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Paul Thies: When you manage a life-essential service, you can't simply shut things off as you sort out how to deploy emerging technologies. You have to be agile in your approach while literally keeping things flowing.

In the world of water management, that is literally the case, as operations managers are learning how to deploy tools such as artificial intelligence, digital twins, and big data, and exciting new ways to enhance how they provide water to their constituents without interrupting service or safety.

Hello, I'm your host, Paul Thies, and on this episode of *If When,* our discussion focused on the topic of digital water. Joining me are John Rickermann, Managing Director Technical Services Group for Jacobs, and Gregg Kennedy, Jacobs Vice President Water Platform. We discuss the role that data science can play in water management, including how it can positively impact operational costs and sustainability endeavors.

Well, John, and Gregg, thank you both so much for joining me today. I'm really looking forward to talking with you about the concept of digital water. Water, of course, is life essential resource, but how we're deploying emerging technology to take care of our water. It is a finite resource. It's hard to believe, but it is, and so we really need to take extra care with it, and so I want to thank you both and I'm looking forward to diving into this with you.

John Rickermann: Great, thanks, Paul.

Paul Thies: John, let me start off with you and let me just ask you to describe what digital water is?

John Rickermann: Yes, not only is water, one of those precious resources but so are the people that produce clean water for us. Digital water, to me, is a set of tools that help that limited resource, our people, do their jobs better.

We hear a lot about the do more with less thing and we're really seeing that in water and wastewater treatment from an operational standpoint at our plant sites for ourselves and our clients, and we're asking our operations and maintenance staff to do a tremendous amount of high-value work, critical to public health, just an incredible amount of responsibility but they really, up until now, haven't had all the tools to be effective in their jobs.

For example, we have predictive tools now with data science with digital twin modeling that allows us and our operations staff to know what's coming before it happens. Traditionally, for the past 100 years, it's been a reactive field, something happens at the plant, because you don't control flows, typically, you react to what the community demand is and you have to respond to that. It's always been reactive. Now we've got tools, which I call digital water that allow you to get proactive, and that changes the game.

Paul Thies: Now, you mentioned digital twins, and one of my initial forays into understanding the concept of digital water was the use of digital twins for plants and

stuff. That flips the script from the reactive model that you're saying to more predictive. I think like potential failures at plants and things like that. Can you walk us through just a little bit what role digital twins play in the concept of digital water?

John Rickermann: Sure. Digital twin means different things to different folks. Some folks consider a digital-- and it's all true. Some folks consider a digital twin an AutoCAD, or a 3D rendered model of the building space, for example. In a sense, that's a digital twin, right? It's a digital representation of reality.

In our case, we're using a digital twin model to represent a treatment process. If you have a wastewater plant, you can build a digital twin that simulates what is happening biologically throughout the treatment process, chemically, biologically, physically, through the treatment process.

With that kind of a calibrated accurate model, you can do an awful lot of what if analysis, new construction, troubleshooting, all kinds of things, operations training. It's a really powerful tool. We're really taking that to the next step by using the data science plugged into these digital twins to say, here's what's coming. Here's what's going to happen, and here's what you do about it, and communicate that to our field staff.

I think that last piece of taking all that knowledge and expertise we already have, combining that with the predictive analytics we now have capable, we're now able to utilize, and getting that in the hands of our field staff so we can just take action. They don't have to understand necessarily all that went into that but now they can take action and that is a big game changer for us.

Paul Thies: Now, Gregg, my next couple of questions are for you and it's really a two-part question. It's around benefits, and then methods or ways. The first part is really about the benefits that deploying a data science focused approach can bring to water management operations, kind of picking up on what John was saying. Can you tell us a little bit about what are some benefits that data science really brings to bear here in water management?

Gregg Kennedy: Yes, thanks, Paul. I'll build on what John said there. I think I've been fortunate, Paul, in my career I've worked for a water company for a long time. I've worked for a lot of water executives. I've worked fairly high up in a water company having to deal with some of the decisions that you make day to day, and I always remember a phrase that my CEO said to me, when I said, "Look, how does it feel to be the Chief Exec of a water utility?" He said, "I'm not the Chief Exec of a water utility."

He said, "I'm the Chief Risk Manager of the water utility since my entire job is to manage risk." He said every time he comes in in the morning, he's looking at his top 10 risks, and he said, and this has stuck with me ever since. He said, "I have to make decisions with imperfect information every day," and where I've been attracted to data science, and where John and I are attracted to bringing this to our clients is the application of data science, minimize the sum of that risk, minimize the sum of that uncertainty.

It creates an ability to have more informed decisions, and that's what every Water Exec is looking for. Whether it's the state of the assets, whether it's the quality of the water, whether it's the number of customer contacts, the number of times we're going out to fix something that should have been fixed the first time, the fact that we can use that data science approach, we're learning the impact that activity has on the system and that's allowing us to make more informed decisions.

What I will say is, there's such a proliferation of tools and data and science-led approaches right now that if I was still a Water Exec, I would struggle to understand how I navigate this world, and I think this is where companies like Jacobs and others really come to the fore, helping water utilities take advantage of the data science and the data tools to make better-informed decisions because we need to remember, when a water utility makes a change to any type of operation, we don't get a possession window, we don't get to stop the traffic and say, by the way, we're not producing water today, you have to do this in a live environment.

I know, John, you and your team have to manage that risk all the time, that we're adopting a new approach but we cannot let the operation stop on a day-to-day basis. That's my main focus on data science. Suppose we use it to be informed decision-makers in water utilities.

Paul Thies: That's amazing, and really to pick up on something that you said, and we'll unpack it here in the next part of the question but just the concept, of course, that the tools are constantly evolving in real-time and just the difficulty it must be to like-- for water executives and people in the water, maybe that's not their primary focus is like staying abreast of the cutting edge technology and all of the universe of digital tools and capabilities that are coming at them, and so being able to make sense of that, and accelerate their learning trajectory for those tools in an environment where, like you said, Gregg, you can't just stop everything and put a pause, "I got to figure this out. I'll come back to you in a couple of days when I know how to use this or that."

It's like you've got to be very agile, I think, as a water executive to stay abreast of this, and still make sure that the water quality is safe and good, and everything. Gregg, what are some of the ways that data science is deployed in this digital water program?

Gregg Kennedy: If I take my own experience, Paul, previously, and when working with Jacobs, we thought about the water cycle. We start with where the water rains, where we collect it, where we treat it, where we convey it to houses, where we collect the wastewater, where we treat it, and where we return it to the environment.

We call that the one water cycle, which I think a lot of people will understand, but that's not necessarily how a water company sees itself. That's maybe how an engineer sees the water cycle. Where we think about the appliance of digital sciences as myself and my team, we now think across four different parts of a water company.

I think about customer interactions, I think about how we're using data science to enhance the customer experience. How do we improve billing? How do we improve collection? How do we inform them about flood protection? How do we inform them

through a customer portal about capital activity that might be going on in their area? That customer interaction is the first pillar.

The second pillar is what I call regulatory compliance or operational compliance. How do we make sure that we've got drinking water quality that is meeting standards? How do we make sure sewer overflows are not happening? How do we prevent some of those incidents from happening and stay within our compliance limits?

It's a big part for data science to play there, to monitor and control how we operate those assets. The third pillar is what I call planning and investment. This is when we're thinking longer term. How do we use the data science? How do we use the data that we're gathering on day-to-day operations to inform the assets, the networks, and the decisions we have to make 5 years, 10 years, 15 years down the trip?

As an economist, I'm attracted to a concept called intergenerational fairness. That means the amount of assets I'm consuming today, I have to make sure I'm handing over an asset stock that's fit for purpose to the generation, to my kids, to their kids. This is where data science plays a big role because we now think across the entire asset lifecycle. Data science has a huge part to play there to help us understand the asset lifecycle.

That takes me to the last point, the physical assets themselves. How do we know what state they're in? How do we know how they're operating? Are they operating with intolerance? How do those assets work together? Data science is giving us the ability now, not just to understand single assets, but to group them across networks, to understand how catchments work, to understand how associated incidents impact other parts of the network.

Data science is really lifting back the cover and letting us see under the ground in real-time how is an entire network working together. It's no longer just in the brains of our people who, as John said, are aging out but it's now giving the rest of us a chance to see it in live real time. It's been a real powerful move for water utilities to adopt these data science techniques.

Paul Thies: Amazing. Then, John, let me ask you about the kinds of data that are getting generated and the insights that we're mining from that. I know a little bit in terms of the digital twins and being able to see the asset lifecycle, how close things are to potential failure needing to be replaced. Can you talk to us a little bit about what kinds of insights we can actually mine from water quality **[unintelligible 00:12:33]** that geography? What are some of the things that data scientists are able to look at in this sector?

John Rickermann: Sure. I could probably cite examples in all four of the pillars that Gregg just described because there are applications for all of that, obviously. I'll just give a couple of examples around the regulatory compliance, water quality and compliance, for example. We take a tremendous amount of lab testing data just to meet regulatory compliance standards.

There's a certain amount of required lab data, so that's a data pool right there. That's usually held in some sort of a laboratory information management system database or an Excel spreadsheet even that might be what we would call small data. It's still very useful.

That's something I've discovered in the past few years working in this space. You don't have to have terabytes, monstrous databases of big data to make use of data science. We are really focused on meeting our clients where they're at with the data they've got and then building from there. We've done this ourselves.

We'll use an example we're working on right now. One of our biggest clients, the lab data we have around residual chlorine, disinfecting pathogens before it's discharged to the river for public health reasons. There's limits set in the regulatory requirements that are pretty conservative when the actual regulatory number of interest is pathogen kill. There's some indicator organisms that we want to make sure are killed off.

We can use data science to say we'll get the pathogen kill and protect the public environment and meet permit but we don't have to overdose all this chlorine chemical, which is harmful to the environment at a certain level and expensive, so let's use the data science that we already have to figure out the right dosage to get the right kill without overdosing and harming the environment in a different way and costing us extra money.

That's a fairly straightforward example but it's a really powerful one. We use millions of dollars of various chlorine disinfectants and a lot of that is excess. We can trim that down with data science.

Paul Thies: Now, Gregg, John's just talking about an example of a cost-benefit, cost savings, and frankly an environmental savings as well of being able to intelligently balance how much is just the right amount of a disinfectant without going overboard. What other kinds of cost benefits and savings can be achieved by deploying data science-driven operations strategy?

Gregg Kennedy: Benefits-led investment decision-making is an area I've worked in for many years. What I've found, Paul, the key to making the right decision, the key to identifying the cost savings or the benefits is all about establishing your baseline. How are you currently operating? If you do nothing, what is the future going to look like? That's my number one tip to anyone thinking about adopting either a new approach or a new technology. Understand the path that you're on, understand your baseline, and be comfortable that that's the path you're on.

If you want to deviate, then begin to build the BCR, the benefit-cost ratio from where you want to invest. In terms of data science, our experience up to this point, we identify benefits across lots of different cost categories, OpEx, CapEx, corporate overhead tax, finance, fines, rewards, regulatory compliance. It's also important to think about them across different timeframes because you get immediate benefit in the operational space. You maybe get immediate benefit in your ability to maybe reduce your power consumption or reduce your chemical consumption as John mentioned, but you then have to think medium term.

If I've adopted this new way of working, if the data science is telling me to operate my assets in a different way, we have a model that predicts how the assets are going to perform. That in turn predicts the cost profile but you have to then track it. You have to see how it's operating.

You then have to take that into your medium to long-term decision-making, and this is where-- and to your capital planning, that third pillar that I mentioned, these are the type of longer-term cost benefits that you can identify. It's a bit harder because, obviously, if you're waiting 5 or 10 years for a benefit to manifest, then how do you justify that to your decision-making board upfront?

There's a lot of trust here. Again, because it's data-led, because it's decision led and it's informed by the data, you're fairly confident in the model that you have with the right baseline, you should be able to see early indicators that you're on the new path. I know John's teams had tremendous success, which we'll talk a little later in the podcast of being able to demonstrate those early wins which then become baked in operational costs that they can have through time.

One final point I want to make on this, though, is you've got your baseline, you've got your cost and saving categories that you identified but you then have to treat benefits realization like any other project.

We manage cost, we manage time, we manage quality. Very often when people make an investment or a change, they don't do benefits realization. You have to commit time and effort actually monitoring that the benefits manifest. Then you can go back and say, "Look, I'm on the path, can I now get the second lot of investment? I would like to move from 2 plants to 10 plants." Benefit realization to me is just as important as time, cost, and quality whenever I'm doing a big investment project, especially if it's involving new data-gathering technology.

Paul Thies: The other part of that is the environmental concerns, the costs and benefits to the environment. Gregg, does a data science strategy have a demonstrable benefit to sustainability endeavors? We talked about the chlorine, for instance, but what other benefits does it have for environmental concerns?

Gregg Kennedy: If I'm being totally honest, Paul, I think the application of data science and digital technology to the water cycle is perhaps the greatest opportunity we've got to contribute toward net zero. Every industry has its targets, we have our targets. We're all on a journey towards net zero, and I think the application of data and this type of technology is really going to create the step change for us.

John and his team have had tremendous success at one of our plants where they've been able to utilize advanced data science to develop a new product that informs our operators on the most efficient way to use power-intensive equipment like blowers.

That approach, they've then expanded to chemicals. John and I have been speaking that it's not a great leap to expand that beyond to look at more areas like process emissions. Process emissions are perhaps one of the dirty secrets of the water industry. It's not just carbon dioxide, it's also nitrous oxide and other types.

The application of data science and what we call these optimizing models helps us to understand when we change the operating parameters of these assets, we can see the impact on these deliverables. That's where we can make a big contribution to the sustainability of the chemical and power use in these assets.

Longer term, I think the real big prize is the impact that we have on the environment itself from supplying portable water and treating wastewater. The more data science can be used to minimize what I call the built asset stock that we need and to minimize the interaction we have with the natural water cycle, we can stop leakage.

If we can actually do reuse, if we don't have to build a storage tank, if we don't have to extend the network, think of all the concrete saved, think of all the rebar that's saved. Think of all the energy and power consumption that's saved, and if we simply minimize the impact on the natural water cycle, that's the greatest contribution to sustainability we can give and that's what I'm looking for from my data scientists.

I'm looking for them to unlock that next level so that when my kids and our kids are actually running the water cycle, they are using less carbon and less concrete now than we are today, despite probably supplying more portable water to a larger population. That's the big price data science can deliver for us.

John Rickermann: Let me jump in and give another real-world example. I try to explain what Gregg just said, and I like to put things in analogies for folks that I talk to a lot. It's very much like what GPS driving aids ways and stuff has done. Think about all the miles saved for drivers globally, the millions, perhaps billions of miles not driven, and all the carbon emissions that has saved by having something to calculate your optimum route that everyone's following. That's the kind of thing we're talking about just in the water space, and that's essentially a digital model and a predictive tool that changes people's behavior. This is really what we're talking about.

Paul Thies: That's amazing. I never thought about that before, but you're right, the optimal driving and you're not driving around trying to, where's that turn off and every-- yes, that's amazing. Let me shift gears a little bit and, John, my next question's for you.

A couple of years ago, about three years ago, I was doing research on a different project and it was really around cybersecurity and it was-- I'm trying to remember, but there was a big cybersecurity attack in the United States that shut down, for a time, a very significant portion of the power grid, I think, in a number of states. The attackers came through like it was like-- I think, perhaps it was a utility, it might have been a construction company, but I think it was somehow in the utility sector and that was the entry point for attack and it compromised the power grid there.

You look at digital water, again, life essential resource, there's no shortage of bad actors out there, regrettably, and if you are a bad person who wants to attack people, attacking their water supply with some waterborne pathogen or just tweaking things so that the water's not being treated quite like it should be or whatever, you use your imagination.

Talk to us a little bit, John, about the cybersecurity aspects impacting digital transformations and how do we, or how do these digital water experts, how do you all counter those to make sure that the water stays safe?

John Rickermann: Yes, it's a great question and something we've been thinking about for years. The cybersecurity landscape, even without doing data science is pretty scary, very sobering. We started about five years ago with a pretty rigorous cybersecurity program at some of our most critical sites, typically water plants for obvious reasons.

In fact, quick story on that, we were running at the time a water plant near where a Super Bowl was being held and there's a security protocol nationally for big public events like that, and there's a security perimeter, physical and cyber that is involved in planning for a big event like that and we were within that circle.

The regulatory agencies, one of the three-letter acronym agencies, says, "What's your cybersecurity posture at this drinking water plant which will supply this event?" Oh, we have some really excellent cyber expertise in Jacobs, so we brought them in and says, "Hey, guys, let's take this up a notch," and we've partnered with a vendor that's topnotch that some of our national security agencies also utilize and implemented that at our water plants and it's been astounding what it can do.

That's just a normal course of business for us in a lot of utilities now, is stepping up their cybersecurity defensive posture in the face of bad actors internationally or just your backyard hacker or the ransomware attackers. Those are the three big attack vectors we see.

From a data science perspective, a lot of the source of our real time monitoring is the industrial control system that we use at a treatment plant. These are pretty sophisticated computer systems. We usually use the acronym SCADA to describe that and this is all the programmable logic controllers and plant control computers out of site. We need to extract information from that system remotely to do a lot of what we do.

Having these cybersecurity defenses in place ahead of time is part of our design for what we're doing. Just leaving the front door open and extracting the information you want so you can optimize operations if that's compromising your security, it's not worth it, so you've really got to do both and that's what we've built into our systems.

Paul Thies: Now, taking that a little further or more holistically, let's say, John, what strategies have been effective in supporting this digital transformation culture change within like in a water organization or somebody who would come to say at Jacobs and say, "Hey, help me out. I need a solution, want to do this digital water, I want to do it right." What's that roadmap look like?

John Rickermann: Yes, that's a really fascinating question, Paul. It's really a top-down and a bottom-up problem. Top-down, there are the risk managers as Gregg describes them that want to recognize, is this real? Is this really going to manage risk? Is it worth the cost? There's a shift in thinking that is happening in the industry already in that regard. Especially the more proactive organizations that really want to be premier providers of water and wastewater services or any utility service globally.

The bottom-up is very interesting as well, so you're asking people to trust what their computer's telling them to do and these are folks that have been running plants for decades in many cases and doing quite well at it. Why should I listen?

I'll go back to that GPS example. Who would've thought that everyone would've paid $500 for a computer to tell them how to drive, but that's what a lot of us do now because there's a benefit. We call that with them, what's in it for me and if we can reach our operations and maintenance staff and let them know this is going to help you. You're overworked. We recognize that. These treatment systems are getting more sophisticated to meet environmental needs. We recognize that. Here's a tool to help you do your job that reaches them.

We also give them time, so that's a big factor at the ground level. We don't just throw the system at them and say "good luck". There's a lot of working them into it, helping them understand, working their way down. That one plant that Gregg alluded to previously where we did a blower optimization, we sent them notifications on their smartphone and tablets in the field, "Here's what we want you to change your blower setpoints at."

They didn't embrace that instantly, they wanted to get comfortable with it. "Can we do it partway of what the computer's telling us?" Sure, and they worked their way down to the full recommendations. Now they trust it. They're like, "This is great, this actually works."

There's another critical piece I'll mention back to the cybersecurity thing. Right now, any recommendations we make from the data science is air-gapped. We're recommending it directly to the field staff, not to the plant control system. If there is a breach in security, it's still up to the operator to say, "No, I don't trust that recommendation. I'm going to ignore it and do what I normally do," and that protects everybody, so that's where we're at right now.

Paul Thies: It still keeps the human in the equation, automation hasn't completely just upended everybody.

John Rickermann: Absolutely not. Now, this is just a tool to help them be more efficient and effective and they've still got veto, if you will. The computer doesn't know that this basin's offline or a storm event's coming through or whatever it is, we still need to run the plant. That's our responsibility and we're just here to help him do it.

Paul Thies: Awesome. Then, Gregg, my last question for our discussion today is where do you think the concept of digital water will evolve to in the next couple of years?

Gregg Kennedy: You've actually, you've used one of the words yourself there, Paul. I see the evolution of digital water along two axes. On the vertical, I see increased automation, and on the horizontal, I see increased, what I call, integration. Starting with automation, it is exactly the point that John raised. Right now, we are comfortable using data science to inform the insights that we need to make better decisions but we're still leaving those decisions in the hands of the operators. Certain areas of the world, they're moving more towards automating some of those

decisions, where you're taking the decision-making process because you have enough trust, and you have enough visibility, and you have enough history to allow the system to almost self-regulate.

One of our clients in the UK, Anglian Water, they're trialing a safe, smart system approach where ultimately the system will self-regulate, and they call it a self-healing system.

Very ambitious, but that is where digital water is moving towards on the automation space.

The integration space is just as interesting for me, and this is where you might have a data-led solution in your networks. You might have a data-led solution in your treatment plan. You might even have a data-led solution in your water catchment. Beginning to bring those adjacent data sets together, that's really going to unlock the next level of efficiency in the next level of optimization.

We started optimizing individual assets, then we started optimizing networks, then we started optimizing systems. Now, we're going to optimize systems of systems. This is where the data science is going to take us. I think that's where digital water is going to get to, and I'll give a big shout-out to the UK regulator, Ofwat, who are, they have an ambition to achieve what they call open data.

What they mean by open data is if they can anonymize it, but make all these trillions of data bytes worth of scatter available. Think of what a data scientist sitting in the back of his room might be the person that finds out the relationship that none of the rest of us saw. This idea of democratizing access to information, not just for the operators of the plan, but for those that are in the supply chain, the innovators, the entrepreneurs. I think that'll be the next exciting development.

If we can find a safe and cyber secure way to do that, and open data because it'll benefit customers, it'll benefit clients, and it'll ultimately be efficient because it'll allow the innovators to bring their entrepreneurial skills to work in what is effectively quite a difficult industry to penetrate, I think open data will bring that next wave of entrepreneurs into the water industry.

Paul Thies: John and Gregg, thank you both so much. It's been really fascinating. I really appreciate it. It's terrific to hear the work that Jacobs is doing, and that y'all are leading on. If folks want to learn more, please visit jacobs.com. We do have information about our intelligent L&M product as well as other efforts that we are doing in the digital water space. John and Gregg, thank you both so much for your time today.

John Rickermann: My pleasure. Thank you.

Gregg Kennedy: Thank you, Paul.

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