Davis Brook CSO Storage Facility in Bangor, Maine

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The City of Bangor, Maine, with a population of 33,000 people, is located in east central Maine. The development of Bangor occurred initially along the banks of the Penobscot River and the Kenduskeag Stream. By the mid-nineteenth century, the city had grown to 20,000 people, and had evolved into a major trade center. The Penobscot River, connecting the large pine forests to the north and the Atlantic Ocean to the south became the catalyst for the development of Bangor as the largest port in the world for the shipping of lumber in the 1870's.

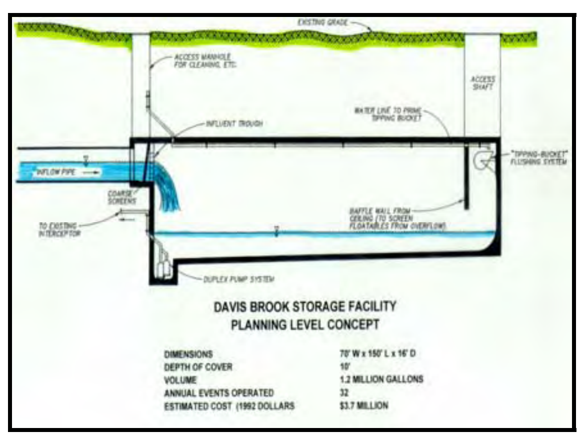
The early sewer records date back to around 1850, a time where cess pools and open ditches were the dominant waste disposal method. As development took place, piped sewers became more common to take residential sewage to the closest brook -- Barkersville Brook, Davis Brook, Sanford Brook, Carr Brook, Meadow Brook, or Arctic Brook. As more and more sewage entered the brooks, the conditions became intolerable, and there were requests for the City to do something about the situation. The solution was to construct large brick pipes in or near the brooks to carry the combined storm and sanitary flows to either the Kenduskeag Stream or the Penobscot River.

By the early 1960s, the Stream and the River were essentially dead, with dissolved oxygen readings of zero. Fishing and water contact recreation were non-existent, and odors were atrocious. In order to alleviate this environmental, health and aesthetic nuisance, Bangor began a multiyear program to collect and treat its wastewater. The City constructed a wastewater treatment plant in 1968, and began construction of a nine-mile interceptor sewer system to collect flows from approximately 25 sewers that discharged wastewater into the Stream and River.

At 22 of these discharge points, Combined Sewer Overflow (CSO) structures were built. Flow exceeding approximately four times the normal dry weather flow during rainfall or snowmelt events overflow untreated into the River and the Stream. In the mid-1980s, CSOs began to be recognized as a significant source of waterway pollution, and policies were developed to address the issue. Since 1987, Bangor has been working on a multi-million dollar program to control Combined Sewer Overflows.

In 1992, a CSO Control Plan was prepared. The Plan identified the most cost effective and water quality effective projects to control CSO discharges. The plan called for a variety of methods, such as sewer separation, treatment plant upgrade, pump station upgrade, overflow structure modification, and storage -- treatment. Sewer separation has been the dominant method of CSO control. To date, the City has expended in excess of $25 million in mostly local funds. Ten of the original twenty-two CSO locations have been eliminated, and CSO activity has been reduced by approximately fifty percent. Projects are scheduled through 2009 and capital expenditures are expected to total in excess of $50 million.

To control CSO discharges in the Davis Brook drainage area of Bangor, the CSO Control Plan recommended the construction of a 1.2 million-gallon storage tank as the preferred method of control. The concept outlined in the CSO Control Plan was a rectangular cast-in-place concrete tank with dimensions of 150 feet long by 70 feet wide by 16 feet high, buried deeply underground.



The tank, through a series of structures and pipes, would capture CSO discharges from the Davis Brook Sewer system. After the overflow event had passed and treatment capacity became available at the wastewater treatment plant, the tank would be pumped out into the interceptor sewer located adjacent to the tank. Included in this storage tank project were washdown facilities, odor control equipment, and the provision for overflow out of the tank should volume of CSO discharge exceed the volume of the tank. The planning level cost estimate was $3.9 million.

Design of this type of storage tank was commenced, with early attention given to subsurface exploration. Several issues of concern were presented to the City at the preliminary design conference. The net result of these issues was a significantly increased estimated cost for the project. The $3.9 million cost estimate had now become a $6.97 million. Bangor City Manager Edward Barrett responded that the City would not spend that amount of money on a CSO storage tank. He then directed the City Engineering Department to find a better, cheaper way to address the Davis Brook CSO discharge issue.

STARTING OVER

So, in early 1996 with a significant amount of geotechnical data that provided lots of reasons not to build the Davis Brook CSO storage tank as originally conceived, the City of Bangor Engineering Department started over.

For the Engineering Department to find a better, cheaper way to do the Davis Brook CSO storage tank, the project would need to be done in a completely different way in order to avoid all of the costly issues that had been identified previously.

NEW SITE

In 1995, additional siting options opened up when the City purchased the adjacent 30-acre switching yard from the Maine Central Railroad.

The City proposed that a part of this property should be reserved for a waterfront park. Siting the tank under the future park area seemed ideal. The existing Davis Brook CSO discharge was located in this area, the tank could be located further away from the river than the previous site, there was no wooden cribwork to deal with, and construction would not disrupt traffic or residents.

NEW DESIGN

Building the same tank in a different location would solve some but not all of the issues associated with the high costs of the original plan. So the City began to explore other ideas. One idea was the use of pre-cast concrete. Locally, pre-cast concrete has been used for Bangor's parking garage, for building floor systems, for septic tanks, for curbing, for retaining walls, for bridges, for drainage structures, for sewer pipe, and for sewer manhole structures.

Bangor staff talked to local and regional pre-cast companies to see what has been done and what products were available. Practically any shape and size could be supplied provided a crane could lift it and a truck could carry it. Fabricating components for the Davis Brook CSO storage tank off-site, possibly during the winter, then doing the installation during the construction season certainly had much merit. Over a period of several weeks using the City's 40-scale maps and cardboard cutouts, many variations of a 1.2-million gallon tank were composed. After many discussions, a single row of pre-cast sections parallel to the existing 42-inch Penobscot Interceptor along the railroad yard near the river seemed to offer the best solution.

With the concept established, the city went to work on the preliminary design. The size was finalized at 8-feet wide by 9-feet high (inside dimensions) by approximately 2400-feet long, sufficient to provide the recommended volume of 1.2 million gallons. Each pre-cast section would be 5-feet long. There would be rubberized sealant between sections. The sections would be bolted together at all four corners. Access openings would be integral. Bends of 4-degrees in the alignment would be achieved by making one side of selected pre-cast sections 8-inches shorter than the other side.

The proposed new concept essentially addressed the issues associated with deep excavations. With maximum excavation depth calculated at around 13-feet, shoring could be accomplished by trench box. There would be no expensive sheet piling, slurry trench construction or water cut-off walls.

It was envisioned that the facility would operate as a surge tank that would take a wide range of inflow with a more or less constant outflow, storing up to 1.2 million gallons in the process.

PRE-CAST DESIGN

City staff discussed solids deposition at great length. Box sections have a flat bottom that spreads out the flow, enhancing solids deposition. For this project, a V-shaped bottom was designed into the project to maintain velocity over a wide range of flows

CSO STORAGE TANK OUTLET

Flow control, when required, is by SCADA operated modulating sluice gates at the inlet and outlet of the tank. Generally, control is not expected to be necessary, with operation relying on the outlet capacity of the structure under most conditions. The existing 42-inch interceptor will be retained for additional storage capacity and to allow the tank to be taken out of service if necessary.

The tank has an overflow provision for high flow conditions. Overflows will be monitored for frequency, duration, and volume by ultrasonic equipment located in a small building at the point of overflow

The construction schedule was discussed with several interested contractors. All contractors agreed that eight 5-foot sections per day would be a reasonable expectation, or about 60 working days to install the pre-cast sections. If this time estimate were doubled to include all other aspects of the project, the entire project could be completed in about six months, considerably less than the fifteen-month construction time estimate for the previous design.

It was decided to have the City pre-purchase the pre-cast concrete sections. The fabrication bid was advertised on June 1, 1998 and the bid opening was held on June 10, 1998. American Concrete Industries of Bangor was awarded the contract in the amount of $602,175.

STOCKPILED PRE-CAST UNITS

The construction contract was advertised for bids on July 29, 1998. The bids were opened on August 12, 1998. Bangor contractor Lou Silver submitted the low bid for construction at $617,924.

CONSTRUCTION

Construction of the Davis Brook CSO Storage Facility began in early September 1998.

The pre-cast sections were manufactured by American Concrete Industries. The company procured three sets of custom designed forms to construct the 8-ft wide by 9-ft high by 5-ft long sections. They were able to produce six sections per day using each form twice daily. The sections were reinforced for H-20 wheel loading, used 5,000 psi concrete, and had steel bolt pockets cast into each corner. ACI provided 1-in thick by 4-in wide flexible butyl resin sealant and 3/4-in stainless steel threaded rods, nuts, and washers to join adjacent sections. Each section weighed 21,000 pounds. Pre-cast sections were delivered to the site two at a time on flatbed trailers. 475 sections were manufactured.

STOCKPILED PRE-CAST UNITS INSIDE VIEW

Construction was by Lou Silver Inc. On a typical day, an excavator dug the trench slightly ahead of the pre-cast installation. Clean excavated materials were used for backfill of the pre-cast sections already installed. Other materials, such as rocks, logs, and materials otherwise not exactly suited for backfill were stockpiled on the site for other uses. Once subgrade was reached, the excavator placed 12 inches of crushed stone in the bottom of the trench. Workers adjusted the grade using lasers. While these activities were taking place, another crew was attaching lifting bolts to a pre-cast section. Then a crane lowered the section into the excavation where workers placed strips of sealant against the face of the tongue end of the section.

INSTALLATION OF NEW SECTION

Once the sealant was in place, the crane placed the section against the previously installed section. Workers using hand-operated hydraulic jacks and a custom designed apparatus that fit into the bottom bolt pockets to pull the sections together. While being held together by jacks at the bottom, the workers bolted the top corners. Then the jacks were removed and the bottom corners were bolted. Twenty sections per day were common.

BOLTED JOINT CONNECTION

Crews trimmed the sealant that had been compressed and had extruded into the tank. Also as part of the project, the bottom joints and all bolt pockets were grouted flush with the surface.

All things considered, the project went very well. The site was open, allowing for work to progress rapidly without concern for traffic, residences, businesses, or other issues that usually arise in a built-up area. The site was also large enough to stockpile the estimated 10,000 cubic yards of excess material taken from the excavation. Although anticipated, there were no contaminated soils encountered.

Some initial assumptions proved to be incorrect. It was contemplated that a large backhoe could do both digging and setting the pre-cast sections. However, a large crane was required due to the weight of the sections and the reach required by the width of the excavation. It was thought that perhaps the bolts could be used to pull the sections together. The weight was too much and the threads stripped out on the rods and nuts. The hydraulic jacking equipment was required to pull the sections together. It was thought that the sealant should be installed on the angled face of the tongue. That did not work well, and the contractor found that placing the sealant on the flat face of the tongue worked best. For some undetermined reason, the tunnel tended to creep to the left as progress was made. The contractor adjusted the alignment by periodically installing a double row of sealant on the left side on the pre-cast sections. Tidal intrusion was negligible until the structure reached the old Davis Brook Overflow Tunnel. The new CSO tank crossed the old tunnel, requiring the top of the old tunnel to be removed. The project was then open to the river, and everything flooded at every high tide. (There is a 13 foot elevation difference between high and low tide). The pre-cast tunnel filled approximately 90 percent until the contractor was able to work beyond this point.

CONSTRUCTION PROGRESSES

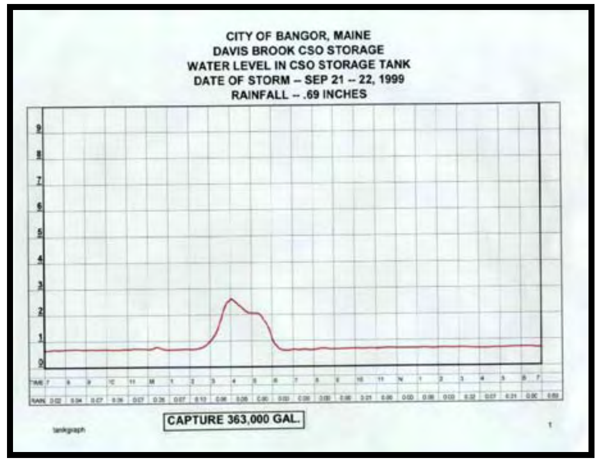
Connection of the Davis Brook CSO Storage Facility to the existing system required bypass pumping of flows around the work area.

There was an unanticipated bottleneck in the project. The contractor started the project with about 75 pre-cast sections on site with fabrication continuing at six per day. No one expected that the contractor would be able to consistently install twenty sections per day. The contractor caught up with the fabricator and had to suspend installation of the precast sections for a two-week period.

OPERATION

On June 1, 1999, the Davis Brook CSO Tunnel was placed in operation. Approximately 80% of Bangor's sewage now flows through this facility on a continuous basis. Normal daily flows stay in the v-shaped area in the bottom of the facility. Several rain events have shown that the facility is operating as anticipated.

SEPTEMBER 10 - 11, 1999



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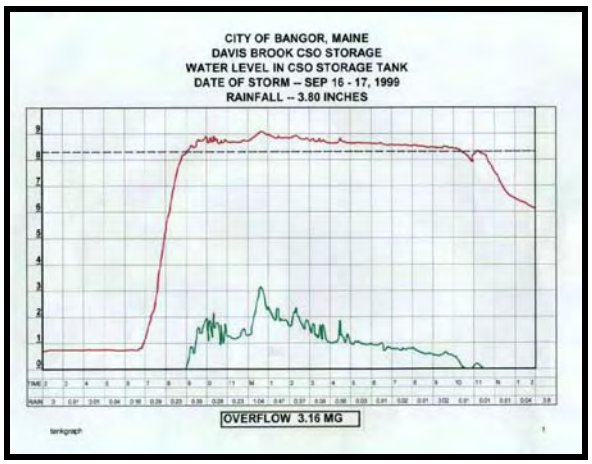

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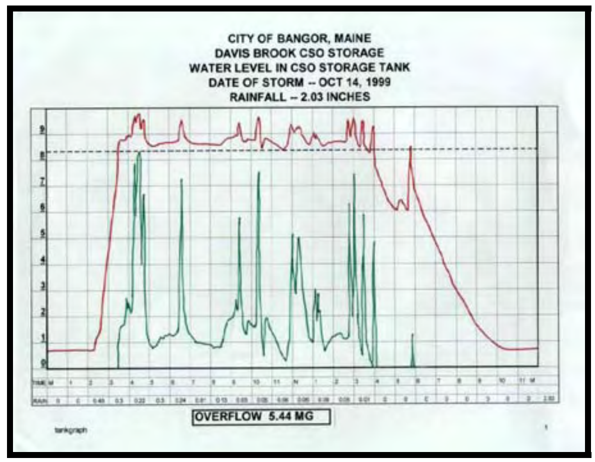

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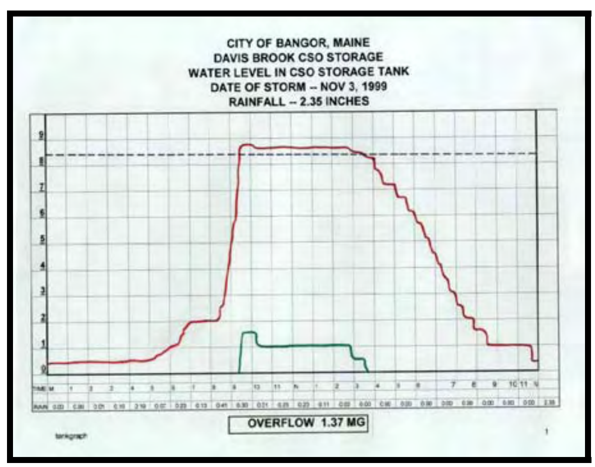

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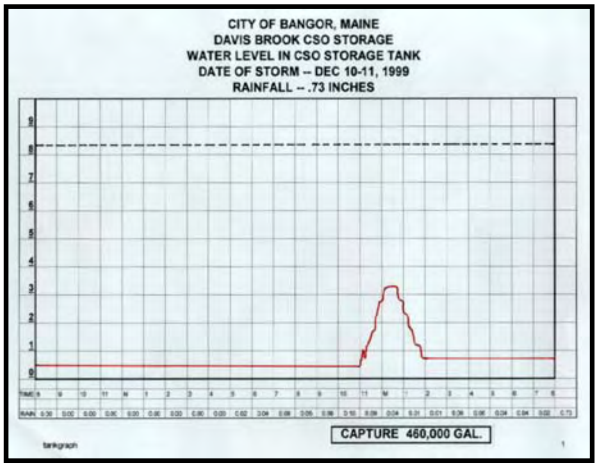

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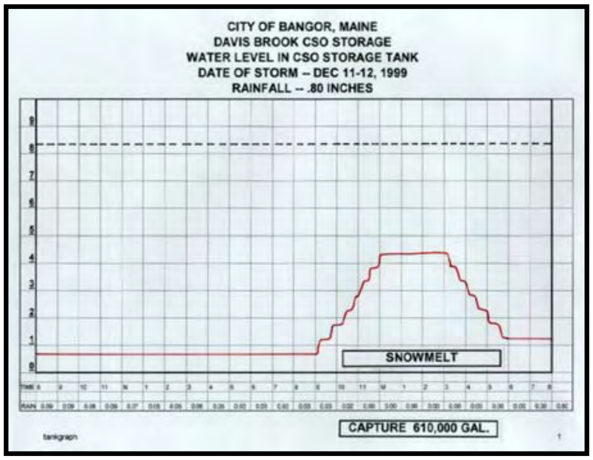

DECEMBER 11-12, 1999

The red line on the above charts records the water level in the Davis Brook CSO Storage Facility.

The vertical axis measures feet of depth.

The horizontal axis measures time in hours. A 24-hour range is depicted, generally beginning near the start of the storm event.

The dashed line near the top of the chart represents the height of the overflow weir at the overflow structure. When the red line goes above the dashed line, the tank has filled and an overflow occurs.

The green line records the overflow at an exaggerated scale. The overflow volume is recorded by the SCADA system and is shown below the chart.

Rainfall is recorded on the bottom line of the chart at hourly intervals.

CONCLUSIONS

The concept of a pre-cast concrete storage facility should be of interest to any community considering CSO storage and treatment projects. For the City of Bangor, there have been numerous benefits, some of which are as follows:

- The total cost of this facility will be less than $1.4 million. This is significantly less than either the planning level cost projection of $3.9 million or the preliminary design cost estimate of $6.9 million. Bangor has saved in excess of $5 million by the use of this concept.

- Most of the project funds will provide economic benefit to the LOCAL community.

  The project was conceived and designed LOCALLY by the City of Bangor staff.

  A LOCAL fabricator, American Concrete Industries, manufactured the pre-cast concrete sections.

  A LOCAL contractor, Lou Silver Inc., constructed the project.

- Specialty (foundation, dewatering, and mechanical) contractors were not required.

- The project was constructed in a relatively shallow excavation avoiding expensive shoring and dewatering costs.

- Construction time was less than one construction season, creating virtually no disruption of the activities along Bangor's waterfront.

- A flow-through design eliminated the need for expensive pumps and other sophisticated equipment.

- Only three small structures were required for SCADA control and monitoring equipment.

- The land above the tank will become a waterfront park.