Reuse, Reduce, Recharge, Restore, and Recreate: Ocala Wetland Park

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Silver Springs, located in north central Florida, is one of the state's largest first-magnitude springs and has attracted many visitors since the 19th century. World famous for its crystal clear waters, it's the ecological and economic engine in the area; however, flow and water quality data over the past nine decades show a significant decline in spring flow and increase in nutrient concentrations, which has led to the ecological degradation of the Silver Springs and Silver River systems. Thus, the Silver Springs system is subject to restrictive total maximum daily load (TMDL) regulations for nitrate, and to help meet its established minimum flows and levels (MFLs), it has a recovery strategy (Florida Department of Environmental Protection [FDEP], 2012; St. Johns River Water Management District [SJRWMD], 2017a).

While not yet required by regulations, the City of Ocala (city), located within the springshed, is implementing a treatment wetland designed for groundwater recharge to offset its use of groundwater and nutrient loads to Silver Springs associated with municipal water and wastewater management. Groundwater recharge wetlands provide a unique opportunity to address water supply and water quality, while giving back to the community through a new park amenity, educational opportunities, and community gathering space.

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Figure 1. Conceptual Design of City of Ocala Wetland Groundwater Recharge Park

In support of the design and permitting of this project, an onsite hydrogeologic investigation, consisting of soil borings and the construction of pumping and monitoring wells across the site, was conducted to produce site-specific data. A groundwater model was then calibrated to this data and used to evaluate the site's capacity to recharge the aquifer, and the fate of the applied water to recover flows in the Silver Springs system. These efforts included innovative applications of a calibrated groundwater model (combined with a wetlands treatment model) to quantify recharge, while ensuring the protection of water quality. It was determined that this system will have a capacity of up to 5 mil gal per day (mgd) and will reduce nitrate levels to background concentrations.

The wetland will consist of a 35-acre organically shaped flowpath designed as an ecological park, with an education area, walking trail, boardwalks, and other park amenities. The system, currently under construction, is expected to receive and polish up to 5 mgd of treated municipal wastewater that will infiltrate to the underlying aquifer to augment flow to Silver Springs, while protecting its water quality. This wetland is expected to reduce nitrate loads to Silver Springs by 10 tons a year.

This article will highlight the factors that led the city to plan this forward-thinking project, the ecological design principles applied to maximize the ecological value of the site, the anticipated water quantity and quality benefits, and the plans to use this as a teaching and recreational tool for the community.

Introduction

Silver Springs

Located just outside of the city in Marion County, Silver Springs has one of the world's largest artesian springs, consisting of more than 30 contributing spring vents, which serve as the headwaters of Silver River, an outstanding Florida waterway, and is encompassed by Silver Springs State Park.

Much like many Florida springs, excess nutrients (particularly nitrate) from anthropogenic effects throughout the 1,200-sq-mi springshed have degraded the water quality and habitat of Silver Springs and the Silver River. With the increase in nutrients over the years, much of the native submerged aquatic vegetation of the springs has been covered or replaced by thick filamentous algae. The decline in spring flows has only exacerbated the degradation of the spring's water quality and habitat.

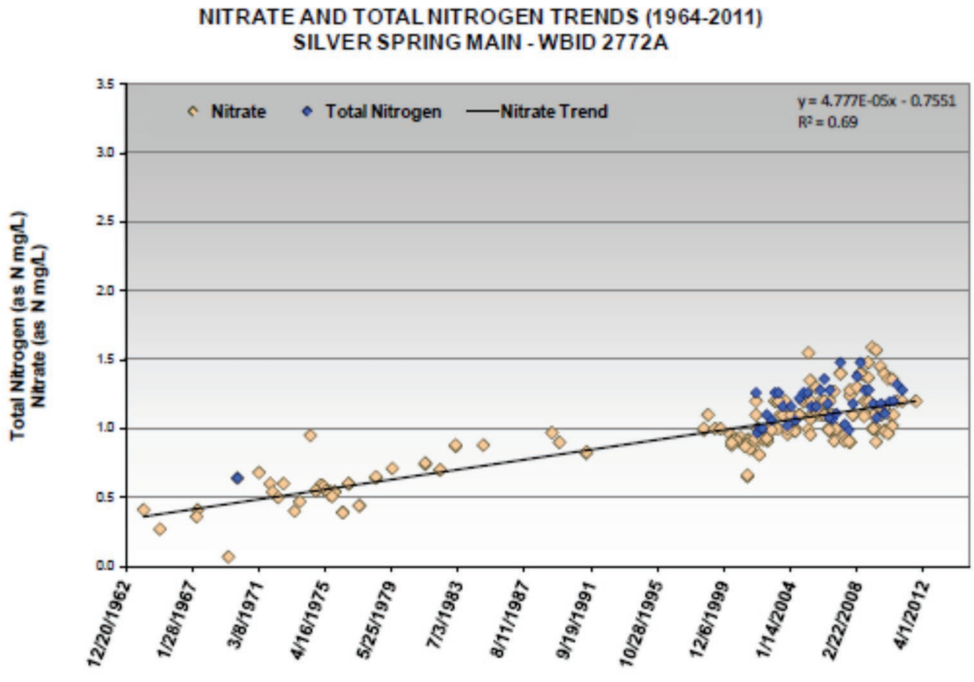

Figure 2. Nitrate and Total Nitrogen Trends at the Silver Spring Main Boil *(data source: FDEP, 2012)*

Groundwater Recharge Wetlands

Wetlands are an important natural resource in Florida. They provide a wide range of ecological and environmental functions. These functions include biological, physical, and chemical processes that take place among water, soil, vegetation, and microbial communities to improve water quality. Treatment wetlands are constructed wetlands designed to capitalize on these natural biogeochemical processes to achieve high-quality treatment of nutrient-laden water, with little energy that results in environmental enhancement.

Groundwater recharge wetlands are constructed treatment wetlands that do not have a wetland outflow, and therefore, contribute to aquifer augmentation. These systems are strategically located where the confining unit between the surficial and Floridan aquifer systems is discontinuous, and where groundwater use has resulted in excessive drawdown and caused adverse effects to lakes and wetlands.

Groundwater recharge wetlands are especially efficient at reducing nitrate to nitrogen gas through microbial processes. Additionally, anaerobic conditions in the underlying soils beneath the wetland cells provide further nitrate reduction as water infiltrates to the underlying aquifer. Water infiltrating to the shallow groundwater beneath a treatment wetland must pass through the sediment interface of accumulated organic matter (i.e., detritus) where conditions are anaerobic (i.e., low oxygen) and, therefore, ideal for denitrification. Groundwater recharge wetlands are a key technical approach for a state such as Florida, which both increase water supply and improve water quality, particularly in springsheds.

City of Ocala Wetland Groundwater Recharge Park

Understanding the plight of Silver Springs, the city desired to evaluate its role and resources to positively impact the health and future of the Silver Springs springshed. The city recognized that the groundwater recharge wetland technology could provide far greater benefits to the region than its current practice of disposing excess reclaimed water through spray fields. Thus, in 2016 the city hired CH2M HILL, now Jacobs Engineering Group Inc. (Jacobs), to design and permit a groundwater recharge wetland park that would beneficially reuse and recharge its reclaimed water, and also serve as a public park.

The designed wetland system consists of 35 acres of infiltration wetlands divided into three cells to receive up to 5 mgd of reclaimed and stormwater on a project area of 60 acres (Figure 1). Layout of the groundwater recharge treatment wetland cells was developed based on onsite hydrogeologic characteristics evaluated during field investigations and the current location of open fairways and ponds on the project site.

The cells are designed to mimic the shape of natural wetlands with their organically shaped perimeters and are graded in-place without the need for import or export of material to construct berms. The design maximizes wetland habitat diversity by creating different ecotones across the cells that range from deep open water to shallow wetlands, islands, and rookery areas. The wetland cells will be planted with native wetland vegetation, which will vary in species, depending on the ecotone to be planted.

The design also includes an innovative valve manifold that controls reuse flows from the city's water reclamation facilities (WRF) #2 and #3, and in the future, potentially stormwater to distribute to each cell independently based on water level setpoints in each wetland cell. Each cell would be operated remotely and individually supplied with reclaimed water and stormwater from the valve manifold. This will allow for seasonal operation of water levels to maximize recharge and wetland ecological value by mimicking wetland hydroperiods that are driven by seasonal rainfall patterns.

The park component of the project will include an educational pavilion and walkways, with signage about the park benefits, ecological communities, and wildlife habitat. The project design will include boardwalks and trails throughout the park, and observation areas in key locations to provide wildlife views. Larger oak hammocks will be maintained onsite and downstream ponds will be used for both observation and catch-and-release fishing.

Continued on page 18

Continued from page 17

Reuse: Beneficial Water Reuse of City of Ocala's Reclaimed Water

Currently, all of the city's excess reclaimed water is conveyed to spray fields for disposal. Although spray fields have been critical in the management of surplus reuse water for many years, they provide no ecological value or significant removal of nitrate. Most water is lost to evapotranspiration (ET) and little nitrate reduction occurs within the water that does percolate. As the city's population size increases, the amount of excess reclaimed water sent to these spray fields will continue to increase, driving the city to consider other reuse management options. In addition, due to regulatory restrictions on daily water consumption and projected population increases, the city also needed to determine ways to offset the daily use of potable water.

To help with reuse management and groundwater supply augmentation, the city decided to implement a groundwater recharge wetland park that will reuse its excess reclaimed water and provide the Upper Floridan aquifer with up to 5 mgd of water. By recharging the excess reclaimed water, the city essentially offsets 5 mgd of its consumption through groundwater withdrawals. This project allows for potential water use permit revision and helps the city secure its water supply into the future, while beneficially reusing its reclaimed water.

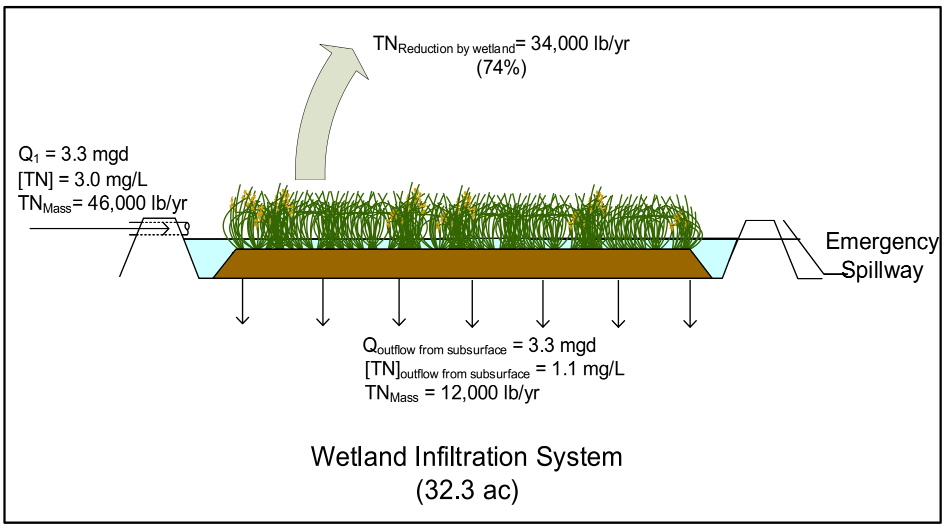

Figure 3. Ocala Wetland Total Nitrogen Performance Forecasting

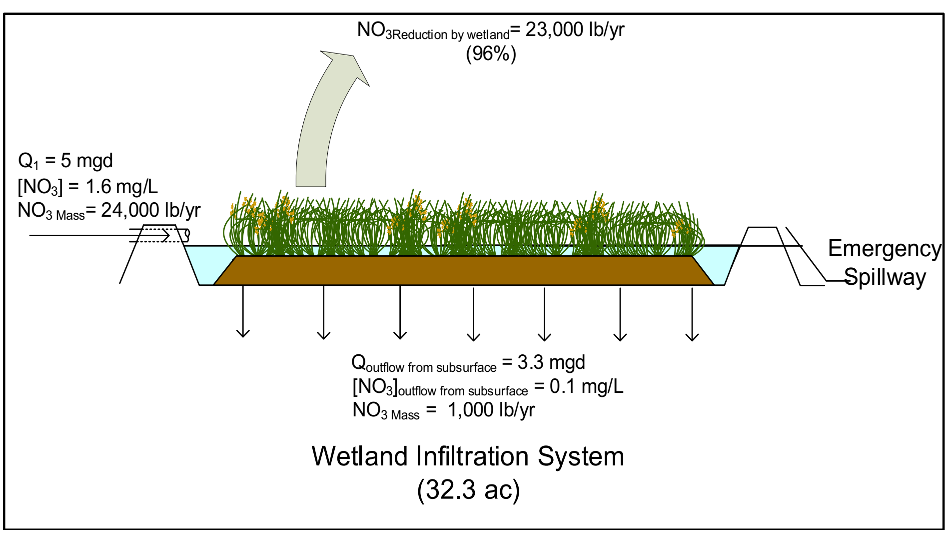

Figure 4. Ocala Wetland Nitrate Performance Forecasting

Reduce: Springshed Nutrient Reduction Through Groundwater Recharge Wetlands

Both Silver Springs and the Upper Silver River have been identified by FDEP as impaired due to a biological imbalance with excessive epiphytic algal growth and increased filamentous algae caused by high concentrations of nitrate (above 0.6 mg/L) in the water. A recent study (Munch et al., 2006) cited by FDEP reported several changes in the submerged aquatic and algal communities of Silver Springs over a 50-year period. The study found that average annual epiphytic algal biomass has increased by about 171 percent over the last 50 years and that benthic algal biomass has increased from biomass estimates that were too low to estimate in the 1950s, to a biomass estimate comparable to other macrophyte and epiphytic biomass estimates (Munch et al., 2006, and FDEP, 2012).

Figure 2 displays the nitrate and total nitrogen (TN) trends reported by FDEP in the "Nutrient TMDL for Silver Springs, Silver Springs Group, and Upper Silver River" (FDEP, 2012). As shown in Figure 2, TN and nitrate trends have steadily risen over the years. Nitrate levels have increased over 1 mg/L, with nitrate levels below 0.5 mg/L in the 1960s to nitrate levels above 1.5 mg/L in the 2000s.

Due to the well-documented increase in both nitrate levels and algal biomass over the last 50 years, FDEP deemed Silver Springs impaired due to consistently elevated concentrations of nitrate (above 0.6 mg/L) and the documented biological imbalance caused by algae smothering. In 2012, FDEP established a TMDL for nitrate as a water quality restoration target for both Silver Springs and the Upper Silver River in 2012. A TMDL is the maximum amount of a given pollutant that a waterbody can assimilate and still meet water quality standards. The TMDLs are developed for waterbodies that are verified as not meeting water quality standards (FDEP, 2012).

The TMDL for Silver Springs was established as 0.35 mg/L nitrate on a long-term monthly average basis and would require a 79 percent reduction in nitrate concentrations based on the existing spring's mean concentration of 1.69 mg/L (FDEP, 2012). The 0.35 mg/L nitrate concentration was determined by FDEP to be the limit at which an imbalance in the ecology of Silver Springs would not occur. To help meet this TMDL, FDEP also developed and adopted a basin management action plan (BMAP) for Silver Springs in June 2018. The BMAP was developed to restore and protect Florida's water quality and identify the actions, policies, and projects that reduce springshed nutrient loads to a level where the spring will meet its TMDL.

In 2018, the Silver Springs BMAP listed the city's Wetland Groundwater Recharge Park as a "stakeholder project to reduce nitrogen sources in the Silver Springs BMAP area." The listing of this project as a stakeholder in nitrogen reduction within the Silver Springs basin is due to the estimated wetland nitrogen reductions expected from the groundwater recharge wetland (FDEP, 2018).

Nitrogen reduction estimates were originally calculated by Jacobs during the feasibility study and design of the wetland groundwater recharge park in 2016. Wetland nutrient reduction calculations were based on reclaimed water flows and water quality, infiltration rates, wetland areas, wetland background concentrations, temperature correction and nutrient weather factors, and first-order removal rate constants documented in the literature. These parameters were used to model the reduction of nitrogen and nitrate by the wetland system (both surface treatment and subsurface treatment) through an area-based treatment wetland model developed by Kadlec and Knight (1996) and updated by Kadlec and Wallace (2009), known as the P-k-C* model.

Nitrogen processing is assumed to consist of conversions of nitrogen in the water and exchanges with sediments, biomass, and the atmosphere. The rate at which these nitrogen processes occur is defined by the first-order removal rate constant, and the exchanges with sediment, biomass, and the atmosphere are defined by wetland background concentrations. These processes are the fundamental basis for simulating nitrogen flows and conversions in treatment wetlands; a number of processes transfer nitrogen compounds from one point to another in the wetlands. The predominant nitrogen cycling processes include ammonification (conversion of organic nitrogen to ammonia), nitrification (conversion of ammonia to nitrate nitrogen), and denitrification (conversion of nitrate nitrogen to nitrogen gas). These conversions are quantified in the treatment wetland forecast model.

For nutrient removal forecasts of the wetland park for nitrogen, both surface treatment and subsurface treatment were evaluated. Water quality estimates were calculated under average monthly temperature, rainfall, and ET conditions for the project location. The model was applied for the maximum annual influent flow anticipated for the wetland groundwater recharge park of 5 mgd annual average daily flow. To calculate the system's nitrogen removal, the WRF #2 average 2016 monthly effluent nitrate concentration of 1.62 mg/L was used as the initial influent nitrate concentration to the surface wetland water quality performance model runs.

Since the ammonia is already fully nitrified at the wastewater treatment facility, the initial influent concentrations of ammonia for the model run was assumed to be 0.001 mg/L ammonium as nitrogen. Since the TN advanced wastewater treatment standards are 3 mg/L TN, the organic nitrogen influent concentration from the reclaimed water system was assumed to be a conservative concentration of the difference between 3 mg/L TN and 1.62 mg/L nitrate, resulting in an influent concentration of 1.38 mg/L organic nitrogen. Thus, the model simulated receiving an effluent with a TN concentration of 3 mg/L.

Based on the P-k-C* wetland treatment model performance calculations, it's estimated that this system will remove 34,000 lbs of TN per year (Figure 3) and 23,000 lbs of nitrate per year (Figure 4). These reductions equate to an annual mass removal of 74 percent and 96 percent, for TN and nitrate, respectively.

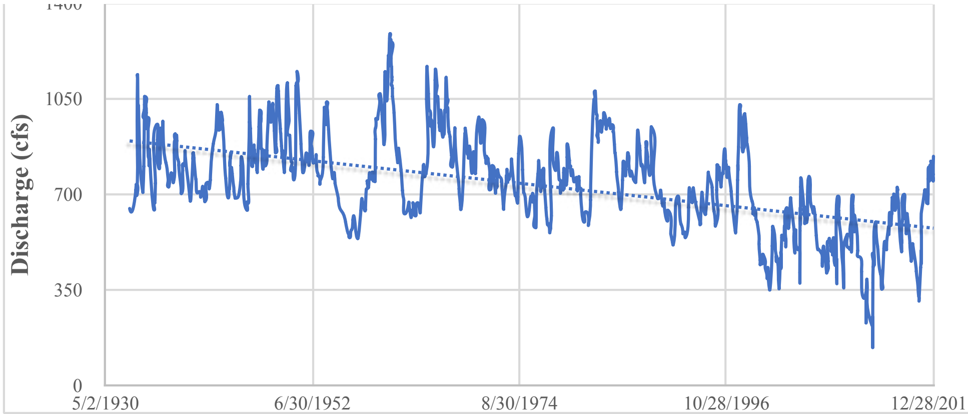

Figure 5. Silver Springs Daily Flow From U.S. Geological Survey Station 02239501 *(data source: USGS, 2019)*

Table 1. Silver Springs Minimum Flows or Levels *(data source: SJRWMD, 2017a)*

Minimum Flows	Flow (cfs)	Duration (days)	Return Interval (years)
Frequent High (FH)	828	30	5
Minimum Average (MA)	638	180	1.7
Frequent Low (FL)	572	120	3

Recharge: Recharging the Silver Springs Springshed

The Silver Springs flows have declined by approximately 30 percent since the 1930s (SJRWMD, 2017a) Figure 5 displays the Silver Springs discharge flow rates measured at the U.S. Geological Survey (USGS) Station 02239501 for the period of record from December 1932 through March 2019. Spring flow reduction has been evaluated by numerous studies and attributed to several factors. According to SJRWMD hydrological statistical and modeling analyses, a long-term rainfall deficit, flow suppression related to submersed aquatic vegetation, and groundwater pumping from the Upper Floridan aquifer system are the three primary contributors to flow reduction (SJRWMD, 2017a).

In July 2017, SJRWMD established MFLs for Silver Springs that determine the flow or level limits and further consumptive use withdrawals that would cause significant harm to the ecology and water resources of the area of concern. Table 1 provides the recommended and adopted minimum flows for Silver Springs: the minimum frequent high, the minimum average, and the minimum frequent low flows. While the three MFLs for Silver Springs are currently being met, water use model projections indicate that these MFLs will not be met by 2025. Since these conditions are not anticipated to be met during the next 20 years, SJRWMD has adopted a prevention strategy to

Continued on page 20

Continued from page 19
determine the necessary projects and regulatory measures that would ensure the MFLs are met in the future (SJRWMD, 2017a; SJRWMD, 2017b).

As reported in "Prevention Strategy for the Implementation of Silver Springs Minimum Flows and Levels," SJRWMD included the wetland groundwater recharge park as a project anticipated to help meet future MFLs under its prevention strategy (SJWRMD, 2017b). The listing of this project as a benefit to the Silver Springs flows is based on SJRWMD recharge calculations and analysis and was supported by Jacobs' extensive hydrogeological investigation and groundwater modeling analysis during the feasibility study and design of the wetland groundwater recharge park.

In 2016, Jacobs began an onsite hydrogeologic investigation of the wetland park site at Pine Oaks Golf Course. The hydrogeologic investigation, consisting of soil borings and the construction of pumping and monitoring wells across the site, was conducted to produce site-specific data. Except for localized areas assumed to be affected by karst solution, the hydrogeologic characteristics of the project site were found to be relatively uniform, and infiltration testing in this area indicated that adequate levels of infiltration can be expected for the proposed infiltration wetland cells. A groundwater model was then calibrated to the site-specific data and was used to evaluate the site's capacity to recharge the aquifer and the fate of the applied water to recover flows in the Silver Springs system.

A calibrated groundwater model was developed to simulate hydraulic loading rates and groundwater mounding underlying the constructed wetland infiltration cells. Hydraulic loading rates (equivalent to normal pool elevation loading depths in the wetland cells) were simulated over 10 years of observed regional and site-specific hydrologic and hydrogeologic conditions, and future loading rates were estimated based on the simulated relationship between total monthly rainfall and loading rates.

In general, simulated loading rates based on observed conditions varied between 1.1 and 5.8 mgd monthly, with an average loading rate of 3.3 mgd during that period, corresponding to an average hydraulic loading rate of approximately 3.8 in. per day. A maximum permitted loading rate of 5 mgd was requested to allow for operational flexibility during drier conditions and for deeper loading depths.

Groundwater model results found that approximately 0.2 to 1 mgd of the loaded volume is predicted to benefit Silver Springs. The remaining fraction of the loaded volume is predicted to go to Silver River and other surface waters and increases to storage in the surficial aquifer and Upper Floridan aquifer system (CH2M, 2017).

Based on the SJRWMD assumption that 2.8 mgd of reclaimed water would actually be available and be recharged through the wetland park, the calculations estimate a benefit of 1.4 cu ft per second (cfs) to Silver Springs. If additional reclaimed water becomes available, the benefits of the project could potentially exceed those estimated (SJRWMD, 2017b).

Recreate: Providing Public Recreational and Educational Opportunities Related to Springshed

Since this park will feature 2.5 mi of walking trails and boardwalks, it will provide an opportunity for environmental recreation and ecotourism. Since 2017, the city has provided more than 30 presentations to various community groups and held two public meetings to promote the park. These groups have provided invaluable community input into the park design and offerings. The local Audubon Society and the Native Plant Society Chapter have been interested stakeholders and instrumental in guiding park features and benefits, and both groups have offered to assist in leading interpretive programming for visitors to the park. Community collaboration during the wetland park design has been integral for the public's acceptance and excitement towards this project.

In addition, it's planned for the trails to be lined with over 20 educational kiosks that will inform visitors of the functions and importance of wetlands and nonpoint source pollution, and the species they will likely see on their visit. A designated education area will also be incorporated in the park, with the potential for a future education center to be built.

Restore: Multibenefit Project Provides Opportunity for Silver Springs

Silver Springs may be considered a prime example of the degradation that many of Florida's springs have experienced over the years. Silver Springs' unique and extensive data period of record indicates that nutrient concentrations continue to increase, springflows continue to decline, and the ecological imbalance continues to widen; however, with this problem there is also opportunity for Silver Springs.

Through implementation of local projects focused on improving water quality and quantity, Silver Springs has the opportunity to showcase the restoration potential of Florida's springs. The city's Wetland Groundwater Recharge Park is an exemplary project that supports the restoration of Silver Springs through water quality benefits of nitrate reduction and augmentation of groundwater supply through aquifer recharge. In addition, the wetland park is a community asset providing public education of the local environment and its associated issues and public recreation.

This park also benefits both society and the natural environment by repurposing reclaimed water to support the restoration of Silver Springs.

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