Two-Phase Project Adds Capacity, Reliability, and Redundancy to 80-year-old Pump Station in Saint Paul

Project Overview

Minnesota's state capital, Saint Paul, is built around the Mississippi and Minnesota rivers in the east central part of the state. The city's downtown area is located above sandstone bluffs that line the north side of the Mississippi River. The city has experienced recent redevelopment along the foot of the river bluffs, notably high-density residential properties.

Sanitary sewer modeling conducted by the city indicated that the Sherman Street Lift Station and Force Main system, which conveys wastewater from Shepard Road near the Mississippi River beneath the Soo Line Railroad and up the sandstone bluff for treatment, was in need of upgrades. Specifically, the city wished to increase capacity, improve reliability, and provide redundancy of the lift station system.

Following completion of a detailed feasibility analysis, project partners TKDA and CNA Consulting Engineers provided engineering and architecture design services for the project, which was constructed in two phases, beginning in October 2015. The project was substantially complete in October 2016.

Background

The Sherman Street Lift Station and Force Main system serves approximately 166 acres of commercial, industrial and residential properties. The area where the lift station is located adjoins the Mississippi River southwest of downtown and is prone to flooding. Since 2010, four flood events had occurred.

The lift station, located near the intersection of Sherman Street and Spring Street, lacked redundancy in its force main system and its pumping capacity was less than required based on previous city sewer modeling efforts, especially in view of recent high-density residential developments in the area.

The station lacked an automatic backup power source and a way to provide capacity during flooding and pump or force main failure.

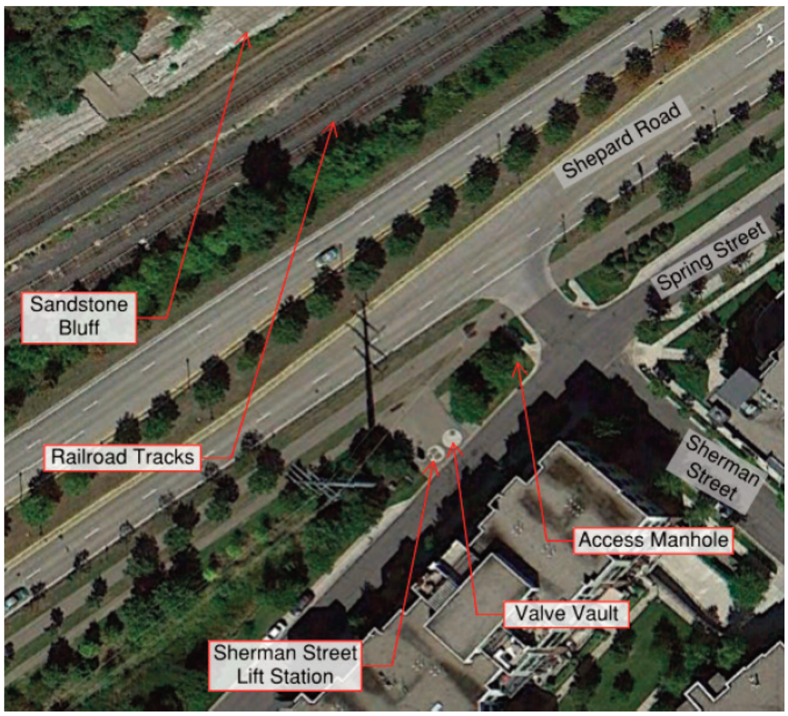

Figure 1. Sanitary sewer flows are collected in the Sherman Street lift station, then pumped through an existing 10-inch force main beneath Shepard Road and the Soo Line Railroad Tracks and up a 40-foot sandstone bluff within the City of Saint Paul's stormwater tunnel. Some segments of the force main – notably, the section within the tunnel – have been operational since 1937.

The 950-foot force main was originally constructed in 1937. Despite intermittent improvements, it had served beyond its intended useful life and was subject to occasional failures and emergency repairs. Complicating matters was that more than half of the force main was encased inside a city stormwater tunnel within the 40-foot sandstone bluff located between the lift station and the discharge manhole at the intersection of Sherman and Exchange streets above. In addition, much of the remaining pipe length at the foot of the bluff was installed beneath busy four-lane Shepard Road and the Soo Line Railroad Company track.

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These factors made maintenance of and access to the force main difficult and left the city at high risk of system failure. TKDA and CNA Consulting Engineers worked with the Saint Paul Public Works Department to determine the most feasible option to increase the capacity, provide redundancy, and improve the reliability of the Sherman Street Lift Station and Force Main system.

Analysis of Project Alternatives

Five tasks were set by the project team to help evaluate options to accomplish these goals and develop contingency plans in the event of system failure. Modification methods and system components were developed based on the Recommended Standards for Wastewater Facilities, as published by the Wastewater Committee of the Great Lakes – Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers.

Task 1. Develop alternatives and determine the feasibility and cost to construct a redundant force main piping system.

The 10-inch-diameter steel force main runs approximately 100 feet from the Sherman Street lift station valve vault to an access manhole, then crosses Shepard Road and the railroad tracks to a transition area before heading up the bluff within the city's sandstone tunnel, which serves primarily to convey stormwater down to the river. At the time it was constructed in 1937, approximately 550 feet of the force main was embedded in the tunnel side wall, where it remains. The tunnel, which is less than 4 feet high in many locations, is irregular in shape and difficult to access (it requires confined space entry planning). In addition, it is intersected by multiple sanitary sewer drifts which connect to an 8-inch gravity sanitary line embedded in concrete at the tunnel bottom. The original section of force main under the highway and railroad was replaced in 1987 following localized failure and subsequently encased in 250 feet of 42-inch reinforced concrete pipe (RCP), which is typically full of water. The static head of the existing force main is approximately 52 feet.

The project team investigated five options.

Option 1: Construct a new dual force main system using directional drilling.

The project team concluded that this approach would be a high-cost, high-risk endeavor. Drilling a 48-inch-diameter casing tunnel up the bluff beneath the existing stormwater tunnel would require sizable drilling pits at the intersection of Exchange and Sherman streets (a depth of 45 feet) and near Sherman and Spring streets (a depth of 30 feet). A geotechnical investigation of the many unknown layers of materials along the route through a densely developed residential area also would be required. Such invasive activities would involve a high degree of risk and would be costly and tremendously disruptive. Benefits of this approach were that the city would have a new dual force main system designed for ultimate capacity and with improved access for operation and maintenance. The estimated cost of Option 1 was $2.7 million.

Option 2: Install a new, redundant force main pipe within the existing tunnel.

A second force main pipe could be constructed by strapping it to the crown of the tunnel or embedding it in concrete at the tunnel invert next to the 8-inch sanitary sewer. This would, however, reduce the stormwater capacity of the tunnel and make it even more difficult for maintenance crews to access the system. Such an approach would also eliminate the opportunity to access the existing 8-inch sewer and its associated connections. For these reasons, this was not considered a feasible option.

Option 3: Improve the tunnel and install a new dual force main system within it.

Tunnel expansion would enlarge the cross-sectional area and make the tunnel more uniform along its length. Two new 12-inch force main pipes embedded in the tunnel side wall would provide additional future capacity and system redundancy, make it easier for maintenance crews to access the system, and preserve the tunnel's existing stormwater conveyance capacity. However, the work would be labor intensive: hand tools would be required to perform the tunnel enlargement work and material would have to be

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manually removed through an enlarged access manhole above the bluff. Special consideration would have to be given to determine the most cost-effective and constructable pipe material given the constricted working conditions.

Drawbacks to this approach were that design and construction costs would be moderately high, the force main pipes would still be wedded to the stormwater tunnel, and bypass pumping could be required to maintain sanitary service during construction. Benefits of this approach were that the city would have a new dual force main system designed for ultimate capacity and with improved access, and the stormwater tunnel would maintain its conveyance capacity. The estimated cost of Option 3 was $1.3 million.

Option 4: Install new force main pipe(s) within the 42-inch RCP casing beneath the highway and railroad tracks.

The 10-inch force main pipe sits at the bottom of the 20-year-old RCP casing. There is enough remaining space in the casing to accommodate one or more redundant 12-inch force main pipes, depending on the choice of pipe materials (due to limited space, two new 12-inch pipes would preclude the use of flanged ductile iron pipe). If two new HDPE pipes were installed to provide for ultimate system capacity, the existing 10-inch pipe could be used as a temporary bypass route during construction, then encased in concrete and abandoned in place. If only one 12-inch force main pipe were installed, the 20-year-old 10-inch force main pipe would remain in place. New piping would need to be restrained using flowable fill or pipe spacers.

To connect the redundant force main from the RCP casing to the sandstone tunnel, it would be necessary to access the casing from the bluff side of the railroad tracks to expand the sandstone tunnel transition area. The current lack of access to the force main at that location would complicate matters. There are at present no access points to the casing between Shepard Road and the railroad tracks, either, which would complicate the pipe installation given the length of the casing and the tight annular space within it. The casing is typically full of water, so construction crews would have to pump the water out to access the force main pipe.

To complete the installation, the existing access manhole at Sherman and Spring streets would need to be expanded by 10 feet to the south within the median to accommodate the new piping. A new valve vault also would be required between the manhole and the existing lift station. The new valve vault would house the 90-degree bends necessary to lower the dual force main pipes to the elevation of the RCP casing, while the new access vault would accommodate the 90-degree bends necessary to tie into the new force main pipes within the casing.

Design and construction costs would be moderately excessive and there would be significant disruptions at the intersection of Sherman and Spring streets during construction. Benefits of this approach were that the city would have a new dual force main system designed for ultimate capacity as well as improved access for system operation and maintenance and to implement an emergency bypass. Assuming two new HDPE pipes are installed, the estimated cost of Option 4 was $377,000.

Option 5: Construct a new casing pipe beneath the highway and railroad tracks to house a new, redundant force main system.

A new 54-inch-diameter casing pipe could be jacked 250 feet across Shepard Road and the Soo Line Railroad tracks. A 20-foot-deep jacking pit would be installed at Sherman and Spring streets; the casing would culminate next to the existing 42-inch RCP casing. Two new 12-inch-diameter force main pipes would be installed in the new, larger casing and the existing tunnel transition area would be excavated to accommodate the new pipe connections. As in Option 4, the existing access manhole would require modification, and an additional valve vault would be required.

Design and construction costs with this approach were found to be excessive, and there would be a high level of risk and disruption in the jacking pit area during construction. Moreover, soil conditions under Shepard Road

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were found to be poor and wet and not conducive to drilling under existing rights-of-way. Benefits of this approach were that the city would have a new dual force main system designed for ultimate capacity as well as improved access for system operation and maintenance and to implement an emergency bypass. The estimated cost of Option 5 was $1.2 million.

Recommendations for Task 1

Based on the alternatives analysis, the project team recommended the city pursue the following options for an estimated combined cost of $1.7 million: improve and enlarge the existing sandstone stormwater tunnel and install a dual force main system consisting of two 12-inch-diameter pipes encased within the tunnel wall (Option 3); and install a new dual 12-inch-diameter force main inside of the existing RCP casing beneath Shepard Road and the Soo Line Railroad tracks (Option 4).

Task 2. Develop alternatives and determine the feasibility and cost to increase the capacity of the lift station.

The Sherman Street lift station is a duplex submersible station composed of a 9-foot diameter precast reinforced concrete wet well and a 10-foot diameter precast reinforced concrete valve vault. It was originally constructed in 1937 as a wet well/dry well station and was converted to a submersible station in 1978. The lift station receives flow from approximately 2.3 miles of sewer conveyed through two 8-inch gravity sewers that discharge to the lift station.

Additional improvements to the lift station have been made within the past three decades. Today, the wet well is approximately 34 feet deep, with a total storage volume of about 2,100 cubic feet (16,000 gallons). The lift station is serviced by two submersible Flygt CP3152 pumps installed in 1999 and rebuilt in 2007. Each pump discharges under approximately 60 feet of total dynamic head; both discharge pipes converge to the single 10-inch force main.

The lift station pumping capacity is about 800 gpm for a single pump — which, based on past modeling efforts by the city, is just adequate to accommodate the theoretical one-year precipitation event (about 800 gpm). The theoretical maximum capacity of the lift station when both pumps are pumping in parallel is 1,150 gpm, well below what is needed to accommodate the theoretical 2,190 gpm 25-year precipitation event.

The project team investigated four options.

Option 1: Install new higher-capacity pumps in the existing lift station wet well.

The capacity of the existing lift station pumping system could be increased by replacing the existing pumps with two new Flygt NP3171 MT3 433 pumps. This would boost capacity to 1,250 gpm with one pump on and 1,650 gpm with both pumps on. As the new pumps are identical in dimensional size as the existing pumps, they could be installed in the existing wet well structure.

Were the new pumps to be installed along with a new dual 12-inch-diameter force main, the lift station pumping system would be 1,550 gpm with one pump on and 2,225 gpm with both pumps on. This would allow the city to accommodate the modeled 25-year precipitation event through a single force main pipe with both pumps on.

Drawbacks of this approach were that the larger 34 HP pumps may require moderate electrical improvements at the lift station site, and that the configuration lacks true redundancy during the 25-year precipitation event. Benefits were that the city would have increased pumping capacity and that the cost of the larger pumps was approximately equivalent to the cost of replacing the existing pumps in kind. The estimated cost of Option 1 was $105,000.

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Option 2: Expand the lift station wet well to install a higher-capacity, three-pump system with 25-year precipitation event redundancy.

The installation of three Flygt 3315MT 60 HP pumps in the lift station wet well would achieve a 25-year precipitation event redundancy. The wet well would need to be expanded to approximately 21 feet in width to house the new pumps and provide space for proper operation and maintenance. The existing utility service would need to be analyzed to determine what modifications would need to be made to accommodate the new pumps.

Significant difficulty was expected in constructing a new wet well of the required dimension at the existing site, largely because of the size of the site, the current depth of the lift station, and the need to maintain pumping capacity during construction. Other drawbacks include the need for additional electrical improvements at the lift station site and high flow velocities of greater than 9 feet per second through the existing 10-inch-diameter force main during maximum pumping. Benefits were that the city would be able to pump the modeled, 25-year storm event with full redundancy.

Option 3: Replace the existing pumps, when needed, with identical model pumps.

City staff reported that the existing, rebuilt pumps operate well and do not require frequent maintenance. Pump replacement could, therefore, ideally be deferred until improvements to the lift station force main system are made. New pumps would likely restore the lift station capacity to handle the one-year precipitation event of 800gpm.

This configuration lacks true redundancy when the second pump is required, and the pumping capacity is less than that required for the modeled 25-year precipitation event. In addition to a slight increase in pumping capacity, electrical modifications would not be required, wet well expansion would not be necessary, and it is the least expensive option. The estimated cost of Option 3 was $46,800.

Option 4: Modify the force main valve vault discharge piping so that each pump has a dedicated force main pipe.

Assuming a redundant force main system is constructed, this option would modify the existing piping within the existing (or expanded) valve vault to allow for each pump to discharge through a dedicated force main pipe when desired. Electrically actuated isolation valves would activate the dedicated force main system by a set level of flow or pressure within the active single force main pipe.

This option requires that a second force main pipe be constructed but would, however, provide flexibility in lift station pumping and increased pumping capacity using smaller pumps. The estimated cost of Option 4 was $92,950.

Recommendations for Task 2

The project team recommended the city pursue the following options for an estimated combined cost of $197,950: install new higher-capacity pumps in the existing lift station wet well (Option 1) and modify the valve vault discharge piping to allow for greater redundancy and increased pumping capacity (Option 4).

Task 3: Develop alternatives and determine the feasibility and cost to construct improvements to the lift station and force main to improve access and provide redundancy and reliability during emergencies.

The Sherman Street lift station is in a flood-prone area and lacks redundancy and an automatic method of maintaining service during power outages. When any portion of the lift station system experiences failure, it leaves the city few options for maintaining service.

Currently, emergency bypass actions taken to prevent sewer backups or overflows involve employing vactor trucks, which convey sewage to the sanitary manhole located one-half mile northeast at Chestnut and Exchange streets. This requires a significant amount of coordination and capital expense.

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Six options were considered to analyze the feasibility of improving emergency service: (1) the use of backup submersible pumps; (2) the installation of a backup emergency force main piping system, either above ground or below grade in a storm drain pipe under Shepard Road; (3) construction of a permanent diesel standby pumping station; (4) continued use of vactor trucks; (5) the acquisition of a permanent diesel or natural gas generator; and (6) construction of quick-connect locations on the force main.

Recommendations for Task 3

Temporary piping systems take time to install in the field, and do not provide an automatic method of redundancy. The standby pumping station was not an ideal fit due to suction lift limits. The use of vactor trucks was not considered to be a viable, permanent solution but may be necessary for short periods of time under any emergency bypass scenario.

As a natural gas utility is nearby, the project team recommended the acquisition of a 70kW natural gas emergency generator to provide a permanent, backup energy source at the site to power the existing pumps. This permanent installation would require a concrete slab, minor grading and upgrades to existing electrical systems and control panels. The estimated cost of Option 5 was $95,550.

Meeting Challenges in the Field

Construction of Phase I of the project began Oct. 15, 2015. ECI Construction, Inc., submitted the lowest responsible bid in the amount of approximately $1.85 million. Most of the work in this phase, on which CNA Consulting Engineers was the lead, centered on enlarging the stormwater tunnel and encasing the segment of the new dual force main within it.

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A manhole at Ryan Avenue up on the bluff was selected as the main construction access for work crews. However, it was necessary to first enlarge the manhole shaft from 4 feet to 8 feet in diameter to complete the tunnel work, move materials in and out, and provide for swift emergency evacuation of work crews should work conditions require it. The shaft casing was extended above the street level and covered by a heavy steel plate when crews were not working. Liner plate was used to shore up the excavation and was abandoned underground at project end.

All construction personnel received confined space training and were required to sign in and out when entering and leaving the tunnel. The contractor's safety program also included a daily safety meeting.

Lighting and power were strung along the interior of the tunnel before work began. Sewage flows from the Sherman Street Lift Station were diverted through a temporary pipe suspended along the tunnel wall opposite to the new force main installation until the new 12-inch force mains had been tested, accepted, and encased in the tunnel wall.

Weather was monitored closely by crew members using smartphone weather apps. Rain events had the potential to put construction personnel at risk and impact work progress. Crews could not be in the tunnel if rain events were underway anywhere within the stormshed, as stormwater flows could overwhelm the workspace very quickly. Changes in the movement of dust particles conveyed by air currents within the confined space also served as an early warning system and were easily spotted by workers.

The tunnel enlargement work was largely carried out by hand using a combination of hand tools and air-powered or electrically powered tools as necessary to dislodge the sandstone and original brick lining, where present. Wheelbarrows were employed to move excavated materials to the access point, as there was not enough room in the tunnel to use a rail conveyance system. Wire mesh and shotcrete provided a smooth finish to tunnel surfaces.

The stormwater tunnel was enlarged to accommodate a new dual 12-inch force main (shown encased in concrete, left) and preserve its conveyance capacity. Sanitary sewer flows were diverted through a temporary pipe (right) during construction. Photo courtesy of the City of Saint Paul.

Phase I work was substantially complete by April 15, 2016 for $2.13 million. The change in cost was primarily because of changes in scope due to differing site conditions. This included additional work to install the access shaft, unknown voids that required additional support materials, and additional dewatering in preparation for Phase II work.

In the meantime, ECI Construction was the successful low bidder on Phase II with a bid of $1.34 million. The company was permitted to leave mobilized equipment on site prior to the beginning of construction in June 2016, and temporary sanitary sewer conveyance systems from Phase I were left intact.

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Phase II included the new dual force main beneath Shepard Road and the Soo Line tracks, a new valve vault, new access vault, lift station wet well rehabilitation and new instrumentation, electrical panel work, and the installation of the new natural gas generator. Most of the work took place in the median located between Spring Street and Shepard Road in public right of way at Spring Street, just across from some new condominiums. TKDA personnel were on site for most of the project duration and provided construction administrative services.

Early on in the project, it was discovered that the new 6-by-10-foot precast access vault designed to fit in the median adjacent to the stormwater tunnel would not quite fit. The stormwater tunnel transitions to a 54-inch concrete pipe in that confined area, and the 10-inch walls of the precast structure were simply too thick to work. Another solution would have to be found.

In lieu of a rectangular precast or cast-in-place concrete structure, designers selected a round HOBAS CCFRPM (centrifugally cast, fiberglass-reinforced, polymer mortar) pipe, manufactured by HOBAS Pipe USA in Houston, to serve in its place. HOBAS CCFRPM is strong, light, with a service life of up to 100 years and was able to be quickly manufactured and installed in the tight site area with no overall impacts to the schedule while maintaining the intent of the original access structure design. The HOBAS pipe wall thickness was a mere 1.5 inches. It would work well within the site constraints, and could be manufactured to the necessary length in a short period.

Much of the work on Phase II of the Sherman Street Lift Station and Force Main project took place in this median located at the corner of Sherman and Spring streets. Downtown Saint Paul is visible, as is the final project landscaping.

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Phase II was substantially complete in October 2017; extensive landscaping work in the median and other work areas was installed the following spring. Final cost was $1.45 million, which included two change orders: the 110-inch-diameter HOBAS pipe and associated flowable fill and structure concrete for backfill, a generator upgrade for consistency in equipment service agreements, additional stabilization and reinforcement of the stormwater outfall due to high river flows, drainage correction work, and additional paving and landscaping in the vicinity of the condominiums.

Phase I Cost: $2.13 million
Design Team: CNA Consulting Engineers, TKDA, American Engineering Testing, Inc.
Contractor: ECI Construction, Inc.
Start Date: October 15, 2015 Substantial Completion: April 15, 2016

Phase II Cost: $1.45 million
Design Team: TKDA
Contractor: ECI Construction, Inc.
Start Date: June 2, 2016 Substantial Completion: October 31, 2016

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