CANADIAN CONSULTING ENGINEERING AWARDS 2012

REAL TIME CONTROL IMPLEMENTATION AND FLOW REGULATOR UPGRADES PROJECT

CATEGORY: WATER RESOURCES
PROJECT OWNER: CITY OF OTTAWA
SUBMITTED BY: STANTEC CONSULTING LTD.

Stantec

Project Highlights

Stantec Consulting Ltd., and its design team partner BPR-CSO, completed the design and integration of a Real Time Control (RTC) System for the automated operation of flow regulating chambers on the City of Ottawa's combined sewer system. The project has provided an innovative and cost-effective approach to reducing combined sewer overflows (CSOs) to the Ottawa River, which will enhance the health of the river and further highlights the City's commitment to protecting this valued resource within the National Capital Region.

The project consisted of upgrading and retrofitting six major hydraulic flow control structures along the Central Interceptor-Outfall system and the integration of the RTC system to automatically and dynamically operate a system of flow modulating gates. The gates are designed to either allow more or reduce the amount of flow directed to the interceptor system and treatment plant in response to observed system conditions. Under wet weather conditions, the system seeks to avoid and minimize overflows by maximizing the capture rate and making full use of available conveyance capacity within the interceptor outfall sewer. The RTC system has already led to an immediate and drastic reduction in the volume of CSOs discharged to the Ottawa River.

In addition to the community and environmental benefits, the project has resulted in the re-vitalization of a number of critical flow control structures on the City's main interceptor sewer system. It provides system operators with a complete view of the operation of the system, enhanced reliability and greater operational flexibility to facilitate maintenance activities or respond to emergency conditions.

This project thus serves as an excellent example of a sustainable and innovative solution to system rehabilitation and CSO control, with a significantly lower environmental footprint than traditional CSO control methods. With only minor and relatively brief construction related inconveniences to popular tourist destinations and public areas in the nation's capital, it has allowed the City to cost-effectively meet operational and CSO control objectives while providing maximum benefit to the receiving waters and the community as a whole. The project has effectively provided an opportunity to maximize environmental benefits while minimizing the financial, social and environmental impacts that would have resulted through the implementation of traditional and more disruptive CSO control measures. Consequently, it now provides the City of Ottawa with the opportunity to move forward with the cost-effective implementation of additional CSO control measures that will allow it to exceed minimum CSO control requirements as envisioned in the City's Ottawa River Action Plan.

Background: The downtown and older sections of the City of Ottawa's wastewater collection system consist of combined sewers that originally discharged directly to the Ottawa and Rideau Rivers. With the construction of its main interceptor sewer system and central wastewater treatment facility by the early 1960's, the City effectively eliminated the direct discharge of untreated wastewater and a certain amount of combined stormwater to its rivers. Each tributary collector sewer along the interceptor system was equipped with a flow regulating chamber to intercept all the dry weather flow (DWF) and, under wet weather flow (WWF) conditions, limit the peak amount of flow that is directed to the interceptor sewer and wastewater treatment plant (WWTP). The flow regulators were equipped with a passive flow control device in the form of a fixed dimension flow control orifice combined with a mechanical gate that opened or closed based on water level in the regulator. The system effectively provided a static maximum flow limit designed to protect the interceptor and downstream WWTP from being overloaded as well as to limit combined sewer overflows (CSO's) to an acceptable limit at that time.

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CSO Control Objective: The City of Ottawa's objective is to reduce the volume of CSOs to the Ottawa River and ultimately have no overflow occurrences in an average rainfall year. This objective effectively exceeds the requirements of the Ontario Ministry of the Environment's CSO Control guidelines (MOE Procedure F-5-5) and is an integral component of the City's Ottawa River Action Plan to improve the water quality of the river and improve the quality of life for area residents and tourists alike. At minimum, Procedure F-5-5 requires that 90% of the WWF volume, generated by the combined sewer system, is captured and sent to the WWTP. This would still lead to 5-10 CSO occurrences in a typical or average year but was considered to be a significant improvement and interim control objective.

Project Objective: Since the 1960's, the City has continued in its efforts to reduce CSOs, largely through sewer separation in the outer fringes of the combined sewer area. Within the core combined area, however, alternative solutions were required. A central storage tunnel through the downtown core was previously identified as the preferred solution to meet the minimum requirements of Procedure F-5-5 (90% capture objective). The City commissioned a Real Time Control (RTC) Feasibility Study to assess whether a more effective use of the existing system could lead to capital cost savings in the investment of new infrastructure to meet and ultimately exceed the minimum control objectives. In addition, the City had a need to upgrade the mechanical flow regulators that were over 50 years old, less reliable in operation and required frequent maintenance.

Solutions and Achievements: Stantec, and its project partner BPR-CSO, completed the RTC Feasibility Study showing that the minimum CSO control objectives could be achieved with an automated flow control system that operates dynamically in real time to optimize the use of residual capacity within the sewers throughout each WWF event. The same team subsequently completed the design and implementation of the project. The RTC solution consisted of upgrading five existing regulators and adding a sixth along the main trunk sewer in conjunction with drawdown of the WWTP pump station wet well level to increase the available conveyance capacity in the main trunk sewer. The regulators were equipped with fully automated dynamic flow control gates, real time monitoring of sewer water level and flow, and communication with the central wastewater operations SCADA system.

The key challenge with the design of an RTC system in a combined sewer application is in defining the appropriate operational strategy and fail-safe response of the system given the highly variable nature of meteorological conditions and the resulting dynamic flow responses that are inherent to combined sewer systems over a broad geographic area. For the Ottawa RTC project, the system-wide RTC optimization analysis and CSO control strategy development was conducted using both analytical techniques and with specialized but commercially available simulation software (namely Infoworks CSTM). These tools were used to evaluate the highly variable system-wide hydrologic response in tandem with the very complex system hydraulics and formed the basis for developing the appropriate design configuration and system operating parameters. At the design stage, further fine-tuning of proportional–integral–derivative (PID) based control logic and control parameters, such as control level set-points and flow allocation ranges, was also performed to optimize the RTC configuration.

Implementation and construction of the RTC system started in 2007 and was fully commissioned in March 2011. Stantec has been working with City Operations staff since implementation to aid in operation and performance optimization. The system recently completed its first operational season, which resulted in a significant reduction of CSO volumes to the Ottawa River. With a more efficient operating strategy, the minimum control objectives were attained at a capital cost of $23M and within a short implementation timeframe (4 years). This was achieved with less disruption to the community and at a significant savings in capital cost (minimum savings of $65M+) compared to a storage or sewer separation based solution.

Project Background

Background

The downtown and older sections of the City of Ottawa's wastewater collection system consist of combined sewers that originally discharged directly to the Ottawa and Rideau Rivers. With the construction of its main interceptor sewer system and central wastewater treatment facility by the early 1960's, the City effectively eliminated the direct discharge of untreated wastewater and a certain amount of combined stormwater to its rivers. Each tributary collector sewer along the interceptor system was equipped with a flow regulating chamber to intercept all the dry weather flow (DWF) and, under wet weather flow (WWF) conditions, limit the peak amount of flow that is directed to the interceptor sewer and wastewater treatment plant (WWTP). The flow regulators were equipped with a passive flow control device in the form of a fixed dimension flow control orifice combined with a mechanical gate that opened or closed based on water level in the regulator. The system effectively provided a static maximum flow limit designed to protect the interceptor and downstream WWTP from being overloaded as well as to limit combined sewer overflows (CSO's) to an acceptable limit at that time.

CSO Control Objective

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Existing combined sewer collector at street level adjacent to the Rideau Canal.

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CATEGORY: WATER RESOURCES

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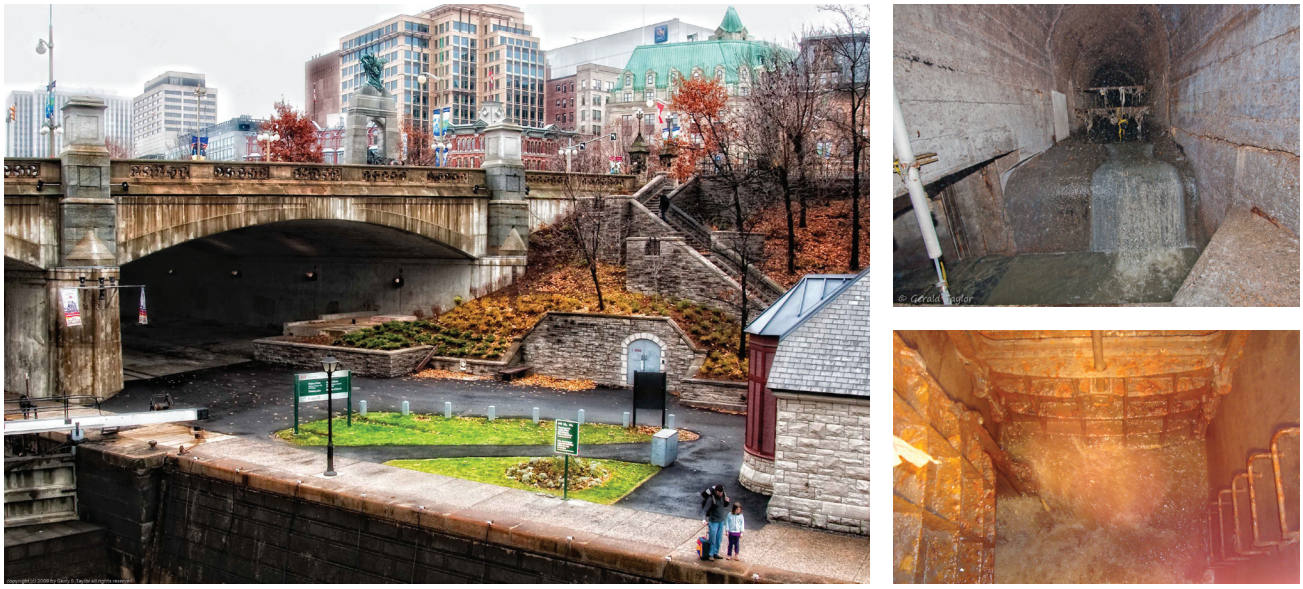
Project Objective

Since the 1960's, the City has continued in its efforts to reduce CSOs, largely through sewer separation in the outer fringes of the combined sewer area. Within the core combined area, however, alternative solutions were required. A central storage tunnel through the downtown core was previously identified as the preferred solution to meet the minimum requirements of Procedure F-5-5 (90% capture objective). The City commissioned a Real Time Control (RTC) Feasibility Study to assess whether a more effective use of the existing system could lead to capital cost savings in the investment of new infrastructure to meet and ultimately exceed the minimum control objectives. In addition, the City had a need to upgrade the mechanical flow regulators that were over 50 years old, less reliable in operation and required frequent maintenance.



View of Rideau regulator location at street level (pre-construction) and view of existing combined sewer and regulator requiring upgrades.

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Aerial view of RTC Regulators and Interceptor Outfall Sewer.

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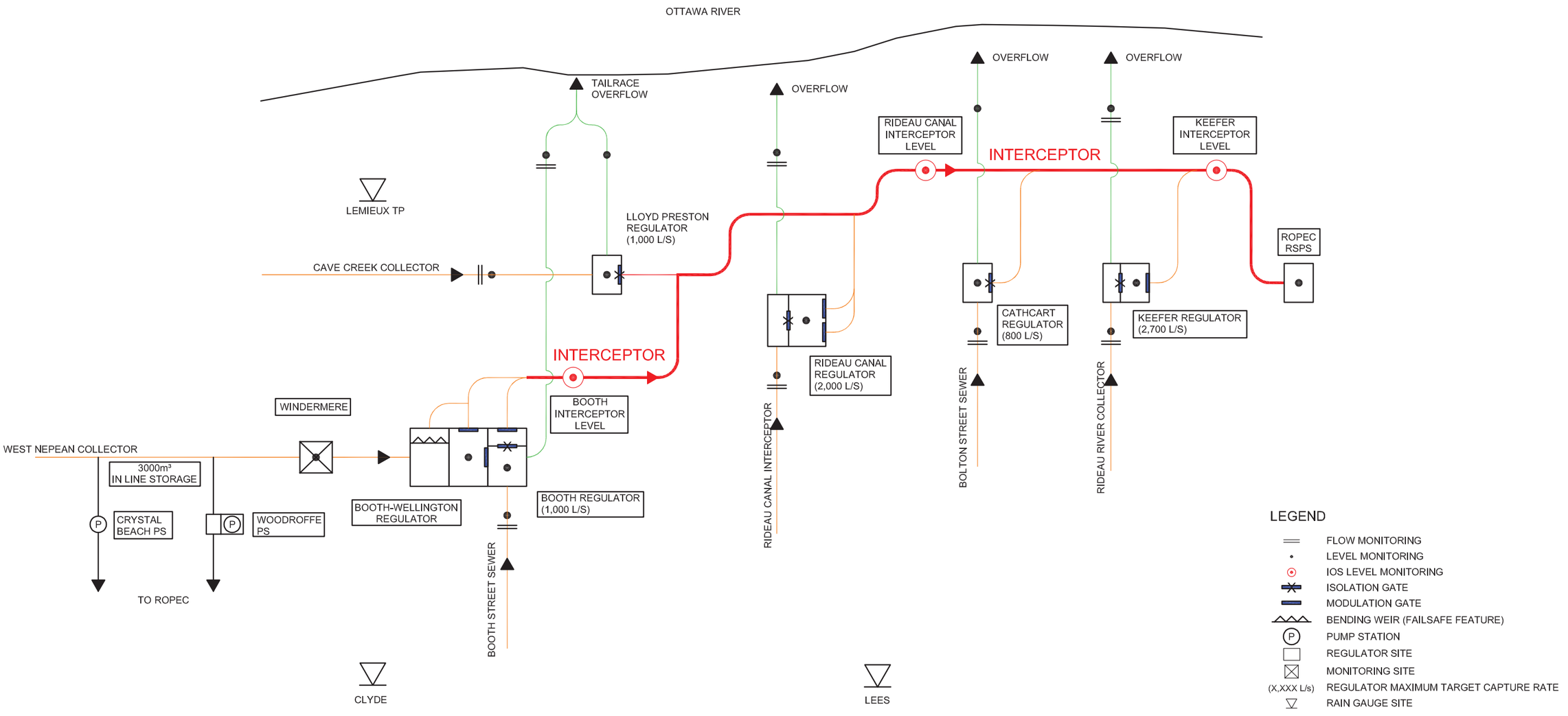
CITY OF OTTAWA RTC SYSTEM SCHEMATIC

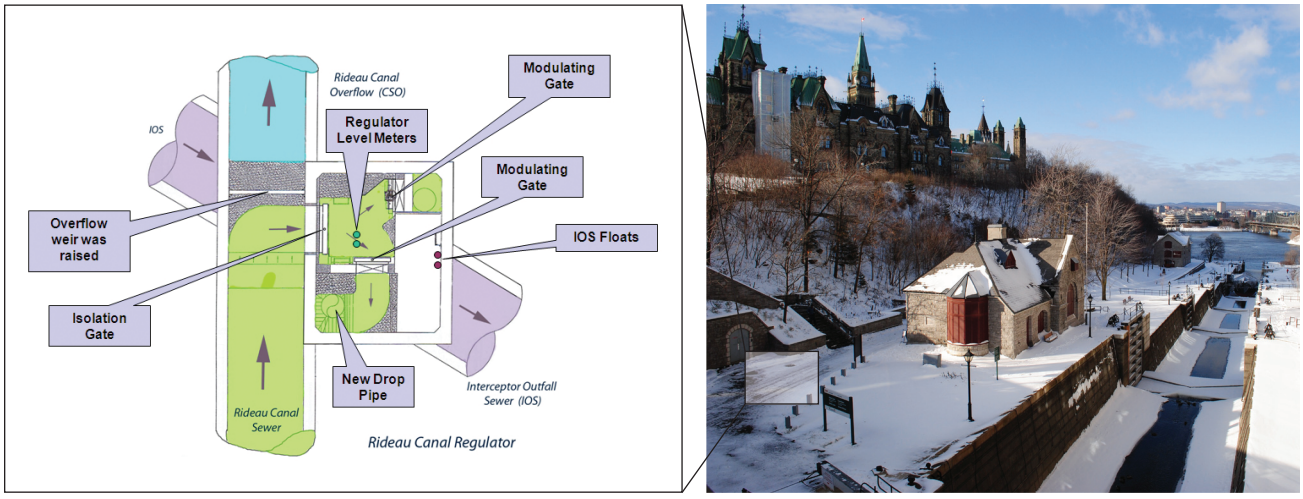


Innovations, Originality and Design Excellence

The automated operation of individual wastewater collection system facilities, such as pumping stations and storage tanks, is now very common and familiar to many system operators through their use of and experience with Supervisory Control and Data Acquisition (SCADA) systems. The fully automated and dynamic operation of an entire or even a large section of a wastewater collection system, however, is not yet common in the wastewater industry.

The key challenge with the design of an RTC system in a combined sewer application is in defining the appropriate operational strategy and fail-safe response of the system given the highly variable nature of meteorological conditions and the resulting dynamic flow responses that are inherent to combined sewer systems over a broad geographic area. For the Ottawa RTC project, the system-wide RTC optimization analysis and CSO control strategy development was conducted using both analytical techniques and with specialized but commercially available simulation software (namely Infoworks CSTM). These tools were used to evaluate the highly variable system-wide hydrologic response in tandem with the very complex system hydraulics, and formed the basis for developing the appropriate design configuration and system operating parameters. At the design stage, further fine-tuning of proportional–integral–derivative (PID) based control logic and control parameters, such as control level set-points and flow allocation ranges, was also performed to optimize the RTC configuration.

Another critical aspect of the design development was the definition of the physical modifications required at each of the flow regulators where the objective was to maximize the flow capacity while minimizing the extent of costly and disruptive structural modifications in either congested urban environments or sensitive public areas (i.e. adjacent to the Rideau Canal a designated UNESCO World Heritage Site). Given the unique configuration and hydraulic complexity of the existing flow regulators, testing of a physical model (1:6 model to prototype scale) of the largest and most important regulator, the Rideau Canal Regulator, was conducted to gain a better understanding of the existing capacity and to provide the basis for developing a preferred option for increasing the flow capture rate at this site. The knowledge gained from the testing of this regulator provided a basis for design development of modifications to this and the other flow regulators.



REAL TIME CONTROL IMPLEMENTATION AND FLOW REGULATOR UPGRADES PROJECT

CATEGORY: WATER RESOURCES

PROJECT DESCRIPTION

Even when the benefits of system optimization are clear, system operators can be reluctant to hand over control of their system to a fully automated system. This is understandable given the industry's unfamiliarity with such system-wide applications in the wastewater collection field; concerns with the reliability and maintenance requirements for specialized flow control and monitoring equipment; as well as the challenges of retrofitting an existing system in congested urban environments under "live" and often elevated flow conditions. The Ottawa RTC system was specifically designed to ensure that the system continued to provide reliable and safe operation during construction and, once implemented, under a variety of equipment failure and extreme event conditions.

Failures during critical event conditions could lead to hydraulic conditions that could damage equipment, hydraulic structures or even private property as a result of flooding. Testing of the preferred configuration was performed under multiple failure scenarios and for critical flooding events. This was to ensure that the control processes would continue to provide acceptable performance and to identify adequate automated safety protocols for continued operation under "degraded" modes, such as power failures, instrument and gate failures, etc. In adapting the design (i.e. control procedures, redundancy and back-up equipment) to meet these requirements, it was determined that, overall, the RTC configuration would be robust and could perform well under these situations. Even with certain system failures; performance under critical events is anticipated to be either better or equal to existing conditions. The design also incorporated added control features to facilitate future maintenance and allow for flexible construction sequencing that would minimize flow handling risks and costs.

For all the above reasons and inherent challenges, the implementation of a fully automated RTC system application for optimizing system operation and providing system-wide control of CSOs, as has been developed and implemented in Ottawa, is still a relatively new and innovative approach.

Upgraded Regulators and RTC Commissioning.

Project Complexity

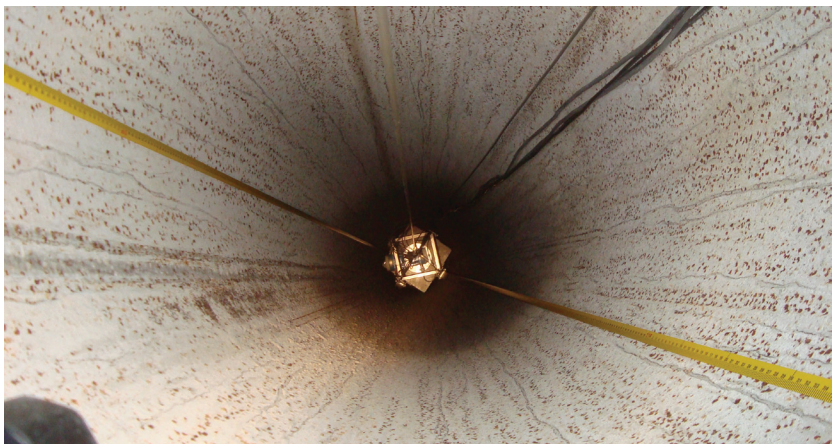
The RTC project presented numerous unique and complex challenges during design, construction and operation. A few key issues are presented below:

Complexity in Control Scheme

Development of the system-wide RTC Scheme and the detailed Process Control Narratives was a complex undertaking and presented unique challenges. Each flow regulator was designed to adapt its operation to rapidly changing sewer conditions during rainfall events while continuing to maximize wet weather flow capture and, at the same time, protect the community and WWTP from the risk of flooding. The selection of control set points was sensitive since the operation of a given regulator directly influences the hydraulic conditions on the overall system and thus the operation of adjacent regulators as they all convey flow to a common trunk sewer. The operating procedures for controlling the WWTP's Raw Sewage Pump Station (RSPS) in tandem with RTC proved to be extremely complex. Certain pump failure scenarios had to be mitigated as they could potentially lead to pressure transients up the trunk sewer that could directly impact the RTC regulator sites.

Complexity in Design and Construction

The regulator sites are all located in the City's downtown core within high-density historic neighbourhoods, tourist destinations and major transit locations. At each flow regulator site, a balance between maximizing the flow capture rate and minimizing the extent of civil modifications to accommodate increased hydraulic capacity had to be struck and factored into the development of the overall control strategy. These constraints led to innovative design solutions but also to challenging implementation requirements, especially at the largest CSO contributor, the Rideau Canal regulator. Located below Parliament Hill and adjacent to the Rideau Canal (a UNESCO designated World Heritage Site), the flow capacity was doubled by drilling a second 600 mm diameter drop pipe from surface, through the regulator chamber and connecting to the interceptor located 30 m below with a new 600mm diameter drop shaft elbow connecting to the side of the interceptor under live flow conditions. This was all completed within the original regulator structure, within very tight tolerance between the edge of the regulator and interceptor sewer walls.



Drop pipe bored 30 m through bedrock into existing Interceptor Outfall Sewer.

Gate installation below Rapid Transit roadway.

REAL TIME CONTROL IMPLEMENTATION AND FLOW REGULATOR UPGRADES PROJECT

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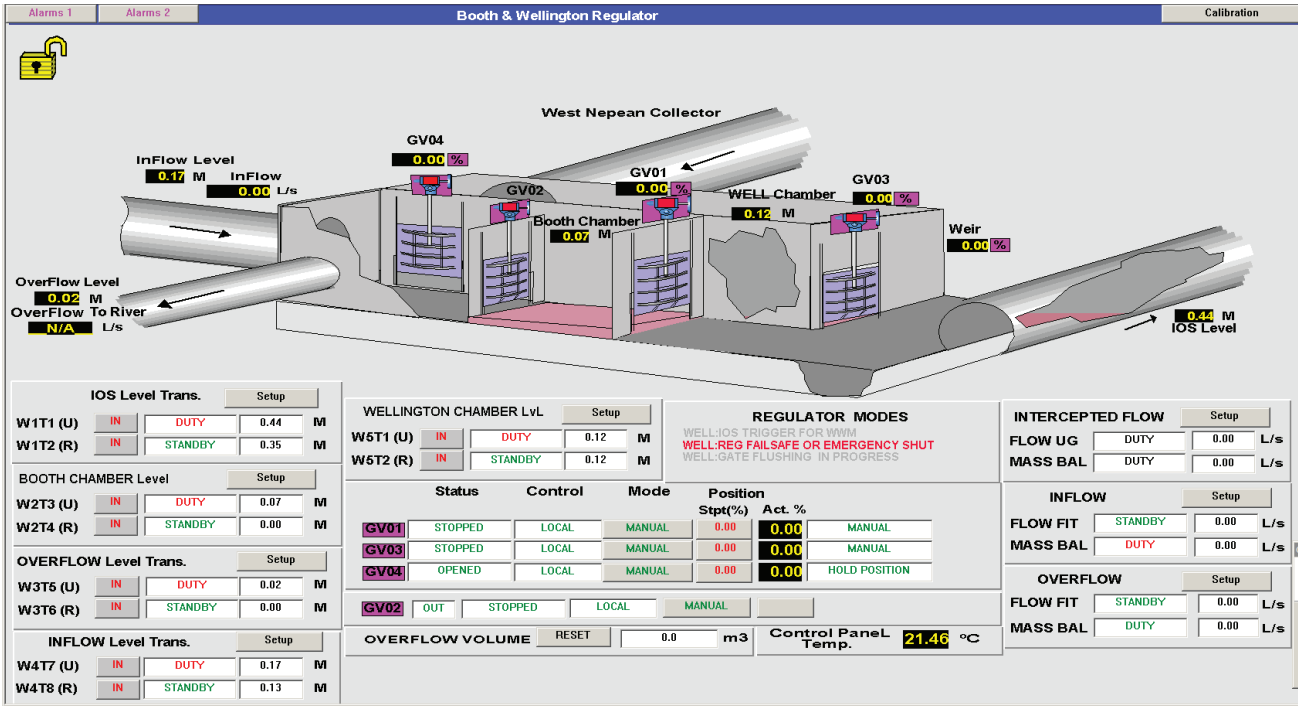
At the Booth-Wellington Site, the functionality of providing for in-line storage within the West Nepean Collector, a new flow regulation chamber for the Booth Street collector system, and emergency flood relief for the West Nepean system was consolidated within the design and construction of a single structure that required the expansion of an existing structure at the junction of three major sewers. This required careful planning and execution of the construction to prevent damage to critical infrastructure as well as challenging flow management plans during construction at all sites. Typical flows in the system had to be managed under dry conditions ranging from 500L/s to 800 L/s and under wet weather flows ranging from 1000L/s to 7000L/s. Close coordination and detailed planning between Stantec, the City of Ottawa and Contractors was crucial in mitigating the risk of construction related by-passes to the Ottawa River and/or sewer back-ups that could lead to basement flooding.

Operational Complexity

Since the City-wide RTC system would be so complex and new to City Operations, a high degree of importance was placed on the development of a logical, straightforward, and manageable RTC solution that could be integrated seamlessly into the City's existing SCADA system and existing operating procedures. In addition, the system was designed to be robust and have enough fail-safe features to ensure reliable performance under any event, including critical rainfall events. In the end, a fine balance was struck between the degree of redundancy and the cost and level of complexity that results in its design, operation and maintenance. During system startup and subsequent operation of the RTC system, Stantec and BPR-CSO staff have worked closely with Operators to adjust set points and operating parameters during rainfall events to calibrate flow calculation algorithms, fine-tune P&ID gate controllers and provide ongoing maintenance and operational support and advice.

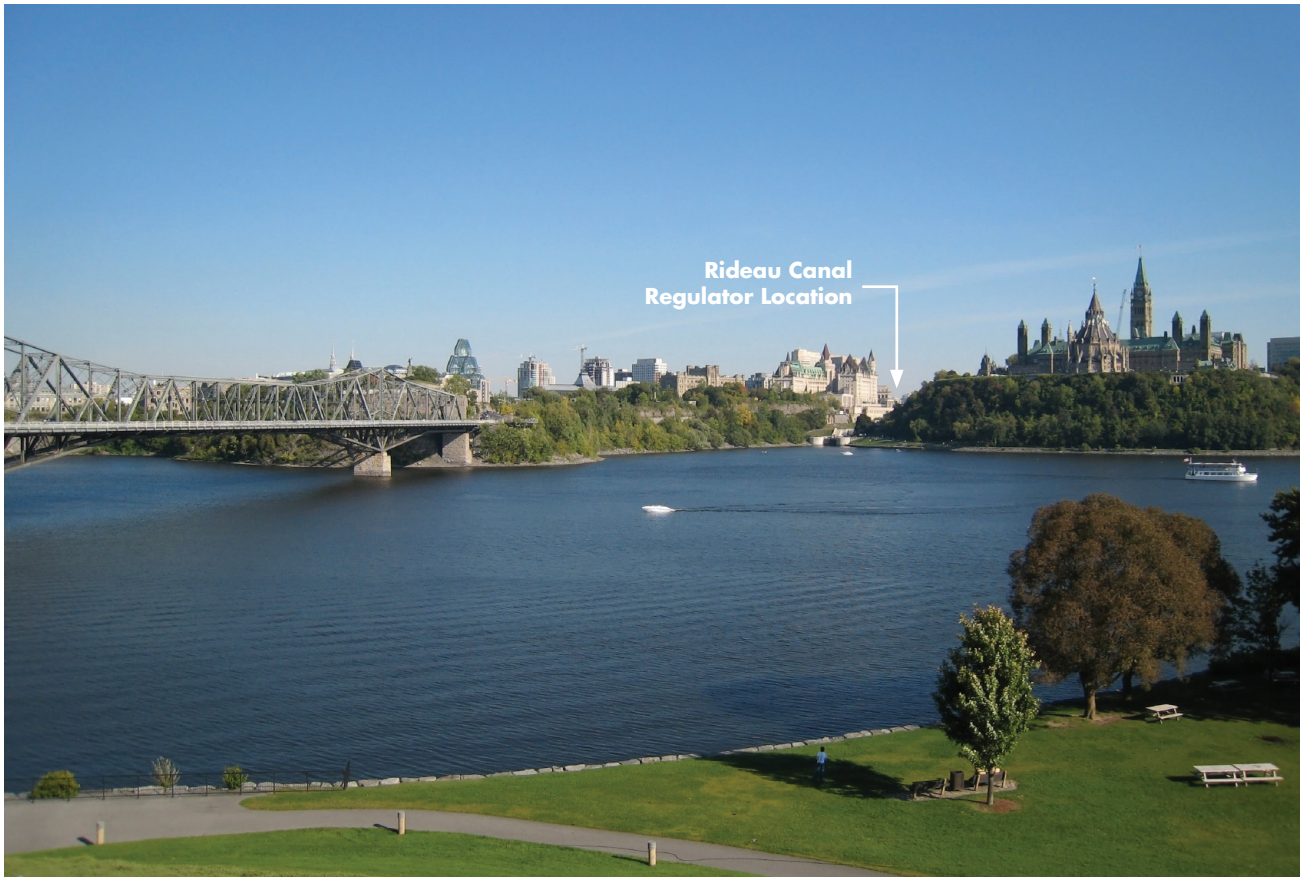


RTC Site Supervisory Control Screen for Operators at Central Control Station.

Environmental Benefits

The Ottawa River is a significant natural resource that is enjoyed by residents of Ottawa and surrounding communities along its entire reach. The river is a multi-purpose system which provides municipal water supplies for several municipalities upstream and downstream of Ottawa, and provides recreational opportunities such as fishing, boating, canoeing and swimming for area residents and tourists alike. By significantly reducing pollutant loadings to the Ottawa River as a result of CSOs, the RTC Project will lead to direct recreational and environmental health benefits for residents of the City of Ottawa and downstream communities.

It will also lead to economic benefits given that the Ottawa River is such an integral and important part of the national capital's history, character and tourist industry. The RTC Project also showcases the City of Ottawa's efforts and innovativeness as a leader in environmental protection among municipalities across Canada.



Economic and Social Benefits

The RTC project is one of the key projects in the City's strategy to improve and protect the health of the Ottawa River (Ottawa River Action Plan). The RTC system will allow the City of Ottawa to exceed the requirements of Procedure F-5-5 (90% wet weather flow capture and treatment objective) with a significant cost savings as compared to alternative methods of CSO reductions (i.e. wastewater storage facilities, combined sewer separation, etc.). This cost-effective solution has led to near-term benefits by effectively using the existing system and will lead to significant capital cost savings in the investment of new infrastructure that is required to meet the City's Ottawa River Action Plan of effectively eliminating overflows in an average rainfall year. With a more efficient operating strategy, the minimum control objectives were attained at a capital cost of $23M and within a short implementation timeframe (4 years), with less disruption to the community and at a significant savings in capital cost (minimum of $65M+) compared to a storage or sewer separation solution.

In addition to the environmental benefits of the RTC system, the ability to operate multiple regulators remotely in real-time gives operators' flexibility in emergency scenarios, which reduces the risk of impacts on residential, business and institutional properties from wastewater flow backups. In July 2011, one of the City's larger and older combined sewer outfalls (constructed in 1911) collapsed. This presented a significant risk for widespread basement flooding in the community if an overflow event were to occur at the affected site. Using RTC, City Operations staff was successfully able to manipulate the operation of both the local regulator and other upstream regulators to minimize the risk of overflow at the pipe collapse location. As a result, no overflows occurred at this site and basement flooding was avoided while the outfall was being repaired, despite numerous rainfall events. The RTC system has thus already proven that it provides the City a level of operational flexibility that it did not previously have and an enhanced ability to protect local residents and infrastructure under emergency conditions.

Rideau Canal - Downtown Ottawa

Owners Expectations & Conclusions

Expectations

The City of Ottawa recognized and expected that a more effective operation of its flow regulating chambers could improve its CSO capture performance and cost-effectively provide added benefits in its efforts to meet both City and Provincial CSO control objectives. In addition, the City had the need to rehabilitate and upgrade its aging combined sewer system with a near-term solution that provided for enhanced system reliability and greater operational flexibility for the full range of operating conditions.

The City also expected that the design would include adequate flexibility and allowances to accommodate future upgrades and/or integration into other systems to further reduce CSOs. The City's ultimate CSO objective is to eliminate all overflows in the average year to the Ottawa River. This will be achieved by integrating the RTC system with the City's proposed Combined Sewer Storage Tunnel (CSST), where the CSST will capture excess CSOs when the existing system is at full capacity.

Conclusions

Through the innovative use of modern equipment and systems controls technology, the project has provided the City of Ottawa with a modernized flow management system for their combined sewer system that makes highly effective use of existing infrastructure and provides better operational control over the system. It has allowed the City to effectively attain its initial control objectives quicker, with much less disruption and at a much lower cost than traditional CSO control methods. Traditional approaches often require investment in large (and often multiple) flow conveyance, storage and/or treatment facilities. The project resulted in savings of more than $65M+ over traditional CSO control methods, allowing the capture of 90% of wet weather flow volumes generated by the collection system.

Implementation and construction of the RTC system started in 2007 and was fully commissioned in March 2011. Stantec has been working with City Operations staff since implementation to aid in operation and performance optimization. The system recently completed its first operational season, which resulted in a significant reduction of CSO volumes to the Ottawa River. Stantec provided extensive operator and management training for the Client prior to system startup. Stantec is continuing to provide services for the City for the second operational control season of the RTC system to further evaluate and optimize the system's performance and to provide ongoing training for City staff on RTC operation.

REAL TIME CONTROL IMPLEMENTATION AND FLOW REGULATOR UPGRADES PROJECT

An Innovative Sustainable Solution

This project thus serves as an excellent example of a sustainable and innovative solution to system rehabilitation and CSO control, with a significantly lower environmental footprint than traditional CSO control methods. With little impact to the environment and local community, it has allowed the City to cost-effectively meet operational and CSO control objectives while providing maximum benefit to the receiving waters and the community as a whole.

Furthermore, in making maximum use of existing infrastructure with RTC implementation, the project has effectively provided an opportunity to maximize environmental benefits while minimizing the financial, social and environmental impacts that would have resulted through the implementation of traditional and more disruptive CSO control measures. It now provides the opportunity to move forward with the cost-effective implementation of additional CSO control measures and exceed minimum control requirements as envisioned in the City's Ottawa River Action Plan.

View of post-construction RTC regulator site at street level in Ottawa's New Edinburgh neighbourhood.