Intelligent Water Systems: The Path to a Smart Utility

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Since the release of the *Utility of the Future Blueprint* in 2013, water sector leaders have been striving for ways to drive the sector towards being *innovative*. Innovation is essential for the future effectiveness and public perception of the water sector. The industry-wide dialog regarding smart or intelligent water systems, enhanced by this Forum, is becoming a key aspect of how water sector innovation is planned and executed.

The Water Environment Federation (WEF) along with the Water Environment and Reuse Foundation (WE&RF) have recognized that there is serious interest in *intelligent water systems (IWS)* by many in the water sector. To begin a "deep dive" into smart/intelligent water systems and promote the enablement of smart/intelligent water systems via new and evolving technologies, WEF and WE&RF hosted a joint Knowledge Development Forum (KDF) on August 1-2, 2016 in conjunction with the International Society of Automation's (ISA) Water/Wastewater and Automation Controls Symposium. KDF participants included representatives from utilities, research foundations, suppliers, vendors, consultants, software companies, and academic institutions.

Unlike a traditional workshop, the KDF was an interactive gathering of industry stakeholders to develop new knowledge, identify collaborative efforts to bridge gaps, and facilitate adoption of new and better ways of problem solving in the water sector. Through a series of highly interactive discussions led by experts driving smart/intelligent solutions for the water sector, participants discussed:

- The definition of intelligent water systems
- The value of integrating intelligent water practices into the water sector
- Common barriers of implementing intelligent water practices into the water sector
- Technology trends in the intelligent water systems realm
- Potential next steps to promoting intelligent water systems and new solutions throughout the water sector

This report outlines the forum discussions on the points mentioned above, and serves as the basis for expanding the vision for intelligent water systems. The hope is that through continuing the conversation, we will be able to separate fact from fiction regarding the implementation of intelligent water solutions and practices and moving towards implementing intelligent water systems in the industry.

Table of Contents

What are Intelligent Water Systems?

"Intelligent Water Systems (IWS) emphasizes the opportunity the water sector has to take advantage of advanced technologies and dramatically shift management decision making."

So, what's driving the increased interest in intelligent water systems? While there are varying ideas of what an intelligent water system may be, there's not one singular definition. Some see the concept as being a small part of the water system which helps in analyzing and processing data both historical and real-time data while others see its integration as an opportunity to overhaul their entire decision making or performance management approach. The Forum clearly supported the notion that intelligent water systems encompass all these notions. To summarize it best, *"Intelligent Water Systems focus on the quality of life, not simply technology"*.

How Does IWS fit into the Water Sector?

Since the idea of intelligent water systems is still in its infancy, the water sector can greatly learn from other industries and countries that have been implementing intelligent systems.

Industries like the electricity sector have been utilizing smart meters and grids for over 10 years. By incorporating these smart systems, electric utilities are able to offload some of the peak loads, and provide capabilities for example, pre-cooling homes to help reduce peak demand. While many in the water sector can't effectively manage peak demand, the incorporation of IWS solutions and practices for innovative decision making can offset some of the peak demand (i.e., such as more effectively allocating storage ahead of wet-weather events). Storm water is also being managed more effectively during wet-weather events using IWS technologies. These are just a couple of examples where IWS has been applied.

When asked the question of how IWS fits into the water sector, the Forum participants came up with several innovative ways to integrate intelligent systems including:

- **Analyzing historical and real-time data.** Many utilities have a vast amount of historical and real-time data available to them. But is this data being effectively utilized? By taking advantage of modern data analysis tools a utility could gain useful information and make decisions based on solid predictive and historical information rather than partial/incomplete data. Many water sector utilities do not have effectively practices or solutions for capturing, processing, assembling data into information, or sharing knowledge. Oftentimes, water sector managers are not able to get the information-enabled insights needed for timely decision making.
- **Delivering the integration of information required for high performance operations.** IWS is not always just about data, it is also about operations management software and practices needed to develop dynamic plans based on goals and objectives. For instance, by integrating predictive analytics into an existing system, utilities can develop real time asset systems modeling which will help run their facilities efficiently, provide predictive intelligence on facilities status, and prepare operations staff to be proactive.
- **Enhancing the use of data by utility personnel.** One of the main objectives of IWS is knowledge and data sharing. By organizing and analyzing existing and new data, IWS provides the opportunity for information sharing and for systems to directly communicate with other systems throughout the treatment process. This broader and deeper sharing of information, which includes the removal of data silos, gives utility personnel access to much more useable data and insightful information. This access to data is not only helpful to utility personnel but also to external stakeholders, who are increasingly seeking transparency for utility operations.
- **Elevating levels of service.** Efficiency and optimization are two of the key strategies for modern water sector goals of operations. By incorporating IWS solutions and practices, operations can be more efficiently optimized and allow personnel to work more efficiently

with transparency and cost-effectiveness. The idea of "working smarter" can affect both utility operations as well as services provided to the customer. An example is advanced metering infrastructure (AMI), in which utilities monitor water use in real time and provide rate payers access to usage statistics. Advanced metering infrastructure (AMI) also provides data on the status of pipelines and the water quality in those pipelines, enabling more proactive approaches to operations and maintenance.

- **Taking advantage of the Internet of Things**. With the emergence of so many new programs and technology, the Internet of Things is rapidly growing. With sensors, real-time data, the cloud, dashboards, data analysis software, and many more, there are many opportunities for water sector utilities to adopt new technologies associated with the Internet of Things to better run their infrastructure.

The potential of intelligent water systems is not limited to these uses. Intelligent water tools can be applied system-wide, throughout a utility and in many more aspects that the ones mentioned above. This includes looking at the integration of IWS from an operational (control systems, equipment operations, etc.), back office (finance, purchasing, etc.), customer service, and planning perspective. There are still many possibilities and capabilities of IWS that still need to be explored and tested.

IWS Components – An evolution of data analysis tools

By integrating intelligent water systems, the utility of the future could be a *smart utility*, not only looking at what's happening now, (*hindsight)*, but also what is could happen in the future, (*foresight)*.

Some ways that IWS can be help utilities have foresight is by building *descriptive* calculations and capitalizing on intersections of data, building cause-effect analyses through *diagnostic* practices, and utilizing *predictive and prescriptive* calculations by integrating planning and scenario analysis.

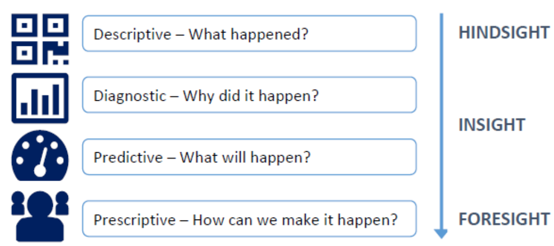


Image 1 – Increasing maturity of decision making.

Forum participants took the IWS components a step farther and broke down the key mechanisms needed to start and run a successful intelligent water systems program.

- **Data Prioritization –** First and foremost, utilities must decide what data is needed and how the data collected will fit into the ultimate strategy and goal of the utility. It's important not to bring in data simply to say that it was accomplished; collecting data takes time, staff, and money. The right data, at the right time, needs to be captured, and this critical data must be accurate, complete, and aligned with business/operational management requirements.

- **Data Governance –** Prior to data capture, it is also important to formulate a data governance approach, including identification of data stewardship, data storage and access rights, and data archiving and deletion. For example, by deciding these responsibilities ahead of time, data processing issues are can be ironed out. Developing a data management and governance plan can also help reveal gaps in the system.

- **Data Capture** – Probably the most notable component is data capture. With all the new and emerging technologies including sensors and monitoring systems, utilities have a vast amount of options for how to capture data and how much data to capture. As many new technologies are promoting able to capture *real-time* data, it is important to note that there is a difference between *real-time data* and *data frequency*. While *real-time data* deals with how quickly the user receives measured data, *data frequency* is how often the data is measured.

- **Data Validation –** With the ability to gather data at a much faster rate and with many different tools available, the validation of data is an important component. While collection of data is easy, it is essential to be confident in the data that you are receiving.
- **Data Processing, Storage, and Access** – Organizing your data! Historically, data organization is a component that is sometimes forgotten. With newer platforms and easier accessibility, the storage, query, and transfer of data is now more manageable than ever. Data organization includes the formulation and sustainment of database table structures that fit the needs for analytics (as distinct from the database table structures for transaction processing).
- **Data Integration –** By prioritizing and organizing data, easier integration of that data into existing systems and processes throughout the utility and networks can be achieved. It is important to look back at what the prioritization and overall purpose of the data was, to be sure that the data is being applied in a useful way.
- **Data Analytics –** "*With Big Data come big opportunities*." By incorporating data analytics, utilities can transform what's been collected into information. There are many types of data analytics tools that utilities can utilize. Depending on what the utility's ultimate performance goal or outcome is, they can choose the right platform or tools to perform the analytics.
- **Business Intelligence/Decision Support –** With the information provided, utility personnel can make operational and business decisions. By incorporating the information provided from the data analytics into modeling, optimization, and even predictive analysis tools, utilities can look at many different scenarios and find the "best solution". By utilizing IWS, water sector agencies can get a "big picture view", with the end goal of making an informed decision. Theses decision support tools are not just for big capital improvement projects (CIP), but can also be applied to real-time situations and scenarios, through dashboards and cloud based operations.
- **Knowledge Sharing –** Once useful information has been attained, it can be integrated throughout the utility's system and utilized in cloud based systems, allowing the information to be centralized and used across all utility functional groups. By sharing information throughout a utility, data silos fall away, allowing stakeholders can incorporate information into their decision-making processes. Further, data can begin to be utilized for beneficial purposes that might not have been originally intended.
- **Performance Reporting and Visualization –** IWS is not always just for predictive and decision making tools, but can also be used to show how efficiently a water sector agency is currently operating. By displaying the data in performance reporting tools and coupling it with visualization tools (like interactive mapping or GIS, dashboards, or chart pop-ups), it can provide useful insight into areas of need and improvement. Once performance gaps are identified via these visualization methods, water sector agencies can utilize optimization tools to improve their operations, energy usage, lower costs, or develop adaptive master planning and CIP. IWS provides the data and information that utilities need to take a step back and look at where improvements may be needed.

Implementing and applying these components water utilities can take the first step towards a comprehensive and effective intelligent water system.

The Value of "Now"

As other industries and other water sectors around the world began implement intelligent systems into their utilities, the United States appears to be lagging behind. But now as technology tools become more prevalent and cheaper and as a younger work force is entering the industry, the US water sector is being pushed into the intelligent systems realm.

There are multiple different drivers that motivate a water sector agency towards integrating IWS. They may include a push from customers, finance, IT, or operations.

Business Drivers

It is important to remember that water utilities are a business, and some of the financial and institutional drivers recognized for needing an intelligent water system include:

- **Utilities are being asked to do more with less resources.** A common trend that is not new to the water industry is the demand on utilities to provide more at the lowest cost possible. To achieve this utilities need to know why they are undertaking projects and how to be more efficient. By incorporating IWS, utilities can develop business cases for least-cost alternatives, as well as develop adaptive master planning. Cost is always going to be an important issue and IWS can be a way to evaluate and make better business decisions for both development and operations.

- **Customers are demanding more information.** The driver doesn't always need to come from inside the utility. Customers, the community, and stakeholders are now wanting to know where and how their money is being spent. In the age of smart phones, social media and online paying, customers are starting to demand more "real-time" and transparent information. This increase in customer accessibility is also causing customer service to become more complex.

- **Regulatory compliance and reporting.** As regulations become more strenuous, the incorporation of IWS will help alleviate (and may become essential) to the reporting of regulatory compliance. By incorporating IWS and a centralized data system, accessing, analyzing and reporting will become much easier and efficient for utilities.

- **Pressure to incorporate greener, cheaper technologies.** With programs like LEED®[1] and ENVISION[2] highlighting the latest, smartest buildings throughout cities, the water sector is also feeling the pressure to incorporate greener, smarter, and more sustainable technologies. Compared to the addition of other green technologies, such as equipment, the addition of IWS can be significantly less costly and may consist a more sustainable utility wide approach than other prevailing technologies.

- **"Working Smarter".** Like all sectors, water utilities are also feeling the pressure to improve efficiency and effectiveness of operations. One of the most beneficial opportunities within IWS is optimization. By incorporating optimization software (often referred to as optimization algorithms or engines) into a water sector agency's existing system, it can allow for optimization of energy, operations, and capital improvement plans (CIP). The business side of a utility may not see the usefulness of integrating IWS until the analysis of the data can be operationalized.

- **The "Grey Haired" Syndrome.** The "grey haired" syndrome is not just a common problem in the water sector, but also in workforces throughout the United States. With the rapid

[1] LEED®, or Leadership in Energy or Environmental Design is a certification program led by the US Green Building Council. http://www.usgbc.org/leed
[2] ENVISION, is a certification program led by the Institute of Sustainable Infrastructure. https://sustainableinfrastructure.org/

retirement of baby boomers, IWS gives water sector agencies an opportunity to capture and transfer critical institutional knowledge of that workforce before they leave.

Technical Drivers

Additionally, IWS can be driven from a technical or operational need within the utility. Some of these drivers identified include:

- **The growing "Fact Gap".** One of the biggest reasons for the water sector to jump into IWS is the growing "fact gap". As the Internet of Things is dramatically increasing, water sector agencies are seeing an increase in the velocity and volume of data they're receiving. The "fact gap" addresses the concerns of the rapid increase in the amount of data versus the resources available to analyze that data.

- **Technology groundwork is in place and ready!** As cloud-based solutions are becoming more acceptable in the water sector and sensors continue to become cheaper and more powerful, the availability and opportunity for utilities is there. Intelligent technology is no longer in the start-up phase and with the resources available, integrating IWS is no longer experimental but proven.

- **Allure of Total Integrated Systems.** From data capture to analytics and predictive based decision making, the idea of a total integrated systems is an enticing one. With the tools and technology available, the possibility of a total integrated system is much cheaper than a few years ago. These systems also provide water sector agencies the opportunity to eliminate data silos, sustain a data management plan, and improve operation efficiency.

- **Proper QA/QC of operations and maintenance efforts.** IWS can also help water sector agencies get a better "big picture" idea of how their utility is efficiently operating. By utilizing data, modeling, and optimization tools, it can provide a better picture of how utility infrastructure, personnel, and operations are running as well as insight on its entire life cycle of operations and when changes may be needed. An example of how IWS can be utilized for proper QA/QC, is real-time asset management, in which different utilities can utilize sensors, models, and cloud based operations to bring different assets into and out of service. Further, IWS technologies and practices can better predict asset failure in order to facilitate required proactive and/or corrective actions.

- **Need to attract technology savvy millennials.** As baby boomers continue to retire, the water sector must hire and retain a younger generation of employees. The millennials entering the workforce today are much more technology dependent and savvy and as the workforce changes, water sector agencies will also change. By introducing IWS into water sector agencies, younger employees can learn and build off both the existing and newer technologies and practices.

While a water sector agency might be driven to start IWS because of one or multiple drivers, it is important to identify what the driver is and look at all the possibilities and opportunities provided.

Utilities where IWS has started

Although IWS may be a relatively new concept in many water sector agencies, there are utilities both internationally and in the US which are already utilizing IWS tools to enhance their performance.

In countries like Australia and Israel, where water is significantly more expensive than the US, every drop of water needs to be accounted for. As a result, they turned to IWS to help with real-time decision making as well as finding ways to optimize their costs and operations. Irish Water has also jumped into the IWS realm and went rapidly into technology deployment, which initially drove up customer fees and caused significant customer revolt.

While there are many success with IWS, there are also many lessons learned. As utilities look at the possibility of incorporating IWS into their systems, it is important to look at what others have done. Below are some examples of utilities here in the US, which have begun utilizing IWS in their systems.

The Holistic Integrated Approach
Clean Water Services (Portland, Oregon)

Clean Water Services (CWS) in Portland, Oregon is an example of utilizing data management to do integrated watershed planning and operations. As the regional wastewater and stormwater district in Washington County, CWS turned to Intelligent Water Systems (IWS) to better manage outcomes, utilize adaptive management, and provide transparent communication to stakeholders.

CWS took the Six Sigma approach in which decisions are made based on verifiable data and statistics, with a focus on achieving measurable, stable, predictable, and quantifiable returns. Since their launch in IWS, CWS has utilized sensing, analyzing, and control tools to look at a couple different things.

CWS has very stringent effluent nutrient limits for phosphorus. With these regulations, one of CWS's strategy was to increase the biological phosphorous removal process stability within the WWTP to reliably and cost effectively reduce phosphorous concentrations to the receiving stream through real time monitoring and process control on a centralized dashboard. The benefit of biological phosphorous removal process also brought additional values to the District, by recovering over 1000 tons of struvite fertilizer every year.

Image 2 – Using HachWims to verify the instrumentation meters for reliable process control with instrumentation and automation. (Image provided by CWS).

CWS also has a focused IWS effort for the optimization of stormwater management facilities. With the deployment of digital technology, sensors and the internet, CWS is able to continuously measure, monitor, adaptively manage and automate the control of stormwater management facilities.

Utilizing incoming Doppler radar point precipitation forecasts, sensors measuring facility storage, stage and outlet flow rate, upstream and downstream stream flow status, in conjunction with logic algorithms, CWS is able to continuously and automatically optimize the facilities ability to prepare for and effectively respond to run-off events providing for the following benefits.

- 60% reduction in wet weather volume
- 70% reduction of wet weather flow rate
- 30% reduction in peak flow rate
- Stream power reduction
- Increased residence time
- Ability to adjust control parameters to target specific stream reach goals.

Improving Customer Service and IT
Washington Suburban Sanitary Commission (Montgomery & Prince George's County, Maryland)

The drive for IWS doesn't always need to come from an operational side, but can sometimes come from a push from the technology (IT) staff. This was the case at the Washington Suburban Sanitation Commission (WSSC) located in Montgomery and Prince George's County, Maryland in metropolitan Washington, DC. The IT staff at WSSC saw an opportunity to utilize data provided to IT to enhance the business performance of the utility.

In 2012, WSSC developed a 5-year Strategic Plan, which focused on specific opportunities where IT-based solutions could unlock the greatest business value. The planning approach was a threefold process in which they looked at:

- **Business Needs Analysis –** Identifying critical business needs to drive success.
- **IT Solutions Overlay –** Identifying the subset of business needs with corresponding IT solutions and specific opportunities where IT-based solutions can address those needs.
- **Prioritization & Sequencing –** Prioritizing among the potential IT opportunities to derive a set of project priorities and sequencing these opportunities appropriately.

During the initial phases of the plan, WSSC recognized that to become a "smart utility" they needed to start investing in IT as a critical infrastructure of the utility organization. One of the identified components of becoming a "smart utility" was the importance of improving customer responsiveness and providing first rate customer service.

One of the ways WSSC improved their customer service was by looking at customer centric analytics, specifically by optimizing their customer contact center. By utilizing data management and analytics tools, they began providing historical and real time analysis of customer calls as well as a looking at customer care and emergency call center (ECC) performance trends. In addition to looking at the analytics of the customer calls, they also paired the data with GIS mapping of the areas that calls were coming from. Since utilizing both the analytical information and visualization, WSSC has increased their answer rate at the call center, as well as increase their level of service for both the call center and operational response staff.

They have also taken advantage of social media data, recognizing that while customers may not always take the time to complete a survey, they do share their thoughts on platforms like Twitter and Facebook. Utilizing data from their Facebook page, WSSC began identifying trends and analytics on their mentions, hashtags, likes, reposts, and comments they were receiving. While this data may seem insignificant to some, it has help WSSC recognize their accomplishments, failures, and customer needs as well as helps their communications and marketing groups with campaigns.

Upgrading Levels of Service and Preparedness
South Bend Water Works Department (South Bend, Indiana)

Located on the St. Joseph River, South Bend Water Works Department (South Bend, Indiana) has, like many municipalities, dealt with combined sewer overflows (CSO). In 2004, the South Bend utility began implementing a computer based optimization tool that combines real-time data, a water model and processing to help solve their combined water issues.

The first step in their process was to "turn on the lights" in the sewer systems with a vast distributed sensor network. For the first time, the utility could see what was happening throughout the core collection system of the trunk line and interceptors. By "turning on the lights", the city could alleviate a number of bottlenecks, remove blockages, and perpetually maintain and clean the most problematic areas of the collection system. Within two years, the number of dry weather overflows went from 27 to 0.

Once the sensor network was in place, they began collecting data every 5 minutes from hundreds of locations throughout the pipeline network. With this amount of data coming it, South Bend is able to monitor all areas of the system during a storm event. This allows them to identify anomalies which signals the utility maintenance team to inspect a specific location. South Bend also utilizes a self-learning model that learns from storm events about how to react for future storm events.

One of the challenges that they ran into with these storm events was that during storm events, rain concentrations vary across the system. This can cause a water "traffic jam" in which some areas of the combined sewer network are more congested than others. To help with this problem, they implemented an *agent-based optimization*, in which they can optimize sewer capacity by utilizing a "bidding" control for the gates and valves throughout the network. This system has helped dramatically reduce the volume of overflows during rain events and has eliminated overflows during dry weather.

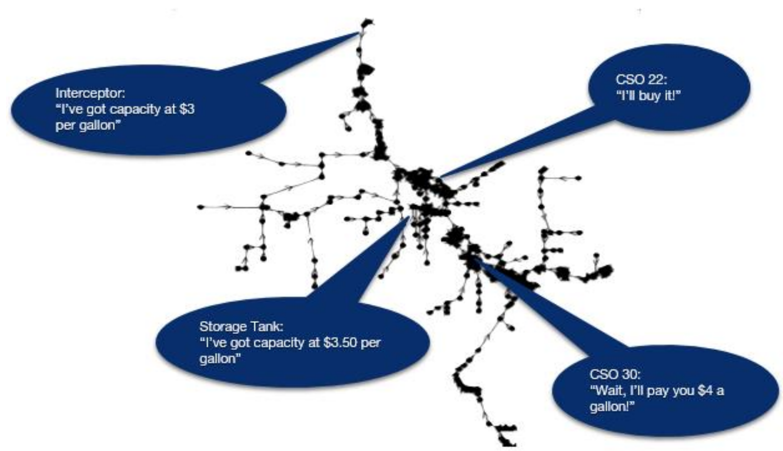


Image 3 – An example of the South Bend network "talking" and "bidding" for flow. (Image provided by EmNet)

Energy reduction using real-time control and optimization of the WRRF
Grand Rapids Water Resource Recovery Facility (WRRF) (Grand Rapids, Michigan)

The Grand Rapids WRRF, located on the Grand River in Michigan currently treats on average 38 MGD and serves a population of approximately 270 000 people in 11 communities. The plant also receives a significant amount of industrial wastewater from the local breweries, landfills, and other industries. The Grand Rapids WRRF currently has no difficulty meeting its effluent permit, however for several years it had set a goal to reduce energy consumption and operational costs. In order to meet their goals the City has been investing in advanced real-time process control since 2010. Following these initial efforts, the City decided to embark in an ambitious project that uses dynamic simulation to develop and implement real time data quality assurance and combines that with a suite of advanced solutions for integrated plant control. They are in the process of implementing several integrated control loops (Image 3) including an ammonia based aeration control linked to SRT control. In the near future the City will be implementing real time control for load balancing as a means to increasing plant capacity to meet future growth.

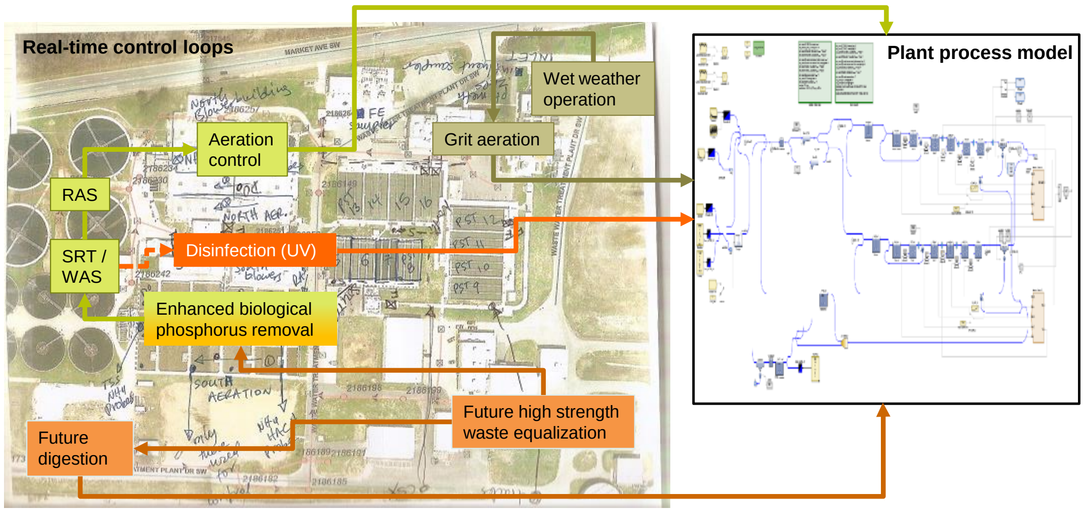


Image 4 – Real-time control loops designed and tested with a dynamic process model. (Image provided by E. Belia)

Are you Ready for IWS?

With so many different possibilities and opportunities that IWS offers and with the water industry having many different organizational structures, it is important to remember that IWS is not a "one size fits all approach". There are challenges that exist for both small and larger utilities. But regardless of the size of the utility, there are several things that a utility can do to be sure that they are *ready* for IWS.

Organizational culture

Like any new technology, the adaption of IWS begins with the people. Before starting any IWS program it is important to establish an organizational culture throughout the utility and community, to ensure that everyone is on the same page. To start establishing an organizational culture requires identifying a leader from the inside who is driving the project and purpose. This leader needs to be understanding and open to change as well as a motivator who can be sure that everyone is on board with the ideas and new systems. Continuity of leadership is also incredibly important, as well as a having a dedicated pool of cross functional staff to help implement and run the program.

Image 5 – Concepts of organizational culture. (Image provided by R. Nagel)

The public sector is generally risk averse and often unwilling to change. By addressing concerns and informing every one of the long timer benefits and goals of IWS in the beginning of the process it can greatly cut down on the unwillingness to change. It can also cut down on personnel concerns regarding job security and work place policies. By ensuring that from leadership down to all employees understand the beliefs, values, and assumptions of what an IWS program brings, it will greatly help in a smooth deployment.

Make sure you have…

So, you're ready to start? Here are a few things to ensure your readiness:

- **Identify your "champion".** As previously mentioned, it is important to identify a "champion" to lead the IWS movement. This champion should be adaptive, innovative, and open to change, as well as a motivator. It is also essential to ensure that your leadership throughout the deployment of your IWS system stays consistent, especially throughout investment and training.
- **Ensure someone wants the data and information being provided**. Nothing's worse than doing something and realizing, no one cares. It's important to ensure that the information provided from the data analytics is wanted, not only by one group but multiple stakeholders.
- **Technical infrastructure is in place**. For a smooth deployment of IWS, technical infrastructure should be built to ensure that platforms integrate smoothly and minimize technological barriers.
- **Establish multi-disciplinary solutions.** Ensure that the information being provided can serve multiple facets and looks at solutions from different viewpoints. In many situations today, solving problems today requires consideration of many different perspectives, whether it is triple bottom line or customer and fiscally driven.
- **Customer understanding and support.** As one of the most important stakeholders of a water sector utility, it is important to inform the customers and community about the impending changes and how it may affect, as well as benefit, their service. By informing

the customers early in the process, it helps prepare them for any changes and allows them to feel engaged with the utility.

- **Employee education and training.** Probably one of the most essential tasks, is to ensure that all personnel working with the new system have the appropriate education and training. While there may be a sense of a learning curve in the initial start of the system, it's important that all employees feel confident and comfortable with IWS and its outcomes.

Challenges of Adopting IWS

Like any new onboarding process, there are some challenges and concerns that personnel and a water sector agency may have with adopting IWS. Similar to the adoption of IWS not being a "one-size fits all approach", the challenges of IWS will vary between utility to utility. Utility size, policy, and operational culture will dramatically impact the challenges.

- **Personnel concerns for job security.** There are many who are concerned that smart systems will impact their job security. While the addition of IWS could eliminate some daily functions, it would not call for layoffs. While the daily operations of the utility may change with the addition of IWS, the historical knowledge and functions of those who are currently employed are still critical.

- **Data connectivity.** Water sector agencies have greatly changed throughout the years, both operationally and technologically. With so many updates, not many utilities have a simplistic and uniform technology platform. One of the difficulties of integrating an IWS system is connecting a new platform to the existing technology. With so many new technologies and software coming in, it's a hope that there will be more generic systems to allow for a smoother integration.

- **Data security.** Just like when online banking was first introduced, personnel will be very skeptical of the data functionality and security of IWS systems. To eliminate some hesitation, it is important to ensure that a *data governance* plan is laid out in the initial steps of planning for IWS. Data governance is a critical foundation for the data strategy, policy, accuracy, and reliability, of the IWS system. It also establishes a "chain of command" for who is responsible for the data at different stages of process, including who can access and delete information.

- **Battle for funding.** Battle of funding is both internal, with capital versus' operational spending, and externally with utilities fighting for funding. And while many utilities may push for IWS from technology and operations staff, funding is usually the stopping point. For many utilities funding, can be incredibly politically driven, which requires buy in or a new technology at not only a utility level, but also a municipality and sometimes city level. By discussing potential outcomes and solutions with all stakeholders in the initial planning stages of IWS, it can help convince those in power, that IWS is worth the money. Internally, water sector agencies also battle with where the funding should come from. Is it considered a capital expense or an operational expense? While IWS can be considered for both, it would depend on the utility culture and personnel on where they would prefer funding to come from.

- **Lack of expertise within Water Sector utilities.** With IWS being new to the water sector, there is going to be a learning curve incorporated with the new technology. While some of the current employees will adapt to IWS, it is also important to look at the water sector's future needs in its personnel. With the integration of new technology into the water sector, we may need to look back at our academia and how they are preparing the future engineers, data analyst, environmental scientist, and water personnel.

With IWS being so new to the water sector, some of these concerns have been addressed, while others may still need further investigation and experience to solve.

Technology Trends in the IWS Realm

As start-ups and the Internet of Things continue to expand, the realm of technological possibility continues to grow. This can be seen in the water sector, with advances in sensor technology, modeling techniques, cloud based systems, and many others. As utilities begin to implement some of these newer "smart technology", there have been some growing trend's in the technology the water sector is leaning towards.

The main two trends that have been seen throughout the water sector industry is the idea of utilizing IWS for *optimization* and *big data analytics*.

System Optimization

Optimization is something that every utility, let alone business is striving for. With increasing operational costs, and a higher demand on utilities to do more with less, optimization is essential to running a utility of the future. With IWS, optimization can hit hard on three problem areas in a utility:

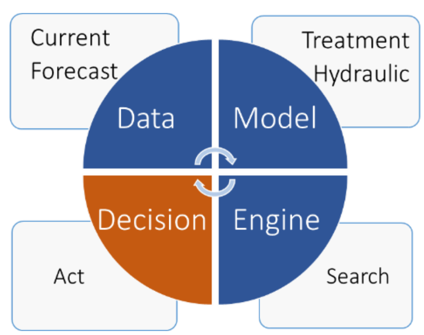
- **Energy.** Utilities are facing higher operational expenses with decreasing revenues. As well as the pressures of climate change and the push to be energy positive utilities.
- **Operations.** Throughout the country, cities are facing aging infrastructure, higher compliance requirements, resilience to climate change and other disasters, retiring institutional personnel and technology, and other competing objectives that can affect personnel's day-to-day operations.
- **Capital Infrastructure/Improvement Projects (CIP).** With increased population, aging infrastructure, and the pressure for wastewater treatment plants to be water resource recovery facilities, many utilities are facing the pressure increase capacity, overhaul their collection systems, and other large capital improvement projects.

With so many problems on the horizon, optimization can be used to intelligently search for the "best solution" based on your current situation and forecasted trajectory. By integrating optimization tools like: big data analytics, utilizing the internet of things, optimization engines, and artificial intelligence programs, utilities can not only identify multiple solutions, but can provide transparent decision support for their chosen tool.

So how is optimization applied?

While not all situations may be clean cut, the general process of optimization is simple.

1. Formulate a **problem** to solve.
2. Determine a **quantitative** measure of success.
3. Determine the **parameters** that can be adjusted.
4. Combine real time data, modeling, and forecasts (if applicable)
5. Utilize an **Optimization engine** find the best set of parameters.



Once, a system is in place the problems that can be solved are endless. Some examples of where optimization has been utilized both inside and outside of the resource recovery facility fence are:

- The use of intelligent algorithms to help reduce CIP and operational costs. By utilizing the cloud and high performance computing, utilities can model "what-if" cost and operational scenarios to minimize and best utilize the money they are spending.
- Multi-objective real time optimization of treatment plant operations. Including plant-wide controls which lead to plant stability and significant reduction in troubleshooting.

- Utilizing smart Continuous Monitoring and Adaptive Control (CMAC), to help reduce storm water runoff, by combining sensor data with weather forecasting information.
- Intelligent sewers, through sensors and cloud based controls, which actively reroute water to reduce overflows.

Big Data Analytics

As the Internet of Things continues to grow, new data sets are being generated from sensing technology. The surplus of data, driven by new methods of data acquisition, cannot be processed by traditional methods.

What's so BIG about big data analytics? Big data is considered datasets whose "size" is beyond the ability of typical/traditional database software tools to **capture,** store, **manage**, and **analyze**. These data sets can be differentiated by what is known in the big data realm as the "V's"[3]:

- **Volume** – The size of the dataset
- **Variety** – Data from multiple repositories, domains, or types
- **Velocity** – The rate of flow the data is coming in
- **Variability** – The change in other characteristics

An additional V, that may be the most important, is **value**.

In recent years, the variety of tools that can analyze Big Data has significantly increased. While each tool is made for a specific purpose, the goal of these tools is to turn the data into information that delivers predictive and prescriptive outcomes, in real time. These data analytic tools are also commonly used to perform:

- **Predictive analysis.** Determining the probable future outcome of an event or the likelihood of a situation occurring. There is incredible value in 'now' or finding the problem before it occurs. Predictive analytics can also be utilized to identify relationships like "cause and effect" and produce random forest algorithms. These can also be produced by *artificial intelligence* tools which are self-learning, neural networks, genetic algorithms that derive insight from data.

- **Pattern recognition.** The identification of a previous occurrence in the current time frame. It can also be utilized to produce time series data analysis algorithms which can help identify convolution, blind source separation, and frequency domain conversion.

- **Anomalous detection.** The identification of multivariate data excursions or outliers from the normal.

By utilizing data analytics tools, a utility can improve their decision-making process, increase the sophistication of their visualization techniques (coupling data with mapping, GIS, and other platforms) and automate systems by putting the data to work.

One of the first steps to data analytics is the identification of a problem. The problem might be that the utility under-utilizes their data or that they have a specific set of data they want analyzed. Some examples of data analytics that are currently in the water sector are:

- Utilizing sensor data to track flows system-wide to better predict where sewer overflows may occur throughout a watershed. By knowing where the overflows may occur, a cloud based system can be used to take preventative action ahead of a wet weather event to minimize overflows.

[3] National Institute of Standards and Technology (NIST), "*NIST Big Data Interoperability Framework: Volume 1, Definitions*". September 2015. pp. 4-5. http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1500-1.pdf

- Utilizing advanced metering infrastructure (AMI) to allow utilities to monitor water usage in real time. It also allows ratepayers to access their personal usage statistics.
- Incorporating consumer calls to visualize and track an algal outbreak. By coupling the consumer provided data with visualization tools, it helps expedite remediation.
- Building additional wet weather infrastructure (real-time controlled overflow storage, stormwater control measures) based on predictive wet weather models, to alleviate the risk of overflows.
- Extending the life of our existing infrastructure by incorporating data driven demand management, sensor driven pipeline monitoring, real-time pressure controls via a cloud based system, and real-time water quality sensing.

With the integration of big data analytics, utilities will also start to see a rise in some new skillsets that are needed, including **data science skills** and **data engineering skills**.

Data science is the extracting of insight from the data. This can be seen in things like statistical analysis, machine learning (classification, validation), visualization and scripting. This differs from **data engineering** which is focused on the underlying architecture and infrastructure required to support the data science. These are services like data processing, stream processing, data optimization, and cloud services.

While current utility personnel may hone some of these skills, these are things that we hope the utility engineer of the future will possess. It is important to make students aware of resources that exist outside the "typical" water engineering realm, and that is evident is the large mix of water personnel we are starting to see today.

What Do We Still Need to Know?

While the Knowledge Development Forum was a great introduction to the realm of intelligent water systems, the conversation does not end there. With the idea of IWS still in it's infancy in the water sector there are still many questions, concepts, and challenges that are in a conceptual stage and still need to be discussed further, such as:

- How will IWS affect regulation reporting for utilities?
- If everyone decides to utilize IWS, do we need to develop standards?
- Politically, how is IWS viewed? Is it a benefit or too abstract?
- How do we get academia involved in integrating IWS into their curriculum?

Though these questions may not be able to be answered now, there are other resources and opportunities for water sector agencies to learn about IWS. One of these programs is the WEF and Water Environment and Reuse Foundation (WE&RF)'s Leaders Innovation Forum for Technology (LIFT) program, which is a joint initiative to encourage and support innovation in water. There are twelve different focus areas in LIFT, with Intelligent Water Systems being one of them. The forum allows utilities to explore and discuss several new technologies and management strategies that will be part of the digital utility of the future. It also provides both technology companies and municipalities the opportunity to connect with others and collaborate on research and technology ideas, proposals, projects, demonstrations, and implementations.

WEF and WE&RF can also help promote the concept of IWS throughout the water sector, by continuing the conversation and encouraging more events like the KDF. Possible future events could be "boot camps" for both utility leader and regulators, to increase their awareness and understanding of IWS in the sector, as well help them understand IWS's role in the sector.

As tools continue to change and smart systems become more prominent, we must continue to have conversation and ask questions to increase the profile of intelligent water systems in the water sector and drive us all towards being a utility of the future.

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