Intelligent infrastructure optimizes stormwater management

Marcus Quigley, **Scott Landers**, and **Alexa Sarmanian** with OptiRTC report on how forecast-based, real-time controls can be applied to independent, distributed pieces of stormwater infrastructure to optimize system performance.

For many decades, the water sector has successfully used real-time control (RTC), an extension of the system operator that serves as a full-time watchdog to ensure system performance. RTC also detects potential failures before they affect service. Both the water supply and wastewater sectors have broadly employed RTC to increase the efficiency of their operations and, more importantly, to improve the reliability of delivering critical services.

Historically, this powerful tool has been limited to facilities with a high density of engineering processes, namely water and wastewater treatment facilities or other critical centralized facilities. A single treatment facility typically includes hundreds to thousands of monitoring and control points. Therefore, the capital investment in RTC would provide a near-immediate return for the facility. Early generation RTC generally took the form of supervisory control and data acquisition (SCADA) systems.

First-generation SCADA was implemented at individual, physically connected locations. Improvements in networking protocols enabled the implementation of networked remote telemetry units (RTUs). Using RTUs, water and wastewater facilities could receive real-time information about conditions outside of the facility's physical boundaries.

While some intractable challenges in water resources management can benefit from remote operational control and autonomous intelligent operation, others do not fit into the traditional SCADA system design assumptions. Stormwater management is one of these challenging areas. Both grey and green stormwater infrastructure systems are typically relatively low-cost passive systems that are often highly distributed across wide geographic areas, which creates opportunities for system improvement through successful RTC integration.

Real-time controls for stormwater

Stormwater is inherently highly distributed. Rain is generated ubiquitously throughout watersheds, and runoff can sometimes flow downhill or across political and institutional boundaries of management and accountability. Unlike wastewater flows, stormwater flows fluctuate with precipitation, and with a changing climate, the short- and long-term variability of stormwater flows is greater than ever.

In cities with older infrastructure and combined sewer systems, stormwater flows can cause major pollution issues. When combined sewer capacity is exceeded, many systems are designed to overflow. During combined sewer overflows (CSOs), both stormwater and wastewater can discharge into streams, wetlands, ponds, and lakes as well as estuaries and coastal waters. One traditional solution to CSOs involves building deep tunnels or "super sewers." These structures are large storage systems that hold excess flow until it is eventually pumped to and treated at the water resource recovery facility. Deep tunnels typically come with a price tag equivalent to hundreds of millions to even billions of US dollars and take decades to implement. Even with these measures, when rain exceeds certain intensities or volumes, many cities may still discharge raw sewage mixed with runoff into waterways.

CSOs present only one of the challenges facing aging stormwater infrastructure. Adding to the complexity of the issue, many cities have significant regulatory and practical burdens resulting from runoff water quality and flooding impacts.

Fortunately, RTC technology has improved tremendously in recent decades and is now able to offer modern solutions designed specifically to manage highly distributed stormwater controls. These solutions are adaptive and intelligent in their ability to automatically and autonomously operate distributed stormwater control features around each storm. RTC is also able to perform continually, even as rainfall patterns change. This improved functionality optimizes the use of existing infrastructure, makes new infrastructure more effective, and – above all – improves community resiliency.

Integrating weather forecasts

With an advancement that is particularly useful for stormwater controls, modern distributed RTC systems can integrate information from sources beyond the infrastructure they control. End consumers do not control runoff generated by storm events, so available historic data cannot adequately inform operators of conditions beyond normal expectations. Stormwater flows are rather controlled by the weather, and to accurately anticipate stormwater flows, a system must take advantage of precipitation forecast models.

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A 2006 report on RTC by the US Environmental Protection Agency (EPA) stated that one of the most promising approaches to integrating precipitation forecasts involves working with a local farmer or park ranger. Today, modern RTC systems can assimilate Internet data, enabling RTC to integrate with multiple forecast models and to provide a worldwide weather forecast. Precipitation forecasts can now directly inform any stormwater management system within a radius of a few kilometers. This powerful capability enables

Rendering of a 7,570-cubic meter pond equipped with forecast-based, real-time controls in Portland, Oregon, USA. The project, by OptiRTC, Clean Water Services, and Geosyntec Consultants, is designed for water quality improvement and to minimize downstream erosion by always releasing water at the slowest rate possible.

municipalities of all sizes to leverage reliable and government-maintained services to predict flows from storm events.

While software improvements have enabled web integration, hardware costs for implementing local monitoring at individual control points have also decreased dramatically. It is now cost efficient to implement RTC on a distributed network of stormwater controls. The ability to monitor distributed networks is aided by the advent of cloud computing and low-cost microcontrollers. This combination of hardware and software provides an industrial-grade commercial solution for connecting both distributed physical systems and third-party web services, such as National Oceanic and Atmospheric Administration (NOAA) forecasts. This collection of technologies is known as the Internet of Things.

Internet of Things technology for stormwater infrastructure enables high-performance applications across the sector. Intelligent forecast-integrated solutions include, but are not limited to, CSO mitigation, rainwater harvesting, hydromodification, flood prevention, and smart green infrastructure. Because the intelligence lives in the software, all types of stormwater facilities are able to fit into the same model, allowing each stormwater storage facility within a city to be connected to the same control system regardless of infrastructure size or form. In effect, each control becomes part of a network, working autonomously, to lay the foundation of a smart city.

Smart cities: smart stormwater

The Internet of Things is often associated with smart cities, which include smart stormwater management. The efficiencies of modern RTC are immediately evident, as they enable low-cost hardware to be deployed throughout a watershed over distributed control points, all of which are connected by cloud computing and informed by national weather forecasts. A 2013 study by Universite Laval in Quebec City, Canada found that the size of detention facilities could be decreased by more than 50 percent when using forecast-based RTC. This finding reveals that retrofitting existing stormwater controls with modern RTC in cities where infrastructure is fully built out can double their efficiency for improving water quality.

One such system deployed by the Boston, Massachusetts-based OptiRTC, Inc. currently provides intelligent rainwater harvesting and stormwater management for the US EPA headquarters in Washington, DC. Operational for just over one year, the system has already successfully optimized the performance of rainwater harvesting cisterns designed to manage runoff. Specifically, the system uses precipitation forecasts to estimate rooftop runoff volume. This estimated volume is compared to the cistern's available capacity for wet-weather capture. If there is not sufficient capacity available in the cisterns, the RTC system will predictively drain the cisterns' water in advance of the forecasted storm. By integrating weather forecast information with autonomous controls, the system is able to accomplish competing objectives, maximizing the volume of harvested rainwater while minimizing wet-weather discharge and contributions to the combined sewer. The project involved a simple retrofit of existing infrastructure and resulted in a low-cost, high-performance solution for optimizing underused cisterns.

Control at the watershed scale

Working on a watershed scale, each part of the RTC network is aware of decisions made at all other control points, so network-level optimization is readily achievable. Networked stormwater control facilities can effectively control the flow of stormwater in an entire watershed to improve flood control, water quality, and reduce CSOs. These benefits are especially valuable when RTC is used to retrofit existing infrastructure. Retrofitting stormwater basins with RTC is much quicker and more cost effective than increasing stormwater capacity with new construction. Financial concerns are a major factor for any municipality with a tight budget that needs to comply with regulations, such as the Clean Water Act or Water Framework Directive.

Even more important than modern RTC's ease of scalability is its adaptability. Passive systems are typically designed for a single use case, such as peak control of the 10-year, 24-hour storm, which is subject to change based on variable climate patterns. Comparatively, RTC systems with predictive controls are designed to adapt to changing precipitation patterns. For example, regardless of the current size of the 2-year storm, a system equipped with RTC is optimized to achieve the highest level of wet weather capture possible.

Cost savings through RTC

When it comes to costs, the appeal of RTC is fairly straightforward. It costs significantly less to double the efficiency of existing infrastructure with RTC than to double infrastructure capacity with new construction. Moreover, a high-performing system could enable municipalities to avoid costly fines and lawsuits for environmental noncompliance. Long-term costs are mitigated by adaptive management capabilities, as operators can continuously improve system performance without deploying an entirely new system. Lifetime value analysis of RTC technology shows that for stormwater controls, RTC is nearly always at least 30 percent less expensive than a passive alternative with similar performance. Particularly in urban areas with limited space, deploying or expanding stormwater infrastructure uses valuable real estate and is often invasive.

The big picture

One definition of intelligence is making a decision in the present that provides the widest range of options in the future. In the context of stormwater management, this type of future-thinking intelligence could involve using RTC to prepare infrastructure for the coming storm regardless of its size. Predictive, forecast-based controls can act ahead of the storm, empowering infrastructure to use its full capacity to control the timing and rate of stormwater flows. Using integrated precipitation forecasts and distributed site data from across a watershed, modern RTC is able to optimize the performance of stormwater management infrastructure. Better stormwater infrastructure performance results in improving water quality, reducing CSOs, and maximizing stormwater control capability for every dollar spent.

Modern distributed RTC is a robust tool that municipalities can use to implement truly intelligent infrastructure in order to prepare today's infrastructure to handle tomorrow's storms.