RESOLVING A LAKESIDE DILEMMA

As it set out to address problems pertaining to a portion of its aging sewer system, the City of Mercer Island, Washington, faced a dilemma. Landowners opposed construction of a new system on their properties, while regulators raised concerns about plans to construct new pipelines in Lake Washington. To resolve this dilemma, the city relied on careful planning, extensive communication with property owners, and close coordination with regulatory agencies. By Jeff Lykken, P.E., Anne Tonella-Howe, P.E., and Kevin Goss, P.E.

Slightly more than 5 mi long and 2 mi wide, Mercer Island, Washington, is an island community within Lake Washington, which lies between Seattle and Bellevue. Home to upscale residential areas, preserved parks, and open space, the island boasts 13 mi of shoreline, much of it lined with multi-million-dollar homes. During the 1950s and early 1960s, a sewer system was constructed just offshore of the island to collect sewage from lakefront properties and convey it, along with flows from a conventional upland sewer collection system, to a regional conveyance system. More than 50 years later, many of these facilities are reaching the end of their design life and require complex replacements.

In the decades since the so-called lake line sewer mains were constructed, numerous shoreline improvements, including bulkheads, docks, and boathouses, have been built, greatly complicating efforts to replace the collection system components. The recent replacement of what is referred to as Reach 3 of the City of Mercer Island's lake line sewer system not only underscores the difficult decisions that regional sewerage agencies face in the coming years but also highlights the need for such agencies to work closely with the regulatory community and the public to achieve workable, cost-effective solutions.

Reaches 3 and 4, which are located at the north end of the island (see the map on page 72), include some of the oldest portions of the Mercer Island sewer system. Reach 3 consisted of two low-pressure pump stations and about 2 mi of sewer offshore in Lake Washington. In general, the lake line sewer mains are within 10 ft of the shoreline. The Reach 3 system relied on the low-pressure pump stations to convey sewage along the perimeter of the island and to flush sediment from the piping. The pump stations received flow from upstream segments of the system, lifted the flow vertically several feet, and discharged it to downstream segments. Made primarily
of asbestos and cement, the Reach 3 sewers had been experiencing physical deterioration, capacity deficiencies, and operational problems. However, the required solution would have to address multiple—and sometimes conflicting—concerns, including those of regulatory agencies and property owners. After years of evaluating alternatives and coordinating its efforts with stakeholders, the city implemented a replacement in the lake. The existing low-pressure system was replaced with a system that uses gravity and pumping to maintain velocities sufficient to prevent sediment accumulation. The project included 20,000 ft of new 6 to 16 in. diameter lake line sewer and a new onshore pump station with a depth of more than 50 ft.

Shoreline properties discharge flow to the lake line sewer mains via side sewers, which are privately owned gravity connections extending from the homes to the mains. Before the recent upgrades, the side sewers were intermittently surcharged when the pumping system operated. Because the hydraulic characteristics of the lake line system are complex, pumping rates and flow velocities had to be limited to prevent sewage from backing up into the connected shoreline properties. However, these low flow velocities promoted settlement of solids in the line, complicating efforts to accommodate the large range of flows in the system.

The lake line system in Reach 3 had to be replaced for three main reasons:

- Most of the reach used asbestos cement pipe, which was experiencing significant deterioration after years in the water. The deterioration made the pipe more susceptible to breakage, and it was failing with increasing frequency, necessitating emergency repairs. Shoreline properties were at serious risk of sewage backup during these breaks and repairs.

- Many portions of the lake line mains were exposed along the bottom of Lake Washington in shallow water, posing a risk of further damage and leaks, which would create environmental and public health risks.

- The pipelines and pump stations lacked adequate capacity to convey peak flows caused by infiltration and inflow during wet weather. During intense rainfall events, peak flows could lead to excessive surcharging in the system and cause not only sewer backups into shoreline residences but also sewage spills into the lake.

Planning and developing alternatives began in early 2003. Tetra Tech, Inc., which has its headquarters in Pasadena, California, served as the prime consultant for the preliminary and final design. The planning process was deliberate and comprehensive as the city recognized the competing interests at stake. For example, because of environmental considerations, mainly the need to protect salmon, regulatory and permitting agencies would encourage solutions that minimized work in the water.

Meanwhile, from an operational and maintenance standpoint, the city would benefit by
removing the conveyance pipelines from the lake. However, such a solution was complicated by the requirement to provide service to the roughly 75 low-lying homes that connect to the lake line along the shoreline. The lakefront homes connecting to the system include some of the most expensive residential properties in the state. Many include such features as tennis courts, bulkheads, boathouses, and elaborate landscaping that extend to the water's edge. The potential for damage to these properties during construction was a significant concern to the owners, and approvals for working on the private properties would be difficult to obtain.

To address the many issues at stake, the city established the following primary objectives that would guide its selection of an approach:

- It would have to be safe and reliable and minimize the potential for wastewater overflows into Lake Washington.
- It would have to be feasible to construct from a logistical and procedural standpoint and not have undue adverse effects on land use or private property.
- It would have to be constructable from an administrative and legal standpoint and minimize the possibility of legal challenges from property owners.
- It would have to have limited environmental effects during construction and operation.
- It would have to be cost effective, that is, have reasonable costs compared with other alternatives.

Alternatives for replacing the lake line system in Reach 3 were developed, analyzed, and ranked by means of a collaborative workshop process that included representatives of the city, regulatory and permitting agencies, and the public. Three options were analyzed: an onshore alignment, an upland alignment, and an alignment in the lake.

The onshore alignment option entailed replacing the existing pipeline in the lake with a sewer line on shore in the area between the shoreline and the residences and above the ordinary high-water line. This option would require installing the new sewer line through the backyards of shoreline properties and would entail multiple complex and expensive easement and restoration issues. The new system would need to continue to operate as a low-pressure system and thus would have the same operational drawbacks as the current system. It would also need to accommodate an even greater range of flows to provide sufficient capacity during wet-weather events.

The upland alignment option involved abandoning the lake line system and installing new pump stations and force mains to convey flows along existing street rights-of-way. Although this option presented a favorable alternative for the conveyance of upland flows, providing service to the shoreline residents would present a number of problems. Because the island has steep slopes leading down to the water's edge, streets are considerably higher than the homes along the shore. The 75 residences along the shoreline would require new individual grinder pump stations to convey sewage from their homes up to the new force mains. New pressure side sewers would be required from every home up to the street (see the image above). In many cases, these side sewers would need to be more than several hundred feet long to pass through extensively landscaped properties.

Finally, the lake option would replace the pipeline in the lake. However, the new system would be configured to function as a more conventional gravity flow and pumped system that would maintain self-cleaning velocities. It would include a gravity collector main that would convey most of the flow from the upland collection system and provide sewer service to the shoreline properties. The gravity main would slope toward a new pump station, Pump Station 4, that would be located near the center of the alignment. Adjacent to the gravity main, a second dedicated force main would convey flows.
from this station to the northern terminus of Reach 3. The existing lake line mains would remain in service until the new gravity and force main pipelines were constructed. After the new lake lines were completed, individual side sewers from the shoreline properties would be extended out to the new gravity main, and the existing lake line main would be abandoned in place.

Each of the developed alternatives presented considerable implementation challenges, ranging from almost insurmountable regulatory requirements for the lake alignment to significant effects on lakefront properties for the onshore and upland alternatives. After several years of evaluating the alternatives and coordinating its efforts with those of stakeholder groups that included environmental and permitting agencies and property owners, the city decided to move forward with the lake alignment alternative.

Initially, regulatory agencies staunchly opposed replacing the pipeline in the lake, primarily because of concerns about spawning and migratory salmon in the area. The agencies favored the onshore alignment and required that the city demonstrate the absence of a feasible alternative. Conversely, public stakeholders adamantly opposed the onshore and upland alignments because of property disruptions. Many vowed they would never grant the easements that would be required, an obstacle that would have forced the city to pursue legal action to carry out the work.

The city prepared an environmental impact statement to address the effects of each alternative. In the end, the permitting and regulatory agencies agreed that the onshore alternatives were impractical and accepted the lake option. The preferred option was confirmed through an independent peer review conducted by Brown and Caldwell, of Walnut Creek, California, that considered the costs and ramifications of the alternatives.

Numerous local, state, and federal approvals and permits were required before the project could be carried out. All told, the project team spent approximately two and a half years preparing the environmental impact statement, securing permits, and negotiating mitigation measures in order to be able to construct the pipelines in the lake.

A key to gaining regulatory approvals was negotiating acceptable mitigation steps to offset the untoward effects of construction in the lake. To this end, the city developed a shoreline mitigation plan that summarized the environmental effects associated with construction along the lake line and recommending mitigation measures to offset any deleterious effects in the water. The plan also specified ways for reducing effects on the environment and outlined compensatory measures for enhancing aquatic habitat.

Four primary compensatory measures were negotiated with regulatory agencies. First, special gravel was placed along disturbed lake bottom areas to enhance the spawning environment for sockeye salmon in Lake Washington. Second, derelict pilings were removed along the shore of the lake. The old pilings provided shelter for aquatic predators that fed on juvenile salmon, and their removal enhanced migration conditions. Third, the shoreline at the location of the new Pump Station 4 was restored within the project alignment to improve salmon migration conditions. The rip-rap bulkhead that lined the shoreline at this location was replaced with woody debris and plantings that enhanced the habitat for wildlife, opposite.
Pump Station 4, was restored within the project alignment to improve salmon migration conditions. The existing riprap bulkhead lining the shore at this location was replaced with woody debris and plantings that enhanced the habitat for wildlife. Fourth, beyond the project alignment, more than 1,000 ft of degraded shoreline at a city park was restored to improve the habitat for wildlife. The park is located roughly 1 mi east of the project area.

Construction began in early 2009 and was substantially completed in late 2010 at a cost of roughly $20 million. Construction of the pipeline and the new pump station was divided into two contracts. The Manson Construction Company, of Seattle, served as the prime contractor for the pipeline work, which totaled approximately $15 million. The Steller J Corporation, of Woodland, Washington, acted as the prime contractor for the roughly $4.5-million pump station. Multiple construction seasons and remobilization of marine equipment were required because project permits allowed work in the water only from mid-July to mid-October along most of the pipeline alignment. The three key construction elements were building the new pump station, replacing the sewer mains in the lake, and connecting the shoreline residences to the new lake line.

The two existing pump stations in Reach 3 were replaced with one centralized submersible station on the shore. Pump Station 4 was located on one of the few lakefront properties along the alignment that was not fully developed. Its centralized location made it possible for the existing low-pressure system to be replaced with a more conventional configuration in which sewage flows to the pump via gravity and is pumped out under pressure.

To facilitate gravity service, the new pump station needed to have a depth of more than 50 ft. Shoring and dewatering for the structure proved difficult because of its depth and proximity to the lake. The shoring system took the form of sheet piles installed to a depth of 80 ft below grade. Ground conditions at the pump station location were extremely hard, necessitating the use of drilling to loosen the soil before the shoring system could be installed. Ground freezing and cofferdam construction had been considered by the contractor and design team as alternative construction methods.

Made of cast-in-place concrete, the wet-well structure was designed for staged construction, minimizing the structural requirements of the sheet piles and bracing of the shoring system. Before construction of the pump station structure, the excavation served as the launch shaft for a steel casing that was extended into Lake Washington by means of microtunneling. Connecting the pump station to the new lake line system, the large-diameter casing was used to house short sections of the incoming gravity lines and the outgoing force main. Because this section of pipeline was up to 50 ft deep, open cut construction was deemed impractical, as it would have required extensive shoring similar to that used for the pump station. Instead, the decision was made to insert the casing by means of tunneling, and the new pipelines were then installed within the casing.

To increase competitiveness, (Continued on Page 79)
(Continued from Page 75) Pump Station 4 was put out for bids and built under a construction contract separate from the one covering the marine pipelines. Because of a much greater pool of qualified pump station contractors, this approach yielded savings of more than $1 million. However, separation of the contracts required close coordination by those working on the two contracts and careful structuring of the bid documents to minimize the potential for construction claims.

Approximately 12,600 ft of new ductile iron sewer main was installed in Lake Washington. New 8 and 16 in. diameter gravity mains convey flows from the upland sewer system and lakeshore properties to the new pump station. A new, 10 in. diameter force main delivers flow from the pump station to the downstream conveyance system. The pipelines were constructed beyond the existing docks to facilitate installation. The alignment follows the deepening lake bottom bathymetry, limiting the installation depth needed to provide gravity service.

A clamshell dredge was used to dig trenches along the lake bottom for the new sewers. Project permits required the containment of turbidity during construction. A floating sediment curtain that moved with the dredging operation met this requirement. Dredged material was stockpiled on an adjacent barge and disposed of at a site in open water in Elliott Bay, near Seattle.

Gravity mains and force mains were installed in 100 ft long sections that were assembled on the barge and put in place by means of a steel beam. Each section was lowered to the dredged marine trench and connected by divers. Before installation, each section, which included roughly four individual ductile iron pipe joints, was subjected to a pressure test on the barge.

The final stage of construction involved connecting the lakeshore residences to the new system once the new sewer mains and pump station were commissioned. Existing side sewers were extended offshore to the gravity sewer main to provide service to lakefront properties. The 40 connections along the shore totaled roughly 6,300 ft of new pipe 6 in. in diameter.

Working among docks and other shoreline improvements proved challenging when connecting the waterfront properties to the new sewer mains. Connections to existing side sewers were made within the lake to limit effects on private property. To make connections “in the dry,” sandbag cofferdams were constructed close to the shoreline.

The shoreline connection work required innovative equipment and construction sequencing because of the constricted working conditions and the need to avoid disturbing the expensive waterfront property improvements. To this end, an amphibious backhoe, dubbed the Swamp Buggy, proved invaluable to the contractor in excavating trenches between waterfront structures in shallow water. The backhoe was small enough to work between the existing docks and boathouses.

The new system has been in operation since 2010 and has performed as intended. No sewer backups, breaks, or capacity issues have been experienced.

Each of the alternatives available to the city for replacing the lake line presented considerable implementation challenges, ranging from nearly insurmountable regulatory requirements for the lake alternative to significant disruption of lakefront properties for the onshore and upland alternatives.
Given the drawbacks of each alternative, the search for a suitable solution looked like a no-win situation in the early days of planning.

After five years of rigorous planning, permitting, and design, the team of city and Tetra Tech representatives was able to work collaboratively to develop a replacement plan and design that stood up to the exacting scrutiny of regulatory agencies, Mercer Island property owners, and city ratepayers. The marine pipeline work along the densely developed and expensive Mercer Island shoreline presented significant construction challenges and risks, yet this $20-million project was implemented with change orders totaling less than 2 percent.

This project will help define replacement strategies for many sewerage agencies in the Puget Sound region that have facilities located along shorelines and within water bodies. The project also illustrates the necessity of extensive planning and comprehensive participation by regulators and the community to ensure successful negotiation of a feasible, cost-effective solution, particularly when multiple and potentially conflicting priorities are involved.

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**PROJECT CREDITS**

Owner: City of Mercer Island, Washington

Preliminary and final design: Tetra Tech, Inc., Pasadena, California

Prime contractor for pipeline construction: Manson Construction Company, Seattle

Prime contractor for pump station: Steller J Corporation, Woodland, Washington

Construction management: Vanir Construction Management, Inc., Sacramento, California