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Artificial Intelligence in Wet Weather Infrastructure

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Artificial Intelligence in Wet Weather Infrastructure

Prepared For:

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Abstract

Effective management of runoff from rain and snowmelt is critical as increased water flows can negatively affect efficiency and reliability at treatment facilities, as well as potentially damage property or the natural environment. Implementation of artificial intelligence for real-time decision making and support in wet weather infrastructure is a recent technological development; as such, a problem has emerged: experience and knowledge of best practices for successful implementation is limited. Artificial intelligence is being employed to inform operational decisions that are intended to improve the efficiency and reliability of physical wet weather infrastructure. The goal of municipalities and utilities in utilizing artificial intelligence is to maximize use of the existing physical infrastructure and reduce the need for future capital investment. Because artificial intelligence for real-time decision making and support in wet weather infrastructure is a relatively new technology, experience and knowledge of best practices for successful implementation is limited. In addition, staff have been reluctant to embrace or trust the decisions and support made by the AI systems in certain cases. This study approaches the problem through comprehensive review of recent literature and interviews of those responsible for previous implementations of artificial intelligence in Saint Paul, MN, Buffalo, NY, and Kansas City, MO. Best practices include continuous operator input and ongoing training throughout the project, effective and proper maintenance of the "inputs" to the artificially intelligent system, and incorporation of failsafe mechanisms in the design. As artificial intelligence becomes more prevalent in the civil engineering industry and computers are increasingly given real-time control of systems, this study could provide future designers with a framework for successful implementation of artificial intelligence in wet weather infrastructure projects.

Objectives and Hypothesis

The objectives of this report are as follows:

- Present an overview of artificial intelligence and its recent applications in wet weather infrastructure.
- Obtain case studies of recent applications of artificial intelligence in wet weather infrastructure.
- Analyze case studies to determine best practices for successful implementation of artificial intelligence in wet weather infrastructure projects.

It is expected that through consideration of operator input, ongoing training, effective maintenance, and inclusion of failsafe mechanisms, artificially intelligent real-time decision support systems can maximize efficiency of new and existing stormwater infrastructure.

Acknowledgments

Special acknowledgement is given to the following individuals for their time and generosity in detailing the case studies contained within this report:

1. Catherine H. Knab, P.E., PMP
   Principal Sanitary Engineer
   Buffalo Sewer Authority

2. Forrest J. Kelley, P.E.
   Regulatory Division Manager
   Capitol Region Watershed District

3. Andy Shively
   Special Assistant City Manager
   City of Kansas City, Missouri

Background – The Intersection of AI and Stormwater Infrastructure

This report presents four case studies of recent stormwater infrastructure projects which utilized artificial intelligence (AI) with real-time controls and establishes three key aspects which must be considered during design and implementation of an AI system to stormwater infrastructure. Artificial intelligence dynamically and automatically adjusts facility operations in response to live, real time field measurements. Real time control requires automated continuous monitoring and data communication.

The term “artificial intelligence” was coined in the summer of 1956 by John McCarthy at a conference held at Dartmouth University. McCarthy defined artificial intelligence as the science of “creating machines with the ability to achieve goals in the world.” Although the term “artificial intelligence” can conjure images of dystopian science fiction and ultra-intelligent, human-like machine minds, present-day AI technologies are not typically intelligent, independently thinking machines. They are computer applications which help humans think better [1]; in other words, they provide “real-time decision support.”

Despite the fact that most artificial intelligence systems today are computer applications intended to guide human decision making, evidence has been presented which suggests that applications have been limited due to ethical concerns and a lack of trust on the part of their users [2]. Many researchers believe that through creation of more transparent or interpretable systems, users will be able to more easily understand and therefore trust the artificial intelligence [2]. This is known as “explainable artificial intelligence.” According to Tim Miller of the University of Melbourne, two approaches accomplish this goal [2]:

1. *Interpretability:* Generating decisions in which one of the criteria taken into account during the computation is how well a human could understand the decisions in the given context.
2. *Explanation:* Explicitly explain decisions to users.

This report will analyze how these approaches can be implemented during creation of artificial intelligences for wet weather infrastructure applications.

Case Study I – Predictive Flood Control and Stormwater Reuse

Capitol Region Watershed District; Saint Paul, Minnesota

Project Background

The Capitol Region Watershed District (CRWD) in Saint Paul, Minnesota currently has two completed projects which utilize real time controls. The first is a predictive flood control system at Curtiss Pond in Falcon Heights, Minnesota. Curtiss Pond collects runoff from a 38-acre watershed consisting primarily of residential development. In the past, large storms have caused the pond to overflow and create several feet of standing water in the vicinity, posing a threat to nearby infrastructure. To eliminate the flooding, the CRWD created an intelligent retention system that utilizes real time controls to predict the amount of runoff in advance of an upcoming storm and automatically draw down the pond to create capacity in advance of the rainfall event. The project was designed to eliminate flooding from a 10-year rainfall event. The system also measures temperature and infiltration rates to improve stormwater management during freezing and thawing cycles [3]. A 390-foot network of 10-foot diameter perforated pipe was installed underneath Curtiss Field. The pipes are fed by overflow from the pond, and stormwater is delivered there to percolate into the ground.

Figure 1. Construction of Curtiss Pond storage pipes.

The second project implemented by the CRWD is a stormwater harvesting cistern installed at their new headquarters building in Saint Paul, Minnesota. The system consists of a cistern which collects rainwater for reuse in irrigation of the building's landscaping. The project to provide as much treatment volume as possible within the budget. In advance of a rainfall event, the computer program automatically predicts the capacity required in the cistern and opens a valve to filter and discharge the appropriate amount of water into a nearby river to create the necessary storage capacity. This project was constructed to demonstrate the feasibility of using real time controls to improve green infrastructure and improve the water quality of stormwater

runoff. The CRWD selected OptiRTC software, created by OptiRTC, Inc., of Boston, Massachusetts, to create the logic and program their real time control projects [4].

Challenges and Solutions

During design of these two projects, the greatest challenge faced by Capitol Region Watershed District staff was development of accurate models to quantify the benefits and ensure they were clear and easily quantifiable. The CRWD did not wish to implement the RTC technology simply for the sake of innovation [4]. Project managers for CRWD, as ultimate owners and operators of the RTC projects, were directly involved during the design process. Partnerships between the CRWD and the cities involved in the projects ensured that all involved parties were engaged with the projects from conceptualization through design and construction to eliminate concerns [4].

In general, the construction phase of the projects went smoothly. The CRWD learned that subcontractors must have a clear scope of work outlined, especially for electrical-related work. This must be made clear in the construction documents for the project. Training of operations and maintenance staff in the new technology proceeded smoothly. OptiRTC, Inc. provides on-site training during start-up and has an online dashboard available to staff for troubleshooting of software. O&M staff have found the system to be intuitive [4]. The controls are entirely web-based, so no software training is required. The risk levels associated with a failure are low for these project locations, so the valve states (normally open or normally closed) are configured to default to one position depending on the specific needs of the project as a failsafe mechanism, thus allowing city staff to become comfortable with the system rather quickly.

Project Benefits & Future Plans

Since deployment in July 2015, the Curtiss Pond system has successfully collected stormwater runoff from the watershed and prevented the flooding of the surrounding residential area. The system also provides real-time and historical data of site performance to CRWD staff. RTC technology also holds potential for expansion to stormwater facilities throughout the region to effectively manage storms at the local watershed scale [3]. The Capitol Region Watershed District has become a proponent of the new technologies and their use in stormwater infrastructure. They plan to continue implementing RTC on their capital improvement projects and developing ways to utilize RTC to meet requirements for water quality of stormwater. To date, they have not had any negative experiences with the technology [4].

Background: Combined Sewer Overflows

Many of the earliest public wastewater collection systems in the United States were Combined Sewer Systems (CSSs). CSSs were intended to combine sanitary wastewater and stormwater into a single transit pipe network for routing to a wastewater treatment plant. During periods of heavy precipitation, most CSSs are designed to discharge overflows directly to surface waters, resulting in a combined sewer overflow (CSO). CSO discharges can contain commercial, domestic, and industrial wastewater as well as pollutants from stormwater runoff. Thus, the EPA issued the CSO control policy on April 19, 1994 [5]. The policy places responsibility for developing a Long-Term Control Plan (LTCP) on each CSO community in order to be in compliance with the Clean Water Act on permitted CSOs. The EPA's CSO Control Policy includes nine minimum controls which can reduce CSOs [6]:

1. Proper operation and regular maintenance programs for the sewer system and CSO outfalls
2. Maximum use of the collection system for storage
3. Review and modification of pretreatment requirements to ensure that CSO impacts are minimized
4. Maximization of flow to the WWTP for treatment
5. Elimination of CSOs during dry weather
6. Control of solid and floatable materials in CSOs
7. Pollution prevention programs to reduce containments in CSOs
8. Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts
9. Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls.

The CSO Control Policy established two objectives for CSO communities: 1) Implement the nine minimum controls and provide documentation of implementation; and 2) to develop a long-term CSO control plan. CSO control will help to prevent water quality impairments and reduce the risk of exposure to untreated sewage. The following two case studies utilized artificial intelligence in these CSO control projects while implementing their long-term control plans.

Case Study II – Real Time Control of Inline Storage

Buffalo Sewer Authority; Buffalo, New York

Project Background

During the past 50 years, the City of Buffalo, New York has seen a significant decline in population along with the loss of most of its industry. Because of this, Buffalo operates a sewer system with a designed capacity of up to 750,000 people, while serving just 250,000 [3]. The excess capacity was recognized as an opportunity for implementation of one of the nine minimum controls to reduce CSOs: maximum use of the collection system for storage. The Buffalo Sewer Authority (BSA) identified 16 candidate sites for inline storage; four sites were selected for initial construction. Two of the four sites were commissioned in 2016. The BSA's experiences in the design, construction, and tuning periods are discussed in the following sections.

Figure 2. Inline storage basin project.

Sewer overflows in the Buffalo sewer system will never be fully eliminated. The overflow points in Buffalo's sewer network serve as relief points to prevent catastrophic damage to the treatment plant. The overflow points are continuously inspected to prevent unnecessary dry weather overflows. Routine inspections and cleanings of sewer lines are also performed regularly to reduce blockages and sediment buildup [7].

Challenges and Solutions

The Buffalo Sewer Authority studied varying strategies that were intended to work toward the same goal of reducing combined sewer overflows. The Buffalo Sewer Authority's Long-Term Control Plan (LTCP) includes real time control in-line storage in addition to interception, green infrastructure, satellite storage, overflow point optimization, and underflow upsizing.

The first step in implementation of RTC was to create and analyze a hydraulic model of the system to identify the locations best suited for an RTC project. These analyses will happen periodically until the program is complete. The BSA will be installing up to 16 RTC projects. Once locations were identified, the design phase for each specific site began. It was found that each site brought its own unique challenge [7].

An example is the Hertel at Deer RTC project, which was slated to be built on one of two lines (Hertel North) that run along Hertel Ave. During the design, it was found the the second line (Hertel South) was so close to the North line that the structure could not be built on just one line. Therefore, the project incorporated storage along both the North and South lines. This modification increased the cost of design, and subsequently construction, but the greater volume of storage is expected to make up for the increase costs.

The treatment plant superintendent, shift supervisors, and maintenance staff are engaged throughout the design of each RTC project. Typically, two review meetings are held between the design consultant and operations and maintenance staff for each project [7]. During the construction phase of the RTC projects, major challenges experienced include managing existing flows during construction, cutting into the existing pipe, dealing with traffic surrounding the site and integrating the site into the existing Supervisory Control and Data Acquisition (SCADA) control system architecture [7].

Each in-line storage structure contains two failsafe mechanisms: one is built into the programming for how the gates/valves operate and the other is incorporated in the design of the structure. In the instance of a failure, the gates will be triggered to open all the way allowing for the full pipe flow of water to pass through. If for some reason the gates fail closed, there is an internal weir that is sized to allow for the full pipe flow to pass over the weir. Therefore, upstream customers will never be flooded due to failure of one of the RTC systems [7]. In addition, if the system operators at the plant see an abnormal operation or reading, the BSA includes a command in their SCADA system which commands the gates to open (or valves to close). Additional manual control over the system is provided using the on-site control panel for each project.

Project Benefits

Although the Buffalo Sewer Authority is implementing the aforementioned strategies in addition to real time controls, RTC infrastructure provides excellent return for relatively little investment by utilizing the existing system to provide storage space. Inline storage is also one of the EPA's Best Management Practices [5].

The BSA’s real time controls are meant to function with very limited operator input. The biggest change is that our maintenance staff have additional sites to check in on. Thus, very little has changed in day-to-day operation of the Buffalo sewer system.

The BSA's RTC projects involve limited operation and maintenance involvement after implementation. Only one gate at one project site has received special maintenance attention. Real time controls are providing additional CSO mitigation without an increase in day-to-day effort on BSA staff [7].

Future Plans

In further implementation of their LTCP, the Buffalo Sewer Authority has learned various strategies to make the sites more user-friendly and easier to maintain. For example, they have begun design of a greasing mechanism that can be accessed from street level so that maintenance staff can grease the gates more quickly and easily. Traffic delays will be decreased, and crews will not have to remove a grate and climb into the interior of the structure [7].

The Buffalo Sewer Authority freely shares with current contractors how previous contractors set up their bypass system for managing flows so that they aren't starting from scratch. In addition, the computer programming for each project is documented and made available for each subsequent project. The BSA would like each of the RTC sites to look as similar as possible in their SCADA system and on the local Human Machine Interface (HMI) screens on site [7].

Through past project experience, the BSA has begun to standardize on preferred equipment for their RTC projects. An example is standardization of AUMA brand actuators, to match the majority of existing actuators already installed in the system [7].

The first projects implemented underwent very little public outreach and some had negative reactions from neighbors during construction. The BSA has now developed a standard informational brochure and procedure for meeting with affected councilmen and block club leaders to inform the public, well in advance, of the projects and their purpose [7].

Case Study III – Smart Sewer Program

KC Water; Kansas City, Missouri

Project Background

In 2010, the City of Kansas City, Missouri entered into a 25-year, $4.5 billion-dollar federal consent decree to reduce combined sewer overflows. Kansas City's Smart Sewer network consists of sensors attached to manhole covers to measure water flow and depth at critical points throughout the City's sewer system, which includes approximately 2,800 miles of sewer mains covering 318 square miles [8]. The sensor data is used to train an artificial intelligence system, through continuous monitoring of how the collection system acts and reacts to events, to predict how the city's sewer system will perform during various storm conditions. Real-time data is continuously input and used to calibrate the hydraulic model of the system, increasing the accuracy of the model. This same AI technology then uses National Oceanic and Atmospheric Administration rainfall forecasts to decide the optimal place to store or direct wastewater in the sewer system. This information is then electronically relayed to pump stations and in-line gates to optimize conveyance, storage, and treatment of wastewater and stormwater [9]. The Smart Sewer system is also used to determine locations suitable for additional in-line storage.

Figure 3. "Smart Sewer" manhole cover sensors

Challenges and Solutions

According to Special Assistant City Manager Andy Shively, one of the most significant challenges associated with the Smart Sewer project has been identifying an effective strategy for training operations staff to utilize the new technology. The artificial intelligence component of the system is intended to be an operational technology, providing operators with real-time decision support. Shively has found that involving and engaging operations staff early on in the project has been an effective solution to this problem. Staff input has been incorporated from the early stages of

the project to ensure that operation of the AI system aligns with the operational techniques the staff is familiar with [8]. Each new portion of the Smart Sewers project includes an ongoing training process. This incremental involvement has helped demonstrate to operations staff that the artificial intelligence is a tool intended to improve the efficiency of the system.

Due to the strategy of utilizing actual flow monitoring data to continuously calibrate the City's hydraulic model, and the infeasibility of deploying a sensor in each of the City's 66,000 manholes, Shively has found that makings decisions on where to deploy manhole cover sensors has been challenging during design of the Smart Sewer system. Manhole cover sensors have been deployed in the critical manholes within each drainage sub-basin to allow monitoring of the effects each has on the system as a whole. Once deployment locations are selected, installation of the manhole cover sensors is very straightforward [8].

The Smart Sewers program has not brought about significant changes for maintenance staff. Staff perform monthly checks on each manhole cover sensor to ensure the sensors are clean and properly positioned, and to replace batteries as required. The City has found that laser sensors require more maintenance, and thus sonar sensors are preferable and will be utilized in future portions of the project [8]. Maintenance of sensors is critical, as decisions made by the artificial intelligence depend on the accuracy of the information being input. The system always has an operator monitoring to ensure accuracy, and manual override can be used to take control of the system whenever necessary. The system includes failsafe mechanisms such as inline storage gates failing in open positions to eliminate risk of overflows during power failures [8].

Analysis of Case Studies

Three key points were observed in all three of the case studies presented in this report:

1. Operator input and ongoing training throughout the design and implementation of the projects proved to be an effective strategy for building trust in the system.

2. The "inputs" to the artificially intelligent system – e.g. the level sensors, flow meters, and other appurtenances – must be effectively and properly maintained.

3. Failsafe mechanisms must be incorporated in the design to prevent property damage or risk of human life during failure events.

According to the U.S. EPA, it is critical to involve operator input during the design of smart data infrastructure, as the operators are ultimately responsible for overall system performance. This strategy was successfully utilized during the above projects in St. Paul, Buffalo, and Kansas City. These projects were successful because in order to create explainable artificial intelligence systems for stormwater decision support, human-centered design is crucial.

Artificial intelligence is capable of automating tasks of both tacit and explicit human knowledge. Explicit human knowledge is knowledge that can be documented in manuals; generally repetitive or time-consuming tasks that can be automated to free up human time for more complex tasks. Tacit human knowledge is more crucial to safe operation of stormwater collection systems; it is automatic, intuitive knowledge that is gained through practice, not through study of rules or manuals. Most human knowledge falls within this category. According to Guszcza [1], "it is tempting to conclude that computers are implementing – or rapidly approaching – a kind of human intelligence in the sense that they 'understand' what they are doing. That's an illusion." Computer programs and artificial intelligences can *demonstrate* this tacit knowledge – but only if they are constructed utilizing data hat encodes the tacit knowledge of a large number of human minds [1].

Thus, it is crucial that operators be involved through the design and implementation of artificially intelligent real-time decision support systems. Operators possess a large, aggregate bank of tacit knowledge about their systems, one which cannot be reproduced and programmed through rules or a manual. By constructing AI systems utilizing this bank of tacit knowledge, it is possible to create an artificial intelligence that is *explainable* to the user – the operator – and thus can be effectively understood and utilized for real-time decision support. AI systems in stormwater infrastructure should be easily capable of using explicit knowledge to run on "autopilot" most of the time but require human intervention and manual control in exceptional situations which require common sense or conceptual understanding.

In scenarios where decisions are not associated with a diverse body of historical data, it is not possible to construct a reliable predictive algorithm to fully automate decision-making. In these scenarios, an imperfect algorithm can be used to augment and improve human decisions [1]. For the case studies previously presented, effective and proper maintenance of the system inputs is critical for this reason. The artificial intelligences form the “imperfect algorithm;” that is, they do not possess enough historical data or tacit knowledge to allow full automation; but though proper maintenance of the inputs, effectiveness of the augmented human decisions can be maximized. Operations staff must have knowledge of how the artificial system uses these inputs to make decisions – that is, the algorithms assumptions and limitations should be explicit and clearly communicated.

Conclusions

Through utilization of operator input throughout the entire design of an artificially intelligence stormwater system, it is possible to create an AI that shows *interpretability*, or the ability of the operator to understand the AI’s decision in a given context. By using AI only to augment human decisions in stormwater management and properly maintaining system inputs, a system will show *explanation*; that is, if the operators can recognize the input data and its accuracy, the AI’s decision will be more easily explainable. These two strategies create an “explainable artificial intelligence” which user can easily understand and therefore trust. By including failsafe mechanisms in the design, and allowing operators to assume manual control as necessary, human life and property can be protected from damages associated with exceptional circumstances which an AI does not possess the tacit knowledge to effectively manage.

References

[1] J. Guszcza, "Smarter Together: Why Artificial Intelligence Needs Human-Centered Design," *Deloitte Review,* no. 22, 2018.

[2] T. Miller, "Associate Professor," University of Melbourne, Melbourne, Australia, 2018.

[3] "Smart Data Infrastructure for Wet Weather Control and Decision Support," U.S. Environmental Protection Agency, Washington, D.C., 2018.

[4] F. Kelley, Interviewee, *Regulatory Division Manager.* [Interview]. 19 February 2018.

[5] "Report to Congress on Combined Sewer Overflows to the Great Lakes Basin," U.S. Environmental Protection Agency, Washington, D.C., 2016.

[6] "Combined Sewer Overflows: Guidance for Nine Minimum Controls," U.S. Environmental Protection Agency, Washington, D.C., 1995.

[7] C. H. Knab, Interviewee, *Principal Sanitary Engineer.* [Interview]. 11 February 2019.

[8] A. Shively, Interviewee, *Special Assistant City Manager.* [Interview]. 7 March 2018.

[9] J. Rusch, "Saving Infrastructure with Sensors in the Sewer," *Water Online,* 4 September 2018.

Appendices

Appendix A – Correspondence with Forrest Kelley, Regulatory Division Manager, Capitol Region Watershed District

Appendix B – Correspondence with Catherine Knabb, Principal Sanitary Engineer, Buffalo Sewer Authority

Appendix C – Correspondence with Andy Shively, Special Assistant City Manager, Kansas City, Missouri

Appendix A

Correspondence with Forrest Kelley, Regulatory Division Manager, Capitol Region Watershed District

Common Challenges faced during design?

- During design, running model to quantify benefit, making sure value is there.
- Making sure benefits are clear & easily quantified
- Not just implementing for innovation.

Common challenges during implementation?

- Construction smooth in general
- Subcontractors must know portion responsible for
- Electrician work
- Clear in construction documents

Day-to-day changes for O&M staff?

- In General smooth
- Opti online dashboard
- Troubleshooting

- Stormwater harvesting/reuse project
- Opti RTC
- Opens value for additional storage in advance of storm
- Flood control, rainwater harvesting
- Taking Green infrastructure further
- Goal is to improve water quality of runoff.
- ~~Capturing~~ In advance of storm, filters & discharges to river

Lessons learned in training O&M staff?

- Very little training required for staff
- Opti provided training
- Have found system to be intuitive
- People monitoring system already, basically just has another window

Anticipated further projects & expected benefits?

- Will consider on capital imp. projects
- Not one size fits all
- Good experience & see benefit

Perception of RTC before/after

- First heard about, intrigued by benefits. New to Minnesota
- Have become proponent of system
- Can be used to meet requirements for water quality
- No negative experiences

Subject: RE: Akron RTC Project Followup Questions
Date: Monday, April 8, 2019 at 5:51:19 PM Eastern Daylight Time
From: Forrest Kelley
To: Matt Hammerstein
Attachments: image003.jpg, image004.jpg, image005.jpg, image006.jpg

Hi Matt,

Apologies for the delayed response. Thanks for the follow up, see below.

We've Moved!

Forrest J. Kelley, PE (MN)
Regulatory Division Manager
595 Aldine Street
St. Paul, MN 55104
Tel: (651) 644-8888 Ext.116 | Mobile:(651) 210-7692
capitolregionwd.org

From: Matt Hammerstein <moh5@zips.uakron.edu>
Sent: Monday, April 8, 2019 4:05 PM
To: Forrest Kelley <forrest@capitolregionwd.org>
Subject: Re: Akron RTC Project Followup Questions

Hey Forrest,

I'm not sure if you received the email sent early last week so I'm sending again. Just wanted to forward on a couple additional questions about your AI projects that were asked during the first review of my report:

1. Was there a certain design storm each project hoped to contain? What level of control or improvement were the projects designed to provide? For Upper Villa, the goals was to remove 45 pounds of TP/year. The project was optimized to provide as much treatment volume as possible within the budget. At Curtiss Field, I believe the goal was to eliminate flooding of the adjacent City Parks building for the 10-yr rainfall event.
2. What methods were used for training? Simulations of events, showing operators the software, user manuals, etc? OptiRTC provides on-site training during start-up, and the dashboard is completely web enabled, so no softwarte is required. The controls are intuitive. Product manuals for the physical components were compiled and provided by the design engineers.
3. Did city staff have any concerns about the system before it was implemented? If so, what were they, and how were they overcome? No. The partnerships between CRWD and the cities are such that all entities were on board from the beginning of project conceptualization through design and construction.

Thanks again for your time and insight for this project!

Matt Hammerstein
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(330) 356-9175 | moh5@zips.uakron.edu

From: Forrest Kelley <forrest@capitolregionwd.org>
Date: Monday, March 11, 2019 at 9:48 AM
To: Matt Hammerstein <moh5@zips.uakron.edu>
Subject: RE: Akron RTC Project Followup Questions

Hello Matt,

Yes, as project managers, and ultimate owners, we were directly involved during the design process.

The valves within the systems are set up to default to various positions depending on the configuration. The risk levels are low for our locations, but regardless, the valve states (normally open or normally closed) depending on the specific needs of the project.

Cheers,

We've Moved!

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From: Matt Hammerstein <moh5@zips.uakron.edu>
Sent: Sunday, March 10, 2019 11:28 AM
To: Forrest Kelley <forrest@capitolregionwd.org>
Subject: Akron RTC Project Followup Questions

Hey Forrest,

Just had a couple follow-up questions regarding our previous discussion of real-time controls:

1. Was operator input utilized during design of the projects?
2. Are there any failsafe mechanisms for events like a loss of power or failure of the computer system to

prevent flooding?

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Appendix B

Correspondence with Catherine Knabb, Principal Sanitary Engineer, Buffalo Sewer Authority

The University of Akron College of Engineering

RTC Honors Research Project Case Study
Buffalo, New York: Real Time Control of Inline Storage

Date: *February 11, 2019*

Initial Questionnaire

1. Prior to implementation of the automated inline storage system, what procedures did the Buffalo Sewer Authority have in place to prevent sewer overflows?

   Overflows will never be fully prevented/eliminated. The overflow points (or Sewer Patrol Points, SPP) are needed to act as relief points to prevent catastrophic damage to our treatment plant. That being said, we continuously perform inspections of the SPPs in order to prevent unncessary dry weather overflows. We also perform routine TV and cleaning of our lines to reduce blockages and sediment buildup.

2. Were any alternatives to the automated inline storage system considered?

   Yes, but not so much alternates, but varying strategies that are intended to work toward the same goal.

   a. If yes, what were they?

   Our Long Term Control Plan (LTCP) includes real time control in-line storage AND interception, green infrastructure, satelite storage, SPP optimization, and underflow upsizing. You can access the LTCP here: http://www.buffalosewer.info/ltcp/index.html

3. Why was the automated storage system selected above more traditional alternatives?

   We are implementing varioius strategies. RTC does offer a big bang for the buck, however, by utilizing the existing system to provide storage space. This also happens to be one of the EPA's Best Management Practices.

4. What were the primary challenges faced during the design phase of the project?

   I see the RTC program as having 2 overarching phases of design. First, our entire system is analysed and models are run in order to identify the locations within our system that are best suited for an RTC project. This analysis has happened and will happen every couple of years or so until the program is complete. Per our LTCP, we will be installing up to 16 RTC projects. Second, once locations are identified, the design phase for that specific project can commence. As with any project, each site brings its own unique challenge. For example, our Hertel at Deer RTC project was slated to be built on one of

two lines (Hertel North) that run along Hertel Ave. During design, it was found the the second line (Hertel South) was so close to the North line that we could not build the structure on just one line. Therefore, we changed the project to incorporate storage in both the North and South lines. This increased the cost of design, and subsequently construction, but the greater volume of storage will make up for the increase costs.

5. What were the primary challenges faced during construction of the four representative sites?

   This is not a straigtfoward answer as each site has its unique challenges. The challenges we have seen so far include managing existing flows during construction, cutting into the existing pipe, dealing with traffic surrounding the site and integrating the site into the existing SCADA system.

6. What lessons were learned during the design and construction of the four representative sites which will be applied to the 12 remaining sites?

   We have learned different ways to make the sites more user-friendly, i.e. easier to maintain. For example, we have started desiging a greasing mechanism that can be accessed from street level so that our maintenance staff can grease the gates quicker and easier; they won't have to block traffic for as long, remove a grate, and climb down into the structure.

   We freely share with current contractors how previous contractors set up their bypass system for managing flows so that they aren't starting from scratch.

   We have learned what parts and pieces work best. For example, we have standardized on AUMA brand acuators as that is the majority of what we already have at the Plant.

   The programming for each project is documented and made available for each subsequent project. We want each of these sites to look as similar as possible in our SCADA system and on the local HMI screens on site.

   And something that may not always be considered is that we have now developed a standard informational brochure and procedure with meeting with affected councilmem and block club leaders to inform the public, well in advance, of the project. The first projects implemented underwent very little public outreach and some had negative reactions from neighbors during construction.

7. What, if any, effect has the new system had on the day-to-day operation of the Buffalo sewer system?

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8. What are the anticipated challenges in further implementation of real-time controls?

   At the start of the program, we tended to tackle the lower hanging fruit; the projects that could give the most benefit for lowest cost or the sites that were easy to access. As we chip away at those projects, we will inevitably be left with sites that have a little more complexity. For example, all of the sites so far have been located within the right-of-way where there has been no need for permanent easements. A site we are starting design on soon is located on private property. While we have an exsting eamement for our existing storm overflow line, we will need to obtain additonal easements. Also, there are sites that, preliminarily at least, are located in heavily trafficked intersections so maintenance and protrection of traffic will be more complicated.

9. Have there been any difficulties in training of operation and maintenance staff?

   Scheduling is our biggest hurdle. We find that our staff is in general eager to learn about the new projects, but their time can be limited in some cases.

10. What are the anticipated further operations and maintenance benefits?

    The beneift in terms of O&M of these projects is that they require limited O&M involvement. Besides one problem gate on our Bird Ave RTC, none of the others have required any special attention. So I guess that would be the benefit - additional CSO mitigation without an increase in day-to-day effort on BSA staff.

Subject: RE: Akron RTC Follow-up Questions
Date: Monday, March 11, 2019 at 12:17:31 PM Eastern Daylight Time
From: Catherine Knab
To: Matt Hammerstein

Hello Matt – see my responses in red below.

Catherine H. Knab, P.E., PMP
Principal Sanitary Engineer
Buffalo Sewer Authority
1038 City Hall, 65 Niagara Square
Buffalo, NY 14202
(716) 851-4664 Ext. 4203

From: Matt Hammerstein <moh5@zips.uakron.edu>
Sent: Sunday, March 10, 2019 12:26 PM
To: Catherine Knab <cknab@buffalosewer.org>
Subject: Akron RTC Follow-up Questions

Catherine,

I have a couple follow-up questions regarding our real-time controls discussion:

1. Has operator input been incorporated throughout the design of the projects? Yes. Our Treatment Plant Superintendent and Shift Supervisors and maintenance staff are engaged throughout the design. Specifically, we get everyone in the same room with our design consultant during review meetings (usually 2 review meetings per project). On a related note, is there any kind of ongoing training (e.g. training incrementally rather than all at once at the end)? Training for each specific project is done at the end. But with each training, we build upon what was learned on previous projects.
2. What kind of failsafe mechanisms have been included for events like a power failure or loss of the computer system? There are 2 failsafes: one built into the programming for how the gates/valves operate and the other in the design of the structure. In the instance of a failure, the gates will be triggered to open all the way allowing for the full pipe flow of water to pass through. If for some reason the gates fail closed, there is an internal weir that is sized to allow for the full pipe flow to pass over the weir. Therefore, we will never flood any customers upstream. Note that the Smith St RTC is designed differently that the rest. In that case, valves will close upon a failure. There is also a wier in Smith St.
3. Can operators easily retake manual control if there is any kind of exceptional circumstance that the computer program hasn't been programmed to handle? We call it our "big red button". If the operators at the plant see something funny going on, they can press this button in SCADA and it will cause the gates to open (or valves to close). That is the only control allowed remotely. We have additional control over the system using the on-site control panel.

Thanks,

Matt Hammerstein
Civil Engineering Senior | The University of Akron
(330) 356-9175 | moh5@zips.uakron.edu

Appendix C

Correspondence with Andy Shively, Special Assistant City Manager, Kansas City, Missouri

=Meet

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Andy Shively Interview
March 7, 2019

Background
How is artificial intelligence being implemented in the Smart Sewer program?

- 318 square mi.; 2800 mi. of sewer, 300 smart sewer sensors. - Learn how collection system acts and reacts. Puts info in hyd. model.
- Accuracy increases with more. info. Identify places for more inline storage.
- Can be used to program lift stations to shift flows between plants.

~~Why did Kansas City decide to utilize artificial intelligence in the Smart Sewer program?~~

- AI will figure out load/ balancing

Challenges
What have been the most common design challenges associated with the artificial intelligence system?

- Working with operators. Operational technology. Real-time Decision Support.
- Operators don't trust/ want to give up control
- Engage operators early on. From beginning, included in process. Taking input on how they operate.
- System then takes human experience.
-

What have been the most common problems and challenges faced during construction of the projects?

- Actual flow monitoring data calibrates model.
- Deployment of sensors straightforward. Deciding where to deploy sensors in lid of 66,000 manholes.
- Monitor each subbasin and how they interact

Have there been any challenges or issues in training operations and maintenance staff in use of the software or equipment?

Have there been any maintenance challenges associated with the Smart Sewer AI?

- Batteries in sensors must be replaced. Monthly check..
- Must make sure sensors are clean / not dislodged.

How accurate has the modeling and forecasting been throughout the project thus far?

- Predictability of model has gotten much better.
- Based on information collected, model gets more accurate

Benefits and Future Plans

How has day-to-day operation changed for the City staff?

- Not a huge change for maintenance staff
- As sewers are rehabilitated, maintenance staff workload goes down
- RTDSS online, but impact yet to be Det.

What improvements could be made to the RTC for future projects?

- Laser sensors require more O&M, sonar sensors.
  - Sonar sensors preferable

What lessons have been learned thus far that will be implemented in future AI projects in Kansas City?

- Operators can take manual control
- Power failure - gate fails in open position so no risk of storage overflow
- Operations staff must be brought in at beginning
  - Would ignore if brought
- Ongoing training process for each new part of program
- Operator can override. Human monitors to make sure something isn't wrong.
- Wanted to make job better
- Incremental involvement shows that it is a tool
- operations staff will resist with every fiber.
- Most powerful computer