A DIGITAL TWIN OF WATER IN AOTEAROA NEW ZEALAND

Michael Howden (Beca)

ABSTRACT

What if we knew everything there was to know about water in New Zealand? The quality of every drop from every tap; the flow rate in every river at every moment; the size and position of every crack in every pipe. And what if you also knew the exact cost for every riparian planting or treatment plant update - and the overall impact that these would have on the health of our waters and people?

We now have the opportunity to provide some of these answers by combining multiple data sources with real-time data streams and complex models to create a digital twin of water in Aotearoa New Zealand. The Ministry of the Environment's River Environment Classification and Land Use Map provide a good foundation, which is complemented by the aggregation of environmental monitoring data by Land and Water Aotearoa, WaterNZ's Waste Water Treatment Plant Inventory and the Drinking-Water Online solution which Beca have implemented for the Ministry of Health.

As part of the Three Waters Review, some of this data is already being brought together to inform policy decisions. There is further opportunity to support better decision making at a regional and local level, by investing in a platform to continually integrate and analyse all water data in New Zealand. Collectively pooling our data will support the development of statistical models, which could be continually tuned and refined to deliver a digital dwin of water in Aotearoa New Zealand. Although this is technically complex, the greatest challenges will be political, organisational and cultural. Exceptional governance would be required to ensure that national standards did not ignore local features or priorities or

The exponential growth of technologies, from remote real-time sensors to Building Information Management (BIM) models of treatment plants makes this challenge more important to tackle. The threat is a cacophony of different tools that do not talk to each other. The opportunity is that we work together to develop a Digital Twin, integrating these new technologies to provide more accessible and holistic insights.

We can all start by talking to each other. A systems approach to digital technologies can identify inefficiencies or gaps and identify easy wins. This can start conversations around opportunities to share learnings, solutions or work together on initiatives. Success will depend on our ability to collaborate rather than compete, and realise the benefits in finding the common ground amongst our unique contexts. The dividend will be the shared knowledge we need to get past the politics and take the action required to improve our national water quality.

KEYWORDS

digital twins, data, drinking water, freshwater, water quality, data analysis, data integration, data modelling, remote real-time sensors, BIM, GIS, collaboration, governance

PRESENTER PROFILE

Michael Howden has international experience delivering digital solutions for water, public health and disaster management. As a Senior Associate in Beca's Digital Services team, leads Beca's Drinking Water Online project for the Ministry of Health, which manages the reporting and compliance of water supplies. Michael is currently studying a Masters in Public Policy at Victoria University of Wellington.

1 INTRODUCTION

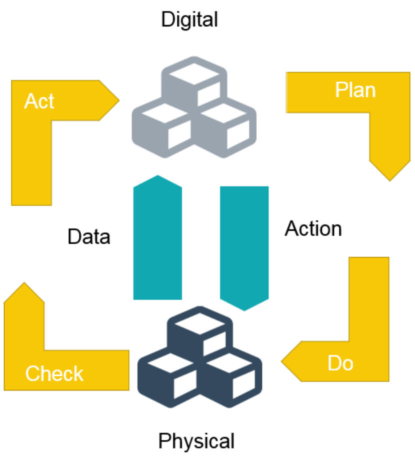
Digital Twins are a digital representation of the physical world. They combine data with models and visualisations to provide better insights to inform better decisions on what actions should be taken, manually or automatically. The quality of a digital twin can be considered based on its completeness, resolution, accuracy, timeliness and trustworthiness. There is a range of different technologies which can be integrated together to realise a digital twin.

This paper proposes a vision of a digital twin of water in Aotearoa New Zealand, outlining the benefits, stakeholders involved, and the data that is already available which could be integrated into a digital twin. Five case studies share efforts currently underway which move us closer to this vision.

Finally, a number of challenges are presented, along with opportunities for people to start working towards a digital twin of water in Aotearoa New Zealand.

2 WHAT IS A DIGITAL TWIN?

Figure 1 - Using data from the Physical world to plan actions



For decades, digital technology has been used to understand the physical world and help inform our actions. For example, you may check the deviation of a pump's energy consumption in order to know when it requires maintenance. However, as the systems we manage start having an increasing number of interacting parts, it is harder to manage the parts individually.

By creating a digital model of how these parts interact, we can start managing the system holistically.

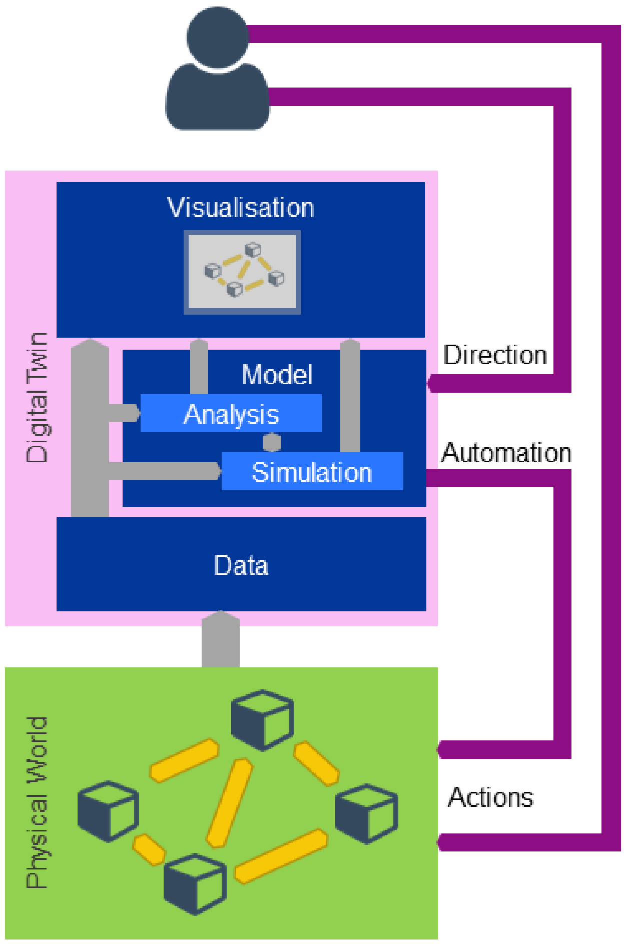
When this model is linked back to continuous data from the physical world, it can be validated and refined on an ongoing basis. This model can run simulations to predict possible future states of the physical world. When provided with directions, the model can analyse the physical world and automatically respond with actions.

The basic components of a digital twin are described in Table 1 and shown in Figure 2.

Table 2: Components of a digital twin

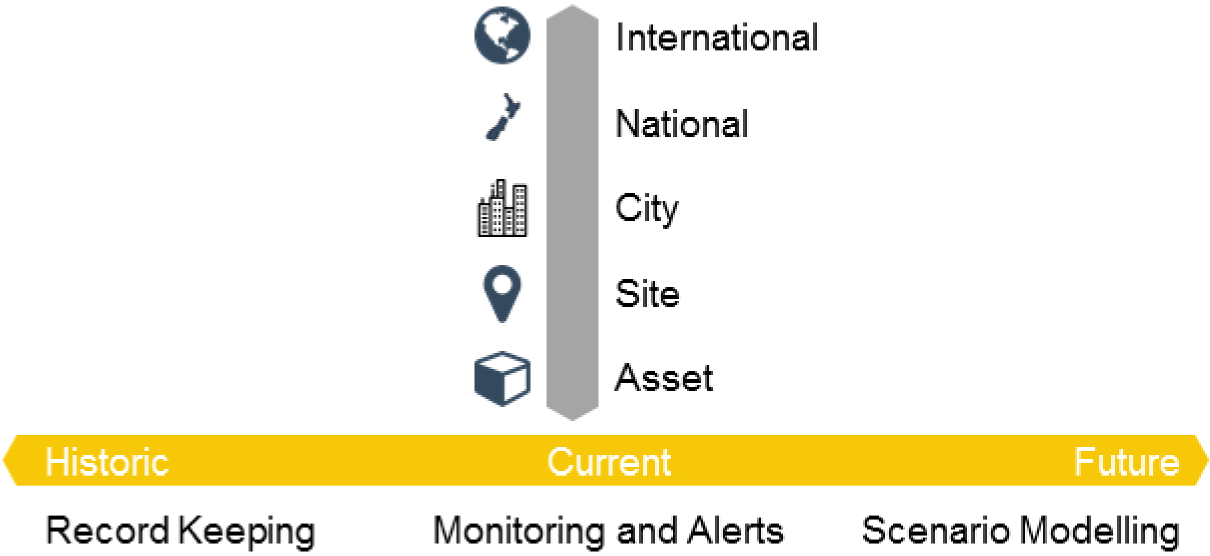
Visualisation	An ability to present the digital representation, either through charts, geospatially, 3D models or virtual reality, in order to provide actionable insight.
Model (analysis)	The comparison of data from the physical world and simulation in order to validate the model and identify where change is needed, set priorities, evaluate options or inform both manual and automatic decisions.
Model (simulation)	A continuously validated algorithm that can interpolate or extrapolate data about the physical world, either current data which is not measured or predicting future data. Advances in machine learning are supporting the development of such models through statistical analysis of large amounts of data. For example, predicting the impact of land use changes on water quality
Data (static)	Static information about your operations. These may include asset registers schematics, 3D models, maps and light detection and ranging (LIDAR)
Data (dynamic)	Ongoing and timely information from the physical world which is used to validate and tune dynamic modelling. This might include data from real-time water quality sensors or energy consumption of plant. Integration into enterprise systems and the development of Internet of Things (IoT) solutions are making data more available.

Figure 2 - Digital Twin



Digital twins can come in all shapes and sizes, depending on the outcome being sort, range from representations of single assets such as a jet engine to national or international systems. It is important to first understand the outcomes the digital twin is trying to seek, to inform the appropriate level of resolution for the data and the models.

Figure 3 - Digital Twins can exist over different spatial and temporal scales



2.1 EXAMPLES

2.1.1 NASA

The origins of digital twins can be traced back to the "mirrored systems" NASA used to manage their moon missions in the 1960s and 1970s. When trouble arose on Apollo 13, NASA was able to use these to help find solutions and rescue the mission. NASA continues to use digital twins today to understand and spacecraft exploring our solar system.

Figure 4: "Huston, we have a problem"

"The ultimate vision for the digital twin is to create, test and build our equipment in a virtual environment. Only when we get it to where it performs to our requirements do we physically manufacture it. We then want that physical build to tie back to its digital twin through sensors so that the digital twin contains all the information that we could have by inspecting the physical build," says John Vickers, NASA's leading manufacturing expert and manager of NASA's National Center for Advanced Manufacturing.

2.1.2 NORTHUMBRIAN WATER "TWINCIDENT"

Northumbrian Water uses a digital model of the physical world to run simulations that will predict the impact of a burst pipe or heavy rainfall. This model combines data from:

- LIDAR maps
- land cover maps
- infrastructure information
- Real-time weather

Knowing which homes and businesses are at risk of being flooded, or environments being polluted, allows the optimal incident response actions to be planned.

Figure 5: Burst pipe – so what?

2.1.3 VIRTUAL SINGAPORE

Figure 6: SimCity

The Singapore Government have built a virtual copy of the city, combining static data on buildings and infrastructure as well as real-time information on the movement of traffic, people and occurrences of diseases such as dengue fever. It provides a 3D visualisation of the city for designers, planners and policy makers to explore future scenarios. The Housing Development Board is using it for cost-benefit analysis on where to install solar roofs, water-retention features, and pneumatic waste systems to make public housing more environmentally friendly.

2.2 SILVER BULLETS AND SNAKE OIL

The global IT research and advisory firm Gartner predict that by 2021 half of large industrial companies will use digital twins, returning gains of 10% in effectiveness. However, Gartner also acknowledges in their Hype Cycle for Emerging Technologies, 2018, that Digital twins are at the top of the Peak of Inflated Expectations.

Digital twins face the risks of both overhyping the benefits of what is currently and realistically possible or overselling current technologies, such as IoT or 3D modelling, that fall short of an actual digital twin.

While it is right to be sceptical about the promises of digital twins, they can provide us with a vision of what might be possible. For this reason, digital twins are a valuable aspiration to guide us on the journey towards greater insights through collecting, integrating, sharing, modelling and visualising data.

Gartner does identify that digital twins are not a new concept, but are evolving in the following ways:

1. The robustness of the models, with a focus on how they support specific business outcomes
2. The link to the real world, potentially in real time for monitoring and control
3. The application of advanced big data analytics and AI to drive new business opportunities
4. The ability to interact with them and evaluate “what if” scenarios

Source: Gartner Top 10 Strategic Technology Trends for 2019

2.3 ARE WE THERE YET?

Rather than giving a specific definition of what is or is not a digital twin, we can consider the quality of a digital twin based on the following attributes.

Table 3: Attributes of a digital twin

Purpose	A digital twin should have a clear purpose, with specified outcomes in order to be able to balance all the following attributes at the appropriate level.
Completeness	How much of the physical world does the digital twin represent? Does it only look at a specific domain (engineering, financial, environmental) or does it combine all the relevant domains?
Resolution	How detailed is the digital twin? Does it only represent a summary of information or provide the details at the asset or component level which are relevant to users.
Accuracy	How accurate is the digital twin? Are their discrepancies between the digital and physical or are there the manual and automatic processes as well as sufficiently reliable models required to ensure that the digital twin is an appropriate representation of the physical world.
Timeliness	Does the digital twin provide information at the time it is needed? This might be achieved through real-time sensors or predictive models.
Trustworthiness	Is the digital twin trusted by users to inform and support their decision making or is it mistrusted or unused by people who resort back to intuitive or heuristic decision making? This is as much about the organisation and the people.

Building digital twins should be a progressive journey, through incrementally improving their quality in order to deliver value to their users. We should not let the perfect digital twin be the enemy of the good (enough for now) digital twin.

2.4 IT IS THE PEOPLE

A Digital twin is achieved when organisation brings together their data and models through an ecosystem of technology platforms to provide a unified visualisation of their physical world which they trust to inform and support their decision making. This might be a single water supplier creating a digital twin of a water treatment plant, or a group of organisations creating a digital twin of a river catchment area.

While this paper will explore some of the technologies that can be used to create digital twins, it will also highlight the importance of organisational factors to realise the full potential of digital twins.

Careful change management is needed to ensure people agree to standardise and share the way they manage their data. For digital twins to be successful, champions will need to build their trust in the representation of the physical world that digital twins will offer. The benefits of sharing data need to be managed in considerations of privacy, security as well as commercial and political factors. Like all technologies, ultimately the most important thing is the people.

3 DIGITAL TWIN TECHNOLOGIES

Digital twins are not a single piece of technology, but the seamless integration of multiple components to deliver a digital representation of a physical system. While many of these technologies in use today contain the components of digital twins, they each only represent a specific part of the physical world. By bringing them together that we create a more complete and realistic representation of part of the the physical world.

Table 4: Technologies that can make up a digital twin

	Data	Model	Visualisation	
GIS	✓	✓	✓	Geospatial Information Systems (GIS) include technologies that range from basic maps to visual data, to 3D spatial rendering and complex spatial models.
BIM	✓		✓	Building Information Management (BIM) facilitates the creation, sharing and reuse of structured data about buildings and other assets throughout their life from design to operation.
Reality Capture	✓			There is a range of technology that is able to capture 3D models of the physical world • Airborne LIDAR records terrain elevation at 15cm accuracy. • Point cloud and laser scanning can map a radius of up to 60 metres at 4 mm accuracy. • Photogrammetry uses multiple photographs to generate a 3D model.
Asset Management Systems	✓	✓	✓	Asset management systems contain data about assets, their operation and maintenance. In advanced cases, they include models that drive maintenance and replacement schedules. An asset management system may be the best current digital representation of an organisation's physical systems, however, the lack of timely, well visualised or, in some cases, accurate data, means it is a long way off a digital twin.
Information Technology (IT) Systems	✓		✓	Different IT systems offer different perspective of the physical world. From customer relationship management systems offer insights into customers, to financial systems show where money is earnt and spent in the physical world.
Mobile Data Collection	✓			Mobile data collection apps are making it easier for people to use mobile phones and tablets to collect data in real-time such as water quality observations, asset conditions and photographs.
SCADA	✓	✓	✓	Supervisory Control and Data Acquisition (SCADA) have been used to collect data and control industrial processes for over 40 years. They are still predominant within heavy asset sites including water treatment plants.
IoT	✓			Internet of Things (IoT) sensor networks link digital twins to the physical world with sensors and actuator. The decreasing cost of

				sensors and increasing availability of low-power wireless networks is making it more feasible to collect sufficient data for a digital representation.
Physical Models		✓		Physical models leverage hydrological, mechanical, electrical or other principles to predict the behaviour of the physical world.
Machine Learning		✓		Machine Learning is a type of artificial intelligence that uses large volumes of data to develop algorithms based on statistical approaches. Instead of having to understand the behaviour of the physical world, machine learning interprets the behaviour based on observed data.
Virtual Reality			✓	Through turning digital data and models into an immersive 3D experience, virtual reality, helps digital twins to better represent the physical world.
Augmented Reality			✓	Augmented reality blurs the separation between the digital and physical world by overlaying digital images onto the physical world, either through heads-up displays, phones or tablets. Augmented reality can allow people to "see" the levels of liquids through stainless steel tanks, or identify specific assets and easily find related data and information.

4 THE VISION: A DIGITAL TWIN OF WATER IN AOTEAROA NEW ZEALAND

How might the aspirational vision of a digital twin help us to improve the quality of water in Aotearoa New Zealand? Water quality is determined by a range of interacting complex systems:

Table 5: Water systems

Natural Environmental	Built Environment	Management
• Meteorological • River systems • Geohydrological • Land use	• Drinking water networks • Storm water networks • Waste water networks	• Legislation and standards • Institutions • Financing • Human resources capability and capacity • Relationships

The processes of managing water are themselves very complicated, involving local, regional central government agencies, with an array of different stakeholders with competing interests. Relevant data is spread across different systems and different agencies.

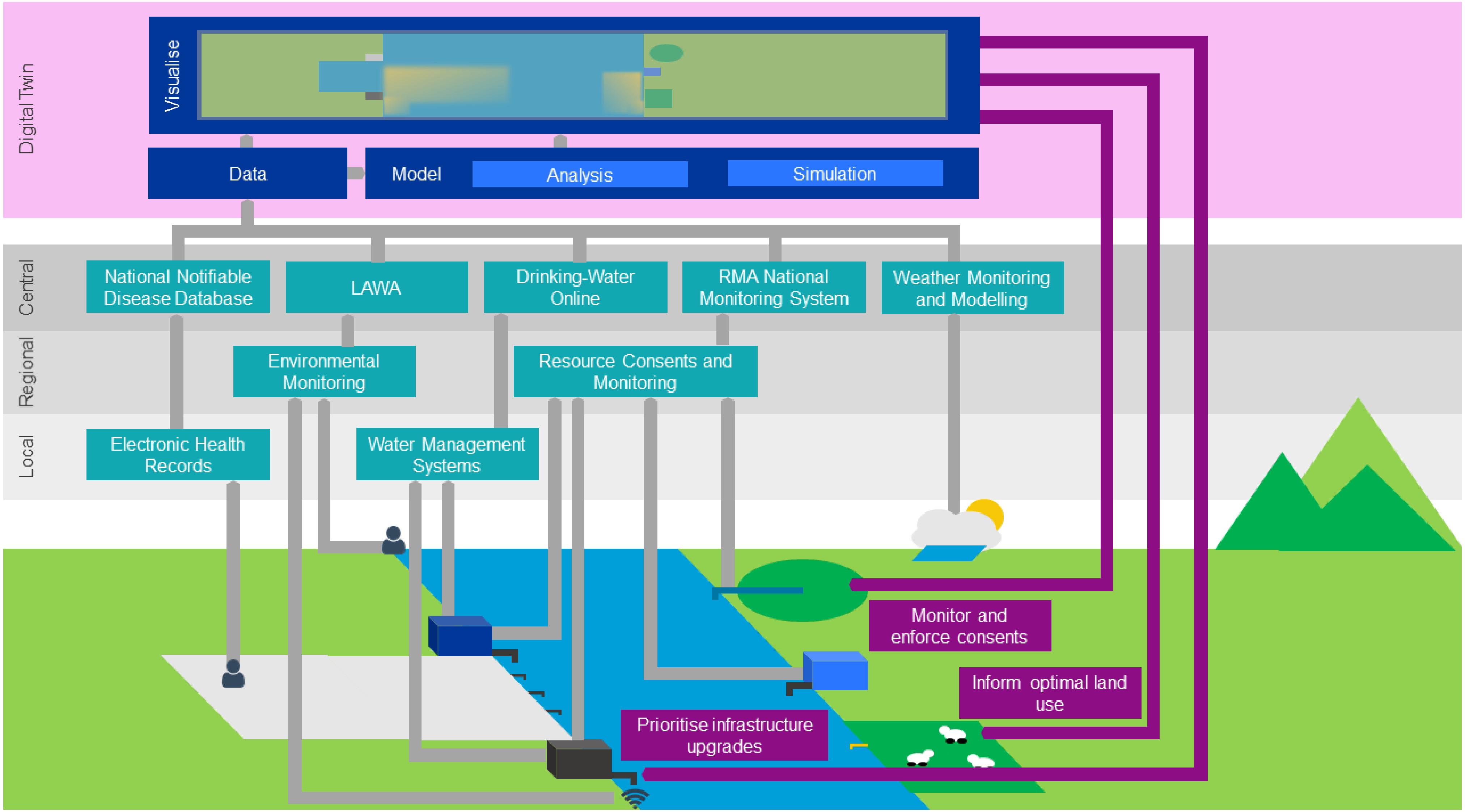
Bringing these systems together would start to create a digital twin of water could provide a unified understanding of the current and future state of water in the country. Clearly understood visualisation could provide a common understanding to a range of stakeholders. Additional sensors and models that can use the full range of available data would increase the completeness, accuracy and timeliness of the data, increasing the trust in the digital twin.

Although a digital twin could be created at a local or regional level, a national digital twin of water would provide economies of scale, and provide large data sets to inform models. A national digital twin could still be designed such that it supported different models and visualisations to support unique local perspectives. A digital twin of water in Aotearoa New Zealand would offer the benefits in Table 6 below.

Table 6: Benefits of a digital twin of water in Aotearoa New Zealand

Identify priorities	Visualising water data at a national level would allow national priorities to be identified, such as at-risk catchments and infrastructure investment. The Ministry for the Environment models river water quality. As part of the 3 Waters review, DIA has conducted an analysis of the investment required to upgrade drinking-water and waste-water treatment plants. A national digital twin could automatically conduct this modelling and analysis on a dynamic and ongoing basis.
Simulate interventions	A digital twin could simulate the immediate, cascading and interacting impacts of a huge range of possible interventions to improve water quality such as regulatory interventions and restoration projects such as the One Billion Trees program. Through advanced cost benefit, the digital twin could identify which interventions would have the best return on investment and who will incur those costs. Present such comprehensive analysis through clear visualisation will help to engage stakeholders.
Monitoring interventions	Real-time measurement and analysis could validate the real impact of interventions, refine simulation and better inform future interventions. For example, the impact of riparian planting around farms could be validated through data collected by a network of specifically deployed sensors. This validation could encourage greater engagement from stakeholders.
Improve management	A digital twin could streamline or automate current processes, making them more effective and efficient.
More accessible information	There is a huge amount of information currently available about water quality and factors that affect or are affect by it, however, this is generated across a range of reports and websites. A digital twin could help to automate reporting process, saving costs, while presenting clearer information to stakeholders. It could also make a wider range of data available.
Better situational awareness	A shared understanding of the current situation to coordinate activities and the allocation of resources, particularly for emergency response.

Figure 7: Concept diagram of a digital twin of water in Aotearoa New Zealand



5 STAKEHOLDERS AND STRUCTURES

One of the challenges of creating a digital twin of water is to identify then engage all of the various stakeholders involved and understanding what they do and what their drivers are.

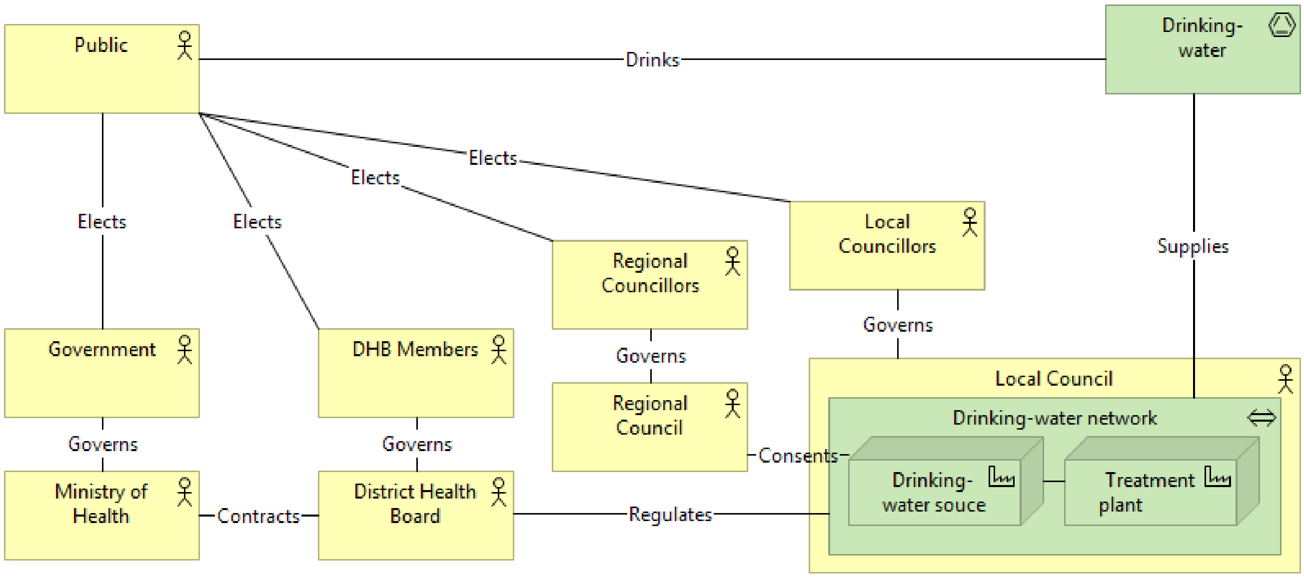
The governance of water in New Zealand involves every layer of government and has been compared by Eppel (2014) as a complex system in itself.

Figure 8 and These figures explain the complexity involved in the governance of water and show how various stakeholders might support or benefit from a digital twin of water in Aotearoa New Zealand. It is important to appreciate the specific obligations of different stakeholders, many of which are specified in legislation. This has resulted in a fragmented view of water in New Zealand, which has been identified through the 3 Waters Review currently being conducted by the Department of Internal Affairs. One possible outcome of this review is the reorganisation of these structures under a single regulator.

A digital twin of water could also support more holistic management of water, providing a single holistic view of water and facilitating information sharing for all stakeholders. However, this would require careful coordination and trusting collaboration.

Figure 9 show the relationships between the levels of government, the roles and responsibilities involved in the supply of drinking-water and well as the management of our freshwater.

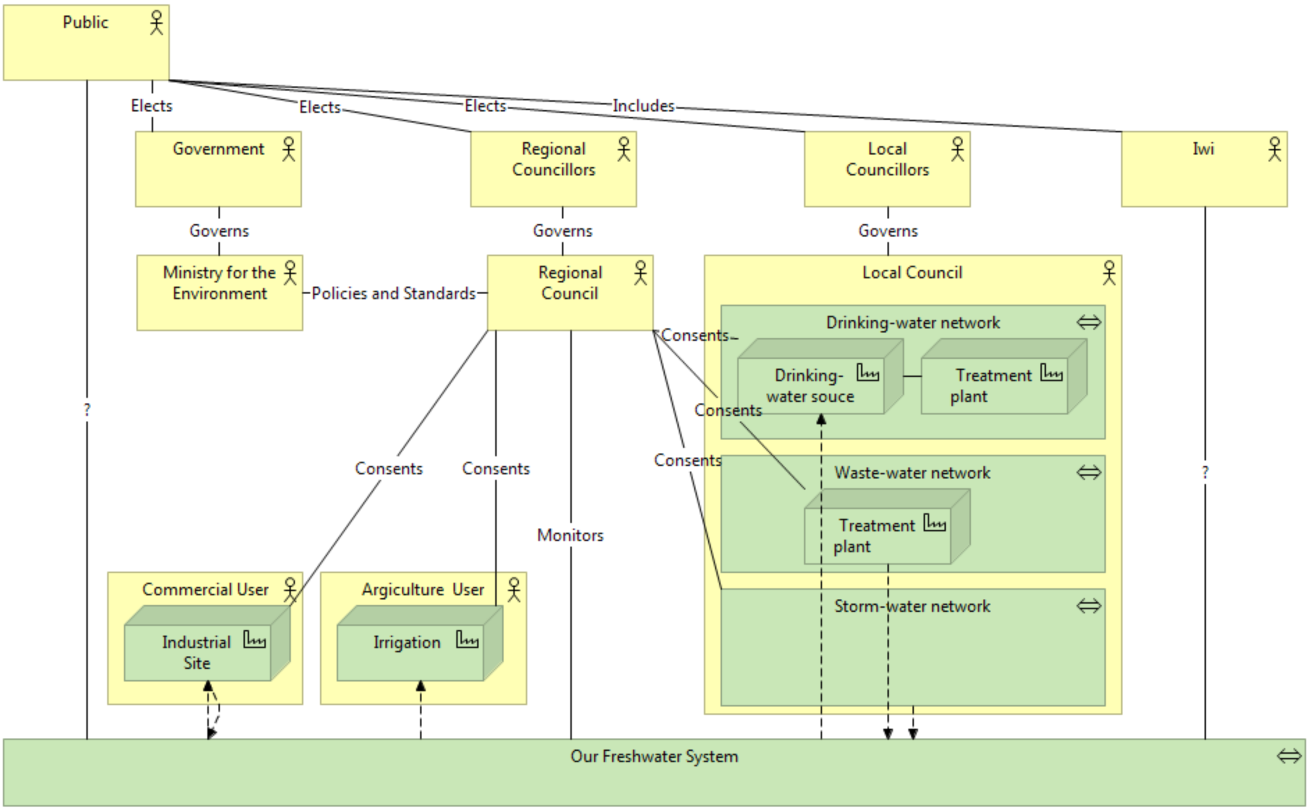
Figure 8: Drinking-water supply: stakeholders and structure



These figures explain the complexity involved in the governance of water and show how various stakeholders might support or benefit from a digital twin of water in Aotearoa New Zealand. It is important to appreciate the specific obligations of different stakeholders, many of which are specified in legislation. This has resulted in a fragmented view of water in New Zealand, which has been identified through the 3 Waters Review currently being conducted by the Department of Internal Affairs. One possible outcome of this review is the reorganisation of these structures under a single regulator.

A digital twin of water could also support more holistic management of water, providing a single holistic view of water and facilitating information sharing for all stakeholders. However, this would require careful coordination and trusting collaboration.

Figure 9: Freshwater management: stakeholders and structure



6 THE DATA

There is already a rich volume of data about water in New Zealand generated by different stakeholders, for different purposes. Table 7 presents a range of the key data sources that are managed by the Ministry for the Environment and Statistics New Zealand.

Table 7: Water data sources

Data Source	From	To	Link
Land use map	1990	2016	https://www.mfe.govt.nz/more/data/available-datasets/land-use-map
River Environment Classification		2010	https://data.mfe.govt.nz/layer/51845-river-environment-classification-new-zealand-2010/
Land cover	1996	2012	http://archive.stats.govt.nz/browse_for_stats/environment/environmental-reporting-series/environmental-indicators/Home/Land/land-cover.aspx
Groundwater quality	2010	2014	https://www.stats.govt.nz/indicators/groundwater-quality
Groundwater pesticides	1998	2014	http://archive.stats.govt.nz/browse_for_stats/environment/environmental-reporting-series/environmental-indicators/Home/Fresh%20water/groundwater-pesticides.aspx
River water quality: clarity and turbidity	2013	2017	https://www.stats.govt.nz/indicators/river-water-quality-clarity-and-turbidity
River water quality: Escherichia coli	2013	2017	https://www.stats.govt.nz/indicators/river-water-quality-escherichia-coli
River water	2013	2017	https://www.stats.govt.nz/indicators/river-water-quality-escherichia-coli

quality: macroinvertebrate community index			
River water quality: nitrogen	2013	2017	https://www.stats.govt.nz/indicators/river-water-quality-nitrogen
River water quality: phosphorus	2013	2017	https://www.stats.govt.nz/indicators/river-water-quality-phosphorus
Lake water quality	2013	2017	https://www.stats.govt.nz/indicators/lake-water-quality
Nitrate leaching from livestock		2017	https://www.stats.govt.nz/indicators/nitrate-leaching-from-livestock
Conservation status of indigenous freshwater species		2017	https://www.stats.govt.nz/indicators/nitrate-leaching-from-livestock
Location and extent of New Zealand's aquifer		2015	http://archive.stats.govt.nz/browse_for_stats/environment/environmental-reporting-series/environmental-indicators/Home/Fresh%20water/area-nz-aquifers.aspx
Cultural health index for freshwater bodies	2005	2016	http://archive.stats.govt.nz/browse_for_stats/environment/environmental-reporting-series/environmental-indicators/Home/Fresh%20water/cultural-health-index.aspx
Consented freshwater takes		2014	http://archive.stats.govt.nz/browse_for_stats/environment/environmental-reporting-series/environmental-indicators/Home/Fresh%20water/consented-freshwater-takes.aspx

These data sources are constructed from collected data through scientific analysis. If models could be developed to automate this analysis, it could be possible to make these data sources available in a more timely manner.

These data sources are primarily to support the legislative obligation to generate the state of the environment report. Table 7 presents a range of data reporting processes that collect the data that supports these data sources as well as to meet a range of other legislative obligations.

Table 8: Water data reporting processes– legislative and voluntary

	What	**Who**	**When**	**Where**	**Why**
Environmental monitoring	The quality of freshwater environments.	Regional and unitary councils	Varied	Regional	Resource Management Act 1991
State of the environment report	A synthesis report on the state of air, freshwater, marine, atmosphere and climate, and land domains.	Ministry for the Environment and Statistics New Zealand	3 Yearly	National	The Environmental Reporting Act of 2015
RMA National Monitoring System	Data from local, regional and unitary councils on their	Ministry for the Environment	Annual	National	Resource Management Act 1991

	processing, monitoring and enforcement of resource consents.				
Land and Water Aotearoa	National aggregation of regional council environmental monitoring data.	Partnership	Daily	National	Voluntary
Local Government Mandatory Performance Measures	Local council drinking-water, stormwater, sewerage and flood protection performance.	Local Council	Annual	District	Local Government Act 2002
Public Health Surveillance	Records of all cases of notifiable diseases.	Ministry of Health	Monthly	National	Health Act 1956.
Register of drinking-water suppliers	A list of every drinking water supply.	Ministry of Health	Annual	National	Health (Drinking Water) Amendment Act 2007
Annual Report on Drinking Water Quality	The quality of drinking water from each supply.	Ministry of Health	Annual	National	Health (Drinking Water) Amendment Act 2007
Wastewater treatment plant Inventory	Data on publicly owned wastewater treatment plants.	WaterNZ	Annual	National	Voluntary
National Performance Review	Performance comparison of drinking water, wastewater and stormwater services	WaterNZ	Annual	National	Voluntary

Like the structure of the stakeholders, Table 7 and Table 8show that the flow of data, as well as the digital representation water in New Zealand, is fragmented.

These tables only represent data which is already available in the public domain. Various stakeholders would have a range of additional data which is not currently published.

Further research would be required to construct a comprehensive list of all data sources and reporting processes relevant to water in New Zealand.

7 CASE STUDIES

The following are examples of the steps that we are taking towards a digital twin of water in Aotearoa New Zealand. They provide us with parts of the system we can start integrating, as well as valuable lessons that can be applied.

7.1 LAND AND WATER AOTEAROA (LAWA)

LAWA is a partnership between New Zealand's 16 regional councils and unitary authorities, Cawthron Institute, and the Ministry for the Environment. It automatically aggregates environmental monitoring data from regional councils and communicates this through a usable website. This gives people the information they need to decide if it is safe to swim or fish in 350 beaches and 1,100 rivers throughout New Zealand.

LAWA demonstrates the strength in collaboration led from a regional level and the efficiencies of building a national solution to consistently provide value to everyone throughout the country.

7.2 DRINKING-WATER ONLINE

Drinking-Water Online is a web-based solution for water suppliers, local councils and District Health Boards to report on the quality and compliance of drinking water. It has been led by the Ministry of Health with support from Beca to replace the legacy Water Information New Zealand, which was an offline Microsoft Access based solution. Drinking-Water Online is being used to support the development of a website that will allow people to check the quality of their drinking water throughout New Zealand.

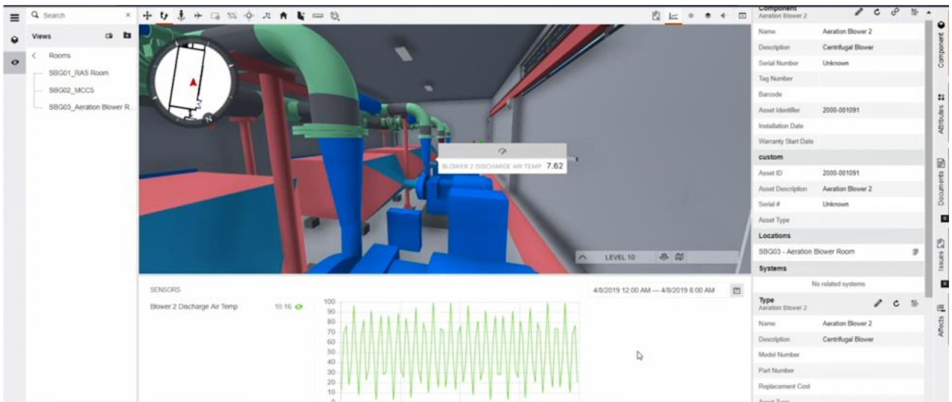
Drinking-Water Online demonstrates the ability of online platforms to facilitate information sharing between stakeholders and make this information more accessible to the public.

7.3 PUKETE WASTE-WATER TREATMENT PANT BIM

In order to improve their asset management and support future upgrades of their only water-water treatment plant, Hamilton City Council engaged Beca to use BIM to create a holistic digital representation which brought together:

- Drone photography
- LIDAR 3D model
- Asset documentation and manuals

Figure 10: An example of how real-time operational data can be integrated with BIM



This use of BIM integrates key data sources to improve Hamilton City Council asset knowledge. While not currently providing the simulations of a digital twin, the components for this are already in place.

Organisations managing their data locally in a more systematic and integrated approach will provide the foundations for the integration of data at a national level required to create a digital twin of water in Aotearoa New Zealand.

7.4 NATIONAL ENVIRONMENTAL MONITORING STANDARDS (NEMS)

The NEMS project is a collaboration between Regional Councils, the Ministry for the Environment (MFE), National Institute of Water and Atmospheric Research (NIWA) and industry to improve the consistency of environmental monitoring data. Since 2013, it has developed 27 standards around how different environmental monitoring data is collected and handled.

Standardisation data from a range of different sources which can be aggregated, analysis and compared is essential in order to provide a complete digital representation of water throughout New Zealand.

8 CHALLENGES

Embarking on the journey to create a digital twin of water we should be aware of the challenges which will be faced.

8.1 LOCALISM

There is tension between the role of central versus local. This has ebbed and flowed with the decentralisation of the 1980s and 1990s delegating to the lowest competent level to the aggregation of water services we have seen in Watercare and Wellington Water. A single digital twin of water for all of New Zealand could risk overlooking local nuances, replacing refined models of local environments with best fit national models and presenting data without the local context.

8.2 SILOS

The hierarchies of our organisations and governance spread out into individual branches, with their own budgets, priorities and even legislative requirements.

Different government organisations have different legislative obligations, which can prevent them from taking a holistic view. Within organisations people can be focused on their specific roles and responsibilities and even digital systems can be silos for specific types of data about financials, assets or customers.

These can all be barriers to coordination and collaboration.

8.3 KNOWLEDGE IS POWER

And data has value. Some government organisations may not be inclined to share their data, despite the fact that data is non-rivalrous, meaning that sharing it does not diminish their value. Especially when regulators are involved, more open data sharing will need to be accompanied by the development of greater trust and understanding.

8.4 THE PRETENCE OF KNOWLEDGE

Nobel Prize winner Friedrich Von Hayek (1989) described the pretence of knowledge as the problem of using scientific approaches, which only use the data available (rather than the data needed), to incorrectly describe and predict complex behaviours in the economy. A digital twin of water risks making the same pretence, further amplified by its ability to visualise this false knowledge in lifelike detail.

We must be cautious with the trust we place in these models, and where possible use timely data from the physical world to provide feedback loops to validate, or invalidate them. Data should go through appropriate quality assurance. People should be able to distinguish between simulated data and measured data and understand the different levels of certainty, and use the data accordingly.

9 OPPORTUNITIES

We all have a number of opportunities in front of us today to help move towards the visions of a digital twin of water

9.1 OPEN DATA

In order to share non-sensitive data between public organisations it can take weeks of time and formal letters to CEOs. Open data is the idea that some data should be freely available to everyone by default.

In 2011, the New Zealand Government approved the Declaration on Open and Transparent Government, committing to actively releasing high-value public data. New Zealand Government Open Access and Licensing (NZGOAL) framework also provides guidance on the sharing and licensing of Open Data.

The more data which organisations can start opening and sharing by default, the easier it will be to integrate the data needed to create a digital twin of water.

9.2 SYSTEMS THINKING

As we use more digital technologies to manage water, we need to standardise thinking about the relationships between these systems and how we might integrate them better. By mapping the different systems, data, business processes and users that support them, you will find opportunities of how they might better integrate together to provide efficiencies and more holistic insights.

9.3 THE GEMINI PRINCIPLES

At the end of 2018, the Centre for a Digital Built Britain proposed a set of principles to guide a national digital twin. They are deliberately simple and solution agnostic, intended to deliver a public good through digital twins that have a clear purpose, are trusted and effective. These principles can equally be applied to the development of a digital twin of water in Aotearoa New Zealand.

Figure 11: The Gemini Principles

9.4 ONE REGULATOR TO RULE THEM ALL

A likely outcome of the current 3 Waters Review being led by DIA is the formation of a single water regulator. This could help provide direction, leadership and less siloed funding to support the creation of a digital twin of water. Better alignment within central government could also streamline some of the data reporting that occurs, reducing the burden on local councils.

It is important not to overinflate the role of a single regulator, as water will still have a diverse range of stakeholders involved with local and regional councils almost certainly still playing key roles. Top-down leadership will need to be matched with bottom-up partnership and collaboration.

9.5 A COALITION OF THE WILLING

In the short term, it is more likely that we will see a digital twin of water start to emerge out of people and organisations who have a desire to innovate and can find the common opportunities to collaborate. By working together organisations can pool resources to create more than they would have individually.

A digital twin of water in Aotearoa New Zealand does not need to be a single model or even a single platform but can be built from a set of principles, standards and technologies that could facilitate an ecosystem of localised digital twins.

10 CONCLUSIONS

With the quality of our freshwater in New Zealand declining and 16% of our drinking water supplies not compliant, a digital twin of water in Aotearoa New Zealand could help us identify the right funding priorities and know which interventions have the best cost-benefit ratio. But this will not happen overnight.

It may not answer all of your questions, but it will show you what data you are missing and need to start to collect.

It may not provide you with accurate models, but it will identify where your current models were incorrect.

It may not provide you with predictions of the future, but it will start to give you a more holistic perspective of the present

Creating a digital twin is a journey, not a destination. A digital twin is not a piece of technology that we can deploy or something a supplier can sell you. A digital twin means changing how you work to be data-driven and changing the culture of your organisation to invest in your data and systems until you trust them.

A digital twin of water in Aotearoa New Zealand is an aspirational vision. But it is a valuable aspiration. Every time you integrate two systems to get a better insight, every time you share data openly, every time you automate a process. Every time you incrementally improve the way we manage water and take a step closer to that vision.

ACKNOWLEDGEMENTS

Chris Chester (Beca) and the Beca Digital Services team for their work on Drinking-Water Online.

Tracey Clode (Beca) for leading the Waikanae borefield monitoring website project

Jan Gregor (ESR) for her review of this paper

Glen Jowett (Beca) for leading the Pukete Waste-water treatment plant BIM project

Garry MacDonald (Beca) for the encouragement to write a paper for Water NZ

Rachael Shaw (Beca) for getting me up to speed with how water works

Dan Stevens (Beca) for his review of this paper

Steve Wallace (Beca) for his review of this paper

Stephen Witherden (Beca) for sharing his thoughts about digital twins

REFERENCES

Bolton, A., Butler, L., Dabson, I., Enzer, M., Evans, M., Fenemore, T., Harradence, F., et al. (2018). Gemini Principles. (CDBB_REP_006) Retrieved from: https://doi.org/10.17863/CAM.32260

Cherry, B, Jones, C and Kilsb, C (2018) *Managing incidents with the 'digital twin'*. Water Industry Journal. Retrieved from: https://www.waterindustryjournal.co.uk/managing-incidents-with-the-digital-twin

Dassault Systèmes (2018) Meet Virtual Singapore, the city's 3D digital twin. GovInsider. Retrieved from: https://govinsider.asia/digital-gov/meet-virtual-singapore-citys-3d-digital-twin/

Eppel, E., 2014. Governance of a complex system: water. Retrieved from: https://www.victoria.ac.nz/__data/assets/pdf_file/0003/1175250/WP14-01-Governance-of-a-Complex-System.pdf

Ministry for the Environment & Statistics New Zealand (2019). Environment Aotearoa 2019. Retrieved from: https://www.mfe.govt.nz/sites/default/files/media/Environmental%20reporting/environment-aotearoa-2019.pdf

Panetta, K (2018) *5 Trends Emerge in the Gartner Hype Cycle for Emerging Technologies, 2018.* Gartner. Retrieved from: https://www.gartner.com/smarterwithgartner/5-trends-emerge-in-gartner-hype-cycle-for-emerging-technologies-2018/

Panetta, K (2018) *Gartner Top 10 Strategic Technology Trends for 2019.* Gartner. Retrieved from: https://www.gartner.com/smarterwithgartner/gartner-top-10-strategic-technology-trends-for-2019/

Pettey, C (2017) *Prepare for the Impact of Digital Twins.* Gartner. Retrieved from: https://www.gartner.com/smarterwithgartner/prepare-for-the-impact-of-digital-twins

The Economist (2017) *Modern manufacturing's triple play: Digital twins, analytics and the internet of things*. The Economist. Retrieved from: https://expectexceptional.economist.com/digital-twins-analytics-internet-of-things.html

Von Hayek, F. (1989). The Pretence of Knowledge. The American Economic Review, 79(6), 3-7. Retrieved from: http://www.jstor.org/stable/1914347