Large-Diameter Parallel Sewer in an Urbanized Setting Requires Precise Above-Ground and Subsurface Utility Engineering

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The City of Raleigh Public Utilities Department (CORPUD) provides municipal wastewater service to approximately 156,000 metered customers and a service population of approximately 485,000. The City has merged its water and wastewater utilities with surrounding communities, including Wake Forest, Garner, Rolesville, Knightdale, Zebulon and Wendell, by taking ownership of their systems. These utility mergers are intended to consolidate these systems and ultimately decrease the customers' utility rates for water and sewer service.

With the mergers, the City's service area covers 270 square miles and extends into three major drainage basins: Crabtree, Neuse, and Walnut. The City's overall wastewater system includes three wastewater treatment facilities. The largest is the Neuse River Wastewater Treatment Facility (WWTF) located in the southeast region of Wake County near the confluence of the Neuse River and Poplar Creek. The facility is currently permitted to treat 60 MGD of wastewater, and the City is now in the first of five expansion phases to increase the permitting capacity by 15 MGD.

Approximately 20 MGD of the City's average daily flow to the facility comes from wastewater collected in the Crabtree Basin. The major wastewater infrastructure within the Crabtree Basin includes parallel gravity sewer interceptors along Crabtree Creek that range in size up to 66 inches in diameter. Dual 60-inch gravity interceptors discharge into the Crabtree Wastewater Lift Station (LS) located at the interchange of I-440 with the US 64/264 Bypass on the eastern side of Raleigh.

Addressing I&I and SSO Challenges

The City has been faced with inflow and infiltration (I/I) challenges in many of its aging gravity sewer systems that collect and convey flow to the Crabtree Basin interceptors. Design is now being finalized for rehabilitation of the North Bank Interceptor, which traverses the north side of Crabtree Creek.

The City is still faced with the critical need to increase wet-weather capacity along this interceptor system. The Crabtree Basin wet-weather flows were estimated to be 56 MGD in 2006, according to the City's Sanitary Sewer Capacity Study (SSCS) completed in 2008. With a 19.9-MGD estimated dry-weather average daily flow in 2006, the basin system was experiencing an average peaking factor of 3.26. The I/I conditions and associated excessive wet-weather peak flows have resulted in sanitary sewer overflows (SSOs) in the Crabtree Basin.

The selected alternative from the SSCS and the other 'high-altitude' evaluations was construction of a 20-MGD wastewater pump station with a 4-MG equalization basin and 52,000 LF of 42-inch force main. This alternative was estimated to be the most economical approach for solving the City's infrastructure problems in the Crabtree Basin.

The project, known as the Crabtree Basin Pump Station and Force Main, was

A portion of the route for the new gravity interceptor will be located along this greenway at Lassiter Mill Park.

included in the City's FY 2008-2009 Capital Improvement Plan (CIP), which covered proposed improvements through 2030. It was estimated to cost $60-70 million of the total $850 million for the wastewater improvement projects in the CIP.

Re-Evaluating the Original Solution

In 2009, the engineering team of Hazen and Sawyer, PC and McKim & Creed was selected by the City of Raleigh to perform a detailed preliminary engineering report (PER) and environmental assessment (EA) for the proposed pump station and force main project. Very early in the PER development, it was apparent that a force main route along the existing interceptor corridor was a likely alternative for a number of reasons. As part of the PER, CORPUD project manager Aaron Brower, PE, asked the team to also evaluate an alternative that would extend the gravity sewer from Glenwood Avenue on the north side of I-440 to the existing Crabtree Creek LS at the I-440 interchange with the US 64/264 Bypass. Brower, who is now the Public Utilities Department's City Construction Projects Administrator, explained to the team that while he understood the previous recommendation for a pump-around option with an upstream pump station and equalization basin, he recommended evaluating the gravity sewer option in more detail before implementing a final design.

The Public Utilities Department generally seeks solutions in which gravity sewer can be installed or extended to avoid or eliminate pump stations. In this case, the concern involved the reality of having a wet-weather pump station that may operate only a handful of times during one year, resulting in significant challenges for maintaining the equalization basin and pump station. The pump station would also have to be located in an area surrounded by existing residential and commercial development.

The results of the team's PER indicated that whether the City extended a force main or gravity interceptor along the project area, the recommended route would be along the existing gravity interceptor corridor paralleling Crabtree Creek. This route allowed either pipe line to avoid higher ground elevations, thus reducing static head for the force main or installation depths for the gravity sewer. The majority of the route is City-owned property designated for public parks and/or greenway trails, which would significantly reduce the impact to private land owners and minimize land acquisition costs.

The engineering team evaluated multiple alternatives for the gravity sewer option that included diverting flow from the north interceptor and minimizing the cost for the North Bank Interceptor project. The team concluded that a new gravity interceptor composed of approximately 40,000 LF of 54-inch, 60-inch and 72-inch diameter sewer, which was an upgrade to the existing Crabtree LS, and 14,600 LF of 42-inch force main from the Crabtree LS to the downstream 66-inch gravity interceptors, could be constructed at a cost nearly equal to or less than the originally proposed pump station, equalization basin and force main in the City's CIP.

The City selected the gravity interceptor alternative, now known as the Crabtree Basin Wastewater System Conveyance Improvements (CBWWSCI). The project will be designed and constructed in phases.

Locating Above-Ground Features and Underground Utilities

The City and the design team knew that routing a large-diameter gravity interceptor through a congested urban area, such as exists along the Crabtree Creek existing sewer corridor, presented many design and construction challenges, including;

- routing through existing greenway trail area adjacent to residential, commercial,

Tunneling will be required to install the gravity sewer under some of the roadway bridges along the alignment.

and industrial properties;
- nine crossings of Crabtree Creek or major tributaries;
- railway crossings and major roadway crossings, including I-440;
- installation under roadway and railway bridges and a highway interchange ramp;
- installation of 3,100 LF of sewer within City streets;
- location very close to existing parallel gravity interceptors and other underground utilities;
- crossing major utility lines, including existing large-diameter gravity sewers, water mains, storm sewer and fiber optic lines;
- deep installations within combinations of rock and wet or saturated soils; and
- installation across industrial and commercial property with potential soil and groundwater contamination.

The CBWWSCI included nearly every design obstacle one could expect in an urbanized area. Although preferred, the gravity sewer alternative limited the flexibility of horizontal and vertical location. Therefore, the proposed route had to be fully evaluated by the design team to accurately determine the existing conditions and select an alignment that provided the most viable sewer placement for constructability, serviceability and future maintenance. Subsurface Utility Engineering (SUE) was the tool to accomplish that task.

SUE is an engineering practice that uses non-destructive geophysical investigating techniques to verify the existence, condition and exact location of underground utilities. SUE is available in four different quality levels:

- **Quality Level D:** Information gathered solely from existing utility records.
- **Quality Level C:** Involves surveying visible, above-ground utility facilities and correlating this information with existing utility records.
- **Quality Level B:** Uses surface geophysical techniques to determine the existence and horizontal position of underground utilities.
- **Quality Level A:** Employs nondestructive digging equipment (vacuum excavation vehicles) at critical points to determine the precise horizontal and vertical position, as well as size and type, of underground utilities.

Survey crews located and mapped above-ground features, and SUE specialists used Quality Level B and Quality Level A services to designate and locate below-ground conditions along the proposed route. The SUE horizontal designation included more than 44,000 LF of underground utilities, including electrical power, natural gas, fiber optic, cable television and telephone duct, potable water lines, sewer force main, water and sewer services, and some gravity sewer. All located features were mapped to the horizontal NC state plane coordinate system and the North American Vertical Datum (NAVD) 88. The current FEMA floodplain mapping for Wake County is also on NAVD 88, making the project design elevations relative.

In one particular location along the proposed sewer alignment, the existing gravity interceptor was anticipated to turn with a buried bend in the line (as opposed to a manhole). The SUE team located the bend utilizing electromagnetic (EM) technology to designate the path of the existing gravity sewer. The team used the same technology to obtain the vertical depth of the bend, allowing the design team to determine the appropriate new gravity sewer alignment.

Following Level B designation, the SUE team performed Quality Level A location at critical points along the alignment. They used two vacuum excavation trucks to excavate test holes, enabling the team to verify horizontal designations and, more importantly, verify the actual depth, material and size of the underground utilities. Approximately 110 test holes, ranging from 1 foot to 12 feet in depth, were performed along the 40,000 LF of alignment. Some of the more critical Level A locations included the major 48-inch transmission water main, the Qwest fiber optic line within a Norfolk Southern railroad right-of-way, and gas mains along a congested city street where the sewer interceptor will be installed within the pavement.

Where existing utility lines could not be accessed by a vacuum truck, the SUE team

Test hole excavations enabled the team to verify horizontal designations, depth, material and size of the underground utilities along the proposed interceptor alignment.

In many locations, the proposed gravity interceptor will have to be routed between the existing gravity interceptor and residential lots within the greenway area.

Above-ground electric transmission lines and buried large-diameter water and sewer mains make accurate above- and below-ground location essential.

used Ground Penetrating Radar (GPR) and EM technology to obtain reliable vertical depth measures so the design team could assess potential vertical conflicts with the gravity interceptor. Many of the utilities that needed to be located and verified with test holes were under pavement, requiring the SUE team to work closely with NCDOT and the City of Raleigh DOT to coordinate traffic control and backfill of the test hole locations.

All test hole data was recorded on a standardized test hole form with the test hole number, coordinates on NAD 83, depth below ground with top of pipe elevation on NAVD 88, material type, outside diameter, nominal diameter, asphalt depth, and utility condition. This information was entered into AutoCAD and provided to the design team for entry into the plan and pipe profile sheets.

Designing Around the Underground Utilities

With the accurate survey and underground utility location work in place, the design team proceeded with the final alignment selection. The first critical alignment selection involved location of the proposed 72-inch gravity interceptor at the low end where the line will connect to the existing Crabtree LS. The interceptor had to be routed under two existing 60-inch gravity interceptors and between concrete pillars that support the overhead interchange ramp. The route terminates at the pump station site, with connection to the existing pump station containing five 20 MGD screw pumps.

Other critical alignment selections included location of the interceptor proximate to the existing sewer interceptor and adjacent to residential lots or steep ridges where there was very limited area. In several of these locations, the engineers designed for relocation of the existing (shallower) interceptor in a common trench with the new interceptor so that both lines can be maintained between Crabtree Creek and the existing uphill obstructions.

When completed, the new interceptor will be 10 to 35 feet deep. The CORPUD staff, with input from the design team, decided to design the proposed gravity interceptor at elevations deep enough for the pipe to maintain cover under all creeks along the alignment. This design eliminates a minimum of nine inverted siphons on the new interceptor, reducing the need for the extensive maintenance that is inherent to siphons and minimizing the potential for sewer failures and/or overflows and odor problems.

Most of the roadway crossings and the railway right-of-way crossings will be accomplished by conventional tunneling using steel plate liners or micro tunneling with pipe jacking. The design team will analyze subsurface geotechnical information collected by soil borings along the alignment to determine the preferred trenchless installation method. Micro tunneling may be considered where groundwater will be encountered and subsurface material is estimated to be fairly consistent.

Researching Other Potential Hazards

In addition to evaluating the existing above-ground and below-ground physical infrastructure, the team must also consider potential hazardous subsurface materials, such as volatile and semi-volatile organic compounds (VOCs and SVOCs), and petroleum hydrocarbons. These materials may cause risk to workers during construction, as well as adversely impacting the integrity of the gravity interceptor over time.

The engineering team is working with specialized environmental subconsultants to perform environmental investigations in two phases. The first phase includes research of environmental records with federal, state and local agencies, site assessments and interviews with property owners. The

There were a wide variety of environments SUE crews were exposed to during the SUE phases of this project. A great deal of work took place on city and state maintained roads and road shoulders. In addition, there were two railroad right-of-ways to consider, multiple creek crossings, several aerial high-powered transmission electrical right-of-ways, greenway areas congested with walkers and cyclists, and COR existing sewer easements.

SUE professionals followed safety regulations at all times. Safety vests were worn constantly, traffic signs were set up on all roads, personal protective equipment (PPE) was used during the vacuum excavation activities (safety glasses, face shield, steel toe boots, hard hats, long pants, hearing protection, gloves, back brace, whip checks on the air hose, etc.) There were no recordable incidences during this project.

second phase includes soil sampling and temporary groundwater monitoring wells. The soil and groundwater sampling will be conducted at critical locations along the alignment where there is potential for contamination based on the research, site assessments and interviews. There are known occurrences of past soil and water contamination in some of the industrial and commercially zoned regions along the alignment. The results of the environmental investigations will be essential in selecting the final alignment in these areas.

Where We Are Now

CORPUD plans to complete the design and permitting of the CBWWSCI gravity interceptor in the fall of 2011. Phase I construction, which includes the first half of the gravity interceptor, is slated to begin in 2012. The second half (Phase II) will begin between 2013 and 2014. The overall project will include a third phase with the upgrade of the existing Crabtree LS and installation of 14,600 LF of a 42-inch force main from the Crabtree LS to the existing downstream dual 66-inch interceptors along the west side of the Neuse River.

In Summary

The City's strong desire to find the most effective, reliable and economical solution to SSOs and I&Is led CORPUD away from the construction of a pump station and equalization basin with a very long force main. Officials recognized that this scenario, slated for a highly developed area, could become a public nuisance and may not be as effective in reducing the risk of an SSO as a gravity sewer alternative.

Further study resulted in the selection of the gravity sewer alternative, which proved to be economically viable. The gravity sewer solution brought with it a new set of engineering challenges, requiring a high level of above- and below-ground survey and SUE, further supported by environmental investigations. A successfully engineered gravity sewer project will minimize SSOs, use resources wisely, protect public and private property, improve customer service, protect surface water, and institute a long-term, sustainable solution to I&I and SSO challenges. ■

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