 9 mg/L.

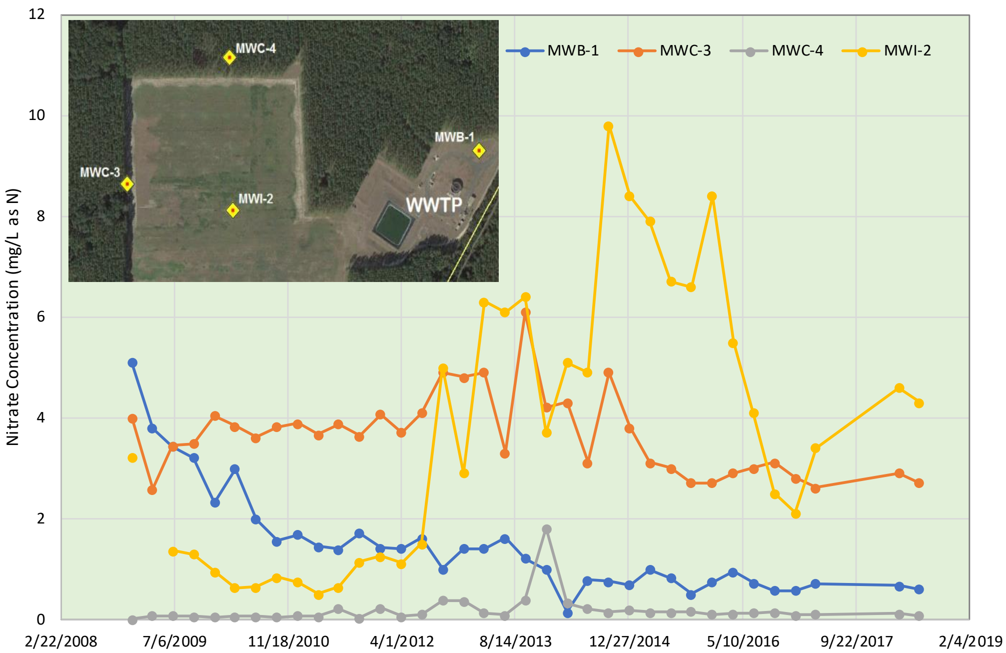

Figure 7. Nitrate Concentrations in High Springs Monitoring Wells

<u>Proposed System Design</u>

The proposed layout includes a multiple cell configuration with a combination of lined, partially lined, and unlined cells. This configuration is proposed to provide flexibility to take one or more cells offline for maintenance or repair. The design anticipates having lined cells placed in two parallel treatment trains. These lined cells will provide treatment with negligible infiltration before water reaches the partially lined and then unlined infiltration cells. A structure is proposed between upstream and downstream cells to allow re-balancing of flows or cell bypass when necessary. The purpose of the partially lined cell is to reduce but not eliminate infiltration to provide additional treatment and allow for hydrologic support of wetland plants that will provide the biology to accomplish this removal. Any water that does not infiltrate in the partially lined cell will flow to the first of the two unlined cells. These unlined cells will be in series and will provide recharge of any remaining water. These cells are planned to be grassed unless hydrology will support wetland or marsh vegetation in a portion or all of one cell. It is anticipated that the first unlined cell will generally receive water, but no water is expected to make it to the later unlined cells unless there is a major rainfall event.

Deep zones are proposed in each cell to distribute/redistribute flow as it travels through the wetland cells. These deep-water areas decrease the formation of short-circuits that reduce treatment performance and provide additional habitat for wetland species. Three deep zones are proposed in each of the lined cells: at the inflow, near the center, and at the outfall perpendicular to the direction of flow. Similarly, the partially lined cell will have three deep zones to minimize the potential for short-circuits and distribute flows in the cell. Each of the unlined cells will have a single deep zone at the inflow to spread the water across the basin more effectively.

Water level control will be accomplished by manipulating adjustable weirs located at the outfall from each wetland cell. Water level recorders will be installed in stilling wells in each cell to track water levels. To compensate for changes in barometric pressure a barometric pressure transducer will be installed in combination with the water level recorders at a location that will not be inundated. These water level recorders serve as a long-term record of levels and are necessary to develop and maintain an accurate water balance. These water level recorders will be in addition to staff gauges installed in each cell to allow for visual determination of water levels on a real-time basis. The staff gauges will be used to guide day-to-day operations. Inflows will be measured with flow meters to track wetland loading at the inflow and weir equations (using the water level recorders) will be used at the outflows.

It is anticipated that all marsh areas in the lined and partially lined cells will be operated approximately one foot deep under normal conditions and will be planted with emergent wetland vegetation. Wetland plants that are selected will be those with quick turnover and propagation from rhizomes. Example recommended wetland species are provided in Table 1. Wetland planting for this project is proposed to occur on a spacing of three feet on center to have a short time to full colonization. Plant turnover will provide a necessary source of carbon to allow for denitrification of the effluent.

Table 1. Proposed Wetland Plant Species

Common Name	**Scientific Name**
Softstem Bulrush	*Schoenoplectus validus*
Fireflag	*Thalia geniculata*
Pickerel Weed	*Pontederia cordata*
Duck Potato	*Sagittaria latifolia*
Lanceleaf Arrowhead	*Sagittaria lancifolia*
Spikerush	*Eleocharis interstincta*

The groundwater recharge wetland layout was developed to provide a level of treatment that would allow total nitrogen to be reduced to less than 3 mg/L during all months. The treatment train was conceptualized to provide significant operational flexibility to allow cells to be taken offline to accomplish any necessary maintenance. The general layout for Phase 1 is for four lined treatment cells placed in two parallel flow paths, each with two cells in series. These flows are then combined into a partially lined cell (modified soil profile) before discharge to three unlined cells in series. This layout was designed to provide treatment for the full permitted flow of 0.240 MGD in Phase 1. Phase 2 mirrors the Phase 1 layout and the full buildout is shown in Figure 8.

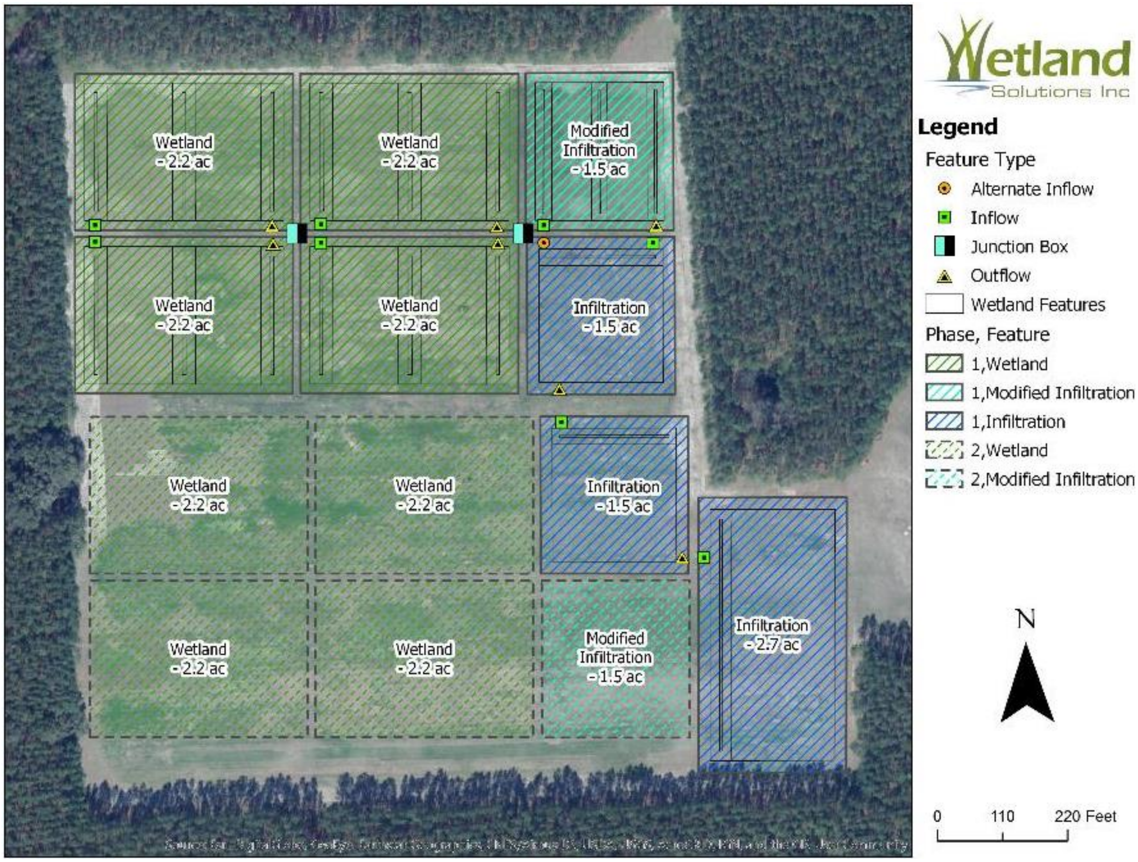

Figure 8. Proposed High Springs Wetland Layout

Inflows will enter the western most wetland cells through an inflow pipe located in the inflow (western most) deep zone. Water will then flow through the wetland and discharge over an adjustable weir to a splitter box that will allow water to be sent to one or both of the second set of lined wetlands. As with the first lined wetland cells, water will inflow to the western deep zone and discharge from the eastern deep zone over an adjustable weir to a second splitter box. This splitter box will allow flows to be combined and sent to the partially lined wetland infiltration cell under normal operations. This cell will have a modified soil profile to reduce infiltration rates to maintain hydration and a vegetative community. This final treatment cell will infiltrate a portion of the water with the remainder overflowing to the infiltration cells.

Operational flexibility is a key feature of the wetland with the ability to bypass any one of the wetland cells (lined or partially lined) if the need for maintenance arises. Bypass will be accomplished by modifying weir positions in the splitter boxes. These splitter boxes will also serve the purpose of balancing and mixing flows between the upstream and downstream wetland cells. Each of the system components is discussed in additional detail in the following sections.

The lined wetland cells are designed to provide the desired level of treatment during all months. As with many systems that rely on biological removal, wetlands will experience reduced treatment performance during cold periods. This was accounted for in the modeling and the most restrictive month for treatment was January. The lined wetland cells will have infiltration rates reduced to near zero to avoid significant infiltration of partially treated water. This layout calls for four equally sized, approximately 2.2-acre cells that will have a total footprint of approximately 8.8 acres. Each of the cells will have 4:1 side slopes and a depth to the marsh grade of four feet. This cell depth is designed to allow for water to stage up during wet periods, accrete sediment over the life of the wetland, and provide freeboard in the event of extreme weather events. The area of each cell at the marsh grade is approximately 1.8 acres for a total estimated treatment area of 7.2 acres. Each cell was designed with three deep zones near the inflow, center, and outflow. Each deep zone is four feet deep with 4:1 side slopes and a bottom width of about six feet. Cells will be constructed at the same elevation for upstream cells and at a lower elevation for downstream cells to allow for gravity flow between the cells. Water from the downstream wetland cells will be discharged generally to the modified infiltrating wetland cell but can also bypass this cell and flow directly to the first unlined infiltration cell if necessary.

Unlike the lined wetland cells the modified infiltration cell will have the soil profile engineered to slow, but not completely restrict infiltration. The general target for infiltration is in the range of 1-2 inches per day. This cell was designed to be approximately 1.5 acres at the top of bank. As with the lined wetland cells the depth from the top of bank to the marsh grade will be four feet. The marsh grade is expected to be approximately 1.2 acres. The anticipated infiltration in this cell at a rate of 1-2 inches will be 32,000-64,000 gallons per day. This is approximately 13-27% of the permitted flow for the facility and 20-40% of the current flow of about 0.16 MGD. The goal of targeting this rate is that flows will be adequate to support wetland vegetation and hydrology that will provide additional treatment and especially nitrate removal while discharging treated water to the Floridan Aquifer. By targeting this rate rather than a higher rate it is likely that even if the 1-2 inches per day infiltration rate is exceeded that the cell will still be capable of maintaining hydrology to support wetland vegetation. This cell will be topographically lower than the lined wetland cells and fed by gravity from those cells. Following additional treatment in this cell, water will flow by gravity to the first of the unmodified infiltration cells.

Wetland treated water remaining after the modified infiltrating wetland cell will be directed to a series of three infiltration cells that will recharge the remaining water to the Floridan Aquifer. These cells were designed to receive all of the remaining water with some additional capacity for future expansion. The cells were sized based on an infiltration rate of 3 inches per day with a total infiltration area of approximately 3 acres required to recharge the entire plant flow (exclusive of any water infiltrated in the modified infiltration cell). To accommodate this flow and a portion of future flows a total of 4.2 acres were provided at the cell bottom with a total of 5.7 acres at the top of bank. The cells would be fed in parallel with all water not recharging in the first cell overflowing to the second cell for recharge. These cells were designed to be five feet deep with 4:1 side slopes to allow for additional storage during extreme weather events. Each cell would be fed by gravity from upstream cells.

To ensure that future expansion of the wetland could be accommodated the design team evaluated the addition of a second phase of wetland construction to meet a future doubling of the plant capacity. The second phase will occur after the initial phase of the wetland had been in operation for several years. Since wetlands each perform differently, and this system was sized to provide conservative performance, the initial system will be re-evaluated to assess current performance before constructing the second phase. If the wetland is performing better than it was modeled to perform, then the second phase could be modified to address these realities and "right-size" the additional wetland treatment system. If, however the wetland has underperformed the second phase layout could be modified to meet the utilities' needs. At the same time the need for addition of more infiltration area will be explored.

Estimated Future Performance

Treatment wetlands have a long and proven history for water quality treatment. The extensive use of wetlands for water quality treatment has produced datasets that are now used to design treatment wetlands as unit processes in wastewater systems. This allows for sizing of wetlands to deliver specific water quality goals with a high degree of certainty similar to other unit processes. Like other unit processes upsets can occur that might have an impact on effluent quality, but can generally be minimized through proper design, operation, and maintenance. Unlike higher-intensity processes that require inputs of energy in the form of electricity or chemical addition, wetlands rely on natural sources of energy from the sun and chemical constituents already in the water. This means fewer moving parts to fail and reduced potential for upsets. In addition, wetlands have a high tolerance for water quality variability in inflows. Operationally wetlands are generally reliable and resilient because of typically long residence times (days to weeks). It is also important to note that wetlands achieve most of the provided treatment through microbial communities rather than vegetative uptake meaning that treatment continues through winter although at a reduced rate as a result of lower temperatures.

The concentration reduction in the wetland features was estimated for individual nitrogen species using the p-K-C* model (Kadlec and Wallace 2009). The Kadlec and Wallace wetland treatment model includes the water balance components of rainfall, evapotranspiration, pumped or gravity surface inflow, gravity surface outflow (to downgradient cells), and groundwater infiltration.

This modeling showed that approximately seven acres of wetland were required to reduce incoming total nitrogen to less than 3 mg/L for the currently permitted flow of 0.240 MGD. Constructed wetlands largely rely on biological processes which are typically slower during cold periods. To achieve a specific goal this temperature impact must be considered to ensure project goals are met in all months. Air temperature data were collected from the University of Florida – Florida Automated Weather Network and used to account for reduced removal during cold periods. To ensure that water is not infiltrated in large quantities until water quality has reached the minimum level of treatment desired the first 7.2 acres of the design are proposed to be lined, as discussed in further detail in subsequent sections. With the 7.2 acres of wetland area, total nitrogen concentrations were modeled to decrease from 10 mg/L to between 1.27 mg/L (July and August) and 2.84 mg/L (January). Furthermore, the average annual total nitrogen concentration was modeled to be 1.79 mg/L, and annual average nitrate was 0.54 mg/L. After infiltration through the modified and unlined cells, nitrate concentrations are estimated to be consistently below 0.35 mg/L.

Treated effluent flow rates to the sprayfield averaged 0.163 MGD over the past year. This flow rate was also modeled to estimate anticipated performance in the wetland at current flows. Estimated total nitrogen reductions were from 10 mg/L in the influent to between 1.11 and 2.03 mg/L with an average annual concentration of 1.39 mg/L in the lined wetland portion.

Cost, Schedule, and Summary of Benefits

Buildout of the wetland project has been estimated to cost $2.78 million. The design phase is nearly complete, and the project is scheduled to begin construction before the end of 2020. At buildout, the annual average TN load reduction is estimated to be 15,300 pounds per year (lbs/yr), with a 20-year operational cost-effectiveness of $9 per pound of TN removed. Net recharge efficiency (applied effluent less evapotranspiration) is estimated at 86% ignoring rainfall contributions. Energy costs at the WWTF are projected to decrease as flow can be delivered to the wetland at lower pressure than is required to run the spray irrigation system.

References

Kadlec R.H., Wallace, S.D. 2009. Treatment Wetlands, Second Edition. CRC Press, Taylor & Francis Group: Boca Raton, FL.

Universal Engineering Sciences, Inc. 2018. Report of Geophysical Surveying Services. Report to Mittauer & Asscociates, Inc.