Low Pressure: A Viable Collection System Alternative

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Low-pressure sewer systems can be an unconventional option for some regions in Florida and other places where conventional systems such as gravity and vacuum do not present as many benefits. A preliminary geotechnical evaluation or soil investigation of the project limits is recommended to finalize its feasibility.

Florida counties such as Charlotte County have found the low-pressure system to be an advantageous alternative that today has become one of their typical operations. This article will discuss the challenges encountered during design, bidding, and construction of several low-pressure sewer systems within the county.

The creation of a hydraulic mini-model aided the evaluation and optimization of the pipeline diameters and layout, considering several low-pressure pump capacities. Later research applied to the results of the hydraulic model yielded a reduction in cumbersome, standardized air-release valve units used for this type of system and modification of some of the typical low-pressure components, such as service connections and clean-outs. These modifications translated into simpler construction with a great potential to lower bid costs and reduce maintenance requirements.

Permitting this system requires close coordination with regulatory agencies to avoid miscommunication due to its uncommon use, allowances, and restrictions. Success of low-pressure systems requires careful planning because of the intricacies of operation and maintenance, including crews, spare parts, and equipment.

Rotonda Sands and Rotonda Meadows are two communities located in Charlotte County, near Florida's west coast. Rotonda Sands is located on the west side of the highway and Rotonda Meadows is located on the east side of the highway, approximately three miles south of the Rotonda Sands boundary. These communities include more than 5,000 equivalent residential units (ERUs), and they are yet to be fully developed.

Currently there are nearly 10 percent existing ERUs, and some of the houses are owned by seasonal residents. Supported by the homeowners association, Charlotte County Utilities initiated the process of public approval to design and construct a sewer system to provide current and future residents this service while eliminating septic systems.

With flat terrain and high groundwater, a low-pressure effluent system was selected as the collection system of choice. In comparison with the most widely used collection systems like gravity and vacuum systems, low-pressure sewers provide a viable collection system alternative for areas like Sands and Meadows, where the common systems will be considered the second choice.

Collection System Alternatives

Gravity

Gravity sewers use natural topography to collect the flow into a lift station. As minimum criterion, scouring velocities must be maintained, so the mean flow velocity should be at least two feet per second during full pipe flow.

Since gravity is providing the force to convey the wastewater, the greater the slope, the smaller the required pipe. In areas where there is limited natural slope, deeper manholes are required in order to keep the slope; as a result, excavation cost can be relatively high.

Gravity sewers have no mechanical parts and usually have low operation and maintenance costs, although in some cases the gravity system may require several lift stations to convey the flow to a main lift station; therefore, the cost of O&M to the utility will be higher.

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Vacuum

Vacuum sewer systems rely on gravity to move wastewater from homes to a vacuum valve pit package. They then use a pressure differential, instead of gravity, to move wastewater to a vacuum station and on to the treatment plant. Differential air pressure is used as the motive force to transport sewage. The main lines are under a vacuum of 16 inches to 20 inches Hg (-0.5 to –0.7 bar), created by vacuum pumps located at the vacuum station (Figure 1).

The vacuum system requires a vacuum/gravity interface valve at each entry-point valve pit. Vacuum collection piping typically consists of four-inch to 10-inch diameter installed with minimum cover and a vacuum station. Vacuum stations are usually concrete block buildings on concrete foundations with minimum plan dimensions of approximately 25 feet by 30 feet.

Vacuum sewers are recommended where there are at least 75 connections, rolling hills with small elevation changes, a high ground-

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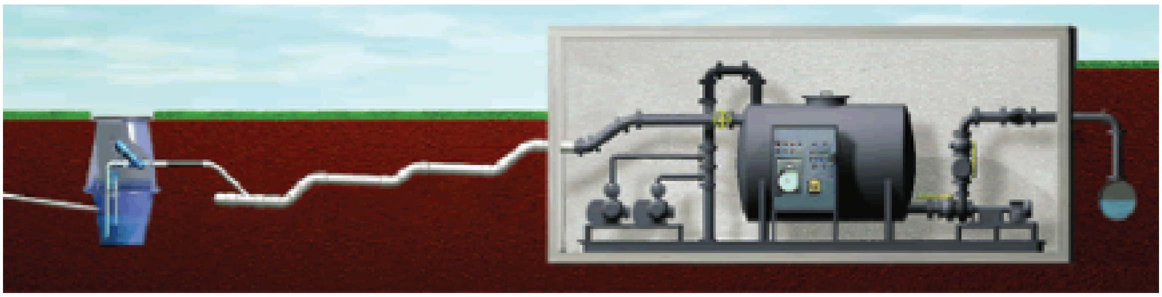

Figure 1: Vacuum Sewer System

Courtesy of AirVaC

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water table, restricted construction conditions, unstable soils, flat terrain, rock, a sensitive ecosystem, or areas where no reliable power is provided to the community. Vacuum stations will have an emergency generator to keep the collection of the flow, regardless of the status of the power sources.

Low Pressure

Low-pressure sewer systems are collection systems that use individual residential pumps to push the flow to a master lift station, where a force main conveys the flow to another lift station or directly to the treatment plant. The main characteristic of a low-pressure system is that the capacity of the residential pumps selected determines the location of the lift station(s).

Other essential components of all low-pressure systems are isolation valves and air-release valves. Similarities of all low-pressure systems are:

- Inflow and infiltration (I/I) reduction.
- Smaller diameter (even smaller than vacuum sewers). Low-pressure sewer can be as small as 1.5-inch to six-inch diameter lines.
- Can be used for both flat and steeply sloping terrain. It doesn't depend on the natural topography of the area to convey wastewater and simplifies the sewer alignment.
- Can be installed in high groundwater areas, reducing the cost of dewatering during construction.
- Can be directionally drilled to avoid environmentally sensitive areas, reducing disturbances to the community.

There are two different types of low-pressure systems: grinder pump and effluent pump types.

Grinder pump systems – With this type of pump, tanks at the residence collect the sewer flows and a grinder pump mixes flow with the solids to be pushed through the pipes to the lift station. Like the effluent pump systems, each residential assembly requires periodic maintenance. Some of the advantages and disadvantage of this type of pump are:

- The tanks do not require periodic solids removal.
- Sewage is not as corrosive because of the air introduced, which may assist with odor reduction.
- Grinder pump repairs usually cost more than effluent pump repairs because the grinder assembly wears faster with sand.
- Velocities need to be between three and five feet per second in order to avoid solids settling and grease buildup, according to the *Myers Design Manual for Pressure Sewers, Based on Grinder & Effluent Pumps.*

Effluent pumps systems – For effluent type systems, the solids settle in the bottom of the tank. Then, the gray/effluent will flow through a weir into a chamber, where an effluent pump will, by level sensors, initiate the push of flow toward the lift station. Some of the advantages and disadvantages of this type of pumps are:

- The tanks require periodic solids removal.
- It is recommended that all the system components be non-metallic.
- Routine maintenance is necessary; however, pump repairs are not frequent.
- Velocities can be a minimum of one foot per second.
- Grease and solids are expected to remain in the tank and not travel through the collection system, reducing the need for flushing maintenance.

In summary, the major decisive factors for low-pressure effluent collection systems are:

- ***A very mild to flat terrain.***
- ***Lower cost of construction***. The low-pressure sewer system allows for shallower pipe installation.
- ***Less above-ground infrastructure***. Unlike the case of the vacuum system that requires a vacuum station and structures above ground, the low-pressure system requires a standard lift station without any significant above-ground structures.
- ***Lower cost of frequent repairs***. It is expected that for grinder pumps, the impellers will require more expensive and more frequent repairs because of the presence of sand in the flows.
- ***Less maintenance cost***. Vacuum systems require a full-time, well-trained operator, while low-pressure systems require only periodic maintenance.

The need to reduce cost, especially during the current money crunch, has driven utilities like Charlotte County Utilities to select low-pressure effluent sewer systems for most of their collection systems.

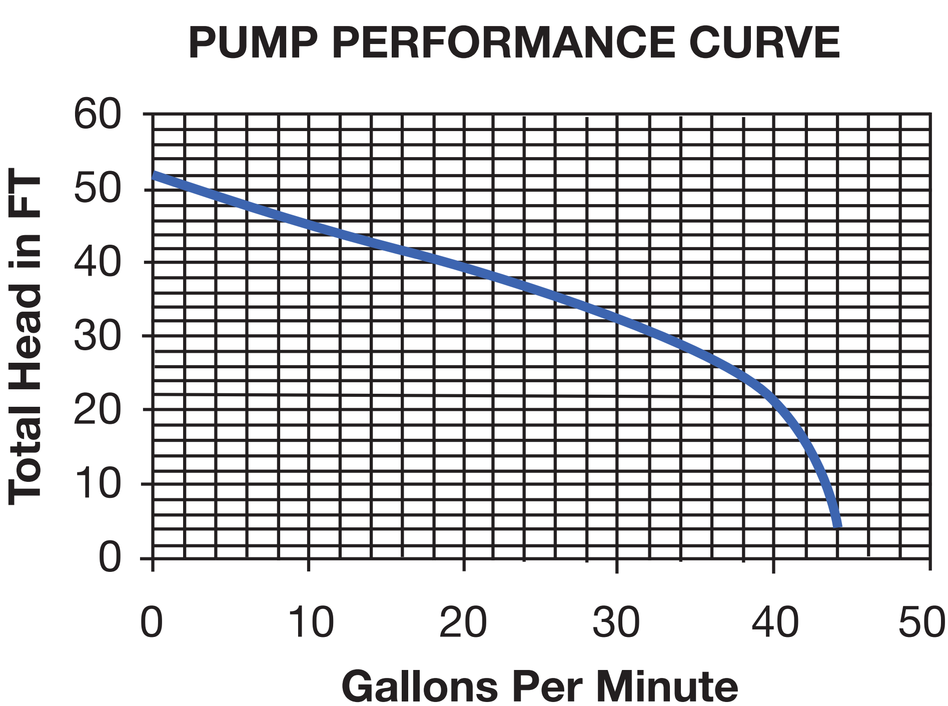

Figure 2: Performance Curve for a ½-Horsepower Effluent Pump

Design Peculiarities

The design of a low-pressure effluent sewer system has many similarities to other types of collection systems—especially during the initial stages:

- Collection of information: existing utilities (as-builts), topographic and geotechnical investigations.
- Land use and equivalent residential unit counts per lot.
- Calculation of the flows (average and peak) per equivalent residential unit.
- Selection of diameters, velocities, and headlosses based on design criteria specific to the low-pressure system (minimum velocities) and materials to be used (friction factors, etc.).
- Layout and alignment.
- Location of isolation valves and potential air entrapment.
- Lift station location.
- Lift station pump selection.
- Design plans and specifications.

For low-pressure effluent sewer systems,

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								Target:	43.0		
								Max:	42.4	6 fps	1 fps
From	**To**	**Add'l Lots**	**Cum Lots**	**Peak Q (gpm)**	**Linesize**	**Peak Vel**	**Seg Len**	**Seg hL**	**Total hL**	Linesize Range	
Sa1	Sa2	35	35	43	3	1.9	260	1.6	42.4	3	4
Sa2	Sa3	19	54	60	3	2.7	260	3.1	40.8	3	4
Sa3	Sa4	20	74	78	4	2.0	260	1.2	37.6	3	4
Sa4	Sa5	19	93	94	4	2.4	260	1.7	36.4	3	6
Sa5	Sa6	19	112	109	4	2.8	280	2.5	34.7	3	6
Sa6	Sa7	1	113	110	4	2.8	788	7.0	32.2	3	6
Sa7	Sa8	22	135	126	4	3.2	260	3.0	25.1	3	6
Sa8	Sa9	7	142	132	6	1.5	260	0.5	22.1	3	6
Sa9	Sa10	15	157	143	6	1.6	260	0.5	21.7	4	6
Sa10	Sb7	15	172	154	6	1.7	260	0.6	21.1	4	6

Figure 3: Hydraulic Evaluation and Results of the LP System for Rotonda Sands

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as with any other collection system, the selection/optimization of diameters is an iterative process; however, since there are no commercial models available for the low-pressure system, we created a model to help us design the system and minimize the effort of iteration. As a result of the evaluations, several lift stations were eliminated, saving thousands of dollars in construction and maintenance costs.

For the model, the following design criteria were used:

- Friction factor C=130 (pumping station design: Robert L. Sanks)
- Hazen Williams formula
- AADF 190 gallons per day per ERU
- Peaking factors
  - For the LP lines: Q peak = 3.5Qavg^0.807
  - For the force main: Q peak =18 $\sqrt{P}$/4 + $\sqrt{P}$. Where P is population in thousands.

Two peaking factors were used because the expected peaks and time of concentration for the low-pressure sewer system is different than for the force main. Low-pressure sewer lines will see peak flow depending on the number of pumps running at the same time, while the force main will see peaks depending on the lift station pump's operation.

- Maximum headloss per run has to be less than 43 feet to reach the lift station because the effluent pump was pre-selected to be a ½-horsepower pump (Figure 2) and typically their operational set up sets the rate of flow at approximately 10 gallons per minute.

Before the model is set up, using base map, a preliminary layout is needed to determine the drainage or collection basins, number of nodes, length of the segments, and anticipated location of the master lift station. The collection basins are defined typically by the topography, and since the topography is essentially flat, the limits of the basins were determined, in great part, by the streets. Looping was avoided in the layout to eliminate the possibility of dead zones, or zones where flows do not typically reach and cleanse the pipe; consequently, at the end of each street, a clean-out was placed to provide easier maintenance.

A closer look at the model shows the setup (portion of Figure 3) where each segment is identified by the **From** node to the **To** node.

- The **Add'l Lot** (additional lots) column is to input the number of lots added at the **To** node.
- The **CumLots** (cumulative lots) column is calculated automatically by adding all the cumulative lots (in the above rows with the same node number in the **To** column as the **From** node of the segment in questions) and the **Add'l Lot** cell. As shown in the example illustrated, for segment **Sa10** to **Sa7**, the cumulative lots are a sum of the **CumLots** of segment **Sa9** to **Sa10** (157 lots) and 15 lots, resulting in a total of 172 lots.
- The **Peak Q** (peak flow) cell calculates the peak flow of the cumulative flows (based on the design criteria mentioned above.
- **Linesize** calculates, by default, the closest practical diameter with the capacity for the flow and velocity no greater than six feet per second.
- The **SegLen** (segment length) is an input that can be obtained from the base map and the preliminary layout.
- The **Seg hL** (segment headloss) is calculated based on the velocity and flow in the pipe (assuming a full pipe).
- The **Total hL** (total headloss) is calculated similarly to the **CumLots**. The model reads the **Total hL** from the segment above with the same node number in the **To** column as the segment's **From** node.
- If the **Total hL** exceeds the 43 feet of headloss in any segment, a revision will be made to the upstream diameters. Diameter size will be increased, having the best cost/benefit in mind, to reduce the headloss starting with the segments where the velocity is equal or higher than six feet per second.

Final Layout

With the results of the model, the layout can be finalized (Rotonda Sands shown in Figure 3) using the base map and the calculated pipe diameters. All diameters were verified to make sure the downstream diameters are equal or larger. Diameters for both the Rotonda Sands and Rotonda Meadows range from two to three inches in diameter in the collector streets and from three to 10 inches in diameter in the mains. The diameters for the force mains to transport the flows from the master lift station to the treatment plant are both 12 inches.

Air Entrapment

Air entrapment in pressure lines can lead to an increase in the system head loss, higher energy costs, and/or the inability of pumps to move flow at all (air lock). One of the "rules of thumb" states that air release valves (ARVs) need to be installed at high points and at 2,500 linear foot intervals along lengths of flat main. Another recommends an air release valve every 14 diameters. Applying either of these typical criteria in these projects, with 43 miles of pipe, may have resulted in an unnecessarily large number of ARVs—more than 91.

Research by Wallingford Hydraulic Research Institute studied the movement of air within pressure lines. Findings indicated that air bubbles can be moved reliably along flat sections of pressure mains and even pass downward through sloping sections of mains, given sufficient velocity. Smaller mains require less velocity in order to move air along; therefore, for smaller diameter pipes, the downward slope can be steeper than for larger diameters.

Table 1 provides a portion of the results of the calculations, as it applies to the Sands and Meadows projects. Since the hydraulic

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Figure 4: Rotonda Sands Final Layout

Pipe Diameter (inches)	Downward Slope (%)	Vc (fps)
3	10	1.1
3	20	1.6
3	40	2.2
3	100	3.0
4	10	1.2
4	20	1.8
4	40	2.5
4	100	3.4
8	10	1.7
8	20	2.5
8	40	3.5
8	100	4.8
12	10	2.1
12	20	3.1
12	40	4.3
12	100	5.9

Table 1: Velocities and Slopes by Diameter Necessary to Avoid Air Entrapment

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analysis for the project resulted in mains' velocities of an average greater than 1.6 feet per second, most mains could have downward slopes of up to 20 percent without experiencing air entrapment. This concept was very useful to cross under existing utilities, resulting in a significantly lower number of ARVs.

Initial system conditions—low flows—were considered where the peak velocities can be near zero; thus, the downward sloping mains will have to be minimized. In fact, design will include an objective of maintaining upward sloping mains to the extent possible and within reason because of potential cost impacts of deep lines. Until the subdivisions become substantially populated, periodic flushing will be required to prevent air locks.

Isolation Valve Locations

Isolation Plug Valves will be located at the intersection of each dead-end street and every 1,000 linear feet of main, as required in *Design and Specification Guidelines for Low Pressure Sewer Systems*, 1981. All plug valves will vary in size and materials; however, for this project all valves were listed in the Charlotte County Utilities Acceptable Materials List. The clean-out at the end of each street also has an isolation valve. The rest of the isolation valves were located strategically to isolate basins to a maximum of 22 residents in case of system problems.

Permitting & Funding

Rules 62-604 and 62-555 of the Florida Administrative Code (FAC) were followed for designing the collection system. The construction permit for the project was prepared and obtained after applying to the Florida Department of Environmental Protection (FDEP), utilizing the form for the Notification/Application for Constructing A Domestic Wastewater Collection/Transmission System (Form 62-604.300(8)(a)). Additional information such as hydraulic calculations were presented with the application to help the reviewer understand this uncommon collection system.

Since there were no wetlands involved in the project, the application to the Southwest Florida Water Management District was prepared as a Notice General. This application was later approved by the FDEP, the new reviewer agency (based on the latest agencies agreement).

The project was funded with a State Revolving Fund load base on the eligibility stated within rule 62-552 FAC. In order to fulfill the funding requirements, the funding agencies also reviewed the preliminary and

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final project design. Other requirements included public hearings and approval, along with notification of the project status until completion.

Bidding

Since most contractors are not familiar with this type of collection system's construction, it is important that the bidding document states clear information to avoid mistakes during construction and problems during operation.

Since the system was designed with a specific residential effluent pump, the documents stated that no substitutions were allowed. Several standard details, such as the clean-out and the service connection details, were simplified to reduce confusion and reduce potential cost of the "unknown factor." In the general notes of the plans, it was stated that the contractors must maintain a flat or positive slope from the cleanouts to the master lift station(s) to help the air travel upward.

Decisions on construction methods were made by considering several factors. One of them was coordination with Charlotte County's public works department and its schedule for re-pavement to minimize the capital cost to the county. Another factor was that most of the lots are not developed; therefore, open trench methods were acceptable. Furthermore, in order to obtain better bid prices, the decision of what methods of construction to use were limited only where necessary, but left for the contractors to decide, allowing them flexibility based on their capabilities.

Maintenance & Operations

Periodic maintenance is essential for a reliable low-pressure system. According to research and the county's experience, a two-person crew can manage annual preventive and emergency maintenance for about 1,000 pump stations. Typical duties during maintenance are:

- Inspecting the control panel.
- Testing the alarm light.
- Checking resistance on power leads and checking ground wire.
- Washing down the holding tank and pump.
- Checking floats for grease build-up.
- Pulling the pump.
- Checking the stainless steel cutter blade for wear.
- Flushing the lines periodically.
- Removing solids from each tank every 10 years, according to the Peabody Barnes Manual.

It was also recommended that the utility keep spare pumps, as a minimum, totaling between 3 and 5 percent of the total number of pumps in service. The percentage will increase after 10 year of service life, to between 5 and 10 percent. Some pumps are known to have a total shelf life of 20 years.

In summary, the low-pressure effluent collection system was selected for these two projects because of its advantages over gravity and vacuum sewer systems in areas with high groundwater and flat terrain, such as these projects. This selection made it possible to minimize cost and provide reliable service to the communities.

Although the design of the projects required consideration of the peculiarities of the low-pressure sewer, value engineering in these projects saved thousands of dollars by eliminating unnecessary lift stations. The design also considered the operation and maintenance for phased growth and the need to reduce costs, even after the community is completely built out.