Exploring Next Generation Water Loss Tracking, Compliance, Management, and Performance Solutions

Report to the
Water Research Commission

by

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The Excel tool accompanying this report has been added as an attachment.

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EXECUTIVE SUMMARY

BACKGROUND

The National Water Balance for the 2012/13 audit year showed a total System Input Volume of 2,997.58 million kl/annum, of which 2,168.97 million kl/a (72.4%) was authorised consumption and 828.61 million kl/a (27.6%) was water losses. The losses were made up of 165.32 million kl/a (20%) apparent losses and 663.29 million kl/a (80%) real losses, which result in a total loss of 1,038.05 million kl/annum (34.6%). Clearly, this situation cannot be accepted as the norm.

With examples of successful implementation of emerging digital cloud-based solutions for minimisation of water losses piling up worldwide and squeezed utility budgets highlighting the need for cost-effective water savings in the wake of COVID-19, the case for digital water loss tracking and minimisation technologies has never been stronger. Water loss tracking and management consists of four fundamental pillars: pressure management, active leak detection, asset condition monitoring and smart analytics. Pressure management, active leak detection and condition monitoring are complementary, with smart asset management platforms sitting on top of all the digital infrastructure, aggregating and visualising the data. Each technology performs a vital role in helping control leakage, whether its actively finding leaks or managing pressure to reduce the risks of leaks and bursts in the first instance. Integrating all these technologies together can reduce non-revenue water (NRW) to below 10%, though few utilities have done this so far.

At the end of the project, the Water Research Commission (WRC) will have an understanding of the innovative technology options available to reduce water losses, and knowledge of trends and developments to provide a pathway to improvement if applied by utilities and asset owners. The research conducted on alternative solutions will inform policy and can feed into wider water loss management strategies, including links to smart water networks management and utilisation of information and communication technologies (ICT) for rapid response and remote monitoring. Successful case studies will provide a rationale to water business decision makers the need to invest in technology to deliver reduced network leakage and better monitoring to help with decision-making.

AIMS

The following were the aims of the project:

1. To conduct an international and national scan of new and emerging solutions to address water loss management, including technologies, tools and operating methods.
2. To find and capture lessons learned from relevant successful case studies of utilities using water loss management technologies.
3. To review the linkages between the innovations in the output from aim 1 and smart water networks.

4. To review the ICT platforms and other requirements for the innovations in the output from aim 1.

METHODOLOGY

The project was comprised of three main stages. The first main deliverable was the Technology Scan. Here, the project team identified existing and emerging cloud-based platform solutions for water loss management. A wide range of data management platforms for reducing NRW were explored. The team also delved deeper into each solution from an operational perspective and highlighted where there are overlaps and synergies between the solutions. All of this data was collected through a mixture of desktop research and interviews with the technology providers. During the third phase, case studies were obtained by interviewing water utilities on their experience of tackling water losses using technological solutions and specifically cloud-based platforms and tools, and solutions using ICT technologies. The final phase of the project entailed a critical analysis, taking into account the technology market and utility insights on how global utilities are using 'next generation' water loss solutions.

CONCLUSIONS

An increasing number of utilities around the world are looking to employ digital technologies in order to meet a range of challenges across the water life cycle, including NRW reduction. This project undertook a market analysis identifying trends and developments in leakage management technology. Smart analytics platforms, with a focus on cloud-based capabilities, is rapidly evolving, with increased competition between large and small technology providers.

The rise of cloud computing has transformed the GIS market. Cloud-based systems enable multiple users to access a GIS system at one time, whilst further enabling operators to download and publish maps to the internet. Furthermore, operators can now leverage cloud-based AI and analytics to analyse spatial data without having to install additional on-premise software or hardware.

AI is expected to be at the core of the asset management market in the future. In asset performance management (APM), AI will play an increasing role in facilitating predictive maintenance, with complex performance data automatically analysed in order to identify early warning signs of device failure. In asset investment planning (AIP), financial decisions will continue to be justified through the use of advanced algorithms, which can search datasets of potential investment decisions to identify optimal financial strategies. These solutions address a number of utility challenges but bring with it their own risks, opportunities and barriers to adoption.

It is also important to note that although new technological solutions offer a long-term pathway to infrastructure management, utilities need to be aware of caveats when choosing these technologies such as the applicability of the solution in different population densities. When choosing a technology option, it is critical for utilities to go through the various processes to decipher which solution is best suited to an operation.

Key opportunities

- **Real-time Monitoring and Predictive Maintenance**: Cloud-based platforms and AI technologies enable real-time monitoring of water infrastructure, such as pipelines, pumps, or reservoirs. Predictive analytics can identify potential failures or maintenance needs, enabling proactive actions to prevent system disruptions and optimize maintenance schedules.
- **Data integration**: Siloed data existing within separate utility departments is a key digital challenge within the sector and can place severe restraints on the level of insight an operator can gain from monitoring operations. Being able to integrate data sets in to one platform offers opportunities to better manage the whole water network long-term.
- **Public perception**: Cloud based platforms offer transparency by being able to integrate with customer communication systems and notify when leak repairs will be carried out for instance. Utilities have quoted up to 60% reduction in customer complaints due to customer transparency.
- **Using data for multiple purposes**: It is possible to pull information such as water quality from sensors and this information can be redirected and used. APIs can be used to send data to different systems from the cloud, rather than data being sent solely to a utility's leakage server for example. There are also opportunities to integrate customer billing systems. Customer meter information can be sent to billing systems and this data can be redirected to relevant places, so for example data which has previously only been used for billing can also be used for leakage targeting.
- **Enhanced decision making**: AI technologies can provide valuable insights and predictive models that support data-driven decision-making. This can help water utilities optimize energy usage, prioritize infrastructure investments, or plan for emergencies, leading to better resource allocation and cost savings.
- **Feedback:** Feedback is critical and any information of leak incidents must be recorded on the system. Once a leak is detected, localised and fixed, the system can automatically update GIS. This means utilities can make better decisions when deciding to repair leaks or replace pipes in the future.
- **Digital Maturity and 4IR Workforce:** AI technologies lend to the digital maturity of utilities and allow for new capabilities and upskilling of utility workforce. These opportunities guide strategic and operational areas of the business.

Key barriers

- **General Conservatism**: Water utilities are generally conservative when it comes to investing in new software, often preferring the stability of legacy solutions rather than embracing new digital platforms. Though GIS software is relatively common within key regional markets (e.g. North America) and climate modelling, uptake in less developed markets, specifically for water, could be impeded by this conservative culture.
- **Resistance to change within utility staff**: Research insights suggested that however ground-breaking or cutting-edge a technology is, it's full potential cannot be fully realised without behavioural change and the correct attitudes to use the system and achieve the most effective results. This speaks to the risk aversion of innovation uptake.

- **Cybersecurity**: Cybersecurity initiatives vary significantly, though intrusion detection, extensive staff training and end-user security are all key focus areas within the sector. Some larger utilities have gone one step further, simulating attacks using 'polite hackers' who are tasked with exposing flaws in digital systems. These efforts are expected to increase as legislation mandates the establishment of cybersecurity protocols in the future.
- **Lack of clear ROI:** Uptake of GIS software may be limited by a lack of clear return-on-investment associated with the software. Whereas uptake of other solutions (e.g. asset investment planning) provides clear lines of sight regarding investment returns, the cost saving potential of GIS is more ambiguous; often linked to associated improvements in network and field service management. This makes it difficult to manage risks and plan business continuity.
- **Lack of Good Data**: AI and machine learning are powerful tools but are only as good as the data available to them. A solid foundation of data collection and validation is key. In markets with ageing network infrastructure, operators may not have extensive data regarding water and wastewater systems, especially if pipes are buried and inaccessible. This lack of information severely limits the uptake of GIS software platforms, which rely on the digital cataloguing of utility assets during integration periods.
- **Skills Gap**: Access to cloud-based platforms and AI technologies may be limited in certain regions or organizations due to factors like infrastructure development or affordability. Additionally, there may be a skills gap, requiring specialized expertise to implement and leverage these technologies effectively.
- **Uncertainty over technology costs:** Technology costs have the potential to rise (as has been seen in 2021 with a global shortage of microprocessor chips), but they can also reduce if market pressures, and efficiencies are exploited. It is unclear how the industrialisation strategies and plans for SA support ICT uptake incentives in strategic sectors such as water.

Recommendations and focus areas for improvement

- Ensuring intra-organisational/departmental alignment across the utility results in utility-wide benefits. Unlocking data from legacy systems, centralising existing datasets and adopting common data standards at the utility level, are all crucial to providing better data accessibility.
- The benefits of sharing and integrating data should not be measured only in a specific project's ROI, but also in the possibilities for further development that it can facilitate. Helping utilities foster innovation and interdepartmental collaboration is an important part of this. Running successful pilots is a good way to demonstrate this value. Utilities should look to engage with partners such as SALGA to develop, test and pilot new technologies for NRW reduction.
- Implementation of digital solutions requires clear objectives against which to measure success. Without this, valuable data and functionalities can sit unused in a utility's system. Outcome-oriented digitisation requires an organisation-wide culture shift. Helping utilities prioritise data literacy in training and recruitment and democratise access to data across the organisation, are important steps in this. Utility staff will also

need to be able to better communicate across departments. Crucial to successful implementation is understanding what is realistically possible and not over-reaching.

- As utilities increasingly look to employ digital technologies in order to meet a range of challenges across the water lifecycle, absorbing technical knowledge from other industries remains a key avenue for developing digital competencies. Collaboration between other industries can overcome practical challenges. This is especially the case when it comes to applications of AI, which have a rich history in other industries such as manufacturing and pharma. One fertile application for absorbing AI competencies lies in construction, where data-driven approaches have been harnessed in order to optimise material use, capital investment and carbon impacts.
- Addressing utility concerns over data security and cybersecurity, a central hub should be implemented which would be managed by a neutral science council such as the WRC's Research Observatory or housed by the eminent Water Infrastructure Agency.
- To overcome reluctance to take on the challenges of change management or risks of failure that come with it, a roll-out of change management and skills development programmes should be implemented alongside technology demonstrations. This will build long-term capabilities as well as short-term capabilities through technology vendor support.
- Methods of enhancing the effectiveness of the technologies was also discussed and multiple utilities highlighted the need to make zones/DMAs smaller with additional flow meters. The optimal DMA size was recommended as 500-1200 properties.
- Extending focus to Transmission Mains Areas was another operational point highlighted. NRW has historically been in distribution mains but transmission mains should also be paid attention to, because if they fail then customers cannot receive water.

- **Further research areas**
    - While this project was centred around next generation solutions to detect leaks, sometimes pipes cannot be repaired repeatedly and may need replacement. Improved repair techniques will be an enabler for future. The development of innovative repair techniques, e.g. in-pipe or keyhole type repairs. If the techniques do not develop in time, this may result in a tipping point where find and fix becomes too expensive.
    - Further research should be done on remote sensing using drones and/ or satellite imagery which have potential uses of vegetation indexing, ground movement or chlorine detection to identify leakage. Relatively new techniques and cost-benefits need to be fully assessed under a variety of different seasonal conditions and spatial variation could impact on benefit. Similar innovations have been taken to market by companies such as SUEZ in Belgium.
    - Permanently deployed loggers and sensors often have constraints related to battery lifetime. The idea of self-powered loggers that run of off the flow of the water is a novel area, requiring intensive further research to bring the idea to reality. Alternate energy sources to power such devices should also be further explored.

- **Policy and frameworks**
    - Although promising conceptual and technological solutions to protect water systems' security and resilience are available, further work is required to bring

them together in an overarching risk management framework, strengthen the capacities of water utilities to protect their systems systematically, determine gaps in security technologies and improve their risk management approaches and technologies. Defending critical infrastructure is a cat-and-mouse game, forcing water utilities to stay on guard, innovate constantly, and implement new technologies.

- Policy frameworks require integration between the Department of Water and Sanitation (DWS) and Science and Innovation (DSI). This could be facilitated by the WRC to provide an enabling environment for utilities to invest.
- Countries with strict regulatory targets that impose financial penalties for high leakage rates, such as the UK and Denmark, have provided particularly appealing markets to leak detection vendors, and hence innovation uptake in these parts of the world is greater. Stricter regulation is required whereby NRW targets are set and penalties issued if they are not met.

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ACRONYMS & ABBREVIATIONS

AI	Artificial intelligence
API	Application programming interface
CSV	Comma separated values
DMA	District metered area
DSI	Department of Science and Innovation
DWS	Department of Water and Sanitation
GIS	Geographic information system
ICT	Information and communications technology
ILI	Infrastructure Leakage Index
IoT	Internet of things
LPWANs	Low-power wide-area networks
NBIoT	NarrowBand-Internet of Things
NRW	Non-revenue water
PMAC	Parallelizable message authentication code
ROI	Return On Investment
SaaS	Software as a service
SCADA	Supervisory control and data acquisition
SFTP	Secure file transfer protocol
SWPN	Strategic Water Partners Network
TRL	Technology readiness level
VPN	Virtual private network
WCWDC	Water Conservation and Water Demand Management
WRC	Water Research Commission

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CHAPTER 1: BACKGROUND

Introduction

The National Development Plan – 2030 (National Planning Commission, 2012) states that reducing growth in water demand is just as important as increasing its supply. The National Development Plan assumes it to be possible to achieve an average reduction in water demand of 15% below baseline levels (i.e. business-as usual levels in 2012) in urban areas by 2030. Detailed targets have been set for different areas through the Reconciliation Strategies and the All-Town Studies. Achieving demand reductions on this scale will require active programmes to reduce water leakage in distribution networks.

The First Order No Drop Assessment Report 2014 (Department of Water and Sanitation and Strategic Water Partners Network, 2015) showed that although the national average of total NRW is 34.6%, the NRW varied from province to province in the range of ~20% to ~45%. Seven of the nine provinces had NRW in excess of 30%, which is the benchmark for poor performance.

South African bulk and domestic water service providers and authorities are under increasing pressure to address the growing concern of water losses from drinking water distribution networks. The annual water loss is breaching 50% of total water supply which directly affects the availability of water for domestic and industrial use, and indirectly lowers the amount of water available for agriculture.

Further, the cost from abstraction, treatment and supply of lost water is energy intensive and unsustainable that is exacerbated with higher demands placed on water usage. NRW can also cause damage and risk to other sectors and infrastructure such as property and roads. Leaking pipes increase costs to other areas increasing public sector maintenance responsibilities. Many water utilities are reviewing strategies to reduce water losses, and this is driving the growth of cloud-based data management systems and artificial intelligence technologies.

Most existing water network infrastructure still requires operators and engineers to understand and anticipate how to respond to continuous changes in the hopes that more sustainable and efficient operations can be achieved.

Real-time data from existing water network assets and monitoring technologies is acquired, and can inform conventional human-driven, trial-and-error process adaptation and optimisation approaches. However, even well-trained operators and engineers with access to 'big data' require time to process, analyse, normalise, trend out and predict what operational changes need to be made at any given time. Such delays in response time can lead to increased water losses. The amount of real time, as a consequence or more real time sensors and cheap and robust data transfer through 'Internet of Things' (IoT) connections, is likely to continue to grow. Growing concern about NRW has spurred a surge of innovation in the leak management sector that has seen both established players and insurgent upstarts bring game changing digital technology to the market. In recent years, the smart water market has boomed with many new types of smart water solution introduced, in particular for water distribution networks. There are four main ways in which water utilities currently use digital solutions to enhance their networks:

- Smart water metering: This is the largest sector of the smart water solutions market for drinking water networks. Smart metering can be used to reduce NRW by improving billing and can contribute towards leak identification and customer service.

- Smart leakage management: This involves preventing leaks by monitoring pressure using sensors, and thus reducing damage to the network that can be caused by excessive pressure. It also involves carrying out strategic repairs and detecting and swiftly responding to leaks when they do occur. It is the largest market for smart technologies for drinking water networks after smart metering.

- Smart water quality management: Smart water quality sensors provide instant contamination alerts to utilities, ensuring that customers receive safe water as well as providing utilities with useful information about the status of their networks.

- Smart network optimisation: The aim of this is to improve operating efficiency, process management and asset management throughout the drinking water network. This is increasingly being achieved through the uptake of optimisation software solutions.

Contextualisation

Leaky pipes contribute to higher costs for water production and supply whilst further deteriorating distribution networks from bursts. The challenges associated with water losses are identifying the location of leaks and timely triage for repair and appropriate maintenance.

Water losses comprise the leakage and wastage from the distribution network; these and other components of non-legitimate use are categorised as:

• Apparent losses: source and supply meter errors, unauthorised or unrecorded consumption.

• Real losses: leakage from transmission and distribution mains and service pipes upstream of
consumers' meters, from valves, hydrants and washouts and leakage and overflows from the water
utility's storage facilities.

Since most of the water pipes are buried underground, it is common for leaks to occur and go unnoticed, contributing to major water supply losses until customers are directly affected by supply or disruption. This problem occurs from not having a good understanding of pipe networks and their state.

There are several methods for detecting water distribution leaks and involve the use of sensors at the physical infrastructural level. Data collected from network assets can be cleansed and analysed using cloud-based platforms to provide operators with a detailed knowledge of the conditions in the network that can be visualised using GIS capabilities. The rapid development of the telecommunication/information and communication technologies (ICT) provide a unique opportunity for water stakeholders to obtain information in real time and to act quickly in response to water loss events. Using digital technologies, the water network can be monitored in real-time and can proactively respond to sudden network events with appropriate diagnostics and decision support outputs, e.g. identifying leaks early and preventing them from becoming larger leaks. In addition, some cloud-based technologies incorporate report generation for regulatory compliance monitoring. Advances in artificial intelligence and machine learning can detect patterns of water usage to predict consumption levels that may vary to help water supply and planning measures.

Outcomes and Expected Impacts of Research

The project will result in two outcomes:
- Report on trends and developments on water loss management
- Position paper and technical brief

At the end of the project, WRC will have an understanding on the innovative technology options available to reduce water losses, and knowledge of trends and developments to provide a pathway to improvement. The research conducted on alternative solutions will inform policy and can feed into wider water loss management strategies, including links to smart water networks management and utilisation of ICT technologies for rapid response and remote monitoring. Successful case studies will provide a rationale to water business decision makers the need to invest in technology to deliver reduced network leakage and better monitoring to help with decision-making.

Knowledge Contributions: While there may be existing data available from water networks, the challenges experienced in utilising it for actionable intelligence remain. Cloud based systems give water utility operators a comprehensive understanding of water network behaviour and event management capabilities. In addition, the application of AI and machine learning algorithms can help to prioritise leak detection, repair activities, and even forecast future water losses that ultimately allow water utilities to run their networks more efficiently to reduce losses.

Economy: The National Water Balance for the 2012/13 audit year showed a total NRW of 1 038.05 million kl/annum. Calculated at a unit cost of R6 /kl, this amounts to R 6 228 million per annum for the country as a whole. The potential financial saving to be made by addressing the root causes of NRW amounts to R1 989.87 million. Since South Africa's socio-economic development is currently constrained by access to utilities (water and electricity), a potential saving of almost R2 billion is worth investing in. This can be broken down into various sub-components, including the cost to abstract, treat and supply the water, which involves a significant amount of energy and chemicals. The proposed technology scan has the potential to identify solutions that can reduce costs associated with water loss.

Environment and Society: Improving water supply management will benefit both the environment and society from reducing stress and abstraction on water resources that are scarce; and providing water that is affordable to promote sustainable development and support the livelihoods of the public.

Informing Policy and Decision Making: The position paper will inform the regulators and water service
providers about solution, new developments and tools available for the management of water losses.

Sustainable Development Solutions: Reducing NRW reduces water demand overall and achieves a lower requirement for energy and chemicals at water treatment works. Reductions in energy consumption also extend to pumping booster stations and are a straightforward way to save electricity and therefore greenhouse gas emissions.

Empowerment of Communities: Not applicable.

New Products and Services for Economic Development: As utilities begin to embrace the digital future, they will look to raise their awareness of the diverse set of savings that can be achieved through the optimisation and efficiency of assets and operations that these types of solutions provide. The savings from monitoring, automation, and control are staggering and have the potential to save in the region of US$320 billion from 2022 to 2026 in an array of utility capital and operational spending.

Scope and Limitations

The project spun the course of two years, with the aim of identifying and reviewing emerging solutions to address water loss management and learning from best practice in the industry. Water loss tracking and management consists of four fundamental pillars: pressure management, active leak detection, asset condition monitoring and smart analytics. While each technology performs a vital role in controlling leakage, few utilities have integrated all the technologies together.

The initial technology scan was completed by Isle through a desktop scan of existing literature and Isle's own Technology Portal. Case studies were selected, and the utilities interviewed on their experiences of tackling water losses using technological solutions. Both of these phases of the project were open to human errors. Human error is an action or decision taken that is unintentional such as missing a step when undertaking a task. Unreliability of interviews can arise due to misinterpretations made by the subject, incorrect transcriptions, failure to ask certain question during the interviews, the possibility of manipulated entries, and withholding of potentially key information. These limitations can be somewhat restricted through improved question clarity and rephrasing. Human error is impossible to eliminate entirely, however the use of regular review techniques such as checklists will significantly limit the chance of human error becoming an issue throughout the project.

Project Aims

The following were the aims of the project:

1. To conduct an international and national scan of new and emerging solutions to address water loss management, including technologies, tools, and operating methods.
2. To find and capture lessons learned from relevant successful case studies of utilities using water loss management technologies.
3. To review the ICT platforms and other requirements for the innovations in the output from aim 1.

CHAPTER 2: METHODOLOGY

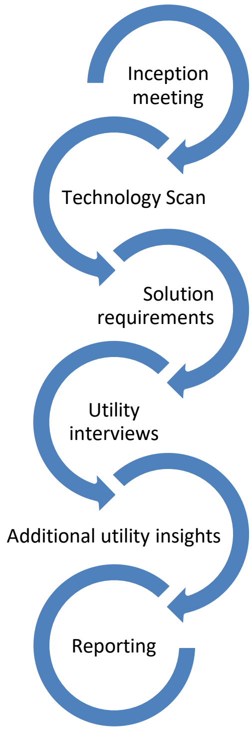

Figure 1: Schematic outlining the key milestones in the project process.

The project kicked off with an inception meeting between the WRC Reference Group and project team. This meeting went through the project requirements to ensure that the project will deliver the expected results and to also agree on the format and timeline. The technology landscape for water loss management applications was reviewed to discuss specific areas of interest and to highlight any project boundaries determined by regulatory, strategic and/or procurement frameworks.

Necessary search parameters/criteria for Isle to abide by (e.g. stage of technological development, supply logistics to the UK market, etc.) was also confirmed. Isle captured all of the agreed information and circulated a project definition document to confirm focus areas for the technology scan and the criteria headings that would be used to collect information.

The project team prepared and presented a list of criteria to allow the review of each technology identified. After establishing the matrix criteria, the team circulated it to the WRC Reference Group before the technology scan was undertaken to ensure that all the relevant information was collected. The criteria included generic information on the company including company name, technology name and contact details for representatives. The Technology Readiness Level (TRL) of the technology was provided and this indicates the stage of development for solutions. The installation and operational requirements were obtained along with the costs of using the technology.

It is common that cloud-based solutions employ software as a service (SaaS) procurement mechanism and this or any other business models were captured.

For the scanning phase, a wide range of data management platforms for reducing NRW were explored. The methods of data collection for this task included a desktop review of literature by Isle, making use of Isle's technology portal. Since 2010, Isle has scouted over 6000 technologies specifically for the water sector and has built an online Technology Portal which contains solutions from various categories such as treatment and resource recovery to sensors and monitoring. The portal houses information on each technology including description, application, TRL, unique selling point, company location, case studies and costs. Technology case studies were described to highlight successful applications and deployments to improve water loss management. Case studies published by technology providers included information on the number of installations, geography of installations and references to specific water utilities and the outcomes.

Following the horizon scan stage, the team utilised its extensive contacts portfolio to engage with the relevant technologies that matched the initial search criteria. This was done by means of predominantly emailing and setting up calls to discuss each solutions ecosystem requirements in terms of ICT platform, installation, operation and other practical factors for implementation. How the solution plays into a 'smart water network' was also explored. Specific questions posed to the supplier included:

- What Pre-existing installation requirements you have from the water utility?
- Solution requirements in terms of ICT platforms
- If there are no pre-existing installation requirements, then what will set up and installation look like?
- Does the installation require special training?
- What are the operational requirements?
- Installation and operational costs

The third main stage of this project was gaining key utility insights. Case studies were obtained by interviewing water utilities on their experience of tackling water losses using technological solutions and specifically cloud-based platforms and tools. As set out in the proposal and initial reference group meeting, the overall aim of the project is to identify applicable technologies for water loss tracking to support NRW reduction and the project will focus on uncovering cloud-based technologies as the 'next generation' solutions. Narrowing the focus means that more meaningful deliverables can be output from this project, such as the Technology Scan – which would be far too extensive if all aspects if all digital leakage technologies were explored.

Three successful case studies were found, and interviews were conducted with the relevant utilities: De Watergroep (Belgium), Johannesburg Water (South Africa) and Sydney Water (Australia).

The team identified suitable companies for interviewing and research outreach within its global network of water utilities. The sampling criteria was to select those that have adopted cloud-based water loss management for knowledge sharing, specifically any technologies that were identified in the Technology Scan (Deliverable 2). Generally, the main approach used to identify relevant utilities to interview was to:

- analyse the Technology Scan to discover which utilities had installed new and emerging cloud-based solutions;
- focus on utilities which had ambitious NRW targets; and
- explore those which operate in drought prone or water scarce regions where reducing leakage becomes even more critical.

Prior to the interviews taking place, a list of interview questions was put together and circulated to the Reference Group and Research Manager, allowing them to make comments, changes, or additions to the interview questions, based on what the WRC and sector representatives would find most beneficial to them. After taking the group's feedback into account and making some additions, the final list of questions used was finalised and is stated below. It should be noted that there may be a few additional questions that were asked in each interview in order to probe if the initial question was not answered, and if it would have improved the richness of the study.

The following semi-structured questions list was used:

- What cloud-based water loss management system or systems were utilised?
- How was this technology selected?
- How would you describe the process of implementing the system?
- What were the challenges of implementing the water loss management system?
- Have you seen a reduction in leakage as a result of implementing this technology?
- What was the technology procurement process like? What were the barriers, if any?
- What additional resources were required, not provided by the technology, to implement the
  technology successfully? (e.g. human resources, additional skills)
- Implementation of new technology has implications for human resources, e.g. training, change in the way of doing business, change in workload, eagerness to implement new technology, etc.
- From a purely financial perspective, was the cost of investment in the technology worth the cost of water lost?
- How easy would it be to change to another technology / service provider?

The final stage of the project is to report back all of the key insights and trends uncovered throughout. This stage included analysing the current status of how leakage is being managed/reduced globally and learning from utilities around the world about what they are doing to reduce NRW from a forward-thinking and Next Generation perspective. A technology market analysis was done, synthesising information from the Technology Scan, utility interviews to present key trends and developments.

CHAPTER 3: CURRENT STATUS OF NRW MANAGEMENT

In order to explore new technological advancements to manage NRW, it is important to understand the current status of NRW management including why it is so crucial to utilities to reduce NRW and the wider environmental effects as well as what approaches are most commonly being taken to reduce leakage from a technology point of view.

Motivation

- **Financial sustainability:** Reducing NRW can lead to significant cost savings for water utilities. By minimising leaks, optimising distribution networks, and improving efficiency, utilities can lower their operational costs associated with pumping, treatment, and energy consumption on "wasted resources".
- **Customer Expectations and Satisfaction:** As with other consumer-facing services in developed countries, expectations are higher than ever before, and utilities are working hard to ensure stable and high-quality services. High levels of NRW can result in water supply disruptions, low pressure, and unreliable service, leading to customer dissatisfaction. By reducing NRW, utilities can ensure consistent water supply, improve service reliability, and enhance customer satisfaction. Reducing NRW demonstrates a water utility's commitment to serving its community and being socially responsible. It shows a dedication to efficient resource management, water conservation, and sustainable development.
- **Environmental Sustainability and Increased Water Scarcity**: Addressing NRW contributes to environmental sustainability by reducing unnecessary water abstraction. It helps conserve valuable water resources, promotes sustainable water management practices, and aligns with the broader goal of environmental stewardship.
- **Regulatory Compliance**: Many regulatory frameworks require water utilities to meet specific targets for NRW reduction. Utilities that fail to meet these targets may face penalties, reputational damage, or limitations on their operations. Therefore, complying with regulatory requirements is a strong motivation for utilities to actively reduce NRW.
- **Public perception**: Even if a utility is not bound by strict penalties for not achieving leakage targets, it is very much in their interest to prioritise reduction of NRW due to the public having higher expectations from their utility from a constitutional, social and environmental perspective. Utilities may have their own targets to reduce their Infrastructure Leakage Index (ILI).
    - *The Infrastructure Leakage Index (ILI) is often used as an alternative to percentages when quantifying the real or physical leakage. The ILI is an empirical measure to look at the losses of a company compared to the theoretical minimum losses that would be expected on the network. The ILI uses the length of network, customers and pressure to produce the theoretical minimum losses that could be expected. The ILI indicator is a simple index which typically ranges from 1 in very well managed*

systems to over 100 in very badly managed systems. The average ILI value for all of the South African Municipalities was estimated to be 6.8, which is worse than most developed countries but better than most developing countries. (WRC, THE STATE OF NON-REVENUE WATER IN SOUTH AFRICA 2012.

- **Water Resource Planning**: Managing NRW allows utilities to accurately assess water availability and plan for future water demand. By understanding their water losses, utilities can make informed decisions about water infrastructure investments, resource allocation, and long-term water supply planning.

Water Energy Nexus

Commonly when a utility is putting forward a business case to reduce NRW, the predominant motivator is to save money through reducing water wastage and preserving natural resources. However, in recent times, the role of the Water Energy Nexus and how Energy and Water are highly interlinked is becoming an increasing priority for water utilities worldwide.

While energy costs are so high, efficiency is being prioritised more by utilities worldwide. This is driving spending in control infrastructure to help utilities optimise energy usage. As significant users of energy resources, utilities are increasingly under scrutiny regarding their carbon footprint. With utilities around the world setting targets for net zero and the price of energy soaring, the need to optimise energy efficiency is now greater than ever before. Network pumping is a highly energy intensive process which is driving utilities to increasingly rely on software platforms to offer decision support.

South Africa in particular has been experiencing an energy crisis characterised by frequent power outages and supply constraints. The energy crisis in South Africa is primarily driven by:

- Aging Infrastructure: South Africa's power infrastructure, particularly the utility Eskom's coal-fired power plants, is aging and requires significant investment for maintenance and upgrades.
- Insufficient Generation Capacity exasperated by Population Growth: The demand for electricity in South Africa has outpaced the growth in generation capacity. As a result, there is a supply-demand imbalance, leading to inadequate electricity supply and rolling blackouts known as "load shedding."
- Dependence on Coal: South Africa heavily relies on coal for power generation, which poses challenges due to issues of affordability, environmental concerns, water consumption and pollution and the need to transition to cleaner and more sustainable energy sources.
- Financial Challenges: Eskom, the country's primary electricity provider, has faced financial difficulties due to a combination of factors, including high debt levels, operational inefficiencies, and revenue collection challenges. These

financial constraints have limited Eskom's ability to invest in infrastructure upgrades and new power projects.

- Political Willingness: This has been raised through various platforms on the water sector's consideration, uptake and adoption of renewable and alternate energy sources to maintain consistent supply.

Non-Revenue Water and Energy Relationship

The presence of NRW directly impacts a utility's energy consumption. According to the latest GWI energy efficiency research, water distribution networks are the second largest consumer of energy in the conventional utility water cycle (after wastewater treatment and excluding desalination and sludge). For utilities with net zero commitments and those in locations with high electricity costs, pumping optimisation across the distribution network and treatment plants is fast becoming a priority. For example, optimal pump scheduling has saved the City of Toronto $1 million (R14.3M) in energy costs annually while Evides NV has reduced energy use at pumping stations by 33% through implementing a hydraulic digital twin of its supply network.

High rates of NRW also have a detrimental impact on Carbon Dioxide emissions. The current estimated figure for NRW is 126 billion m^3/year which equates to 187.2 million metric tons CO_2/year. This figure is one third of the CO_2 produced from Aviation, which is quite alarming.

The International Water Association (IWA) has carried out studies trying to understand the global impact of NRW on greenhouse gas emissions and it has been estimated that the global volume of NRW is 126 billion m^3/year which equates to $39 billion/year (R750B). To offset the current carbon emissions due to real losses, 218.4Ha of trees need to be planted, which equates to one quarter of the land size of Brazil. It is clearly not feasible to take such largescale actions such as planting this many trees, so it places more emphasis on the need to make serious efforts to reduce their NRW. (R. Liemberger & A. Wyatt)

Current Approaches

In spite of major advances in the efficiency and cost-effectiveness of leak management technologies, they are still mostly the preserve of advanced utilities. For less advanced utilities, mainly (but not exclusively) in the developing world, the first step is usually to invest first in network awareness tools, sectorising the network and pressure management before installing active leak detection technologies. The most advanced utilities, in places like the UK and Singapore, are increasingly interested in smart analytics platforms that sit on top of all their digital tools, aggregating information across the network to deliver actionable insights.

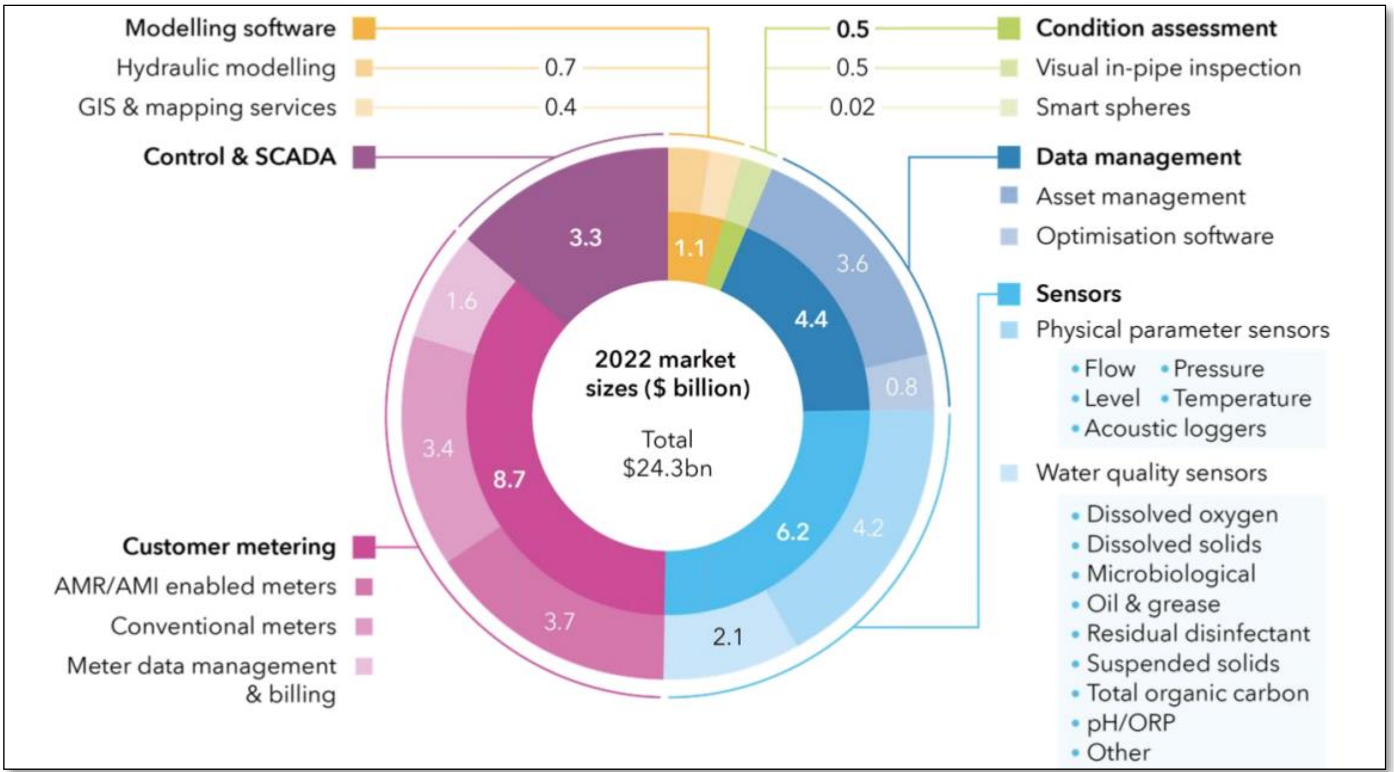

Figure 2: Pie chart showing the 2022 market breakdown in terms of leakage solutions, GWI Water 2021

Smart Meters

Smart meters, also known as advanced metering infrastructure (AMI), have an increasingly prominent role to play in reducing leakage in household and service pipes as they are fitted with more advanced remote connection capabilities and acoustic sensors. It is estimated that 30-40% of leakage is on the customer side, as opposed to the mains, so innovations in this sector are likely to yield major commercial opportunities. The WRC project titled 'Smart Water Metering Trends, Risks, Opportunities and Policy' has recently kicked off and will explore the role of enhanced smart water metering and its capabilities for NRW reduction. The role of smart meters has not been looked into extensively for this current project, as the focus is more around Next Generation Leakage solutions.

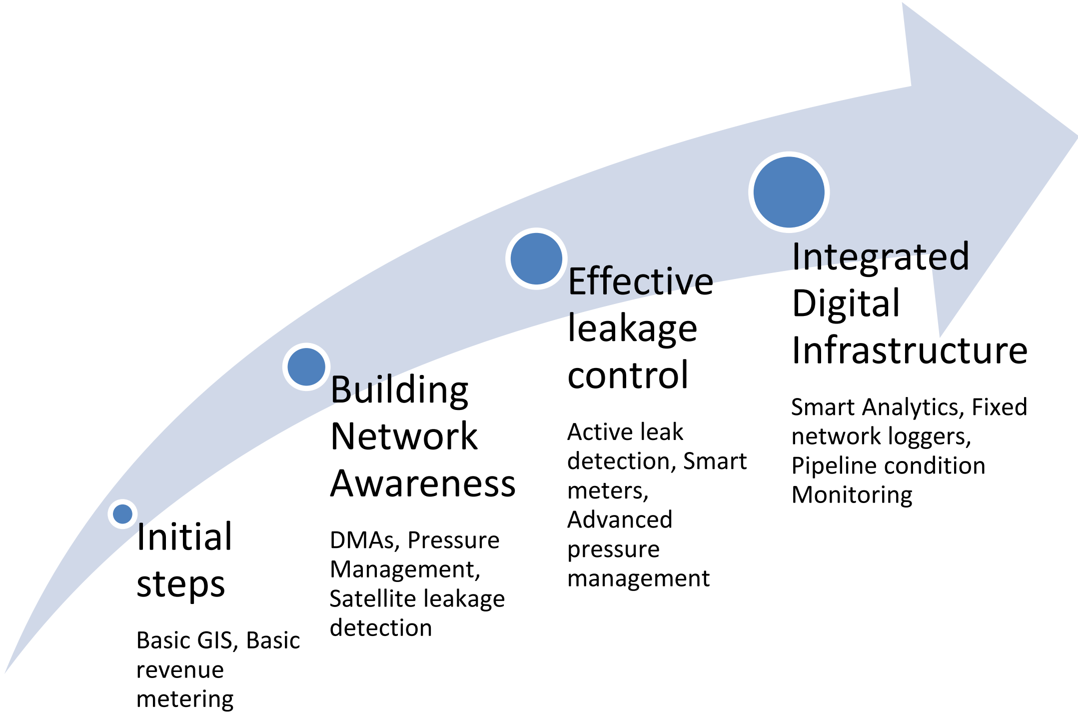

Figure 3: Stages of Digital leak management maturity in utilities, GWI Water 2021

Establishing basic network awareness

Referencing figure 3 above, an essential first step for utilities starting from 'square one' is to establish basic network awareness, involving SCADA systems to enable remote control and monitoring of sites across the network, a basic geographic information system (GIS) to plot data on maps and some input metering for measuring water entering the network. The WRC Digital Maturity Project (DUMA) has highlighted this as a key area for improvement.

Pressure Management at Cape Town

The initial method for managing leakage, is not to allow leaks to occur in the first place. This is largely done through asset renewal, pressure management and network calming. For utilities with high leakage rates, pressure management is often the most cost effective-solution and consequently is favoured by many utilities that are not yet in a technological or financial position to roll out advanced leak detection on a mass scale. Johannesburg Water for example has been using a technology called Zednet to indicate the pressure at critical points to enable pressure management and reduce background leakage.

Cape Town, South Africa, is another utility that relied heavily on a technology from i2O to manage pressure and reduce leakage during its 2017-18 'Day Zero' water crisis. As population was growing from 2.9 million to 3.7 million in the past decade, and was expected to reach 4.4 million by 2020, Cape Town's water supply was under severe strain. An average main burst frequency of 21 bursts per 100km per year and a 21%

leakage rate meant the City of Cape Town (CoCT) needed to find more effective ways of managing pressure in its water distribution network.

The city had already established District Metered Areas (DMAs) and installed pressure reducing valves (PRVs) for basic pressure management, but they were keen to reduce pressure further to tackle leakages and burst pipe problems. Referencing figure 3, CoCT had already built their network awareness and wanted to move to effective leakage control through advanced pressure management.

A two-phase trial was run in the Eersterivier PRV zone, which comprised 89.3km of mains and 6,218 connections. In the first phase, the solution successfully maintained a constant critical point pressure of 27m, which had previously averaged 34.5m during peak periods and 37m in off-peak. In the second phase, it was set to target critical point pressures of 27m during peak periods and 23m during off peak.

The advanced pressure management scheme was a success and achieved:

- 58% reduction in burst frequency.
- 38% reduction in leakage – minimising wastage and improving customer service levels.
- Average critical point pressure reduction by 27% during peak periods and 26% in off-peak periods.
- Annual savings of more than R7mil through rolling out the installation to 15 DMAs.
- Extended asset life by more than 5 years.

Along with i2O, The City of Cape Town has also been using Technolog loggers since circa 2004. The data from these loggers is sent to a Technolog portal and from there it is pushed to a Zednet platform for hosting. Technolog is based in the UK but they have WRP as a distributor in South Africa, making the solution readily available in the region. Currently, Technolog is used in 20 of CoCT's zones and has proved efficient value for money and has achieved good results through ongoing monitoring. At a few sites such as Mitchells Plain, CoCT replaced Technolog with i2O. With Technolog, CoCT staff were not able to make changes and would have to contact the service provider to make any changes whereas i2O allows intelligent control.

CoCT noted that vandalism was an issue with the Technolog loggers however actions were taken to reduce this such as housing the loggers in chambers, preventing access to chambers and using special keys to access the chambers. These actions have massively helped in vandalism mitigation.

In the future, CoCT would ideally want to find a solution that connects to their internal site rather than data being sent to off-shore servers.

Pressure Management Restraints

It should be noted that while the impact of pressure management reduced NRW, it can sometimes to be counterintuitive in terms of leak localisation. Lowering pressure means less water is being pumped into the network, meaning leaks become smaller and more difficult to detect and localise. Over time, these small undetected leaks can have a much larger effect.

Effective leakage control

Active leak detection technologies, such as acoustic loggers, are most commonly used in utilities that have already invested heavily in digital development as they require data on where the high-risk leakage zones are to be deployed most efficiently. Countries with strict regulatory targets that impose financial penalties for high leakage rates, such as the UK and Denmark, have provided particularly appealing markets to leak detection vendors.

Some sectorisation in the form of DMAs is usually a prerequisite requirement. Permanently deployed sensors, such as fixed network loggers and pressure transient monitors, are also expensive to install and maintain due to the demands of battery replacement. It is therefore utilities with large budgets, usually in developed countries, that have the most experience with this type of technology.

Top level of digital development

Owning a reputation for being innovative and cutting edge is a key factor in motivating the most advanced utilities to invest in emerging technologies. The types of technologies that are emerging in the market will be discussed in the following chapter.

PALM Model

In the water sector, different variations of the PALM model are used to describe how NRW is managed. The "leak life cycle" is broken into 4 phases shown below in Figure 4:

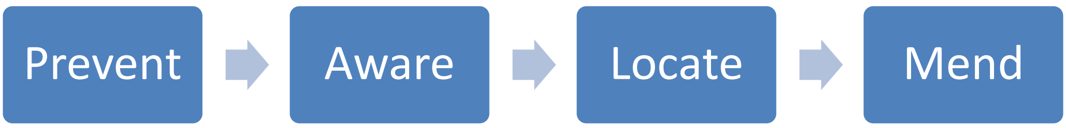

Figure 4: The PALM model for NRW management (Water UK A leakage Routemap to 2050, 2022)

Figure 3 showed the stages of Digital leak management maturity in utilities and covered how leaks are prevented, discovered and located from a digital perspective. This project focuses on digital solutions. However, several utilities have expressed the need

to not neglect the Mend stage in the model. The Water Research Centre (Independent Centre of Excellence for Innovation and Growth, based in the UK, has emphasised that for successful leakage management all aspects of PALM are needed to manage NRW effectively. If a pipe consistently leaks then despite being able to actively detect, localise and repair leaks, the fundamental issue of a leaky pipe still pertains. For the longer-term it is better to mend a pipe rather than repairing on a very frequent basis.
Fixing leaks is normally carried out through digging a hole and either a clamp being applied to the leak, or a small section of main is cut out and replaced. Generally, mending the pipes accounts for approximately 80% of the total cost of the “find and fix” process. In areas where there is a dense population and crowding of underground utility networks can typically make some small footprint techniques less effective, and this is an area requiring further innovation.

To date there has been limited research and development in improvements in repair techniques, however technology is starting to emerge that some companies are using to reduce the footprint of repairs.

CHAPTER 4: TRENDS AND DEVELOPMENTS IN THE TECHNOLOGY MARKET

With examples of successful implementation piling up worldwide and squeezed utility budgets highlighting the need for cost-effective water savings in the wake of COVID-19, the case for digital transformation is becoming stronger and stronger. However, for every early adopter there are many more utilities that are reluctant or unable to move forward with digital leak reduction programmes. Barriers to adoption can range from the lack of larger-scale demonstrations in a sufficiently similar context, concerns over control and security surrounding sensitive data, or reluctance to take on the challenges of change management or risks of failure that come with it.

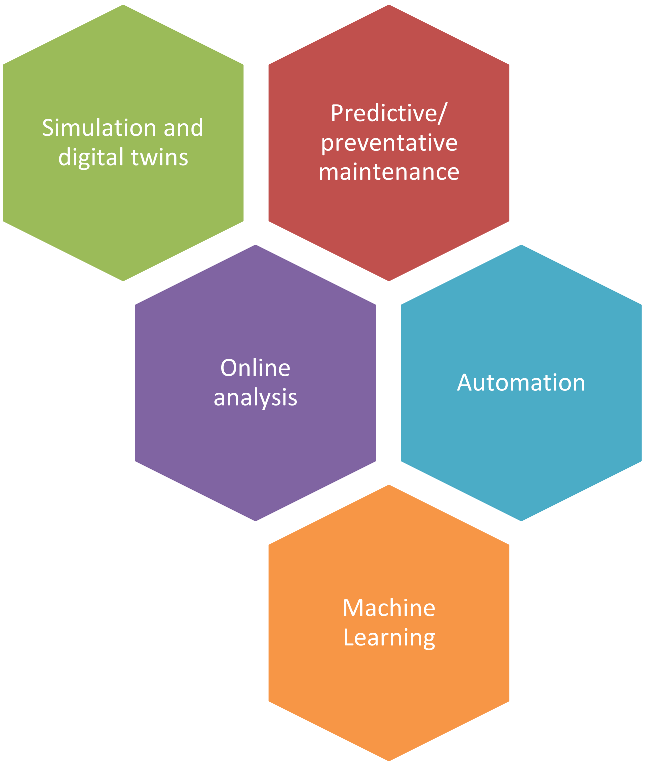

Figure 5: Schematic showing the key areas and opportunities in digital leak management, GWI

Breaking down the key opportunities in figure 5, the types of emerging technologies are summarised below.

Pipe condition monitoring

The advantage of pipeline condition assessment is in determining where leaks are likely to happen before they occur. Many new technologies have emerged in recent years to fill this niche. One of the most widely adopted of these is Mueller's Echologics solution range, which uses acoustic signals to examine the integrity of pipelines and predicts the likelihood of failure. These capabilities have been enhanced using VODA.ai's machine learning engine following a partnership announced in September 2020. This technology has been used on a large scale by utilities such as PUB in Singapore and SES Water in the UK. The technology is shown to be effective, but it can cost up to $8000 per kilometre of pipe to inspect, making it prohibitively expensive for many utilities. A new alternative is Electro Scan, which uses electrical signals to find defects in the pipes more accurately than any other existing technology, though it has not yet been widely used beyond the trial stage.

Invasive technologies

Several invasive technologies are beginning to see utility adoption, especially within wide diameter transmission mains, where above-ground acoustic sensors are not as effective. These include Pure Technologies' SmartBall, where a ball packed with acoustic sensors travels along a pipe, identifying defects such as air pockets and unevenness in the pipe surface. Aganova offers a similar solution called Nautilus, which also consists of a sphere that is inserted into wide diameter pipes and listens for leaks. The Canadian start-up Ingu has developed an acoustic smart sphere capable of sensing additional variables, including in-pipe temperature. For more information on these devices, see Smart Spheres. Though utility application of smart sphere devices is currently low, other tethered acoustic solutions have been more widely adopted, such as Pure Technologies' Sahara platform, which has been extensively used by Thames Water for trunk main inspection. The device uses CCTV capabilities to accurately detect leaks over a 2km area, though the solution usually requires the installation of expensive additional infrastructure, such as pits, that can cost up to R577k.

Satellite and aerial imagery

Another increasingly popular innovation is satellite and aerial image analysis. Satellites are capable of taking high resolution pictures using synthetic aperture radar sensors (SAR) to send and receive electromagnetic signals that penetrate the earth and pick up the spectral signature of potable water in the ground. It can cost up to $3000 to assess each kilometre of pipe in this way, making it reasonably expensive, and it is also unlikely to find all the leaks in an area, so it is mostly used in conjunction with other technologies, or in sparse, rural areas where there is no alternative. Planes and drones can be used to gather imagery more quickly, though drones take longer to cover an area. The market for satellite imagery in water is still small, led by start-ups with software engineering backgrounds, namely Utilis and Rezatec. Utilis actively pinpoint leaks, while Rezatec produces risk maps to determine where leaks are most likely to occur. Both have partnered with Suez and are actively seeking opportunities with utilities in North America, the UK and Europe.

Communication tech

The arrival of NBIoT communications has created exciting new potential for a whole range of fixed network devices, such as acoustic loggers, pressure transient monitors and PRVs. NB-IoT uses the 4G and 5G spectrum, which can carry significantly more data than 3G, and has much deeper penetration so signal can still be received underground and through boundary boxes or hydrants with heavy lids. Long range, wide area network (LoRaWAN) communications have helped bring digital technology to less developed markets.

LoRaWAN gateways can communicate over a range of 30km, use very little energy and operate on free-to-use unlicensed bandwidths, making them highly cost effective in areas with little infrastructure.

Virtual DMAs

Virtual district metered areas (VDMAs) leverage real-time consumption data from smart meters along with acoustic correlators and hydraulic modelling to identify anomalies in the water flow. Rather than physically dividing and closing certain areas of the network with valves, as is done in traditional DMAs, smart technologies leave the network “open” by placing sensors at strategic points, delimiting the virtual area. VDMAs have the same objective as conventional DMAs – identifying areas of the network which require a more detailed inspection. Conventional DMAs are currently less costly than VDMAs due to the high expense of purchasing large numbers of sensors. However, if the cost of sensors continues to fall, VDMAs may eventually be the more cost-effective option, considering conventional DMAs entail the cost and inconvenience of installing flow meters and boundary valves which can in turn reduce the network’s hydraulic efficiency.

Smart analytic platforms

One of the most important innovations that utilities with substantial digital infrastructure are investing in is smart analytics, to centralise all data on one platform to provide actionable insights. The AI company FIDO, for instance, uses machine learning to prioritise the leaks that need fixing. Others such as DHI provide ‘digital twins’ that reproduce a virtual model of the network and forecast its behaviour under certain conditions, like stormwater events. This predictive model provides advanced analytical insights to enhance leakage management by anticipating where pipes are coming under strain and therefore where leaks are likely to occur. The market for smart analytics is characterised mainly by large companies with extensive experience either producing or implementing a range of smart technologies, such as Xylem and Royal HaskoningDHV. Startups such as FIDO are also entering the smart analytics field, indicating that future competition may come increasingly from startups with data software expertise. Deliverable 2 – The Technology Scan was primarily focused on these kinds of solutions due to the need to overcome data siloes, centralise data, and explore cloud-based solutions – which is truly the direction that most utilities globally are headed towards.

Competition

Competition mainly takes place between vendors within each technology category, though the tendency across the market is to invest in data analytics services to complement the hardware. This means competition is increasingly converging with software start-ups over the development of data platforms. Larger companies have a growing interest in acquiring such start-ups.

Hydraulic modelling

Hydraulic modelling is currently a semi consolidated market meaning that established players are facing competition from startups. While hydraulic modelling has traditionally been used for asset management, there is rising demand for the use of hydraulic modelling to optimise operations. Utilities are increasingly exploring the possibility of using hydraulic models to create network digital twins which offer many benefits ranging from improved water quality management through to lowering water and energy consumption. For example, in 2020 Yorkshire Water in the UK implemented a real-time informed hydraulic digital twin which helped prevent problems with customer supply, including water quality issues. Artificial intelligence (AI) and machine learning (ML) will play a crucial role in the ability that hydraulic modelling software has to optimise operations. For water distribution networks, using ML for demand forecasting enables accurate models to be generated to help with supply and pressure optimisation. ML can also aid with modelling optimal flushing schedules which can help utilities reduce NRW loss and minimise resource consumption. For wastewater networks, applying ML to hydraulic models can enable accurate treatment plant inflow predictions several hours ahead of a flooding event. This enables utility operators to be able to adjust the necessary settings before the network becomes overloaded.

Utilities, particularly those that are smaller in area served, will often not have all the network data available that is required to create a comprehensive hydraulic model. This can make it difficult to implement modelling software and can also deter utilities from considering hydraulic models.

Digital Twins

Digital Twins are still very much an emerging technology market characterised by a few pioneering companies. The market for digital twins is dominated by established players with a rich history in developing digital solutions. Though vendors typically specialise in deploying twins for a specific application, a handful of key vendors (e.g. Siemens and DHI) provide digital twins of both treatment facilities and networks.

Due to greater financial, customer and climate challenges, advanced utilities are beginning to implement digital twins as a means of maximising operational efficiencies, reducing climate impacts and conserving scarce water resources. By combining real-time operational data with advanced process models, digital twins unleash a range of previously unimagined functionalities for operators across the water lifecycle.

However, despite this promise, the water sector's fragmented progress has ensured practical use-cases remains confined to large, well-funded utilities with a comprehensive level of existing digital infrastructure. Examples of such advanced organisations embarking on digital twin projects include Águas do Porto (Portugal), Global Omnium (Spain), DC Water (US) and PUB (Singapore). Though this client-base has proved a rewarding avenue for solution providers in the past, accelerating uptake amongst a broader array of small and medium sized clients remains key to unlocking growth within the market.

Digital twins can bring key benefits to key utility applications such as:

- Simulating the behaviour of the network under a range of conditions. For example, during a pipe burst, virtual models can analyse expected consequences, enabling operators to develop optimal response plans.
- Enabling operators to define optimal pump schedules in relation to external factors, such as customer demand and energy costs. This can deliver strong capital and energy savings.

Cloud based platforms

Traditionally, utilities have employed desktop GIS solutions in order to visualise assets and networks. These systems were designed to be operated on high-performance desktop computer systems by trained GIS specialists. Visual data would then be hosted locally on a utility's on-premise server, which risked downtime and data-loss in the event of device failure. Though legacy GIS software has often been sold as a perpetual license, the rise of cloud-based applications has instigated a wave of SaaS, subscription-based models. With these solutions, utilities will pay an initial integration cost, with assets digitally catalogued and uploaded to a spatial platform. Following this, subscription fees will be paid on an annual basis, often structured over a set period of time (e.g. 5 years).

Trends in cloud-based technologies

The rise of cloud computing has transformed the GIS market. Cloud-based systems enable multiple users to access a GIS system at one time, whilst further enabling operators to download and publish maps to the internet. Furthermore, operators can now leverage cloud-based AI and analytics to analyse spatial data without having to install additional on-premise software or hardware. Over the next 5-10 years, more utilities are likely to move to cloud-based SCADA systems as opposed to on-premise.

While cloud-based software is being offered by vendors, the majority of utilities have not moved over to the cloud and are still using desktop-based software. This is primarily due to strict security rules surrounding infrastructure data. Receptiveness to cloud-based software varies regionally. Some countries such as Australia and New Zealand have been very receptive to adopting cloud-based software whereas others such as the US, France and Sweden in particular, have been more limited in adoption. However, as cybersecurity measures continue to improve and storing data on the cloud becomes increasingly common in other sectors, adoption of cloud-based hydraulic modelling software is expected to rapidly increase over the next few years.

Benefits of cloud-based platforms

There are several advantages to cloud-based systems, notably lower upfront and ongoing costs, reduction in downtime and instant access from anywhere. Cloud-based SCADA specialist Xio has recently worked with several US utilities across California to update

SCADA systems, including Pleasant Valley County Water District, Cottonwood Water District and the City of Tehama. Other specialised players such as High Tide Technologies and RealiteQ are also making headway alongside major players, such as Emerson and Schneider, who are increasingly offering alternative options to on-premise SCADA, such as cloud and edge computing.

One of the biggest benefits of utilising cloud-based platforms is being able to centralise data from all systems and have them in one easy to visualise location. It is possible to pull information such as water quality from sensors and this information can be redirected and used. APIs can be used to send data to different systems from the cloud, rather than data being sent solely to a utility's leakage server for example. There are also opportunities to integrate customer billing systems. Customer meter information can be sent to billing systems and this data can be redirected to relevant places, so for example data which has previously only been used for billing can also be used for leakage targeting.

Furthermore, cloud-based solutions provide better granularity of data due to receiving far more frequent data from SCADA systems, allowing better targeting and awareness.

Cloud based solutions address these main challenges:

- Data silos: Legacy and/or proprietary systems create data silos that stand in the way of successful digitisation. Service-based offerings and migration to the cloud can be part of the solution, but many utilities still prefer the certainty of operating inhouse and on-premise.
- Frequent Data collection: Artificial intelligence and machine learning are powerful tools, but are only as good as the data available to them. A solid foundation of data collection and validation is key.

Mobile GIS

The rise of cloud-based GIS platforms has also facilitated an increase in mobile GIS use, with multiple users accessing spatial datasets through a range of internet connected devices (e.g. mobile phones, tablets). This enables field workers to capture, update and manipulate geospatial data on-site in response to changes in a physical environment (e.g. pipe burst), whilst simultaneously relating this data back to a central operator.

Mobile GIS systems rely heavily on cloud computing in order to facilitate data sharing and multi-user access, with SaaS, subscription based-models typical within the market.

Concerns around using cloud-based solutions

Although the market for data management software is increasingly moving towards cloud-based digital offerings, data security is a prevalent issue. Data sovereignty laws in certain regions require localised datacentres to host sensitive information. This is the case in regional markets such as the UAE and China and has the potential to severely limit uptake of cloud-based software from vendors operating outside such regions.

Furthermore, public perception of the word ‘cloud’ has typically been negative in the water sector. One of the main benefits of using the cloud is to be able to receive data far more frequently, allowing for better insights. However, suppose a utility wishes to send data from household meters to the cloud at fifteen-minute intervals – this could potentially be a breach of customers privacy GDPR issues. Utilities such as Anglian Water and Thames Water in the UK have been recording at fifteen-minute intervals but only sending this data once at the end of the day. It could be argued that this is counterintuitive to what cloud-based solutions are supposed to achieve.

Increasing utility concern along with regulatory emphasis is driving cybersecurity investment. For example, in 2022 the US the EPA introduced its Industrial Systems Cybersecurity Initiative – Water and Wastewater Sector Action Plan which is driving deployment of technologies to protect against cyber-related threats. This follows a 2021 State of the Water Industry survey indicating that only 20% of the participating US water utilities, had fully implemented some form of plan to address cyber intrusion. Vendor collaboration has become an important part of meeting utility cybersecurity needs (e.g. Rockwell and Cisco, Schneider and Fortinet).

Cyber Attacks

With the growing impact of climate change, critical infrastructure is exposed to advanced cyber-attackers more than ever. For example, in May 2021 alone, one of the largest pipelines in the United States was shut down after an apparent cyber-attack. This resulted in a shutdown of a pipeline nearly 9,000 km in length (5,592 miles), which carries 45% of the east coast's fuel supplies and expands to 14 US states.

In 2020, Israel's water network was also targeted. Six municipal water facilities were hacked as a cyber-attacker succeeded in infiltrating a certain water network but failed to cause any disruption in the water supply or waste management. At one of the facilities, operators detected the cyberattack on time and immediately disconnected the site's command and control system. Israel’s national water company, Mekorot, has invested heavily in security technology and it ranks the highest standard of cyber qualification by leveraging brainpower to source the best cyber defense tools to build and surround it with a solid, robust cyber architecture. Unfortunately, most water companies do not have this philosophy, budget or the necessary resources. Most commonly, it's the smaller or less experienced water utilities that are hacked. Another factor to consider is the balance between cloud computing or cloud servers and an on-premises server. Naturally, an on-premises server is much more secure and manageable, but the reality is that the cloud is much more advanced and scalable.

Supporting cloud-based solutions in South Africa

The South African government also promotes the use of cloud computing to drive digital transformation. To support this, the government has been working to establish the South African National Cloud Strategy, which provides guidelines and recommendations for the adoption and utilization of cloud services in both the public and private sectors. This policy is currently being finalised (2023). The national data and cloud policy "seeks to strengthen the capacity of the State to deliver services to its citizens, ensure informed policy development based on data analytics, as well as promote South Africa's data sovereignty and the security thereof". The policy aims to enable South Africans to realise the socio-economic value of data through the alignment of existing policies, legislation and regulations. The policy also will put in place a conducive and enabling environment for the data ecosystem to thrive.

Key players in the market

The selected players chart below indicates that most vendors specialise in one kind of technology for the leakage management space and build their products out with smarter analytics capabilities. Larger companies like Mueller and Xylem have tried to build out an extensive portfolio of solutions by acquiring a range of technology developers.

Company	Management
ABB Water Solutions	Pressure / flow sensors
Aclara Technologies	Smart metering
Aganova	Acoustic sensors
Aquarius Spectrum	Acoustic sensors
Arad Group	Smart metering
Arnold	Pressure / flow sensors
AVEVA	Smart asset management
Badger Meter	Smart metering
Bentley Systems	Smart asset management
DHI	Smart asset management
Diehl Metering	Smart metering
Elster	Smart metering
FIDO	Smart asset management
Fracta	Condition monitoring
Gutermann	Acoustic sensors
HWM	Acoustic sensors
Hydromax USA	Condition monitoring
i2O	Pressure / flow sensors
Idrica	Smart asset management
Inflowmatix	Pressure / flow sensors
Innovyze	Smart asset management
Itron	Condition monitoring, Smart metering
Jiangxi Sanchuan Water Meter	Smart metering
Kamstrup	Acoustic sensors, Smart metering
Landis+Gyr	Smart metering
Matchpoint	Acoustic sensors, Pressure / flow sensors
Mueller Water Products	Smart asset management, Acoustic sensors, Condition monitoring, Smart metering
Neptune	Smart metering
Ovarro	Acoustic sensors
Ramboll	Pressure / flow sensors, Satellite imagery
Rezatec	Satellite imagery
Roper Technologies	Pressure / flow sensors, Smart metering
Royal Haskoning DHV	Smart asset management
Shenzhen Star Instrument	Smart metering
Siemens	Pressure / flow sensors
Syrinix	Acoustic sensors, Pressure / flow sensors
TaKaDu	Smart asset management
Technolog	Pressure / flow sensors
Trimble	Acoustic sensors
Utilis	Satellite imagery
VODA.ai	Smart asset management, Smart metering
Water Intelligence	Smart metering
Xylem	Smart asset management, Condition monitoring, Pressure / flow sensors, Smart metering
Yokogawa Electric Corporation	Smart asset management

Acoustic sensors
Sensors that detect noises produced by leaks in the water flow of pipes.

Smart asset management
Software platforms that aggregate, analyse & present data from various sources within a network in order to optimise efficiency.

Condition monitoring
Tech that proactively assesses the condition of pipes and the risk of asset failure.

Satellite imagery
Analysis of satellite imagery to identify signs of leakage in the environment.

Pressure / flow sensors
Solutions that monitor pressure / flow rates and / or transients in a network to calm it.

Smart metering
Digital devices that measure and communicate water consumption data.

Figure 6: Schematic showing the key players in various technology sectors

Technology Scan

As seen in figure 6, the market tends are dominated by bigger companies. Whilst all of the technology areas in figure 6 play a vital role in reducing NRW, the focus of the Technology Scan was around Smart analytic platforms with a focus on cloud-based platforms. The need for utilities to digitally transform has never been greater and smart analytic platforms allow data centralisation, eliminating silos and allowing data to be used for multiple purposes and feed into several utility systems. Furthermore, better granularity of data is achieved due to more frequent data collection. Carrying out a technology scan on other leakage approaches highlighted above (satellite, telecommunications, smart analytics, acoustic loggers, pressure sensors and condition monitoring) would result in an extremely extensive scan, so it was important to narrow our search focus.

As a result of the horizon scan, 35 technologies were identified that matched the criteria for the technology search. 33 of the technologies listed in the matrix are cloud-based solutions or have mentioned cloud-based capabilities. The list below shows the data collected on each technology. The full Technology Scan can be found in Deliverable 1 along with a Technology Scan report.

- Technology name
- Company Name
- Location
- TRL
- Contact Details
- Key technology functional areas
- Brief description
- Monitoring parameters, e.g. Flow, pressure, Temperature, etc.
- Parameter management capabilities, if any (e.g. feedback loops to manage pressure automatically)
- Output / Type of Data that will be made available (how is the data communicated and visualised?)
- Any pipe restrictions (e.g. material / diameter) or location restrictions (e.g. cannot be in underground chamber), if relevant
- Minimum and maximum pressure requirement of the solution, if applicable.
- Any relevant approvals already obtained nationally or overseas (SABS, WRAS, DWI, NSF, etc.) (only relevant for post-treatment potable supply networks)
- Track record, including information on the number of installations, the longest running installation, geography of installations and references to specific water utilities and the outcomes.
- Installation requirements (e.g. ICT platform in place, integration with existing LIMS, SCADA, etc.)
- Operational requirements (e.g. external power supply 24/7, mobile data subscription)
- Ability to determine leak or burst size/location down to X cm or meters

- Business model, e.g. cloud-based solutions would normally have software as a service (SaaS) procurement mechanism
- Costs
- Additional benefits
- Limitations
- Link(s) to technology supplier and/or technology
- Link(s) to available case studies

Two technologies listed in the horizon scan did not have mention of cloud-based capability but were still thought worth including – the companies FiberSense and CRALEY. These were included as they involve turning existing fibre optic cables into leakage solutions. This is an interesting area as it is using existing infrastructure and one echoed in the reference group meeting.

The geographical spread of the solutions is large, as can be seen in figure 7, with the majority with headquarters in UK and Europe. One company, Explore Utilities, had their head office in Cape Town. The technologies included in the horizon scan originate from the following countries: England, France, Switzerland, Germany, South Africa, Australia, Canada, USA, Israel, Finland and Portugal.

Figure 7: Map showing the geographical spread of the technologies in the scan

As shown in figure 8, the TRLs (technology readiness levels) varied although most were at TRL 9 meaning that they were a fully commercially ready solution, with many case studies to validate the product. A few technologies were at TRL 6 meaning that the system has a proof-of-concept product or has just begun their piloting phase. The lowest TRL technology was the Waterwise system which allows for the integration of real-time network control and water quality monitoring at the same time, leveraging existing SCADA. It is a software solution that gives the water utility the ability to read, store and process large volumes of data from the network and related systems to uncover new operational knowledge. The technology was developed in the context of a research and development project supported by the Portugal 2020 program. There are no commercial installations yet. Around 10-15 technologies were included at first, but later rejected because they did not mention cloud-based capabilities and were not really 'next generation' solutions but rather more traditional approaches.

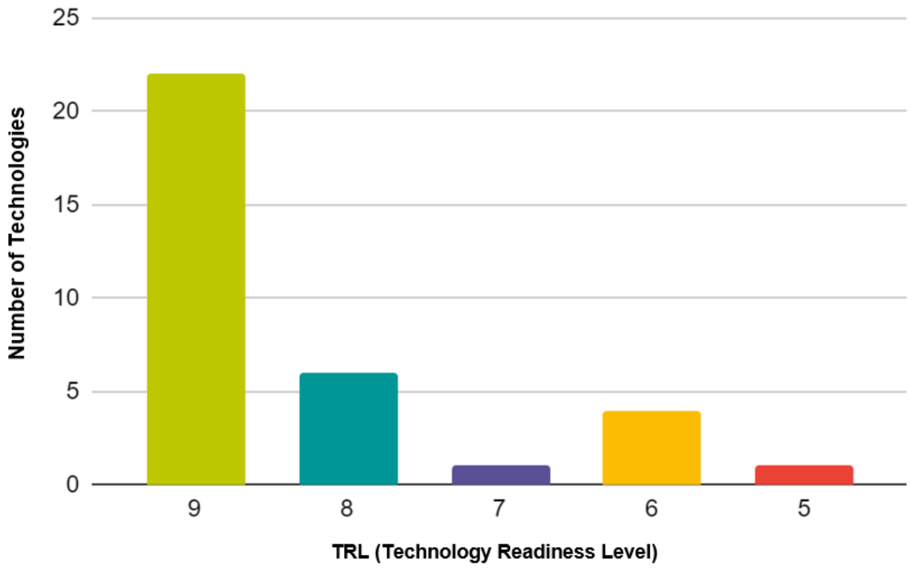

Figure 8: Chart showing the different TRLs of the technologies in the scan

CHAPTER 5: UTILITY IMPLEMENTATION OF NEXT GENERATION SOLUTIONS

The following chapter discusses next generation and digitally cutting-edge examples of implementation that provide key learnings and results relevant to water companies around the world.

De Watergroep – LeakRedux

LeakRedux is an online, cloud based, real-time leakage detection and decision support system for water distribution networks. The only inputs the system requires are measurements from DMA flowmeters, already installed across distribution networks. Initially, LeakRedux develops a unique flow data fingerprint of each DMA. This is continuously compared to real data. Operational alarms are triggered when network behaviour differs from the fingerprint. The LeakRedux fingerprint represents the actual consumption patterns of the DMA, including year-round variations, and takes into account other exceptional circumstances such as drought or firefighting. Furthermore, LeakRedux can predict bursts hours before they happen, and before they damage infrastructure. One of the features of LeakRedux is the ability of the software to detect and predict how small leaks will change over time. A 'time to intervention' is provided, based on cost, which allows for prioritisation and planning of leak detection and repair. The operator is also alerted to defective telemetry systems.

The technology was trialled at De Watergroep, an integrated water utility in Flanders, Belgium.
The utility serves 303 million customers plus 41 industrial customers. De Watergroep had a number of motivating factors to trial LeakRedux, including the fact that Flanders is the European region most at risk for water scarcity and droughts. Hence, reducing water losses is a strategic objective of De Watergroep and they have an ambitious target to reduce the infrastructure leakage index (ILI) to 0.45 by 2025 from 1.5 in 2021. The Flemish board sets out targets to reduce NRW but this is just a goal, and there is no legal mandate or fines associated with it. Hence, the main driver for De Watergroep to push for reducing NRW is more social and customer satisfaction linked.

De Watergroep shared that although it is not economical to find the smallest leaks, public image matters and in 2018 and 2019 the utility had a particularly dry summer. The public was not happy to know that 25% of water was being lost as NRW.

De Watergroep used LeakRedux for DMAs that have good data coverage. The solution was used to create a fingerprint of the water consumption in the DMA. Separately, different fingerprints were made for the weekends, nights, different seasons, etc. before setting minimum and maximum flow rates and if these flow rates were crossed, then an alarm was activated. The implementation phase begun with a small-scale pilot for 1 DMA only, but De Watergroep have confirmed that LeakRedux will now be rolled out to 400 DMAs.

The utility uses simple devices to look at night-time flow, and when night-time flow is too high, then the area is marked as a certain priority. It also considers the availability of flow sensors. The utility currently has poor functionality in flow sensors, old systems, different types of sensors and lots of data quality issues such as manual collection, disconnected meters, data not getting through to the data lake and several SCADA systems in place. It is currently not possible to make a water balance for all DMAs as some sensors are not connected to the cloud or only submit once a day readings.

Data quality is an obstacle as De Watergroep have a variety of old systems/pipes/flow meters. They are engaging in another project to ensure sure old devices are connected to the cloud or replace old ones.

De Watergroep has highlighted that attitude of field technicians needs to be more data minded, instead of the standard approach of finding and fixing a leak. Behavioural change is needed and since the pilot of LeakRedux began, there has been a positive shift in attitude.

Investment in technology was found to be worth it as the technology reduces and prioritises the area to look and improves data quality. Technology implementation has also resulted in improved understanding of the network and other issues for the future which will save the utility money.

Overall, implementation of LeakRedux helped De Watergroep improve their prioritisation and they are now working on a business case for NRW, not per DMA but per region which will include which regions to focus on with projects and technologies. De Watergroep is also looking at making DMAs smaller where NRW is an issue to get better insights.

Sydney Water – TakaDu

TaKaDu provides a cloud-based Software-as-a-Service (SaaS) water network monitoring solution, detecting problems in the water distribution network up to 3x faster and up to 5x more accurately than existing best practice. Using the existing data from SCADA and GIS systems, and requiring no additional meters or sensors, TaKaDu's algorithmic engine detects, classifies, alerts and provides real-time insight on leaks, bursts, DMA breaches, meter faults and other network inefficiencies. TaKaDu's service is being used by leading water utilities worldwide.

TaKaDu's IoT solution is operational 24/7 in leading water utilities in over 13 countries. One specific case is TakaDu's trial at Sydney Water, which is Australia's largest water utility supplying water, wastewater, recycled water and some stormwater services to more than five million people in Sydney.

Implementation began with a trial phase which lasted twelve months. A key requirement from Sydney Water staff was that data did not go offshore and subsequently TaKaDu set up an Amazon server in Sydney where data is sent to hourly.

In order to implement TaKaDu most effectively, there was a requirement for a level of monitoring that allows the breaking up of zones into manageable chunks to narrow it down and pick up changes in flow. Sydney Water had 25% of their network broken into pressure managed zones which each had a pressure reducing valve going into that zone with a flow meter, and each zone feeding 5000-10,000 properties.

Sydney Water echoed similar learnings from De Watergroep, noting that although they did not install any additional flow meters to use TaKaDu but potential next steps could be to further break up larger zones to break up into smaller zones and install new flow meters in.

During early implementation, the cloud-based solution just focussed on leakage, and it slowly became a central event management system, so it was focussed on looking at leakage alerts, water pressure alerts, sewage blockage detection, faults in pumps in both water and wastewater.

Resistance to change was a challenge encountered by Sydney Water. The word ‘cloud’ was dubbed as evil, and it took many months to get a level of comfort with pushing data to the cloud. Sydney Water implemented change management processes such as having regular meetings with TaKaDu to maintain engagement and provide an opportunity for Sydney Water staff to become comfortable with the technology, through asking questions and suggesting improvements from a user side.
For further peace of mind, TaKaDu set up an Amazon server in Sydney to ensure data did not go offshore, and gradually people’s behaviour and attitudes towards digital technologies changed. Despite the challenge of mindset, implementing TaKaDu has cleared the way for other similar data export services (cloud based) that Sydney Water use, so it helped to break down barriers so that other projects were easier to get off the ground.

TaKaDu realised that for utilities to benefit from their approach, there needs to be enthusiastic people in the utility to find leakage related events. TaKaDu therefore set up a regular forum with the key people from Sydney Water to keep engagement going, raise any issues that come up, and also take on board improvement ideas, e.g. tweaking an algorithm or new type of event to be detected. These meetings were monthly, then they moved to quarterly meetings.

Technology implementation resulted in great NRW reductions. The volumes of leakage that Sydney Water picked up ranged from typically 0.05ML/D (smallest) and 4.5ML/D. If the leak size is over 1ML/D, then uncovering a leak like that means that the investment in TaKaDu has quickly paid for itself. Overall, TaKaDu has enabled Sydney Water to avoid or minimise water interruptions to over 140,000 properties that would have otherwise been affected. There was one specific leak that was losing 1.3 million litres per day – enough water to fill an Olympic size swimming pool every 36 hours. If Sydney Water were to rely on the old way of detecting such leaks (i.e. wait for customers to report), it would have continued for a prolonged period, losing almost R12.5M worth of water every 12 months (based on what Sydney Water’s customers pay). It may also have grown to a main break, which would have caused a large customer impact.

The functionality of TaKaDu is dependent on the maturity of the utility. It requires a good SCADA system with many years of historical data and patterns that can be learnt, as well as good monitoring in place. This way, the best financial benefits can be achieved.

Thames Water – FIDO

FIDO (Free Intelligent Domain Observers) AI is a software-as-a-service (SaaS) end-to-end leak detection cloud AI solution which identifies leak/no leak and the size of leaks to reduce the run time of each leak and remove false positives and human error in analysis. It is 92% accurate and FIDO's leak sizing is unique to prioritize the maintenance work. FIDO uses differential analysis algorithms and the world's largest library of leak data to deliver instant results. It has the unique data set of including in-pipe data from the FIDO bug when it has been used to collect data from within the pipe taking audio, speed and turbulence data. The FIDO bug is a 49-mm 49.5-gm low-cost simple device that is designed to cover any part of the water network to deliver data to FIDO AI for real time data analysis. The bugs attach to any hydrant, stop tap, and also customer boundary boxes such as Atplas boxes. The FIDO bug can also act as a listening stick – picking up low vibrations. By empowering the engineer to detect and pinpoint leaks quickly, FIDO reduces the time to repair.

The technology has been installed at approximately ten different sites around the world including the UK and North America.

Thames Water supplies 2.6 billion litres of water, but at the moment, almost 24% of the water they supply is lost through leakage – which is a combination of water lost on pipes, water lost on customers' pipes and an element of unmeasured consumption (46% of billed customers are unmeasured with 17% of individual customers having smart meters).

The weather conditions during 2022/23 challenged Thames Water operationally. The hot and dry summer last year created an unprecedented 'soil moisture deficit'. As the ground dried out, pipes and customers' pipes moved and cracked, leading to an increase in leakage. Large increases in demand, as much as 50%, led to increases in unmeasured consumption impacting leakage further as they pumped more water through their pipes. They estimated that this event increased their leakage position by at least 10%.

With 10 million water customers across London and the Thames Valley, Thames Water has a massive water supply infrastructure to manage. A target of reducing reportable leakage by 20% between 2020 and 2025 means leakage detection and repair is a major focus for the company. Thames approached FIDO Tech to help target leakage in a defined region due to increasing challenges around the identification, verification and successful repair of leaks. The company also wanted to evaluate whether to retain, maintain and expand its existing logger estate of 27,000 devices that is nearing renewal.

A four-week trial was set up with Thames' Leakage Strategy Team to demonstrate the value of the FIDO service. The objective was to show how FIDO AI and FIDO<1 hardware can deliver accurate, objective results with a clear call to action and take leakage teams within 1m of leaks. The first step was to run the past four months' worth of acoustic logger records through the FIDO AI algorithm and classify each point of interest (POI) as either a leak, possible leak or non-leak. The results identified two DMAs that were of particular concern. Over a two-week period, FIDO leakage engineers accompanied two of Thames' leakage detection service providers, Hydrosav and RPS, to visit as many POIs in the two DMAs as possible.

FIDO AI analysed over 35,000 historic sound files in 2.5 hours and returned a report which Thames Water retrospectively followed up with its own leakage repair records and dig data. FIDO then carried out analysis of Thames Water's entire logger estate, an additional 6,810 new acoustic files. From daily reports, Thames identified 33 POIs for on-site verification by its leakage detection service providers and FIDO staff. Of these, 11 led to the discovery of misaligned loggers, and 20 were correctly confirmed as leaks or not leaks (including four customer side leaks), an accuracy of over 92%. Post-trial analysis showed 13 successful digs out of 13 work orders raised. FIDO AI also identified additional POIs which would not have been flagged for investigation using Thames' traditional detection methods. All new logger alarm files were processed by FIDO AI overnight to provide a start-of-day report showing new leaks over the full trial period. This allowed Thames Water to create their logic table of POIs and therefore target, plan, and schedule POI visits with greater accuracy. FIDO also helped demonstrate that the company's current acoustic loggers were an important and integral part of their leakage process that would support their future leakage strategy.

Applying FIDO AI gave Thames Water a step change improvement in the confidence with which they could correctly predict the presence of a leak from their acoustic loggers. This would ensure Thames Water would not be missing leaks whilst maximising the efficiency of the follow-on activity in the field.

The growing power of AI has created new opportunities for start-ups to compete with established players in the water technology market. The AI start-up FIDO (Sebata Holdings), for instance, uses machine learning to prioritise the leaks that need fixing. Now is the ideal time for water service providers and authorities to survey the competing and complementary solutions available here and now to bring water losses under control technologies. The final phase of the project entails a deep critical analysis that will develop general considerations and recommended next steps.

Mekorot – Fiber optics

Israel has been a strong innovator in the water sector, and the country's utilities are constantly looking for new ways to reduce leakage rates and have a well-established track record of piloting new digital solutions to achieve this. Aquarius Spectrum's acoustic leak detection system and Takadu's network event management software is among the most prominent digital startups to have started in Israel before finding global success.

The country's national water carrier, Mekorot, also has a strong record in piloting new digital technologies. Mekorot is Israel's national water company, providing 80% of the drinking water in Israel and consistently achieving some of the lowest NRW rates in the world. The average water loss rate of water utility providers in the OECD (Organisation for Economic Co-operation and Development) is 15%, Mekorot boasts a 3% NRW rate.

Today Mekorot operates a water supply network, comprising 13,000 km of water pipelines and 3,000 water production and supply installations. While Israel is years behind the fiber optics revolution, Mekorot, is fast-tracking the ability for Israelis to have access to these technologies. Mekorot began investing heavily in breakthrough technologies in March of 2018, when the Knesset approved an initiative allowing companies like Mekorot, who are involved with and subsidized by the Israeli government, to do so.

Focusing on fiber optics, the water company developed a way to probe fiber optic lines throughout the country using its existing pipeline infrastructure that stretches from the far reaches of the North back down to the southern borders. One of the recent projects was to connect the Negev's capital – the city of Beersheba – to Eilat, through a 280-km. pipeline. The technology can pick up and pinpoint sounds allowing insights into what is happening in every centimetre or inch of pipe in real time.

Initially, fiber optic technology was utilised to identify water theft but Mekorot realised it's potential to listen for leakage. The fiber optics are placed near the pipes to pick up the acoustics and locate where the leakage is. To distribute the lines throughout the country, Mekorot created a way to insert fiber optics cables into the pipelines and dispatch them throughout the country – 2 km. at a time – using an innovative system that uses both water and air pressure to carry and transport the communication lines from one section of the country to the other. Once placed, the engineer has the ability to connect the line to the surrounding area and then continue fishing the cable 2 km. down the line where another waits to repeat the process, and this process continues.

Following the initial deployment of the fiber optic lines beside the pipes, Mekorot decided to install the cables directly into the pipelines, within the water. Mekorot researchers then ran studies and found the insertion of lines to have no effect on the fiber optics themselves or the water surrounding it.

As well as reducing NRW, using fiber optics in existing pipelines can open up new opportunities to link other utility sectors. As Mekorot has pipes all across the country – even in the remote sections – essentially by using the pipes, communications companies can connect to these remote areas quickly, instead of waiting three to four years to do it. Communication companies are already engaging with this idea and Mekorot is in negotiations with a number of the large communications stakeholders in Israel, including Bezeq and Cellcom. Mekorot has leased out around 100 km of pipe to get the project off the ground. One of the stakeholders has already requested 400 km of Mekorot's pipelines to deploy a fiber optic network that would connect Beersheba to Eilat. There has previously not been any fiber network throughout this entire area. The idea is that Mekorot sells the use of the pipe to the communications companies, which allows them the ability to disseminate the fiber optic lines to remote locations covered by Mekorot's water system and convert them into infrastructure to house communications lines in, instead of having to dig, obtain permits and create the infrastructure themselves. Overall, Israel stands to be fully covered by a national fiber-optic high-speed network within the next five years.

Global Omnium – GoAigua

The Global Omnium Group manages, throughout the Spanish geography, 28 drinking water treatment plants, supplying more than 400 cities and more than 5 million people . It also manages 308 wastewater treatment facilities , 25 septic tanks, 155 external pumping stations and 2 sludge facilities.

The company that gives rise to the Global Omnium Group, Aguas de Valencia, began its journey in 1890 and was born with the vocation of supplying the City of Valencia and its metropolitan area and, progressively, was incorporated into the municipalities of the provinces of Valencia, Castellón and Alicante.

In the areas that Global Omnium were managing, they were serval water scarcity problems – they were facing almost 50% NRW. Initially they embarked on a journey of smart metering, deploying 50,000 smart meters from different technology providers. Their biggest problem was the silo of information, as they had 1 million sensors in total and more than 10 different software to manage all these sensors. All these different software had information that was isolated from the rest of the network. Furthermore, they also could not achieve KPIs to find out how their municipalities were performing.

As a result, Global Omnium began a pioneering digitization process based on the extraction and analysis of data from infrastructure sensorisation, which led to the development of a platform called GoAigua. Goaigua was formed through a partnership between Xylem and Idrica.

The platform is a solution that enables the integration of all data types to be integrated and analysed under a single login portal.

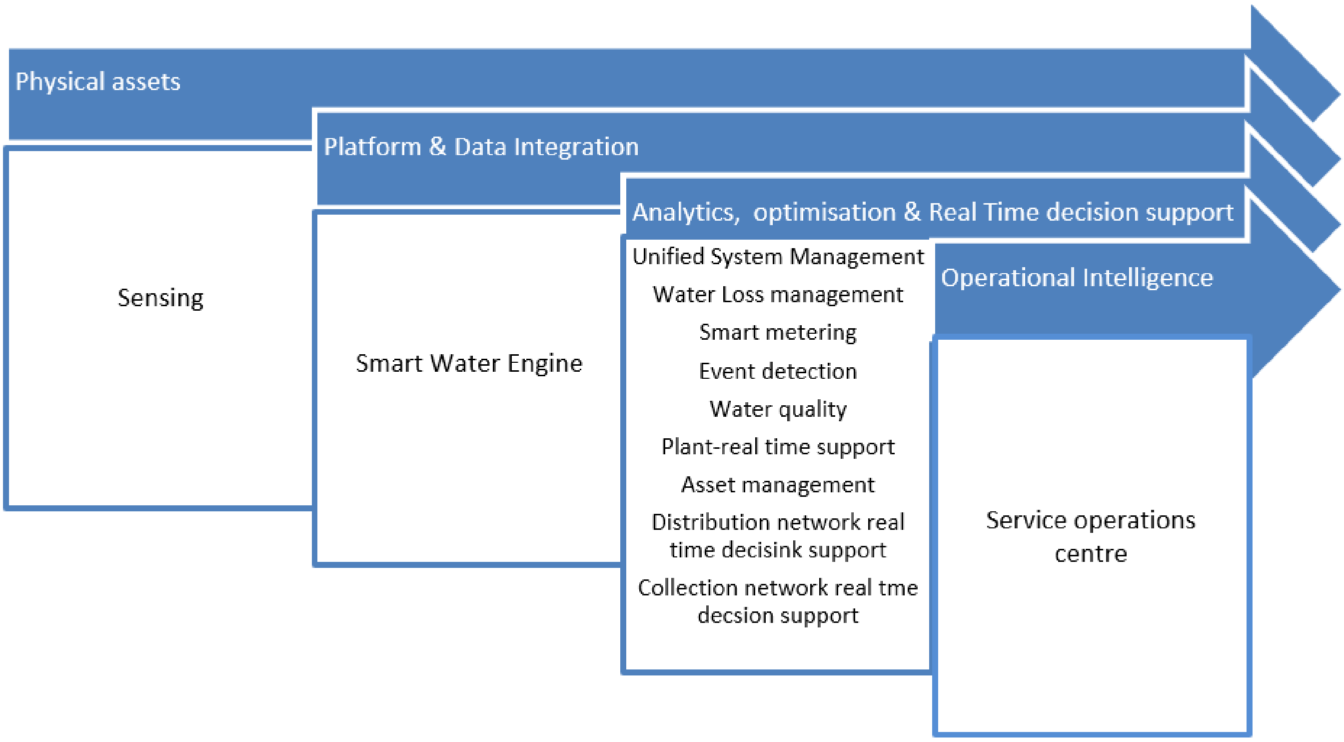

Figure 9: Process diagram different capabilities of the GoAigua platform

Global Omnium are now managing 12,000 km of pipe and more than 400 municipalities using just this one platform. The platform is used to manage 3100 DMAs and 1 million smart meters. Leak identification and detection is possible in less than 24 hours and once the detected leak is located, physical DMAs with flow meters (centralising 7000 supply point per DMA), can locate the leak between 1-3 days.

In municipalities where virtual DMAs are used then this time to locate reduces to 1-2 hours. Furthermore, anywhere there are optic fibres or acoustic loggers already in place, then leak location time is less than one hour.

A major benefit of this solution is transparency and being able to notify staff and colleagues when events occur. For example, if a leaky pipe ultimately needs to be replaced, then the operator can create a network order on the platform to inform the maintenance team and warehouse to repair leak. This information can also be shared with customers so that they can be notified when a leak will be repaired and between what times their water supply may be shut off to repair.

Feedback is critical and this information must be recorded on the system – the system automatically updates GIS in case this leaky pipe has several leaks in the coming months meaning that the utility can then decide to repair leaks or replace pipe.

Global Omnium has now reduced NRW by more than 80% in 400 municipalities, saving water and energy. In the past, a utility in Valencia improved their NRW by 35% over the course of 20 years, but now they are close to 88% reduction in NRW due to digital transformation.

How the population is perceiving utility service is another KPI, and a 60% reduction in customer complaints was achieved due to customer transparency through notifications for leak repair for example.

CHAPTER 6: UPDATED CASE STUDY FACT SHEETS

The Isle team interviewed three utilities on their experiences of using cloud-based water loss management solutions. Due to each utility's different geography, their motivation, experiences, and challenges were unique, however there were some points and considerations that were raised by multiple utilities.

Methods of enhancing the effectiveness of the technologies was also discussed and multiple utilities highlighted the need to make zones/DMAs smaller with additional flow meters. Wider challenges associated with this were also highlighted including pushback from municipalities about the installation of new devices and digging.

It was also very interesting to understand the reasons to implement the cloud-based solutions, from economic social and environmental angles and each utility had more of a driving force in specific areas.

De Watergroep Case Study

Background

De Watergroep is an integrated water utility in Flanders, Belgium and Flanders is the European region most at risk for water scarcity and droughts. Hence, De Watergroep have run a program of interventions to reduce NRW and this has been implemented for more than three years to date.

De Watergroep have been used as a pilot reference site for technologies such as LeakRedux (online, cloud based, real-time leakage detection and decision support system) which was also a technology that was included as part of Deliverable 2 – Technology Scan.

Location/Geography

Flanders, Belgium

Scale of utility

- Biggest drinking water utility in the Flanders region in Belgium
- 3.3 million domestic customers
- 41 industrial customers
- 1.5 million connections
- 177 municipalities

Infrastructure

- 34,400 km of pipeline
- 282 permanently monitored DMAs for the water supply network

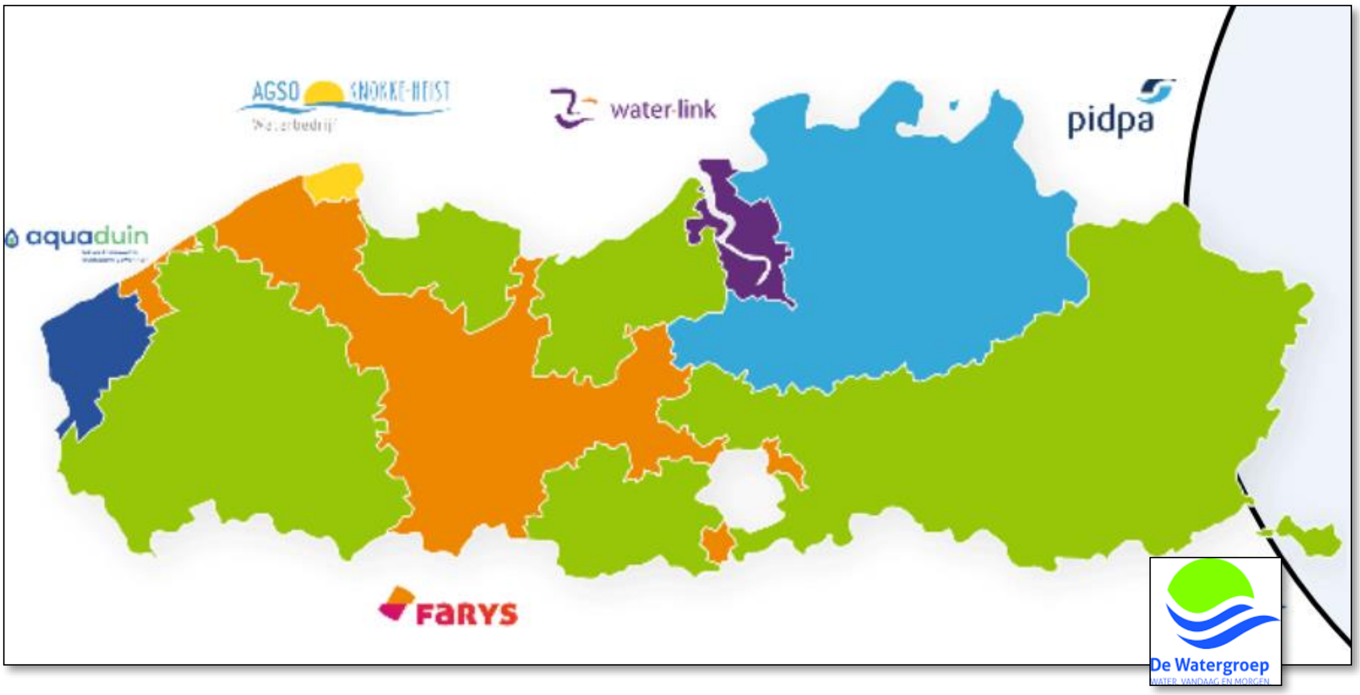

Figure 10: Map of coverage by water utility in Flanders, Belgium

Challenge

As the climate changes, and there are experiencing longer periods of drought, water starts to become scarcer. This makes efficient water provision even more critical. Each year, an estimated 35% of the entire water supply in Europe gets lost, which corresponds to the yearly consumption of 200 million people.

Objective

The below figure outlines De Watergroep's NRW goals. It can be seen that reducing water losses is a strategic objective of De Watergroep and they have an ambitious target to reduce the infrastructure leakage index (ILI) to 0.45 by 2025 from 1.5 in 2021.

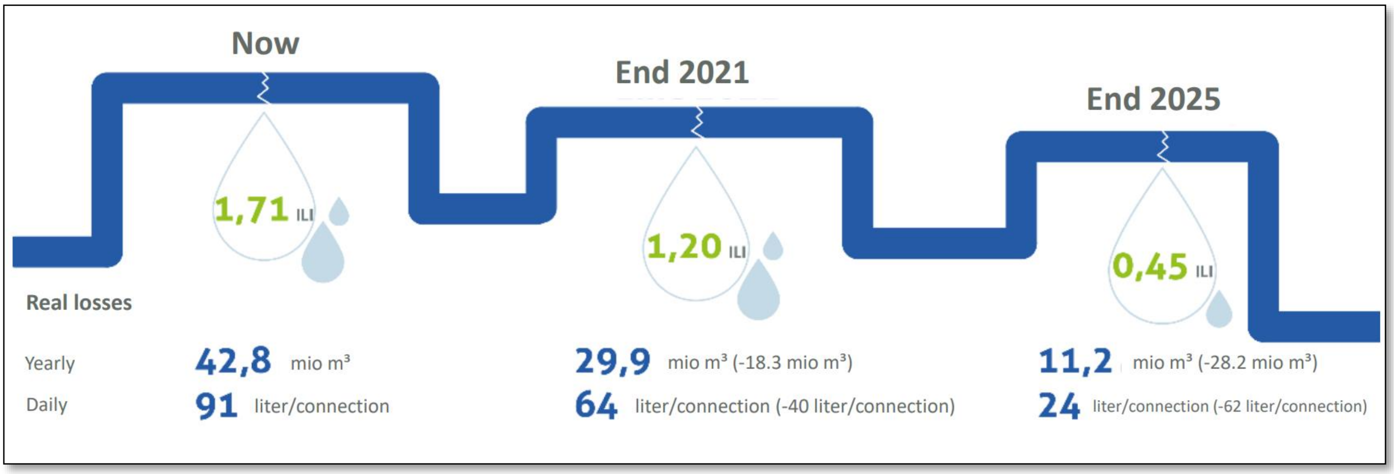

Figure 11: Schematic showing De Watergroep future goals for NRW reduction

State-of-the-art NRW initiatives

- A research project was carried out, the SmartWaterGrid project, which consisted of various research and industry partners: Aloxy, De Watergroep, Hydroscan, Itineris, IDLab UGent, and IDLab UAntwerpen. A hybrid AI twin of the water supply network was created, using input from Internet of Things (IoT) sensors, Geographical Information System (GIS) data, hydraulic models, and customer and expert feedback. By using machine learning models, this input was translated into leak alerts and the localisation of the leak in the water network, and as a result, leak localisation improved from 70 km to street level, and from weeks to a few hours. A dashboard was created in a Microsoft Customer Service demo environment, displaying customer service feedback, planned service orders, and the hybrid model output. This way customer service agents have a holistic view, allowing them to better inform their customers, which significantly increases customer engagement and satisfaction.
- Pilot of a commercially ready solution, LeakRedux by Hydroscan, was rolled out. LeakRedux is an online, cloud based, real-time leakage detection and decision support system for water distribution networks. The only inputs the system requires are measurements from DMA flowmeters, already installed across distribution networks. Initially, LeakRedux develops a unique flow data fingerprint of each DMA. This is continuously compared to real data. Operational alarms are triggered when network behaviour differs from the fingerprint. The LeakRedux fingerprint represents the actual consumption patterns of the DMA, including year-round variations, and takes into account other exceptional circumstances such as drought or firefighting. Furthermore, LeakRedux can predict bursts hours before they happen before they damage infrastructure. One of the features of LeakRedux is the ability of the software to detect and predict how small leaks will change over time. A 'time to intervention' is provided, based on cost, which allows for prioritisation and planning of leak detection and repair. The operator is also alerted to defective telemetry systems.

Technology specific interview

Utility interview was held with Nele Philips who is the Program Manager in the Research & Development department. Nele is always looking for new technologies globally to apply in De Watergroep to achieve goals, including reducing NRW. The interview was held virtually, and the findings have been summarised into a fact sheet below.	
What cloud-based water loss management system was utilised?	For DMAs (District Metered Areas) in De Watergroep that have good data coverage, LeakRedux by HydroScan was used to create a fingerprint of the water consumption in the DMA. Separately, different fingerprints were made for the weekends, nights, different seasons, etc. before setting minimum and maximum flow rates. If these flow rates are crossed, then an alarm is activated.
What other approach is being used for water loss management?	• The utility uses simple devices to look at night-time flow, and when night-time flow is too high, then the area is marked as a certain priority. It also considers the availability of flow sensors. The utility currently has poor functionality in flow sensors, old systems, different types of sensors and lots of data quality issues such as manual collection; meters not

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	connected to, or does not get through, to the data lake; several SCADA systems in place. It is currently not possible to make a water balance for all DMAs as some sensors are not connected to the cloud or only submit once a day readings. ● De Watergroep is also looking at making DMAs smaller where NRW is an issue to get better insights.
How was the cloud-based technology selected?	LeakRedux was selected through a tendering procedure with several companies to obtain a system to be able to detect leaks based on their data. The tender was awarded then to HydroScan due to their water and hydraulic modelling expertise, and Delaware (IT/data company).
How would you describe the process of implementing the system?	● The implementation phase begun with a small-scale pilot for 1 DMA which consisted of 210 km of pipe and contains 6 flow meters and 9600 connections. De Watergroep have confirmed that LeakRedux will now be rolled out to 400 DMAs. Further clarification will be needed as to how many DMAs the solution is currently applied to in their network.
What were the challenges of implementing the water loss management system?	● Data quality is an obstacle. De Watergroep have a variety of old systems/pipes/flow meters. They are engaging in another project to ensure sure old devices are connected to cloud or replace old ones. ● Engagement with the municipality is also an issue. De Watergroep have looked into installing extra flow meters to make DMAs smaller as their current DNA is large. After a study is done to analyse where to put extra flow meters, permission is needed from the municipality to dig and often a negative response is received due to the fear of newly built roads being damaged. ● Attitude of field technicians needs to be more data minded, instead of the standard approach of finding and fixing a leak. Behavioural change is needed and since the pilot of LeakRedux began, there has been a shift in attitude.
Have you seen a reduction in leakage as a result of implementing this technology?	● It is difficult to quantify savings because De Watergroep have several approaches they use to reduce leakage. It is hard to differentiate and link it to HydroScan's technology. As a result of combined actions, the utility has definitely seen a reduction in NRW. ● Positive results have been seen in terms of having more insights into regions, being able to know which DMA to screen for hidden leaks and making evidence-based decisions, rather than using an ad hoc procedure.
What was the technology procurement process like?	During the tendering procedure, a type of procedure called Best Value Procurement was used. This includes a one-year testing phase (for suppliers to show what they can do with their system). This is beneficial because if De Watergroep is not satisfied, they would be able to move to the technology that is in second place, without the need for tendering again).
Implications for human resources	Training was needed mainly for team leaders for whom the LeakRedux rollout was intended. They are the ones who will decide on which priorities to work on, check data quality, and make changes if necessary. The same number of people are in the field to detect leaks; however this allows faster location of leaks. Two further job roles have since been included in the distribution and transport network that are necessary for this implementation.

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From a purely financial perspective, was the cost of investment in the technology worth it?	• Yes. Financially the investment was worth it as the technology reduces and prioritises the area to look and improves data quality. Technology implementation has also resulted in improved understanding of the network and other issues for the future which will save the utility money. • Implementation of LeakRedux helped De Watergroep improve their prioritisation and they are now working on a business case for NRW, not per DMA but per region which will include which regions to focus on with projects and technologies.
How easy would it be to change to another technology / service provider?	• It would not be easy to change to another system. Fingerprinting studies take several weeks to obtain data so it would result in a lengthy process. • The contract with HydroScan runs for eight years, as do most public contracts in Belgium. It is most likely that a clause was included in the contract that the data is owned by De Watergroep and they can extract the data from the system without a cost after the eight years. This is something that should always be included in a contract with technology vendors.
Other (non-economic) drivers and benefits of implementing cloud-based water loss technologies	• The programme to reduce NRW has been running for more than three years now and it is a combination of environmental, economic and social reasons. • The Flemish board sets out targets to reduce NRW but this is just a goal, there is no legal mandate or fines associated with it. Hence, the main driver for De Watergroep to push for reducing NRW is more social and customer satisfaction linked. • Although it is not economical to find the smallest leaks, public image matters and in 2018 and 2019 the utility had a particularly dry summer. The public was not happy to know that 25% of water was being lost as NRW.
Did you look at any other technologies on this topic?	• No other technologies in this space were looked at. • De Watergroep use noise loggers more frequently in lift/shift operation. The data is sent to the cloud and interpreted to see if there seems to be a leak, before sending out a technician to pinpoint.

Sydney Water Case Study

Background

Sydney Water is Australia's largest water utility, suffering from water scarcity problems on a yearly basis. Sydney Water were used as a trial site for technologies such TakaDu which was also a technology that was included as part of Deliverable 2 – Technology Scan.

Location served

Greater Sydney, Australia covering Sydney, the Illawarra and the Blue Mountains

Challenge

Conservation of Water Resources: Sydney, like many other regions, faces water scarcity and the need for sustainable water management. By reducing leakage, Sydney Water aims to conserve its water resources and ensure the long-term availability of water for its customers and the environment. Too much rain, not enough rain, changes in temperature or ground conditions, tree roots, heavy traffic and construction work all contribute to the issue.

Scale of utility

- Australia's largest water utility supplies water, wastewater, recycled water and some stormwater services
- 5 million customers served

Infrastructure

- Coverage of12,700 km^2
- Over 21,000 kms of water pipes
- 251 reservoirs
- 164 pumping stations.

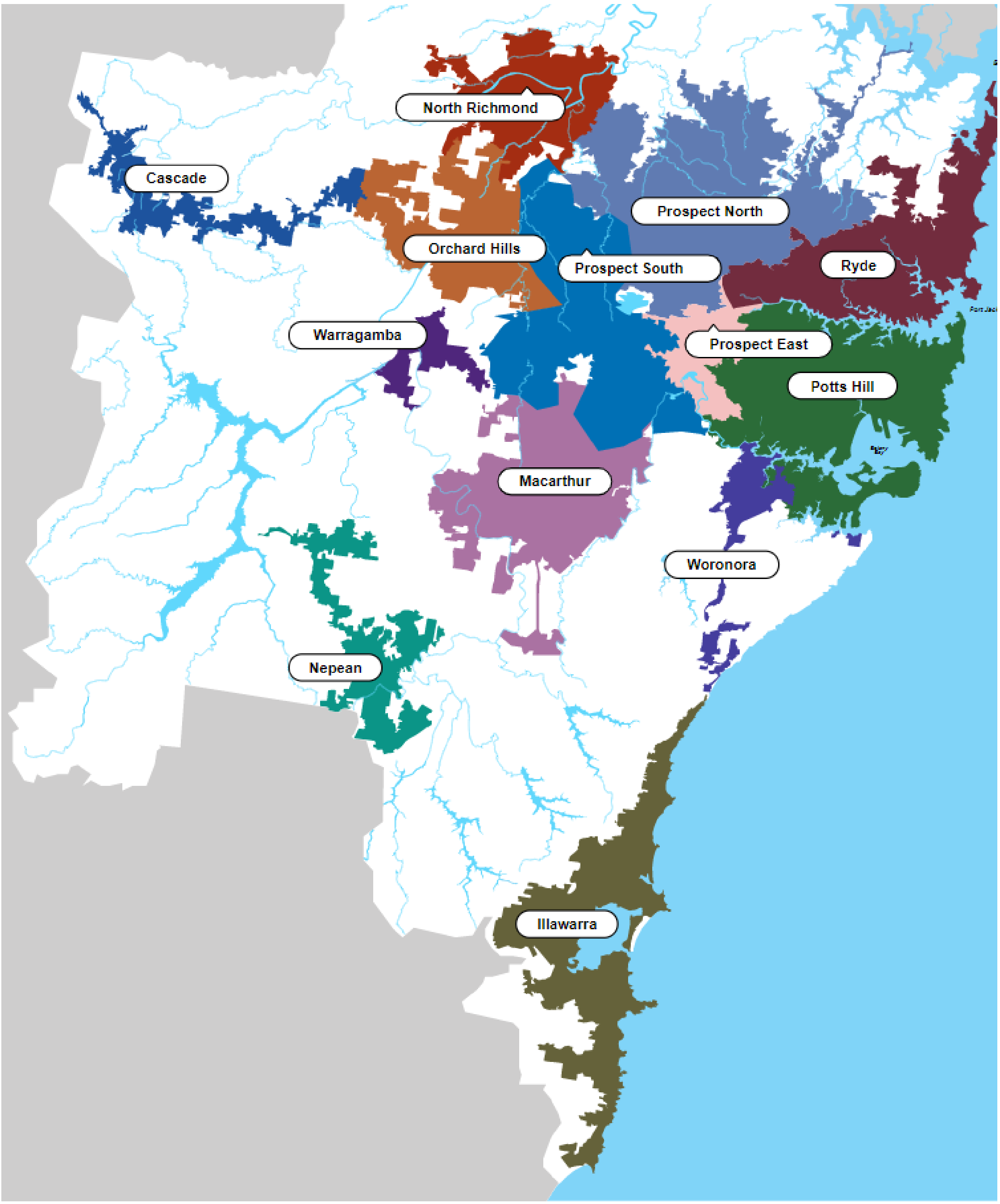

Figure 12: Map showing coverage of Sydney Water across Australia

NRW initiatives

- Sydney Water have a Leak Reduction Program which primarily includes acoustic devices and a leak detection dog to pick up the noise that water makes as it leaks from pipes. This saves about 20 billion litres of water each year, helping Sydney Water to quickly identify and repair hidden leaks.
- Sydney Water also has a Water Pressure Program to adjust and achieve more consistent pressure levels in the water supply system. The current overall average pressure in Sydney Water systems is 52 metres. Some customers receive significantly higher pressure – above 100 metres. It is an ongoing

program to reduce water pressure and targets areas across Sydney where the pressure is excessively high.

- Similarly to De Watergroep, it was found that Sydney Water has been using a cloud-based technology which was included in the Technology Scan. TaKaDu's IoT solution is operational 24/7 in leading water utilities in 13 countries including at Sydney Water. TaKaDu essentially works on the same basis as Zednet and provides a cloud-based Software-as-a-Service (SaaS) water network monitoring solution, detecting problems in the water distribution network up to 3x faster and up to 5x more accurately than any existing best practice. Using only the existing data from SCADA and GIS systems, and requiring no additional meters or sensors, TaKaDu's algorithmic engine detects, classifies, alerts and provides real-time insight on leaks, bursts, DMA breaches, meter faults and other network inefficiencies.

Technology specific interview

The interview was held with Darren Cash who is a Senior Manager for Customer Delivery at Sydney Water. The interview was held virtually, and the findings have been summarised into a fact sheet below.	
What cloud-based water loss management system was utilised?	TaKaDu's Central Event Management (CEM) solution since 2015 to reduce water loss and improve operational efficiency.
How was the cloud-based technology selected?	Sydney Water came across TaKaDu through one of their consulting partners, Jacobs, who proposed that Sydney Water trial TaKaDu. TaKaDu was suggested by Jacobs as Sydney Water did not have the internal capability to perform the same analysis that TaKaDu could do at the time. After an initial trialling phase, the technology was selected after Sydney Water experienced consistent value in the form of early detection of leaks and water loss avoidance. Sydney Water has gradually expanded the network coverage monitored by TaKaDu.
How would you describe the process of implementing the system?	• Implementation began with a trial phase which lasted twelve months. • A key requirement from Sydney Water staff was that data did not go offshore and subsequently TaKaDu set up an Amazon server in Sydney where data is sent to hourly. • In order to implement TaKaDu most effectively, there was a requirement for a level of monitoring that allows the breaking up of zones into manageable chunks to narrow it down and pick up changes in flow. Sydney Water had 25% of their network broken into pressure managed zones which each had a pressure reducing valve going into that zone with a flow meter, and each zone feeds 5000-10,000 properties. • Sydney Water did not install any additional flow meters to use TaKaDu but potential next steps could be to further break up larger zones to break up into smaller zones and install new flow meters in. It was expressed by Sydney Water that you may lose a lot of system reliability/contingency in situations like that, so they have not yet taken that approach. • Sydney Water used TaKaDu from 2015-2022. The reason was not due to any failings on TaKaDu's side, but Sydney Water decided to pursue

The interview was held with Darren Cash who is a Senior Manager for Customer Delivery at Sydney Water. The interview was held virtually, and the findings have been summarised into a fact sheet below.	
	an internal way of essentially doing a similar analysis which they did not have the capability to do when they first started using TaKaDu. ● During early implementation, the solution just focussed on leakage, and it slowly became a central event management system, so it was focussed on looking at leakage alerts, water pressure alerts, sewage blockage detection, faults in pumps in both water and wastewater. ● Implementation was also very flexible. The algorithms for TaKaDu are configurable to use cases and the platform is intuitive and easy to use. ● Throughout the years, Sydney Water moved to a model where the controller modelling team were looking at TaKaDu in addition to the SCADA system that monitors for faults. This was not so much a training requirement, but more of a change of mindset. The SCADA team is a long-standing team at Sydney Water and there tends to be a trend where SCADA monitoring experts do not categorise something as an issue unless an alarm is raised in SCADA. The implementation phase required ongoing work to change mindset.
What were the challenges of implementing the water loss management system?	● Resistance to change was a challenge. The word 'cloud' was dubbed as evil, and it took many months to get a level of comfort with pushing data to the cloud. For peace of mind, TaKaDu set up an Amazon server in Sydney to ensure data did not go offshore, and gradually people's behaviour and attitudes towards digital technologies changed. This is less of an issue now. ● It took Sydney Water a while to change the attitude of the staff working in the control room. These staff members are longstanding SCADA monitoring experts and were used to the approach of just reacting to alerts of assets failing. A change in mindset was required to get them to realise the benefit of using a predictive approach and pick up something before it gets to alarm stage, and potentially prevent a main break. ● Despite the challenge of mindset, implementing TaKaDu has cleared the way for other similar data export services (cloud based) that Sydney Water use, so it helped to break down barriers so that other projects were easier to get off the ground.
Have you seen a reduction in leakage as a result of implementing this technology?	● Yes, a reduction was seen. The volumes of leakage that Sydney Water picked up ranged from typically 0.05ML/D (smallest) and 4.5ML/D (largest. Detecting these leaks resulted in a significant cost saving. ● If the leak size is over 1ML/D, then uncovering a leak like that means that the investment in TaKaDu has quickly paid for itself. ● TaKaDu has enabled Sydney Water to avoid or minimise water interruptions to over 140,000 properties that would have otherwise been affected.
What was the technology procurement process like?	● The procurement process was relatively straightforward. Sydney Water did not encounter any notable challenges. ● TaKaDu had already demonstrated that they were at a TRL 8/9 before Sydney Water began trialling in 2015. The first installation of TaKaDu was in 2012 at Yarra Valley Water (Australia) where the system was used for three years and reduced the utility's water loss from about 14% to 10.8.

The interview was held with Darren Cash who is a Senior Manager for Customer Delivery at Sydney Water. The interview was held virtually, and the findings have been summarised into a fact sheet below.	
	• There were more challenges for Sydney Water in terms of digital perspective and data security.
Implications for human resources	TaKaDu did not require time-consuming training. It has an easy-to-use interface. Enthusiasm and engagement were more important and required more time to get right than expertise of using the solution. Sydney Water implemented change management processes such as having regular meetings with TaKaDu to maintain engagement and provide an opportunity for Sydney Water staff to become comfortable with the technology, through asking questions and suggesting improvements from a user side.
From a purely financial perspective, was the cost of investment in the technology worth it?	• Yes, the solution quickly paid for itself when achieving leakage detection to the levels that Sydney Water were (down to 0.05ML/D). • Analytics methodology, such as that used by TaKaDu is an important element of Sydney Water's long-term strategy to leverage the wealth of data that they have from SCADA and IoT. • There was one specific leak that was losing 1.3 mil litres per day – enough water to fill an Olympic size swimming pool every 36 hours. If Sydney Water were to rely on the old way of detecting such leaks (i.e. wait for customers to report), it would have continued for a prolonged period, losing almost $1M worth of water every 12 months (based on what Sydney Water's customers pay). It may also have grown to a main break, which would have caused a large customer impact. • Having said that, the functionality of TaKaDu is dependent on the maturity of the utility. It requires a good SCADA system with many years of historical data and patterns that can be learnt, as well as good monitoring in place. This way, the best financial benefits can be achieved.
How easy would it be to change to another technology / service provider?	• There was no lengthy contract in place so at the end of twelve months, another technology provider could be selected/used. Contracts typically tend to be longer, but Sydney Water opted for the annual renewal option. • Sydney Water has an annual renewal with TaKaDu where they pay for twelve months at a time. Sydney Water have extended their annual contract six times and used the system, from 2015-2022.
What was the after-sales service like?	• Sydney Water found TaKaDu's after sales service very good. Initially they were using a third-party company (Jacob's consultant) to give support, then after a couple of years Sydney Water set up a grant directly with TaKaDu. • TaKaDu realised that for utilities to benefit from their approach, there needs to be enthusiastic people in the utility to find leakage related events. TaKaDu therefore set up a regular forum with the key people from Sydney Water to keep engagement going, raise any issues that come up, and also take on board improvement ideas, e.g. tweaking an algorithm or new type of event to be detected. These meetings were monthly, then they moved to quarterly meetings.

The interview was held with Darren Cash who is a Senior Manager for Customer Delivery at Sydney Water. The interview was held virtually, and the findings have been summarised into a fact sheet below.	
Did you look at any other technologies on this topic?	• Sydney Water have explored acoustic listening technologies. One trial saved 9000 megalitres of water over two years by detecting hidden leaks in its subterranean water network. • The trial involved fitting 600 acoustic sensors – developed with the University of Technology Sydney, Detection Services, WaterGroup and Ovarro – to 13 kilometres of water mains in the Sydney CBD.

Johannesburg Water Case Study

<u>Background</u>

Johannesburg Water is a municipal entity in South Africa that has explored cloud-based water loss solutions in the past and looks ahead in terms of digital solutions for water management, hence it made them a suitable interviewee for this project. Furthermore, sustainable development through the protection of the environment and the adoption of relevant technologies is listed as one of Johannesburg Water's five strategic objectives.

The NRW for the 2021/22 financial year at Johannesburg Water was 44.8% (commercial losses at 8.9%, unbilled authorised consumption at 13.0%, and physical losses at 22.9%) against a target of 32%. This is a 5.4% increase compared to the 39.4% of the previous financial year, which is of significant concern for the Entity.

The various benchmark levels of NRW were published in the latest South African WRC report on the State of Non-Revenue Water in South Africa, 2012 classifies NRW in the following categories:

	Legend	Description
1	<15%	Low level of NRW, very good performance
2	15-30%	Low level of NRW, good performance
3	30-40%	Average level of NRW, average performance
4	40-50%	High level of NRW, poor performance
5	<50%	Very high level of NRW, very poor performance

Table 1: Table showing the varying levels of NRW with description of performance

A team has been established to investigate the increase in NRW which includes a detailed review of the reduction in the billing volumes and enhancing the current meter reading system to enable a zonal tracking of the revenue water and NRW. This will enable the Entity to prioritise the investment in water demand strategies that will yield a better return in the short and long term. The aim is to improve on the calculation of some of these volumes in the 2022/23 financial year. Some of the Water Conservation and Water Demand Management (WCWDM) interventions to improve in the calculation include the repair, enhancement and maintenance of zonal meters; the implementation of Advanced Metering Infrastructure (AMI) technology for large water users and the roll out of STS prepaid water meters, to mention but a few.

Location

Orange Farm, in the south of Johannesburg, to Midrand in the north, Roodepoort in the west and Alexandra in the east., South Africa

Scale

- 3.8 million customers
- supplies 1.6 billion litres of potable water per day, procured from Rand Water.

Infrastructure

- The integrated company's main services are made up of 12 364 km of water pipes
- 100 reservoirs and service towers
- 11 000 km wastewater network.

Challenges

- Water scarcity
- Population growth
- Aging assets
- Data
- Cost of maintenance

NRW action plans

- Tender for the supply and delivery of bulk flow meters and repair component was a partial award, the procurement process was restarted and is currently underway.
- Tender for the repair and maintenance of zonal bulk meters was cancelled. The procurement process was restarted and is underway.
- Tender for the supply and delivery of PRV Smart Controllers to be used to regulate minimum night flow was a cancellation. The procurement process has since been re-initiated.
- The tender for the advance leak detection equipment was cancelled. The procurement process has since been re-initiated and is underway.
- There has been delays in the projects at Orange Farm, Soweto and Alexander as a result of a shortage of prepaid meters due to cancellation of the tender for the supply and delivery of STS prepaid meters, which was cancelled and has since been re-advertised.
- The service provider for the level 3 cut-off and reconnection was awarded late towards the end of the 21/22 FY.

- Johannesburg Water implemented Zednet for pressure management. Zednet is a cloud-based data acquisition and display service designed to collect and display water management data from remote monitoring devices.

Region A	Diepsloot, Kya Sands, Dainfern, Midrand, Lanseria, Fourways
Region B	Randburg, Rosebank, Emmarentia, Greenside, Melville, Mayfair, Northcliff, Rosebank, Parktown, North
Region C	Roodeport, Constantia Kloof, Northgate, Florida, Bram Fischerville
Region D	Doornkop, Soweto, Dobsonville, Protea Glen
Region E	Alexandra, Wynberg, Sandton, Orange Grove, Houghton
Region F	Inner city, Johannesburg South
Region G	Orange Farm, Weilers Farm, Ennerdale, Lenasia, Eldorado Park, Protea South

Figure 13: Map showing the seven regions of the city. Source: Chirisa & Matamanda (2019)

<u>Technology Specific interview</u>

The interview was held with Dr Zakhele Khuzwayo who is the Innovation and Technology Manager at Johannesburg Water.	
What cloud-based water loss management system was utilised?	• Zednet, a web-based software solution that aims to supply management information about both the water resource itself and the monitoring hardware installed in a water distribution system. Zednet aggregates data from a range of logging devices, most often via GSM, and includes default support for measurements such as flows, pressures, reservoir levels, borehole depth, river gauging, rainfall and water quality.

The interview was held with Dr Zakhele Khuzwayo who is the Innovation and Technology Manager at Johannesburg Water.	
How was this technology selected?	• Johannesburg Water selected the technology by direct appointment by recommendation from WRP (contractor), who delivered the contract.
How would you describe the process of implementing the system?	• Johannesburg Water contracted a third party (WRP) to implement the Zednet system which was used for real time monitoring between 2014-2017, after which the contract came to an end. The objectives for the project were achieved and thereafter maintained using information that was gathered during the 3-year project; it was decided not to renew the contract. • There was a big drive toward pressure management as one of the 8-point strategies for reducing water loss. Modelling in terms of water pressure for different zones was carried out, after which Zednet was used to indicate the pressure at critical points to enable pressure management and reduce background leakage. A baseline was established, monitored, and the operating pressure was reduced and tracked using Zednet at topological high and low points in the system. Customer feedback was monitored regarding pressure changes during this time due to concern of customer complaints regarding drops in pressure, however no such problems were observed. • Zednet was piloted at PRVs before expansion to city wide scale including up to 46 PRVs, installing their own sensors. • There were no problems identified in the installation of the system, WRP were confident in their area and Johannesburg Water appreciated the delivery of the contract.
What were the challenges of implementing the water loss management system?	• Lack of understanding and reluctance to tweak parameters, lack of advance training, and vandalism were identified as challenges for this system. There were cases where chambers were broken into and equipment was stolen. Mitigation of this was not an option, the locations were within chambers where the construction had one point of entry through a heavy manhole, however theft was still a problem.
Have you seen a reduction in leakage as a result of implementing this technology?	• Johannesburg water observed a reduction in leakage as a result of using Zednet. This technology was used to check operating pressures rather than directly for reducing leakage. As the topology of the area is undulating, this influences pressures available in the distribution system and so Zednet was introduced to monitor this and compare the data with hydraulic models. Kinetic data identified a small number of changes/improvements that were then actioned and led to observed improvements in water losses.
What was the technology procurement process like?	• Johannesburg found very few barriers in the technology procurement process. They indicated that the supply chain management process was straightforward and the OPEX budget was used for this.
Implications for human resources	• The implementation of the technology was managed by the Planning Department, where relevant managers were in direct contact with the contractor.

The interview was held with Dr Zakhele Khuzwayo who is the Innovation and Technology Manager at Johannesburg Water.	
	• This was organised as a third-party contract (WRP) and most of these fell outside of Johannesburg Water's Mandate.
From a purely financial perspective, was the cost of investment in the technology worth it?	• Johannesburg Water found that the solution was worth the investment, resulting in implementation of PRV systems city wide. • The costs to Johannesburg Water were low, allowing the investment to not go through tender.
How easy would it be to change to another technology / service provider?	• The Johannesburg Water procurement system is advanced enough to allow for procurement of other technologies, the method of which would include RFIs.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Key trends and developments

The following section summarises the key conclusions obtained from utility case studies, the technology market analysis and the technology scan.

An increasing number of utilities around the world are looking to employ digital technologies in order to meet a range of challenges across the water life cycle, including NRW reduction. This project undertook a market analysis of where the trends and developments are in leakage management technology. Smart analytics platforms, with a focus on cloud-based capabilities was an area which is rapidly evolving, with more competition between large and small technology providers to provide service.

The rise of cloud computing has transformed the GIS market. Cloud-based systems enable multiple users to access a GIS system at one time, whilst further enabling operators to download and publish maps to the internet. Furthermore, operators can now leverage cloud-based AI and analytics to analyse spatial data without having to install additional on-premise software or hardware.

AI is expected to be at the core of the asset management market in the future. In asset performance management (APM), AI will play an increasing role in facilitating predictive maintenance, with complex performance data automatically analysed in order to identify early warning signs of device failure. In asset investment planning (AIP), financial decisions will continue to be justified through the use of advanced algorithms, which can search datasets of potential investment decisions to identify optimal financial strategies. These solutions address a number of utility challenges but bring with it their own risks, opportunities and barriers to adoption.

A number of utilities globally were engaged on this project, and it was noted that while cloud-based water loss platforms are definitely the way forward, attention and innovation should also be prioritised in all aspects of the PALM (Prevent, Aware, Locate, Mend) model, and Infrastructure Management, and through doing this NRW can be successfully managed and reduced.

Opportunities

Utilizing cloud-based water loss platforms and AI technologies offer a range of opportunities to better manage utility networks for the long term. The key opportunities are highlighted below.

Real-time Monitoring and Predictive Maintenance

Cloud-based platforms and AI technologies enable real-time monitoring of water infrastructure, such as pipelines, pumps, or reservoirs. Predictive analytics can identify potential failures or maintenance needs, enabling proactive actions to prevent system disruptions and optimize maintenance schedules.

Data integration

Siloed data existing within separate utility departments is a key digital challenge within the sector and can place severe restraints on the level of insight an operator can gain from monitoring operations. Being able to integrate data sets in to one platform offers opportunities to better manage the whole water network long-term. Utilities who have undertaken successful digitisation projects have underlined the importance of creating a universal platform capable of integrating data from previously separate streams. Cloud based platforms can ensure organisations are both transparent and efficient when it comes to operational decision making through data sharing and integration among different stakeholders in the water sector, such as water utilities, regulators, researchers, and customers.

Public perception

While the word ‘cloud’ and ‘AI’ causes scepticism amongst some customers, cloud-based platforms can actually increase customer satisfaction. More frequent readings mean it is easier to pick up leaks, and although it is not economical to find the smallest leaks, public image matters and utilities are trying their best to maintain good public perception from a social and environmental perspective. Cloud based platforms offer transparency by being able to integrate with customer communication systems and notify when leak repairs will be carried out for instance. Utilities have quoted up to 60% reduction in customer complaints due to customer transparency.

Efficient Customer Service is also another advantage, with cloud-based platforms and AI-powered chatbots or virtual assistants. These technologies can handle customer inquiries, provide real-time information, or offer personalized suggestions, enhancing customer satisfaction and reducing the load on customer support teams.

Using data for multiple purposes

Faced with mounting regulatory pressures regarding water quality, utilities have stressed a desire for digital technology to report on water quality more frequently. It is possible to pull information such as water quality from sensors and this information can be redirected and used. APIs can be used to send data to different systems from the cloud, rather than data being sent solely to a utility’s leakage server for example. There are also opportunities to integrate customer billing systems. Customer meter information can be sent to billing systems and this data can be redirected to relevant places, so for example data which has previously only been used for billing can also be used for leakage targeting.

AI algorithms can analyse vast amounts of data, including historical patterns, weather forecasts, or sensor data, to optimize water management strategies. This can help with demand forecasting, leakage detection, water quality monitoring, and resource allocation, leading to more efficient water distribution and conservation.

Data can be used to feed directly into communication systems as well. For example, if a leaky pipe ultimately needs to be replaced, then the operator can create a network order on the platform to inform the maintenance team and warehouse to repair leak. This information can also be shared with customers so that they can be notified when a leak will be repaired and between what times their water supply may be shut off to repair.

Enhanced decision making

AI technologies can provide valuable insights and predictive models that support data-driven decision-making. This can help water utilities optimize energy usage, prioritize infrastructure investments, or plan for emergencies, leading to better resource allocation and cost savings.

Feedback

Feedback is critical and any information of leak incidents must be recorded on the system. Once a leak is detected, localised and fixed, the system can automatically update GIS. This means utilities can make better decisions when deciding to repair leaks or replace pipes in the future, in case a leaky pipe has several leaks in the near future.

Digital Maturity and 4IR Workforce

AI technologies lend to the digital maturity of utilities and allow for new capabilities and upskilling of utility workforce. These opportunities guide strategic and operational areas of the business.

Barriers to adopting cloud-based water loss platforms

It's important to acknowledge and address the risks while leveraging the opportunities offered by cloud-based platforms and AI technologies in the water sector. Proper planning, robust security measures, and ethical considerations are crucial to maximizing the benefits and minimizing potential drawback.

General Conservatism

Water utilities are generally conservative when it comes to investing in new software, often preferring the stability of legacy solutions rather than embracing new digital platforms. Though GIS software is relatively common within key regional markets (e.g.

North America), uptake in less developed markets could be impeded by this conservative culture.

The rapid rise of cloud-based technologies has triggered mixed reactions within the utility sector. Some operators welcome the scalability, ease-of-use and lower integration costs associated with cloud-based systems. On the other hand, utilities preferring capex models often remain resistant to the monthly OpEx fees associated with cloud-based systems. Though cloud-based technologies have often triggered cybersecurity concerns amongst operators, a broad consensus is beginning to form in the sector that cloud offerings can be just as secure as on-premise alternatives.

Resistance to change by utility staff

Resistance to change was another key point echoed by more than one utility. The attitude of field technicians and staff working in the control room tends to be reactive rather than proactive. It was found that it was difficult to engage Supervisory Control And Data Acquisition (SCADA) monitoring experts unless there was an alert or alarm set off. More than one utility mentioned that staff needs to be more data minded and that a change in mindset was required to get them to realise the benefit of using a predictive approach and pick up events before it gets to alarm stage, potentially preventing bigger incidents like a main break. A lot of the discussion suggested that however ground-breaking or cutting-edge a technology is, it’s full potential can absolutely not be realised without behavioural change and the correct attitudes to use the system and achieve the most effective results.

Despite hurdles related to mindset and behaviour, the utilities expressed that the challenges were worth it. Going forward, the cloud based technological installations have cleared the way for other similar data export services that the utilities use, helping to break down barriers and change mindsets so that other projects were easier to get off the ground. Furthermore, improved data quality improved understanding of the network and other issues for the future which will save the utility money long-term.

Cybersecurity

During utility interviews it was found that most commonly, there was scepticism over data security and fear over the word ‘cloud’ was a recording theme. Data security concerns around pushing data to the cloud and going offshore was a concern of many staff. Driven by a string of recent attacks, and developing national legislation regarding the protection of critical infrastructure, cybersecurity is becoming a heightening concern for utility operators. Cybersecurity initiatives vary significantly, though intrusion detection, extensive staff training and end-user security are all key focus areas within the sector. Some larger utilities have gone one step further, simulating attacks using ‘polite hackers’ who are tasked with exposing flaws in digital systems. These efforts are expected to increase as legislation mandates the establishment of cybersecurity protocols in the future.

Lack of clear ROI

Uptake of GIS software may be limited by a lack of clear ROI (return-on-investment) associated with the software. Whereas uptake of other solutions (e.g. asset investment planning) provides visibility regarding investment returns, the cost saving potential of GIS is more ambiguous; often linked to associated improvements in network and field service management. This restraint is especially present in less developed markets, where utility budgets are already strained.

Lack of Good data

Artificial intelligence and machine learning are powerful tools but are only as good as the data available to them. A solid foundation of data collection and validation is key. In markets with ageing network infrastructure, operators may not have extensive data regarding water and wastewater systems, especially if pipes are buried and inaccessible. This lack of information severely limits the uptake of GIS software platforms, which rely on the digital cataloguing of utility assets during integration periods. In markets where pre-existing records of infrastructure remain limited, integration could take a significant amount of time and money.

Skills Gap

Access to cloud-based platforms and AI technologies may be limited in certain regions or organizations due to factors like infrastructure development or affordability. Additionally, there may be a skills gap, requiring specialized expertise to implement and leverage these technologies effectively.

Uncertainty over technology costs

Technology costs have the potential to rise (as has been seen in 2021 with a global shortage of microprocessor chips), but they can also reduce if market pressures, and efficiencies are exploited. This will make a significant difference to the overall cost of this scenario. The cost of a wide roll out of Advance Metering Infrastructure is also not fully understood. Potentially this could reduce if all utilities and other users share spare bandwidth of these solutions.

Recommendations and focus areas for improvement

- Ensuring intra-organisational/departmental alignment across the utility results in utility-wide benefits. Unlocking data from legacy systems, centralising existing datasets and adopting common data standards at the utility level, are all crucial to providing better data accessibility.
- The benefits of sharing and integrating data should not be measured only in a specific project's ROI, but also in the possibilities for further development that it can facilitate. Helping utilities foster innovation and interdepartmental

collaboration is an important part of this. Running successful pilots is a good way to demonstrate this value. Utilities should look to engage with partners such as SALGA to develop, test and pilot new technologies for NRW reduction.
- Implementation of digital solutions requires clear objectives against which to measure success. Without this, valuable data and functionalities can sit unused in a utility's system. Outcome-oriented digitisation requires an organisation-wide culture shift. Helping utilities prioritise data literacy in training and recruitment and democratise access to data across the organisation, are important steps in this. Utility staff will also need to be able to better communicate across departments. Crucial to successful implementation is understanding what is realistically possible and not over-reaching.
- As utilities increasingly look to employ digital technologies in order to meet a range of challenges across the water lifecycle, absorbing technical knowledge from other industries remains a key avenue for developing digital competencies. Collaboration between other industries can overcome practical challenges. This is especially the case when it comes to applications of AI, which have a rich history in other industries such as manufacturing and pharma. One fertile application for absorbing AI competencies lies in construction, where data-driven approaches have been harnessed in order to optimise material use, capital investment and carbon impacts.
- Addressing utility concerns over data security and cybersecurity, a central hub should be implemented which would be managed by a neutral science council such as the WRC's Research Observatory or housed by the eminent Water Infrastructure Agency.
- To overcome reluctance to take on the challenges of change management or risks of failure that come with it, a roll-out of change management and skills development programmes should be implemented alongside technology demonstrations. This will build long-term capabilities as well as short-term capabilities through technology vendor support.
- Methods of enhancing the effectiveness of the technologies was also discussed and multiple utilities highlighted the need to make zones/DMAs smaller with additional flow meters. The optimal DMA size was recommended as 500-1200 properties.
- Extending focus to Transmission Mains Areas: NRW has historically been in distribution mains but transmission mains should also be paid attention, because if they fail then customers cannot receive water.

- **Further research areas**
  - While this project was centred around next generation solutions to detect leaks, sometimes pipes cannot be repaired repeatedly and may need replacement. Improved repair techniques will be an enabler for future. The development of innovative repair techniques, e.g. in-pipe or keyhole type repairs. If the techniques do not develop in time, this may result in a tipping point where find and fix becomes too expensive.
  - Further research should be done on remote sensing using drones and/ or satellite imagery which have potential uses of vegetation indexing, ground

movement or chlorine detection to identify leakage. Relatively new techniques and cost-benefits need to be fully assessed under a variety of different seasonal conditions and spatial variation could impact on benefit. Similar innovations have been taken to market by companies such as SUEZ in Belgium.
  - Permanently deployed loggers and sensors often have constraints related to battery lifetime. The idea of self-powered loggers that run of off the flow of the water is a novel area, requiring intensive further research to bring the idea to reality. Alternate energy sources to power such devices should also be further explored.

- **Policy and frameworks**
  - Although promising conceptual and technological solutions to protect water systems' security and resilience are available, further work is required to bring them together in an overarching risk management framework, strengthen the capacities of water utilities to protect their systems systematically, determine gaps in security technologies and improve their risk management approaches and technologies. Defending critical infrastructure is a cat-and-mouse game, forcing water utilities to stay on guard, innovate constantly, and implement new technologies.
  - Policy frameworks require integration between the Department of Water and Sanitation (DWS) and Science and Innovation (DSI). This could be facilitated by the WRC to provide an enabling environment for utilities to invest.
  - The government has been working to establish the South African National Cloud Strategy, which provides guidelines and recommendations for the adoption and utilization of cloud services in both the public and private sectors. This will hopefully allow utilities to have better guidance over the adoption of cloud-based technologies. This policy should be finalised and strengthened with utility inputs.
  - Countries with strict regulatory targets that impose financial penalties for high leakage rates, such as the UK and Denmark, have provided particularly appealing markets to leak detection vendors, and hence innovation uptake in these parts of the world is greater. Stricter regulation is required whereby NRW targets are set and penalties issued if they are not met.

REFERENCES

Department of Water and Sanitation and Strategic Water Partners Network (2015). First Order No Drop Assessment Report 2014: the status of water loss, water use efficiency and non-revenue water in municipalities.

National Planning Commission (2012). National Development Plan – 2030. Available at ttps://www.gov.za/sites/default/files/gcis_document/201409/ndp-2030-our-future-make-it-workr.pdf

Advantages of Implementing Smart Water Networks – 2011. Available at https://www.waterworld.com/home/article/16192389/advantages-of-implementing-smart-water-networks

GWI Water Data, Water supply priorities – Available at: https://www.gwiwaterdata.com/digital/utility#card-303922

THE STATE OF NON-REVENUE WATER IN SOUTH AFRICA (2012) – Available at: https://green-cape.co.za/assets/Sector-files/water/Water-conservation-and-demand-management-WCDM/WRC-The-state-of-non-revenue-water-in-South-Africa-2012.pdf

Water UK, A leakage Routemap to 2050 (2022), Available at: https://www.water.org.uk/wp-content/uploads/2022/03/Water-UK-A-leakage-Routemap-to-2050.pdf

City of Cape Town Case Study i20 – Available at: https://en.i2owater.com/clients/city-of-cape-town/

Maintaining Our Water Supply, Sydney Water – Available at: https://www.sydneywater.com.au/water-the-environment/what-we-are-doing/current-projects/maintaining-our-water-supply.html

Johannesburg Water Annual report 2022 – Available at: https://johannesburgwater.co.za/annual-reports/

Understanding household water-use behaviour in the city of Johannesburg, South Africa, 2021 – Available at: https://www.researchgate.net/figure/Map-of-Johannesburg-showing-the-seven-regions-of-the-city-Source-Chirisa-Matamanda_fig1_354620375

Leakage Performance, Thames Water – Available at: https://www.thameswater.co.uk/about-us/performance/leakage-performance

The Jerusalem post, How is water powering the Israeli fiber optics revolution (2021) – Available at: https://www.jpost.com/jpost-tech/how-is-water-powering-the-israeli-fiber-optics-revolution-684083

Mekorot continues efforts to secure its critical infrastructure against cyber-attacks, GWI Water – Available at: https://www.globalwaterintel.com/sponsored-content/mekorot-continues-efforts-to-secure-its-critical-infrastructure-against-cyber-attacks-mekorot

South African Government News Agency, Government finalising national data, cloud policy – Available at: https://www.sanews.gov.za/south-africa/government-finalising-national-data-cloudpolicy policy#:~:text=The%20national%20data%20and%20cloud%20policy%20%E2%80%9Cseeks%20to%20strengthen%20the,sovereignty%20and%20the%20security%20thereof%E2%80%9D.

FIDO, Thames Water Case Study – Available at:https://fido.tech/case-studies/thames-water-leak-team-gets-total-success-from-fido-led-work-orders/

International Water Association & Xylem, how digitalisation is driving operational decision-making (2023) – Available at: IWA webinars