Low-Impact Wastewater Collection System Reduces Nutrient Loads in Vero Beach

Lindsay Tucker and Rob Bolton

The city of Vero Beach (city) is located adjacent to the Indian River Lagoon along the Atlantic Coast of Florida. According to the Indian River Lagoon National Estuary Program, this area "is home to a rich array of plants and animals whose existence depends on the quality of water within the lagoon. More than 2,000 species of plants, 600 species of fish, 300 species of birds, and 53 threatened or endangered species inhabit the lagoon for at least some portion of their lives, and scientists have shown the lagoon to be one of the most biologically diverse estuaries in North America, with approximately 4,000 species documented" (IRLNEP, 2017). The environmental health of the lagoon is also essential to the economy of Florida's east coast.

The lagoon's ecosystem is under increased threat from pollution. In 2013, more than 160 manatees, 300 pelicans, and 76 bottlenose dolphins in the lagoon system died of unknown causes (Gibbs, 2015). Another major die-off occurred in 2014, and others continue to this day. Inadequate wastewater treatment has been identified as one of many culprits in the degradation of the lagoon's water quality and health.

The city's septic systems serve most of the older homes in barrier island neighborhoods, the majority of which were built under antiquated regulatory codes. Homes constructed before 1983 were likely installed with inadequate septic drainfield separation to groundwater, which is unsuitable for proper septic system performance and contaminant removal.

About 900 septic systems are installed on the barrier island and 600 along open drainage systems on the mainland in the city. Nutrient discharge from various sources, including poorly designed and installed septic systems, negatively affects seagrass beds, the biological foundation of the ecosystem. Nitrogen and phosphorus inputs also distress mangroves, oyster reefs, algae, and wetlands, all of which influence lagoon and ocean fisheries, as well as habitat for birds and other wildlife. Reversing this trend was of utmost importance to the city and its constituents.

Figure 1. Typical street in Vero Beach.

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Preliminary Evaluation

As with any infrastructure project, financial considerations were paramount. Cost was the primary obstacle to effectively launching a new wastewater management system in the city.

The four main cost considerations were:

- Capital costs
- Operations and maintenance (O&M) costs
- Social costs
- Availability costs

Until proven otherwise by affordability and implementation challenges, gravity sewers (because of their perceived lower O&M costs) were the initial preference for the city project. In 2004, through voluntary assessment projects, around 60 additional homes were connected to the city's gravity sewer network. At the time, costs ranged from $6,200 to nearly $20,000 per gravity sewer connection.

In 2007, the city attempted to expand the gravity sewer network on a more extensive basis than before into more sensitive areas around the lagoon; however, this project was eventually suspended due to lackluster support from the community and the fact that the proposed state funding stream supporting the planned expansion needed approval from the public. Due to the disruptions caused by the expansion in 2004—as well as the high costs involved—only 14 percent of the residents supported the project. This was far below the required 60 percent level of community support required.

Concerns about social costs, or indirect construction costs, were critical to the city's decision-making process. Disruption to vehicular traffic, road and pavement damage, potential damage to adjacent utilities, air pollution, risks to pedestrian safety, higher tendency for citizen complaints, and increased environmental impact were all major considerations.

Stately live oak trees form a canopy throughout much of the narrow streets and densely populated neighborhoods in the city. Due to past experiences, the construction impact of gravity sewers, which require large-diameter (8-in. minimum) pipe, installed at a constant slope, often with the aid of major lift stations (USEPA, 2002, 1), generated tremendous alarm among the city's residents. Any sewer project that jeopardized the health or life of the community's live oak trees was not an option.

The ability to implement a sewer solution without requiring mandatory connections was also vital. To effectively launch the sewer project, the city needed an affordable option that didn't require each household to connect to the new sewer. It needed a solution that allowed residents with properly functioning onsite systems to opt out of the city sewer project initially, while requiring future connection if the onsite systems failed.

Because of the construction impact and high costs of mainlines, the city embarked on a research initiative to identify gravity sewer alternatives. The nearby City of Palm Bay, along with other General Development Corporation communities in Florida, had implemented effluent sewer systems in the 1970s and 1980s. After quickly reaching a dead-end with the gravity sewer option, effluent sewers, a type of pressure sewer, were thoroughly investigated. Information was solicited from other communities utilizing this technology, as well as from manufacturers in the industry.

Effluent Sewer Technology

Effluent sewers (also known as septic tank effluent pumping, or STEP systems) for residential applications usually consist of an on-lot portion and a right-of-way (ROW) portion. Typically, the on-lot components are a short (10-30 ft) building sewer, a 1,000-gal tank, a pump package with a 1/8-in. mesh filter, and a 1-in.-diameter service lateral that connects to the ROW portion of the system. The on-lot tanks provide the following:

- Passive anaerobic digestion
- Solids separation and removal (excellent primary clarification)
- Reserve storage for 24-48 hours (minimizing the need for after-hours service calls)
- Surge capacity for daily flow modulation to the wastewater treatment facility
- Long-term sludge digestion (Crites and Tchnobanoglous, 1988, 317)

The right-of-way portion consists of small-diameter, low-pressure force mains (typically 2 to 4 in. in diameter, depending on population,

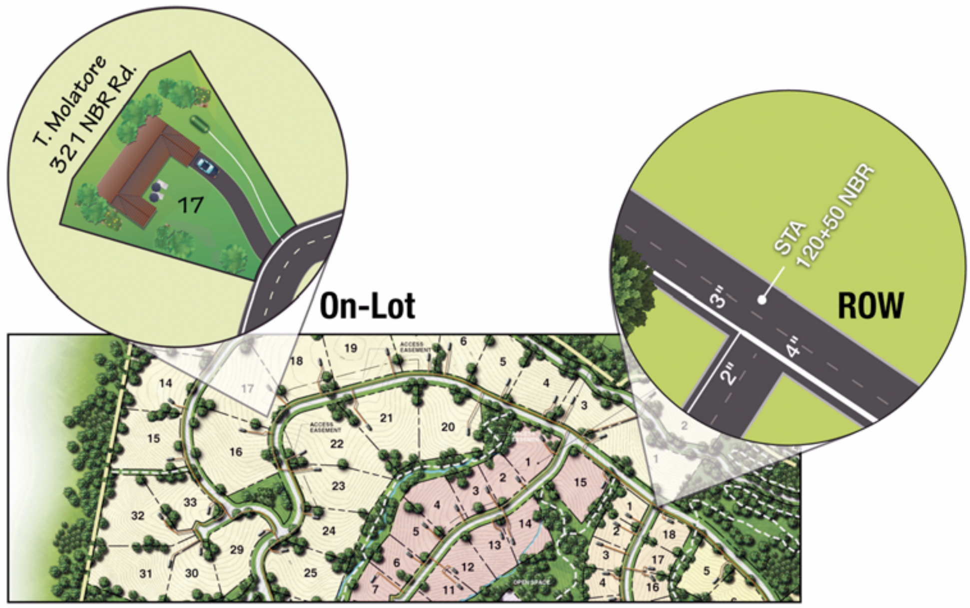

Figure 2. Overview of a typical effluent sewer collection system.

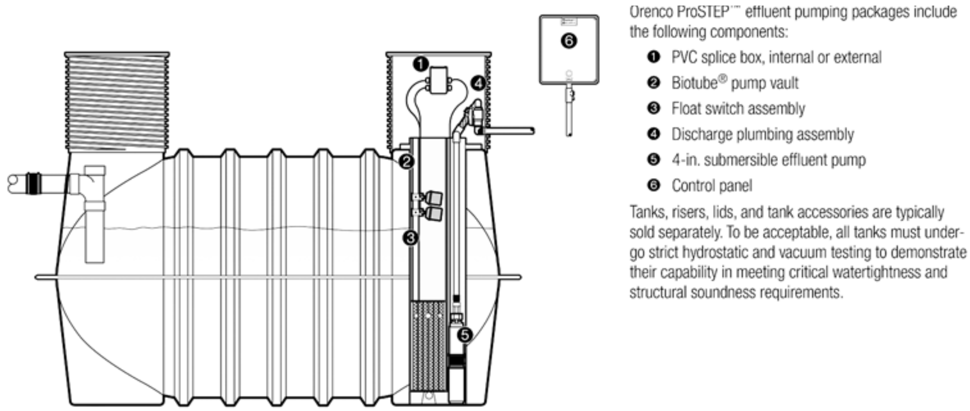

Figure 3. Effluent sewer septic tank effluent pumping package.

distance, and static head) that are shallowly buried, in the right of way adjacent to the road surface, and following the contour of the land. This eliminates the manholes and lift stations common to gravity sewers (USEPA, 2002, 1). Figure 2 illustrates an overview of an effluent sewer collection system, and Figure 3 illustrates typical on-lot STEP components.

Unlike other collection systems, effluent sewers modulate flows at the source. At the same time, they capture and digest over two-thirds of gross solids, grease, and oils, producing effluent that is primary-clarified, treated, and fine-screened before it is conveyed to the wastewater facility (Crites and Tchobanoglous, 1998, 183). Table 1 lists the wastewater characteristics for various types of collection systems.

With the high groundwater prevalent throughout the coastal community, a pressure sewer provides distinct benefits. Mainlines are watertight and largely resistant to infiltration. Effluent sewers experience minimal infiltration and inflow (I&I) throughout the collection system because service laterals and mainlines are pressurized, mains are shallowly buried, and manholes are eliminated. As reported in the U.S. Environmental Protection Agency (EPA) manual, *Alternative Wastewater Collection Systems*, "At this time, thousands of flow measurements have been made on pressure sewer systems with wide demographic spread. The result of these measurements has corroborated findings of the earlier studies: that flows are typically 40-60 gal/capita/day, with little weekly or seasonal variation" (USEPA, 1991, 41).

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Capital Cost Estimates

Expanding the existing gravity sewer in the city would have been unreasonably expensive; the streets are narrow, the area is plagued with high groundwater, and the terrain is very flat. The gravity sewer design required deep excavations, elaborate and costly dewatering infrastructure, numerous manholes, and extensive road replacement. It was estimated that extending the gravity sewer to critical areas of unsewered residents would cost around $22.5 million; in contrast, the effluent sewer was estimated to cost around $11 million (Chart 1).

Operation and Maintenance Cost Estimates

Due to a sewer system's anticipated lifespan of 30 or more years, its O&M costs are generally more important than up-front capital costs. Long-term costs of collection systems can overshadow up-front capital costs (USEPA, 1978, 1-2), and historical gravity sewer expenditures and personal experience to extrapolate gravity sewer O&M costs were referenced. The city owns and operates an existing gravity sewer system, which includes 123 mi of gravity sewer lines, 48 mi of force mains, 118 electrical panels, 236 lift stations, and 2,660 manholes. A monthly O&M cost for the city's existing gravity sewer system was estimated at $13.99 per connection, per month. This included the solids-handling cost of the wastewater treatment process.

To calculate O&M estimates for the effluent sewer, real-world operational data was collected from existing effluent sewers to specifically look for systems that had been operational for more than 30 years. The estimated monthly O&M cost, which conservatively included tank pump-outs every eight years, was $12.91 per connection, per month, for properties utilizing existing septic tanks, and $15.26 per connection, per month, for properties installing completely new systems. This evaluation included full replacement or rehabilitation of all components based on individual component life cycles over a 75-year time frame (monthly costs were updated in December 2016).

With reasonably similar O&M costs between gravity sewers and effluent sewers, and considering the significantly lower capital costs associated with effluent sewers, it was concluded that the overall long-term cost of ownership for effluent sewers was a fraction of gravity sewer costs.

Table 1. Typical wastewater loading rates for effluent sewer, grinder sewer, and gravity sewer.

Constituent Loading Assumptions	Effluent Sewer	Grinder Sewer	Gravity Sewer
Design Average Flow	50 gpcd	50 gpcd	120 gpcd
Biochemical Oxygen Demand (BOD_5)	150 mg/L	450 mg/L	200 mg/L
Chemical Oxygen Demand (COD)	381 mg/L	1143 mg/L	508 mg/L
Total Suspended Solids (TSS)	40 mg/L	500 mg/L	210 mg/L
Total Kjeldahl Nitrogen (TKN)	65 mg/L	70 mg/L	35 mg/L
Ammonia (NH_3-N)	40 mg/L	55 mg/L	21 mg/L
Total Phosphorus	16 mg/L	17 mg/L	7 mg/L
Fats, Oils, Greases (FOG)	15 mg/L	164 mg/L	80 mg/L

[1]*Adapted from Metcalf & Eddy 2003, Crites and Tchobanoglous 1998, USEPA 2002, Winneberger 1984.*
[2]*Use of garbage grinders increases both settleable and floatable solids to septic tank solids accumulation rates by about 37 percent (USEPA 1980, Public Health Service 1967).*

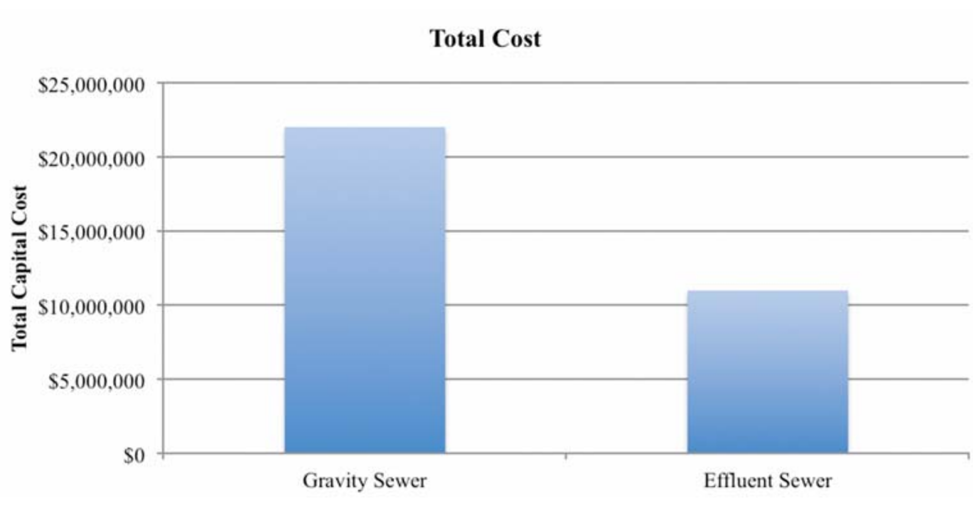

Chart 1. Capital cost of gravity sewer versus effluent sewer.

Social Cost Considerations

As mentioned, many residents were sensitive to how the installation of the sewer system would impact established oak trees, landscaping, and roads. The city's prior experience with gravity sewers had been negative, which resulted in widespread opposition, as roads had been destroyed, traffic had been disrupted, and trees and landscapes had been altered. The gravity sewer construction process had been highly intrusive and unanimously unwelcome.

The principal advantage of effluent sewers is the ability to convey primary-treated effluent through small-diameter mainlines that are shallowly buried and follow the contour of the land, much like a water distribution system. With an effluent sewer, all of the mainlines are installed using trenchless construction, where pipes are pulled through bores and can be easily navigated around existing utilities. Also, the time required to install the effluent sewer was estimated at less than one-eighth of the time required for a gravity sewer.

Availability Cost Estimates

The original gravity sewer proposal—the aforementioned $22.5 million gravity sewer expansion—was highly controversial, especially considering the requirement that everyone had to connect to it. Gravity sewers almost always require mandatory connections, which is due to a municipality's need for cash flow to retire the debt associated with the high cost of installing the necessary infrastructure, including large-diameter mainlines, manholes, and lift stations.

While some residents supported new sewers, dissent was rampant among those whose onsite systems were functioning properly. Other residents were opposed to the expected disruption during installation, and still others were concerned about the cost. To successfully launch a sewer system, a nonmandatory approach was critical.

Effluent sewers provide options by enabling nonmandatory connections, a pivotal tool for eliciting political support for sewer projects. The city provided incentives for connections, but residents with properly performing onsite systems were not required to connect. The city developed an inspection process to monitor the performance of the existing septic systems, where all existing septic systems that do not connect to the effluent sewer system are inspected every five years. If the city determines, based on established criteria, that the existing system is deficient, the homeowner is required to connect to the effluent sewer system in accordance with state law.

Costs of effluent sewers are segmented into two main categories: on-lot and ROW. The majority of effluent sewer system costs, usually about 90 percent of the total, are associated with the on-lot equipment; conversely, only 10 percent of the costs are related to the mainlines. The term "availability cost" was coined, which is defined as the cost of the effluent mainlines, excluding the on-lot components. This availability cost, or the cost to make sewer service available to the residents, was estimated at $885,000 for the effluent sewer, but nearly $18 million for the gravity sewer (Chart 2). The low availability cost of the effluent sewer facilitated nonmandatory connections, allowing properly functioning onsite systems to remain in service until determined otherwise.

Funding

To construct the effluent mainlines and service laterals, the St. Johns River Water Management District, a branch of the Florida Department of Environmental Protection, issued two cost-share agreements totaling approximately $493,000. The cost-share agreements provided 33 percent of the funding for the effluent mainlines ($885,000) and 26 percent of the funding for the individual lateral taps ($750,000), and immediately provided sewer availability to the residents.

The majority of the homes in the city will be equipped with an on-lot 1,000-gal tank and a 500-gal STEP package, plus a service lateral estimated to cost a total of about $7,500 per connection, after incentives. The costs of the on-lot equipment are privately funded; incentives are designed to encourage residents to connect by not charging for the ROW costs and providing credits for wastewater impact fees. For all residents who sign up within the first 12 months of sewer availability, the city designed a "STEP Up and Save" program that offers a $2,290 credit.

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Figure 4. Gravity sewer main excavation.

Figure 5. Directional drilling of 2-in. main.

Figure 6. 2-in. main installed.

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The credit offsets the wastewater impact fee that is normally required for new sewer customers. The second incentive for residents to connect is a wastewater utility extension credit of $1,100. This credit is available only to homeowners who pay in full for their equipment at the time of the application.

Costs are lower for homes with a recently constructed onsite system that may include components that are adaptable to the effluent sewer system. If the city, through a series of inspections, declares the existing tank to be watertight and structurally sound, the tank will be retained and the total cost of construction at the home would be reduced to about $6,000. In this case, the existing tank is followed by a 500-gal STEP package, plus a service lateral.

Effluent Sewer Service Areas

Neighborhoods were prioritized for STEP installation based on the age of the homes and other factors, including depth to groundwater, soil conditions, proximity to surface water, and lot size. Because of the use of small-diameter mainlines and a low availability cost, an effluent sewer allowed the city to deliberately cherry-pick the critical areas that would result in the greatest elimination of nutrient loading into the lagoon ecosystem. In contrast, gravity sewers, because of the inherently high costs associated with mainline construction, prohibit the winnowing out of properly functioning onsite systems. Gravity systems indiscriminately require residents with all types of onsite systems to connect, whether the system is six months old or 30 years old. This inability to differentiate based on the type of system triggers automatic dissent and public opposition and can delay or halt projects.

Within each sewer service zone, the city's interactive map lists properties that are eligible to connect to the effluent sewer mains (Figure 7); sites that have already connected to the effluent sewer are shown in green. For redundancy purposes, mainly to provide uninterrupted service during hurricane events, some sites have the option of keeping their existing drainfield in service, to enable discharge in the event of an extended power outage. The properties with drainfields that have been left in place are shown as dark green parcels (Figure 8).

Construction

Approximately 93,000 lin ft of 2-in.-diameter effluent mainlines needed to be installed within the service areas. The city started installing effluent mainlines in March 2015, and in March 2017, had effluent mains available to 1,189 of the 1,550 lots that were on septic systems. During this time, 86 homes connected because of failed septic systems, new construction, or remodeling of existing homes. The city has a list of 43 additional households with homeowners who want to connect.

In May 2017, the city launched its formal "Sign Up and Save" program by sending letters to residents that will start the one-year clock. The city expects a lot of interest from residents since the savings will be approximately 33 percent of the total cost.

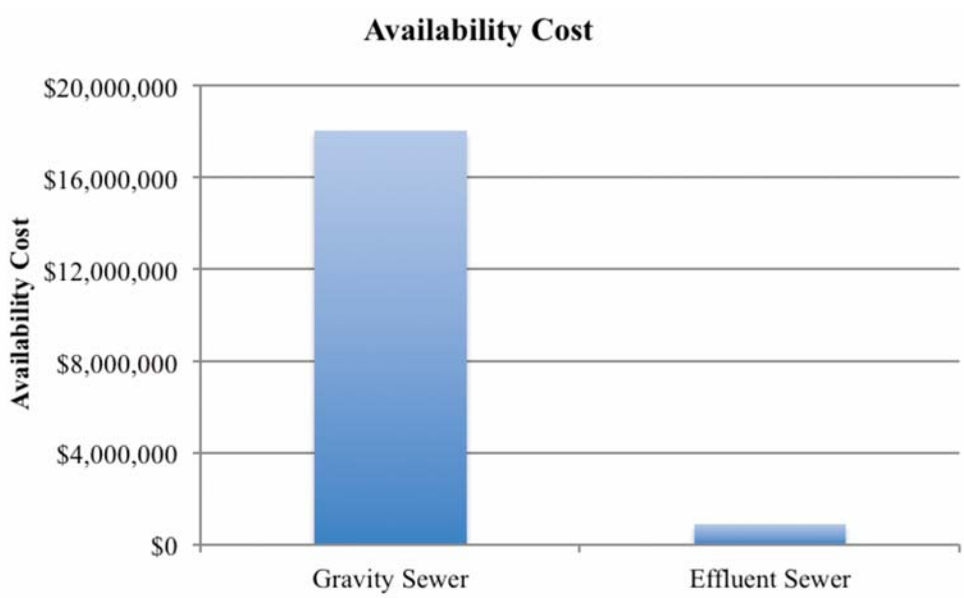

Chart 2. Availability cost of gravity sewer versus effluent sewer.

The majority of the residences will use a 1,000-gal tank, along with a 500-gal pump tank equipped with an Orenco STEP package. Commercial and multiresidential applications will use larger tanks and duplex pump packages.

For quality control and consistency purposes, all contractors undergo a certification process to become eligible to install STEP packages within the city. Installer trainings occur twice a year, all in coordination with the equipment manufacturer.

Residents are encouraged to navigate the installation process by using the city's cell phone application, available for download from iTunes or Android. The mobile app provides an overview of the project, answers to frequently asked questions, diagrams, homeowner guides, area maps, a list of certified installers, installation photos, and links to important documents.

Operation and Maintenance

The city owns and operates the entire effluent sewer system, including the on-lot tanks and associated equipment, through a utility easement. Monthly costs for residents include a base fee of $19.89/month per home, plus a usage charge of $3.59 per 1,000 gal of wastewater. The maximum monthly user charge is set at $55.79.

The O&M requirements for effluent sewer systems are relatively simple, and despite an anticipated 1,550 connections, will likely not require full-time oversight. The on-lot equipment is specifically designed to allow infrequent maintenance activities, typically one site visit every three to five years.

The pumps are the most important mechanical component of the system and are designed to last more than 25 years. These pumps are high-head effluent pumps that only convey filtered and clarified effluent, and customarily operate just 10 to 20 minutes per day. Unlike low-pressure sewers that require discharge to a gravity sewer system or a repump system, effluent sewers (with their high-head pumps) allow the city to connect the effluent mains directly to its force main network. The high-head pump is equipped with a flow controller plate that operates the pump at 8 gal per minute (gpm) at 150 ft of head.

The city installed the first STEP system on April 4, 2015, and currently has 86 connections. Over the last two years, the city has had nine trouble calls; six of the calls were immediately after installation and were a result of loose electrical connections or improper float settings, two were pump issues, and one was a customer who disconnected the power supply to the STEP system.

On Oct. 6, 2016, Hurricane Matthew hit the east coast of Florida, including Vero Beach. The city experienced a power outage for three days, but did not get any calls for backups of the STEP system. Unlike low-pressure grinder systems that have small collection basins (usually 50 to 80 gal), the city's STEP system was designed with a minimum of 200 gal of capacity at each residence to allow for a three- to four-day power outage. In addition, the city required an electrical panel equipped with an emergency generator receptacle (115 volts) at each address. Since the Orenco STEP pump is a 115-volt, ½-horsepower unit, any 2,500-watt generator will power the STEP pump.

Conclusion

At full build-out, an estimated 1,550 homes will connect to the effluent sewer system. By diverting up to 300,000 gal per day (gpd) of wastewater from the lagoon to the wastewater treatment facility, water quality in the lagoon is expected to improve. Through the use of small-diameter mainlines and by designing and implementing a nonmandatory connection approach, the city was able to obtain public support for the project. The low availability cost of the effluent sewer system enabled the city to install the mains for a fraction of what gravity sewers would have cost.

The small-diameter mainlines allowed trenchless construction, a nonintrusive approach that preserved roads, landscapes, and old oak trees. Today, Vero Beach is completing the expansion of sewer availability to critical areas, and residents are pleased with the flexible options, as well as the progress toward cleaning up the lagoon.

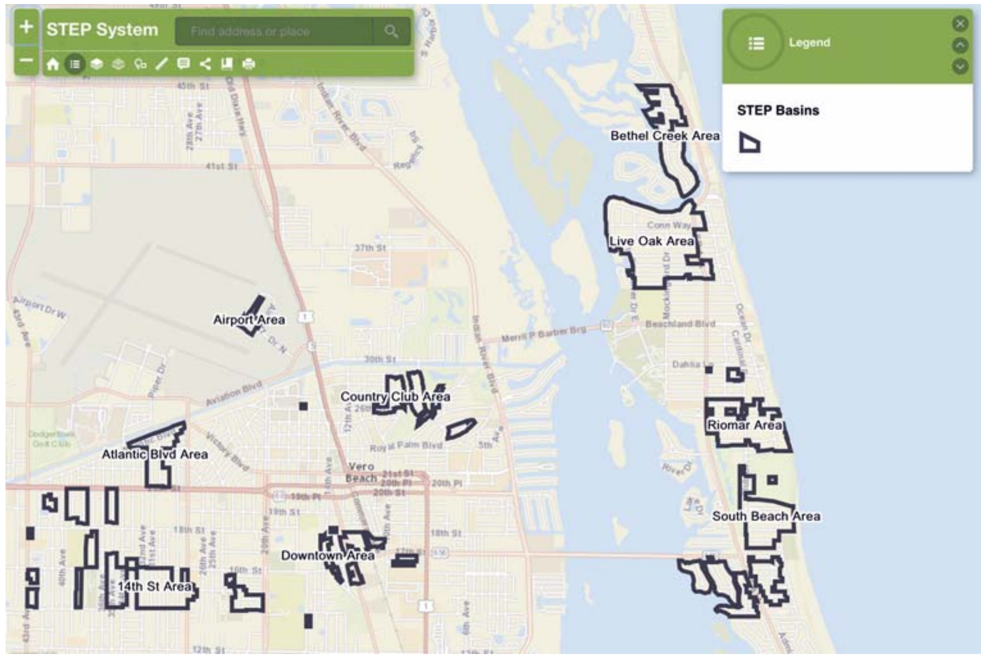

Figure 7. Effluent sewer septic tank effluent pumping system areas in Vero Beach.

Figure 8. Septic tank effluent pumping system availability in Vero Beach.

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