SMART WATER MANAGEMENT

Case Study Report

Executive Summary

K water

IWRA

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Contents

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I. Introduction

This report is the major output of the Smart Water Management (SWM) project, a joint effort led by K-water (the Korea Water Resources Corporation) and the International Water Resources Association (IWRA), with contributions from over 40 organisations from around the world. The report showcases ten exemplary SWM projects based in both developed and emerging regions, along with 9 upcoming and potential SWM projects, which address the use of innovative smart technologies and solutions to address a wide range of water challenges across a number of scales (from household to transboundary). Table 1 below shows the SWM projects and their smart solutions in the order they appear in the report. The map below shows the global distribution of these projects and the text boxes included within the report.

Table 1. Case study location, project name and SWM solutions

Case study location	Project Name	SWM Solution
South Korea (national)	K-HIT	Flood and drought integrated network
Paju, South Korea	Paju Smart City	Water quality real-time monitoring for drinking water
Seosan, South Korea	Seosan Smart City	Smart sensors and real-time display increased leak detection and community satisfaction
Paris, France	SIAAP	Integrated network for improved real-time water quality in sanitation
Guantao County, China	Handan Pilot	Groundwater monitoring and modelling to reduce over abstraction
Mexico City, Mexico	PUMAGUA, UNAM	Smart sensors for drinking and wastewater quality and leak detection
Thailand, Tanzania, Kenya, Uganda, Rwanda, Burundi, Benin, Burkina Faso, Cote d'Ivoire, Ghana, Mali and Togo	Flood and Drought Monitoring Tools (FDMT)	Flood and drought monitoring and planning using satellite data
Zimbabwe, Mozambique, Tanzania	Small-scale agriculture productivity and efficient irrigation in Southern Africa	Efficient irrigation using real-time soil monitors and an Agricultural Innovation Platform (AIP)
Spain, The Netherlands, United Kingdom and France (SW4EU)	Smart Water for Europe (SW4EU)	Four demonstration sites addressing leak detection, water quality, community satisfaction and energy optimization using smart sensors and DMAs
Toronto, Canada	Stormwater SmartGrid	Real-time rainwater collection and monitoring for household stormwater management

The following section provides an overview of the ten SWM projects selected by K-water and IWRA for development into case studies as part of this report. From the case studies received, the ten identified for inclusion were selected to present a diverse range of scales, geographic locations in both developed and developing regions, water challenges faced, and technology solutions implemented. The report also includes 9 upcoming 'project highlights' looking to implement SWM or in the beginning of their implementation. These are presented as text boxes in the relevant sections of the report.

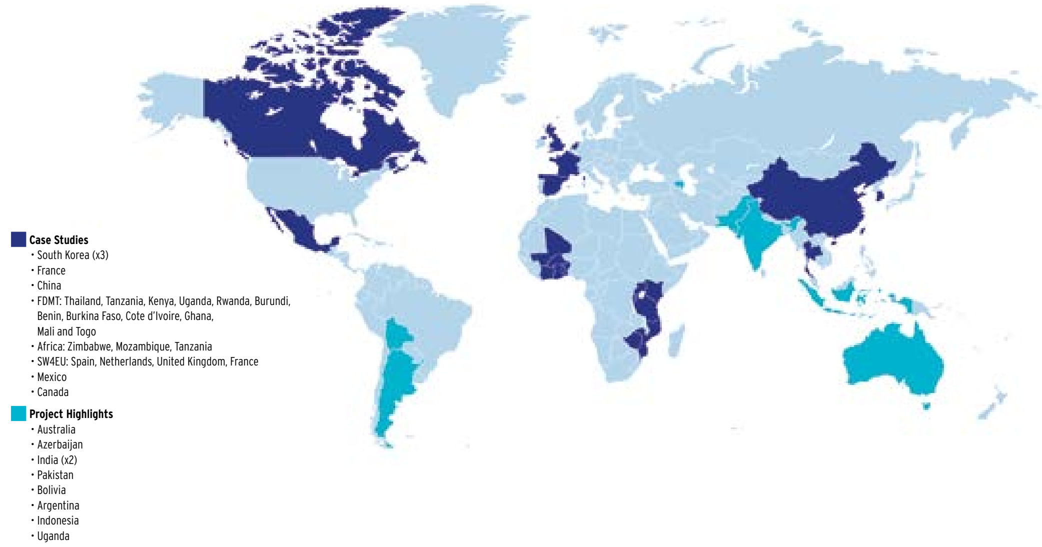

Figure 1: Map showing location of SWM Project case studies and text boxes

The purpose of the SWM report is to:

1. Demonstrate the potential for SWM implementation in a range of contexts, geographic locations, scales, and water challenges in both developing and developed countries.
2. Provide cross-case analysis of the case studies to illustrate the various enablers, barriers and lessons learned in each project during SWM implementation and operation.
3. Provide policy recommendations based on the findings of the analysis to support future SWM implementation.
4. Demonstrate the potential for SWM to assist in reaching the Sustainable Development Goals (SDGs).

SWM has become an area of increasing interest over the past decade as governments, industries and utilities move towards real-time data collection and use to optimise their operations and knowledge. K-water has championed the development of SWM during this time, developing various tools and technologies to address a range of water challenges. Within this report K-water will share their projects and the lessons learned of SWM over the past decade, to provide insight into the solutions available and to present the challenges that are still to be overcome. To present a broader view of the possibilities of SWM, case studies from around the world will also be presented to show how SWM technology has been implemented, at various scales and across various contexts, and the successes, and at times challenges, that these projects have faced.

The case studies within this report demonstrate the role smart technology can play in assisting to resolve numerous water challenges (e.g. water access and quality, efficient irrigation, reduced demand, flood and drought management and planning and inclusive governance and data management) across a diversity of scales. It also shows the potential for SWM projects to aid in the achievement of the Sustainable Development Goals (SDGs) (e.g. by improving livelihoods and economic and gender equity, reducing hunger, broadening access to knowledge and education, enhancing health and wellbeing, adapting to climate change and improving safety).

The full edition of this report on SWM includes policy recommendations aimed at stakeholders looking to adopt SWM policies at the local, national and regional level, as well as pointing to next steps to support the continued successful implementation of SWM across the world.

II. What is Smart Water Management?

Box 1. Definition of Smart Water Management

Smart Water Management (SWM) is the use of Information and Communication Technology (ICT) to provide real-time, automated data for use in resolving water challenges through IWRM.

SWM can be used for planning and operational purposes, from daily use to organisational and policy planning at a range of scales, across contexts and regions.

SWM enables governments, industries and utilities from around the world to integrate smart principles (using ICT) into their urban, regional and national strategies. The potential application of smart systems in water management is wide, and includes solutions for water quality, water quantity, efficient irrigation, leak detection, pressure and flow, ecosystems, floods, droughts and much more.

By applying SWM infrastructure such as sensors, monitors, GIS, satellite mapping and other data sharing tools to water management, real-time solutions can be implemented and broader networks can work together to reduce current water management challenges.

SWM is a response to the need for shared information, collaborative practices and automated responses across the field of integrated water resource management (IWRM), in order to increase security and efficiency while decreasing risk and uncertainty. A key assertion of SWM is that by introducing real-time data and automation, services will become more efficient, water management will become more reliable, while decision-making will become more inclusive and knowledge-sharing and collaboration will improve.

The Republic of Korea has championed SWM since 2008 in an effort to achieve smarter technologies and more efficient and reliable water resource management. Since then Korea has developed world class projects in SWM which they will share within this report to demonstrate the potential of SWM and to support other countries interested in investing in SWM in the future.

III. International cooperation

Part of the Republic of Korea's policy on SWM is aimed at becoming a leader and role model for smart technologies in water management, in particular so as to impart its experience and expertise to developing countries through international cooperation.

As a country that has experienced rapid urbanization and economic growth in the past 50 years, transitioning from a developing to a developed economy, the Republic of Korea understands better than most both the challenges and needs faced by developing countries and the potential for improvements and lessons learned by developed countries. The Republic of Korea can therefore act as a messenger between the two, sharing the possibilities of smart technologies to both developed and developing countries interested in investing in SWM.

In order to meet the complex water challenges currently facing developing countries and to mitigate and adapt to an ever-changing climate, technological advances will need to be introduced. For some developing countries limited access to electricity or wireless internet connections, or limited basic water infrastructure, can result in challenging barriers to the successful implementation of SWM. Without basic infrastructure and resources, smart technology may seem limited in its potential. Nonetheless as shown within this report, not all smart tools required extensive physical infrastructure to succeed, and many challenges can be resolved. To support developing countries to participate in the emerging field of SWM, developed countries can provide access to smart tools and technologies, but to ensure the sustainability of these projects in the long-term, it is critical that capacity building and knowledge sharing be at the core of SWM development.

To demonstrate the types of projects not yet using smart technology that could greatly benefit from SWM implementation, this report also includes short textbox case studies on projects from around the world either in the initial stages of SWM implementation, or looking to introduce SWM once solutions are found to the barriers currently in place. It is intended that by sharing these stories and the challenges they face in adopting SWM, solutions can be found to enable their future implementation.

As water challenges vary greatly around the world, from water access concerns in dry climates to flooding in temperate and tropical climates, it was considered important to showcase SWM projects that cover a wide range of water challenges across both cities and regional areas. SWM projects located in cities face challenges such as improved water and sanitation quality, stormwater management, leak management, community engagement and decision-making. In regional and rural areas the projects focused more on water access, water quality and efficient irrigation.

It was also considered important to present a broad geographical range of projects as technologies are developed at varying speeds and in different ways in every country and region, based on knowledge, capacity, funding, and need. While some countries are already in the process of including smart technologies as a core element to their IWRM approaches, others are yet to begin this process. By sharing the lessons learned and solutions to challenges faced from the countries and regions where SWM has been successfully implemented, the aim is that countries interested in SWM will be able to better overcome or deal with the challenges faced by the early adopters of SWM presented within this report.

IV. Core elements of Smart Water Management

The analysis showed numerous benefits from the implementation of SWM as shown in Box 2. Across the 10 case studies, certain factors for success appeared consistently as critical for successful SWM implementation, across scales, geographic locations, levels of development and the water challenges being addressed. These factors for success are detailed in Box 3.

Box 2. Benefits of Smart Water Management Implementation

Social benefits

- **Access to clean water and sanitation** through water treatment and monitoring
- **Health improvements** through increased access to clean, safe water
- **Improved livelihoods** through job creation, greater opportunity for further education, higher productivity and other opportunities
- I**ncreased training and capacity building** for the local community and staff
- **Increased sharing of solutions** to support sustainable development
- **Increased decision-making opportunities** through increased engagement and knowledge-sharing
- **Greater collaboration with community** through engaging with local stakeholders at the beginning of the project
- **Greater security** by improving water security and increased resilience to climate change
- **Increased trust** in water suppliers and the safety of water sources
- **Improved access to data and information** through real-time data sharing with all water users
- **Increased gender equality** through increased opportunities for capacity building and further education
- **Reduced conflict over water access** leading to increased trust and willingness to engage in collective action

Economic benefits

- **Increased efficiency** in irrigation systems and wastewater treatment systems
- **Reduced waste** by the reduction of water loss through leakages
- **Job and opportunity growth** through job creation through SWM project research, design, development and implementation
- **Improved capacity** in water systems improving their capacity to manage flows and reduce damage during storms/floods
- **Reduction in future infrastructure costs** by integrating smart technology tools to improve capacity/efficiency, resulting in less need for additional infrastructure
- **Mobilisation of funds** from public and private sources, as well as international funding sources

Environmental benefits

- **Improved water quality** through reduced pollution and contamination in waterways
- **Improved ecosystem health and protection** through improved water quality and quantity
- **Reduction in groundwater depletion** through reduced over abstraction
- **Reduced land degradation** through flood and drought management and reduced nutrient loss in the soil
- **Reductions in CO^2 emissions** through energy optimisation and reduced energy consumption
- **Reduced water consumption** through leak detection and reduced demand and increased reuse

Governance benefits

- **Improved management and knowledge**, as measurement is critical for effective management
- **Improved accuracy of data**, as real-time data should also be SMART (specific, measurable, actionable, relevant and time-bound) data
- **Increased community-led decision-making opportunities** as water users can make decisions based on real-time water use and information
- **Improved transparency** as water users have access to water use and quality in real-time

Technology benefits

- **The opportunity to test and develop** new and innovative tools for water management
- **Innovative technologies created** with the potential for commercialization
- **Identification of the remaining gaps** in technology adoption (e.g. standardisation of software and tools to make it easier to adopt the 'right' mix of tools for each situation
- **Showing the potential for SWM tools** to deliver successful outcomes and in turn lead to significant social, environmental, governance and financial impacts

Box 3. Factors for success

Cross-cutting factors

- Political commitment from government at all levels
- Support from national government policy, legislation, and regulation
- Use of two-pronged approach (i.e. combining the use of SWM tools with engagement, governance and/or a strong business model) to support the implementation and increase the adoption for, and positive outcomes from, SWM technologies.
- Strong stakeholder engagement from the beginning of the project across and within sectors, (especially) including local agencies and communities, to ensure active community participation and decision-making.
- A multidisciplinary approach (both across sectors and within sectors) to ensure all factors can be taken into account (e.g. environmental, technical, scientific, policy, regulation, financial, maintenance, etc.).

Social factors

- Active stakeholder engagement from the beginning of the project
- Local stakeholders to be involved in decision-making and implementation
- Improved livelihoods from job creation and increased opportunities such as time for further education and skill development
- Increased trust in the community towards water suppliers and water resources
- Education, training and capacity building for local communities

SMART WATER MANAGEMENT
CASE STUDY REPORT - EXECUTIVE SUMMARY

Economic factors

- Long-term investment to enable on-going research, development, testing and implementation, to support taking SWM solutions to market
- External financial support to assist in the implementation of projects in the short-term/ financial support from both public and private investors
- Consideration of the non-financial benefits (e.g. environmental, social, governance), which are often apparent in the short-term, alongside the financial returns, which are medium- to long-term
- Strong business cases to support replication and scaling
- Demand management and improved efficiency as a means to water and energy savings

Environmental factors

- Regulations, economic instruments and information to encourage behavioural changes to improve water quality, efficient water use, natural resource protection
- National plans to improve/resolve water challenges
- Commitments from international funding bodies to meet and address the Sustainable Development Goals, including water
- Commitment from leading organisations and stakeholders to address these environmental challenges

Technical factors

- Allowing adequate time to design, develop, test and adjust technology for greater/more accurate results
- Undertaking a baseline assessment of the challenges and what needs to be addressed to ensure that the right mix of technology and non-technological solutions are implemented.
- Collaborating with all sectors to ensure adequate and accurate data (e.g. electricity data) are shared to support decision-making
- Integrating smart tools and systems across networks to enable collaborative decision making
- Integrating smart tools with traditional infrastructure
- Willingness of water utilities and governments to test the possibilities of smart technologies

V. Replication and scaling

Each of the projects report in these case studies has the potential to be scaled up and out, scaled down (for small-scale projects) and replicated in both developed and (under the right circumstances) developing regions to assist with resolving water challenges . As every project presented in these case studies is specific to the area and country where it was implemented, replication mandates an understanding of the different contexts faced by the initial project and the adopting region. An assessment on whether the conditions are similar enough to attempt the same approach, and what additional support is required prior to planning the replication is also recommended. However, with the right financial, policy and technology support, knowledge sharing and collaborative decision-making, each of these projects has the potential to be adopted in both developed and developing regions with long-term success.

To support other areas interested in adopting SWM, these case studies provide directions and identify factors of success; and equally important they identify the barriers faced during implementation. In is the hope that future projects can learn from these experiences so that they can easier and more quickly overcome these challenges.

The pilot projects (e.g. Paju, Seosan, Mexico, IWA, Africa, China, Canada), show how SWM can be adopted in stages, from minor adjustments to improve the efficiency of a system, to introducing a whole new suite of tools to change the way a challenge is addressed. While smaller in scale when compared with some of the larger citywide projects, these case studies show the significant benefits that can be achieved through adopting a SWM approach. The larger projects (e.g. K-HIT, SIAAP and SW4E), provide ambitious examples of fully integrated systems, showing what can be achieved when policy, financial and technology resources and strong collaboration are in place.

Based on these findings, the following section provides a series of policy recommendations in relation to social, economic, environmental, technological and governance strategies aimed at policy makers from all levels of government interested in supporting the future successful implementation of SWM in both developed and developing regions. It also provides a classification of the types of SWM implementation that occur and the levels of support required for each type to increase the chances of successful implementation.

VI. Policy recommendations

Table 2: Policy recommendations for Smart Water Management implementation

Strategies	Policy direction
SWM for an improved quality of life (Society)	**1.** Facilitate adoption of SWM tools, especially in developing countries, to support access to basic services, and to support equality for poverty reduction, public health and quality of life. Include capacity development, technology sharing, collaborative business models and community governance and decision-making opportunities.
	2. Build trust and community engagement using SWM tools in areas where the community feel unsafe using the local water sources.
	3. Empower people in developing countries with smart tools to reduce the time spent on water management and increase farm income and time available for other activities (e.g. further schooling, and additional work opportunities).
Investment in SWM for improved resilience and sustainable development (Economy)	**4.** Strengthen collaboration across and within sectors to provide opportunities for networks to share information and data to assist with effective and efficient water management.
	5.Value non-financial benefits (e.g. environmental, social, governance and technical benefits) as equally important as financial benefits for SWM implementation, as they contribute to building resilience to the effects of climate change and increasing populations.
	6. Support long-term investments for SWM implementation to enable adequate research, development and testing.
SWM for protecting and conserving water resources and ecosystems (Environment)	**7.** Introduce policies, regulations and incentives to drive environmental and ecosystem protection through use of SWM.
	8. Encourage SWM solutions to increase water quality, manage demand and use, water reuse, reducing groundwater depletion and increase energy efficiency, etc.
	9. Introduce SWM solutions for climate adaptation plans for flood and drought planning and management and major storm events.

Support evolving smart technology development and adoption (Technology)	**10.** Develop standards to ensure all SWM technologies are compatible (can communicate) with each other to enable tools to be purchased across various suppliers to enable those implementing SWM to create the right set of tools for each context.
	11. Support on-going research, testing and development of SWM tools to advance them to a point where they are robust and require minimum maintenance and are ready to be commercialized (Government policies that support taking SWM tools from R&D to market).
	12. Support technology to assist in regions without built infrastructure or the adequate resources (e.g. electricity), as currently SWM infrastructure is (almost always) reliant on built infrastructure
Building capacity and networks for increased resilience and collaboration (Governance)	**13.** Empower people, especially those in developing countries, by providing them with SWM tools, data and capacity development and education to enhance/ support local decision-making.
	14. Strengthen the capacity to adapt to climate change by adopting SWM planning and operational technology.
	15. Plan for water disasters in advance by creating proactive policies instead of reactive policies.

Through this analysis several SWM implementation 'types' became evident. As the context of each SWM project is different, understanding the various types of SWM implementation and the tools and solutions for each type is critical for successful implementation. A description of these types is provided in Box 4 below.

Box 4. Smart Water Management Implementation Types

Implementing SWM technology by itself will not always resolve the water challenges faced by a project. In some cases, a two-pronged approach is necessary to address the complex nature of each challenge. The second element of the two-pronged approach can include community engagement, governance schemes or business models, and is equally as important to the success of many of the projects as the SWM tools themselves.

Based on the case studies presented within this report we have categorised SWM technologies into three different types depending on who is using/adopting the technology. Each type requires a different approach to ensure the technology achieves its potential benefits.

Type 1 – Institutional users

Type 1 addresses technologies aimed at major institutional users such as water suppliers, water managers, mines, water treatment plants, etc. (e.g. SIAAP, K-HIT, China). The implementation of these technologies is mostly straightforward as industries and utilities can be encouraged to adopt SWM through incentives (improving efficiency, environmental benefits) or drivers (meeting regulations or targets) introduced by governments or the agencies themselves. Regulations and policies that encourage these institutions to develop and implement SWM technologies are relatively easy to introduce (depending on the government), and the institutes will more easily fund the necessary research (often with government support) to develop and successfully implement SWM.

Type 2 – Individual users

The second type is the technologies aimed at a large number of individual users such as households and farmers (e.g. Africa and Canada). These are far more complicated to implement, as they require a very large number of individuals to change what they are doing, and they do not always respond in the same way to economic incentives. Often the main benefits are to the society at large, rather than the individual. The savings from introducing smart technologies in homes might be small compared to the cost and inconvenience of adopting it, however the total impact might be significant and therefore the societal benefit high. In this second type, a two-pronged approach is more critical in order to achieve the potential societal benefit.

Type 3 – Institutional and individual users combined

The third type involves a combination of both the institutional and individual user. This is seen when an institution develops and implements the SWM technology but the success of the technology partly relies on the individual user (e.g. Mexico and IWA). This approach requires some engagement, but is less dependent on a second-prong than Type 2, due to the implementation being conducted by the institution.

VII. Summary of the case studies

The following section provides an overview of the ten SWM projects selected by K-water and IWRA for development into case studies as part of this report. From the case studies received, the ten identified for inclusion were selected to present a diverse range of scales, geographic locations in both developed and developing regions, water challenges faced, and technology solutions implemented. The report also includes 9 upcoming 'project highlights' looking to implement SWM or in the beginning of their implementation. These are presented as text boxes in the relevant sections of the report.

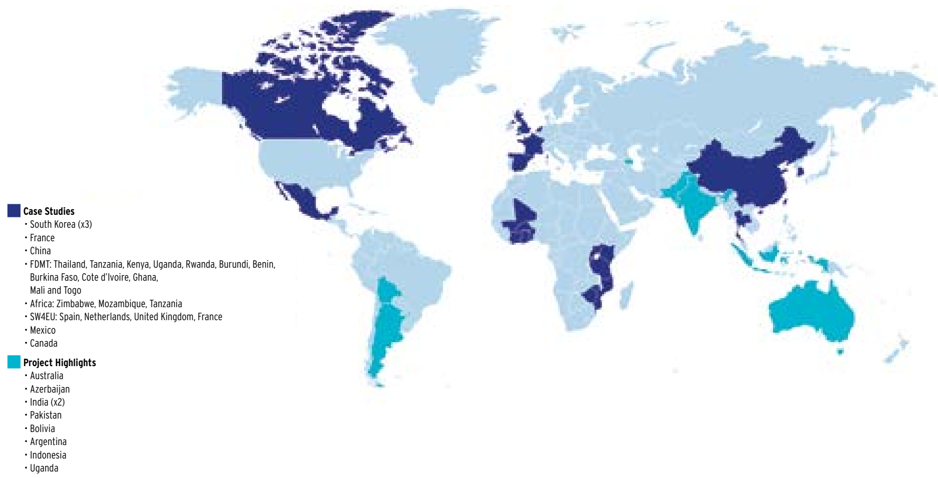

Figure 2: Map showing location of SWM Project case studies and text boxes

Table 3: Case study location, project name and SWM solutions

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Canada	Stormwater SmartGrid	Real-time rainwater collection and monitoring for household stormwater management

As K-water has been a leader in SWM for the past decade, this report leads with three exemplary case studies from across Korea to share lessons learned and solutions to floods and droughts, non-revenue water, water quality and improved customer satisfaction. Following the three Korea case studies are seven projects from around the world presenting solutions on sanitation, water quality, efficient irrigation, groundwater depletion, community satisfaction, energy optimization and stormwater management. These case studies are supplemented by a number of text boxes that contain information on SWM projects that are in the pipeline.

K-water Hydro Intelligent Toolkit (K-HIT)

Water management is a challenge in Korea due to limiting geographical features, such as short watercourses, and high rainfall variability across the regions and seasons. Korea also faces regular water-related disasters such as extreme flooding and droughts, increasing in intensity due to the change in climate. These challenges are creating increased pressure on national water management and security. To address this, Korea has placed great effort to resolve temporal and regional variability through the construction of multi-purpose dams and multi-regional water supply systems. Such an investment in water resources in Korea has increased the water supply for industrial and domestic use alongside supporting Korea's national economic development.

K-water is responsible for managing flood water and for supplying water through the operation of water resources infrastructure including: 34 multipurpose and water supply dams, 4 flood control dams and reservoirs, 16 weirs, and one estuary barrage (similar to a low dam wall). Of these, the multi-purpose dams operated by K-water account for 62% of total dam supply and 94% of flood control capacity. In order to protect the people from drought and flood disasters through more efficient water resource management, K-water has constructed a scientific river operation system which links the rivers in the connecting watersheds. The aim of this system is to implement integrated water resource management technology in rivers for the purpose of increasing water quantity and water quality concurrently.

In 2002, the K-water Hydro Intelligent Toolkit (K-HIT) was introduced, to provide an integrated water management system based on Information and Communication Technology (ICT). K-HIT has five functions including real-time hydrological data acquisition, precipitation forecasting, flood analysis, reservoir water supply, and hydropower generation. By using K-HIT, K-water can minimize the flood damages by storing more water during the flood season and can prevent droughts by supplying stored water during the dry season through the use of scientific and effective operation of this system.

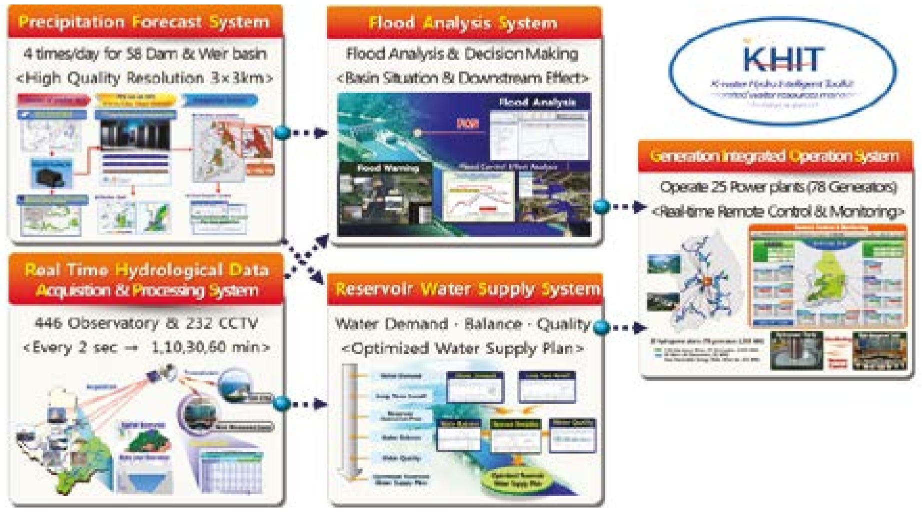


Figure 3: K-water's water resources management procedures based on K-HIT (Source, K-water)

Through the introduction of K-HIT, K-water have been able to effectively deal with floods that occurred in 2012, 2013 and 2015. In this way K-HIT also contributes to the achievement of sustainable development goals including SDG 6 (availability and sustainable management of water) and SDG 11 (making cities inclusive, safe, resilience and sustainable) by preventing disasters such as floods and securing water in droughts.

Seosan Smart City, Korea

Water management has become increasingly important over the past decades with the increase of the natural hazards and disasters caused by climate change, deteriorating water management facilities, and increased water consumption due to population growth and urbanisation in Korea. To solve these water challenges and improve the efficiency of water management, K-water has introduced ICT in their water management. Water management using ICT, known as Smart Water Management (SWM), enables sustainable water supply to every citizen by water resource monitoring, problem diagnosis, efficiency improvement and harmonising management.

The Smart Seosan City project started when the City of Seosan asked for a smart metering system for the Seosan local water supply system as a drought measure in January 2016. Seosan city decided to employ smart metering to the local water system when regional and national drought reaction plans were established according to laws and plans. Before this project, K-water was operating smart metering as a pilot project in the Goryeng area (from January to May 2015) and had consigned Seosan's local water supply. K-water suggested smart metering to Seosan city and the city accepted this suggestion. The main purpose of the project was to construct SWM systems, which focus on reducing water leakages and consequently improving revenue water ratio by using remote metering, smart meters and ICT. Unlike meters, which rely on a person to manually check the data on a meter on site, these smart meters deliver a user's hourly water usage recorded by a digital meter (smart meter) and wireless communication technology (ICT).

Figure 4: Smart monitoring system in the Smart Seosan City

The project results show a 20% improvement in the revenue to water ratio and a 190,000 m^3 of water per year decrease in leakage. This will result in a benefit of USD 590,000 over the next 8 years, which is expected to increase. By switching to remote meters for water use and quality, customers' satisfaction has improved as it has become possible to handle complaints promptly and to provide additional water quality management services. **Government support played a major role in the implementation of this project**, as the planning and execution of the drought policy, existing laws and system helped state and local government and public institutions plan measures systematically and react in a concerted manner. In addition to this, the government budget support for the project was essential in facilitating the project's implementation. Seosan SWM required early facility investment and operating costs but in the long term, an increase in net profit is expected. **As the smart water market is becoming more active with many companies competing, future costs are expected to decrease. Smart metering enables a sustainable water supply by reducing water leakages and saving water and energy.** When water supply is reduced or limited by drought or other challenges, new water resource development is needed to supply water stably.

Paju City, Korea

Despite the nearly universal availability of high quality drinking water in Korea, the direct tap water drinking rate of Korea is only around 5%, which when compared to advanced countries such as the United States (56%) and Japan (52%), is extremely low. The main reason why Koreans do not drink tap water directly is distrust. More specifically, the general public has a strong distrust of tap water quality due to concerns about the aging water pipes, the smell of tap water and the taste of tap water. As a result, K-water has focused its investments on improving the water quality of existing waterworks projects and community perceptions of the water rather than on quantitative centered investments. In order to reassure people of the quality of tap water and to remove any anxieties, K-water introduced the *Smart Water City (SWC) healthy water services* with the goal to increase the consumption of tap water.

A SWC integrates ICT throughout the entire tap water supply process, from treatment to faucet, so that people can directly check for themselves in real-time the status of the tap water supply process and water quality. By implementing ICT into a city's water management in this way, a SWC can effectively reduce the general public's distrust in tap water thereby increasing the consumption of tap water.

Figure 5: Healthy water supply system, Paju Smart City

In Paju Smart City, ICT technology including real-time sensors and on the ground staff engagement increased the the consumption of tap water substantially from 1% to 36.3% in three years. In addition to increased consumption of tap water, community trust in water safety also increased. This shows the potential for SWCs to assist with raising community awareness of the safety of drinking water, leading to increased access to low cost safe drinking water and improved decision-making for the community interested in contributing to the efficient use of water management.

MAGES - SIAAP, Greater Paris, France

The greatest challenge that the sanitation system of the greater Paris region had to face in the final decades of the twentieth century was the quality water extracted from the Seine and Marne rivers. The pollution of the rivers was caused by a lack of treatment capacity, technical performance and combined sewer overflows during rain events.

After decades of investments, huge improvements in river water quality were achieved and the objectives of the European Water Framework Directive (WFD) are close to being reached thanks to the development of wastewater treatment plants and a sewage transport system. At the same time Syndicat Interdépartemental pour l'Assainissement de l'Agglomération Parisienne (SIAAP), the public utility in charge of the transport and treatment of wastewater for the Greater Paris region, also invested in a real-time control system following a 1997 sanitation masterplan study that recommended the implementation of real-time control for better control of stormwater pollution caused by combined sewer overflows, allowing a reduced need for storage facilities.

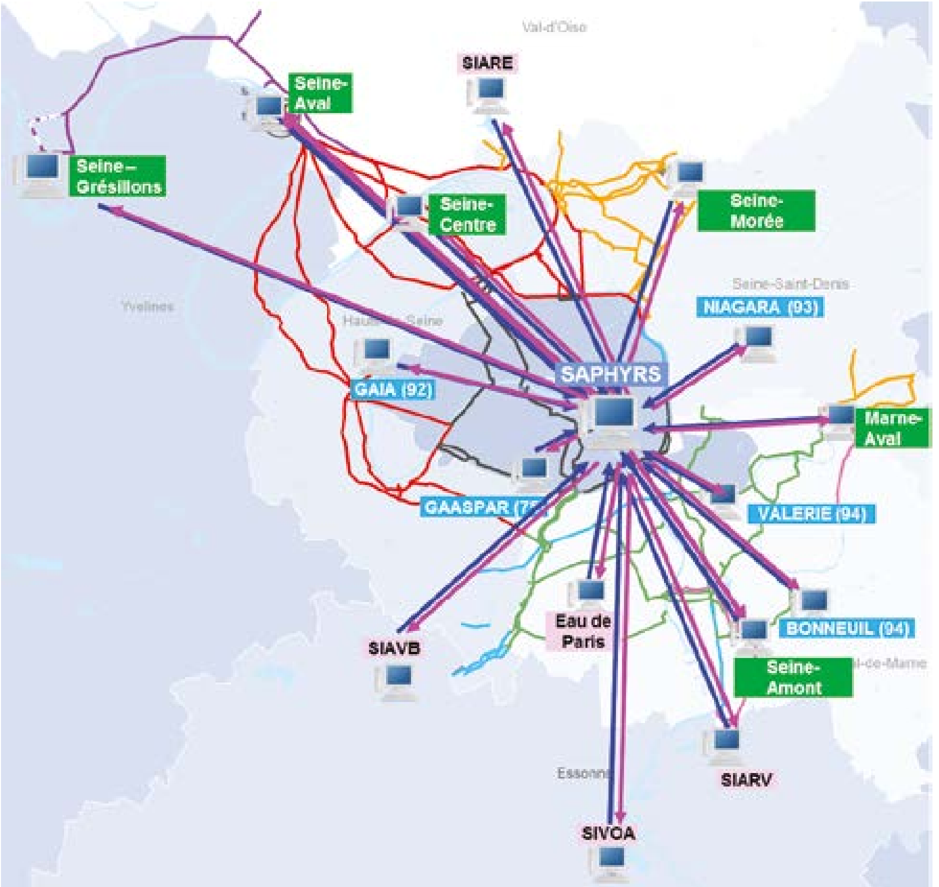


Figure 6: Main data transfers between control room and MAGES with WWTPs (in green), SIAAP operator members (in blue) and outside operators (in pink)

Building upon existing systems and the experience acquired since the mid-1980s at SIAAP as well as each of the its constitutive *départements*: Paris, Hauts-de-Seine, Seine-Saint-Denis and Val-de-Marne, this real-time control system called MAGES (*Modèle d'Aide à la Gestion des Emissaires du SIAAP)* began operation in 2008. The new system integrates all the data from each *département* system, and is powered by a hydraulic deterministic model fed in real-time by 2000 sensors. It provides flow forecasts for a trend scenario in each part of SIAAP's networks and at each treatment plant on different time scales depending on the weather conditions. This trend scenario is used by the operators to adjust the management of the system.

This smart system takes advantage of the capacity to transfer sewage from one wastewater treatment plant (WWTP) to another. Such transfers enhance system wide security in case of shutdown due to events such as planned works or incidents. **MAGES has been the driver of several changes in the way to see and operate the sanitation system is operated. First, each operating site has the knowledge in real-time of what has happened elsewhere on the sanitation system, resulting in a shared and global view of the system.** At the same time, the SIAAP department that operates MAGES has a global overview of the hydraulic running condition of the whole system.

Ten years after the commissioning of MAGES, it is still difficult to assess its benefits in terms of savings either on investment or operation costs. Nonetheless, smart management is here to stay. Projected constraints on the operation of Paris's regional sanitation system from tighter

SMART WATER MANAGEMENT
CASE STUDY REPORT - EXECUTIVE SUMMARY

regulations, population growth and effects of climate change on the Seine hydrology are impelling SIAAP to develop smarter tools aimed at reducing pollutant loads discharged into the rivers without entailing excessive costs.

Groundwater modelling, China

Where water quality is not an issue, groundwater is more reliable than surface water supply from existing surface reservoirs and irrigation canals, especially during persistent droughts. Unlike surface reservoir releases however, groundwater abstraction is neither easily monitored nor effectively controlled by local water authorities due to the large number of wells that are not fully equipped with expensive registered meters.

This weakness in oversight, combined with pressures to extend cropping, has inevitably resulted in over-abstraction and severe groundwater depletion in arid and semi-arid regions in China such the North China Plain, which has become China's granary. The over-abstraction has a number of serious consequences. Firstly, it decreases the amount of water stored and thus the ability of aquifers to serve as reservoirs for drought relief. Secondly, it increases the amount of energy required to lift the groundwater to the surface. Thirdly, it harms aquatic ecosystems by reducing the amount of groundwater discharging to streams (and constituting the streams' base flow) and by drying up wetlands and springs. Finally it leads to land subsidence. Thus, in northern China where groundwater is intensively utilized, a number of challenges have been identified, such as: increasing gap between fresh water supply and demand in mid and long term; difficulties in groundwater management due to the vast number of unregistered pumping wells with pumping rate of less than 1000m^3/d (registering and monitoring all of these wells would require a significant investment); current groundwater metering and monitoring systems of low efficiency.

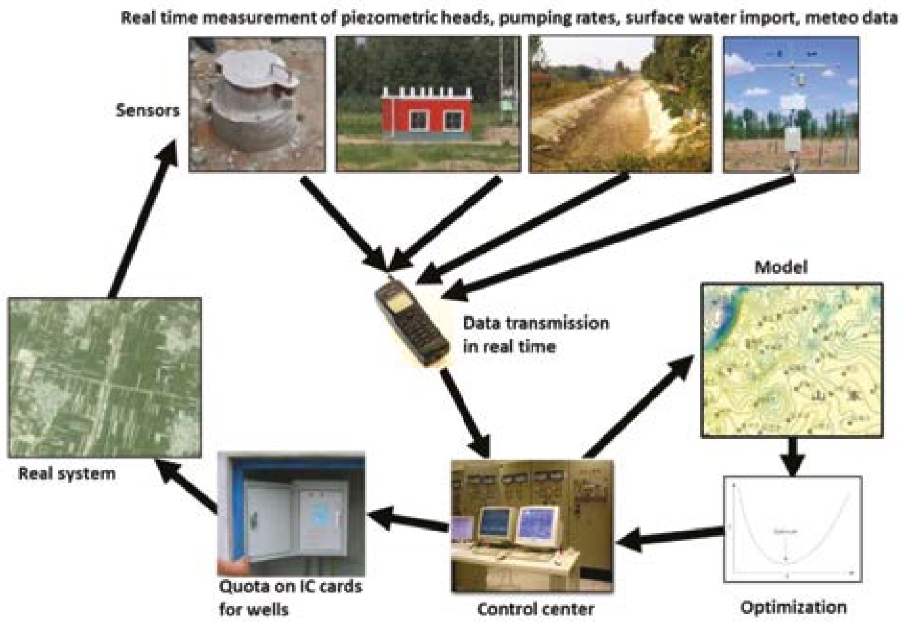


Figure 7: The Architecture of the real-time groundwater monitoring, modelling and controlling system.

Confronted with the aforementioned challenges, the project presented in this report aims at optimizing and controlling the real-time allocation and consumption of groundwater under climate variability. **The focus is placed on developing and implementing a real-time**

monitoring, modelling and controlling system for groundwater management to address climatic variability and to prevent groundwater depletion. The main elements of this smart water system are: (1) automatic monitoring of groundwater levels in observation wells, (2) automatic monitoring of pumping rates of wells, (3) wireless transfer of those data in real time to a control center, (4) a real time model of the aquifer assimilating the data and (5) a method to exert control over the maximum seasonal pumping volumes of wells.

The development and pilot use of the smart water system is done in a typical aquifer sub basin located in coastal Guantao County, Hebei Province, China, which is part of North China Plain. The North China Plain is the site of extremely severe groundwater depletion, exemplified by the significant groundwater level drop under sites of intensive abstraction. The project will pilot a smart water system for the sub basin, which can be scaled up to the whole basin. The implementation of the project allows a comparative approach with different climate conditions, different cropping patterns and intensity of farming practices, and different farming communities.

Flood and Drought Monitoring Tools, IWA and DHI

The high prevalence and severe impacts of flood and drought events on water resources, human communities and ecosystems demonstrate the need for building resilience against such events. Inadequate access to climate, hydrological and other data required for effective decision-making has left communities and organisations unable to properly prepare and plan appropriate management techniques as a method of protection.

To address this need and enhance capabilities for planning for extreme weather events, a SWM approach was initiated: the Flood and Drought Management Tools (FDMT) project. The project is funded by the Global Environment Facility (GEF) under its International Waters (IW) portfolio, and is being implemented by UN Environment and jointly executed by DHI and the International Water Association (IWA). Its objective is to improve the ability of water managers in transboundary river basins to recognize and address the implications of the increased frequency, magnitude, and unpredictability of flood and drought events arising from climate variability and change. FDMT planning includes Transboundary Diagnostic Analysis/Strategic Action Programme (TDA/SAP), Integrated Water Resources Management (IWRM), and Water Safety Planning (WSP) processes. The project is developing a methodology to support water utilities and basin organisations, involving web-based technical applications to share data and planning tools with stakeholders in their basins.

The Flood and Drought Portal (www.flooddroughtmonitor.com) is the main output of the project and has a series of technical applications supporting stakeholders to carry out baseline assessments using readily available satellite data, impact assessments through the analysis of the data, planning options and a means for disseminating information to relevant groups or individuals. Within the Portal, there is a data and information tool which provides near real-time satellite based data related to determining floods and drought, seasonal and medium range climate forecasts, climate change projections and information relevant for basin and local planning. Other applications hosted on the Flood and Drought Portal include water indicators, drought assessments, water safety planning, issue analysis, and reporting. Each application or tool can be applied individually or together to include information about floods, droughts and future scenarios. The applications in the Portal support planning across scales from the water utility to transboundary basin level, enabling both water basin authorities and local water utilities, which supply drinking water to citizens, to be better prepared and equipped for extreme weather events.

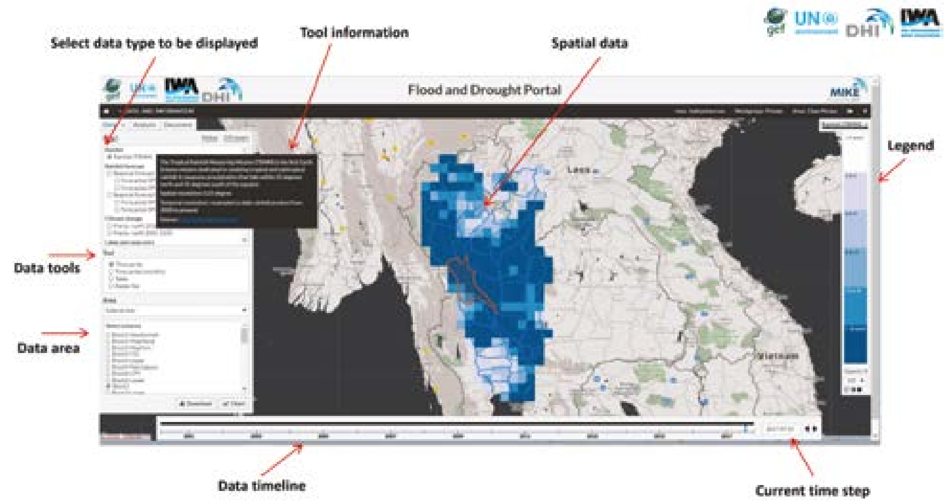


Figure 8: Data and information application displaying a sample of available data, and information box for selected data set. Source: Jessen & Cross, 2018.

The methodology and tools have been developed to have a global approach to flood and drought planning, which can then be applied to local settings around the world, and three pilot locations affected by extreme weather challenges were selected to develop, test and validate the FDMT methodology. The FDMT project was implemented from 2014-2018 in the Chao Phraya Basin (Thailand), Lake Victoria Basin (East Africa) and Volta Basin (West Africa). Further to the near real-time SWM tools used within the FDMT project, implementation of the project was assisted through capacity building, stakeholder engagement and information dissemination. Stakeholders in the pilot basins, including basin authorities and water utilities, were consulted regularly over the course of the project, including technical training workshops and stakeholder feedback during the final two years of the project. The pilot basins participated in testing and provided feedback to support development of the applications in the Portal. **The Portal already has users from 42 transboundary basins from across six continents who have access to the tools and satellite data required to support their short- and long-term planning and management for flooding and droughts.**

PUMAGUA efficient water management programme, Mexico

Mexico faces a number of water challenges including water quality, access and inefficient management of water. On a smaller scale, Mexico's largest university (and indeed the largest university in Latin America), the National Autonomous University of Mexico (UNAM) also faces these challenges. To address these challenges, UNAM launched the Program for Management, Use, and Reuse of Water (PUMAGUA) in 2008 with the aim of implementing the efficient management of water at the campuses of UNAM. The three key objectives of PUMAGUA were to: 1) reduce potable water consumption by 50% through improved practices and leak detection, 2) improve the quality of drinking water and treated wastewater in accordance to Mexican regulations and 3) promote participation of the entire UNAM community in the efficient use of water. Prior to PUMAGUA, UNAM faced up to 50% water loss through leakages in the university pipelines, irregularities in drinking water disinfection, treated wastewater did not comply with regulation, and there were no continuous capacity development activities or communication campaigns to save and conserve water.

Since PUMAGUA was initiated in 2008, it has achieved a reduction of 25% in water supply in the University City campus (CU), despite a population increase of more than 37% from 2008 to 2018. Drinking water and treated wastewater are now both of excellent quality. PUMAGUA has also enhanced the responsible use of water by key actors, as well as the participation of students and lecturers in generating proposals to solve water problems. In addition, it has carried out workshops addressed to maintenance staff and gardeners to enhance water saving actions.

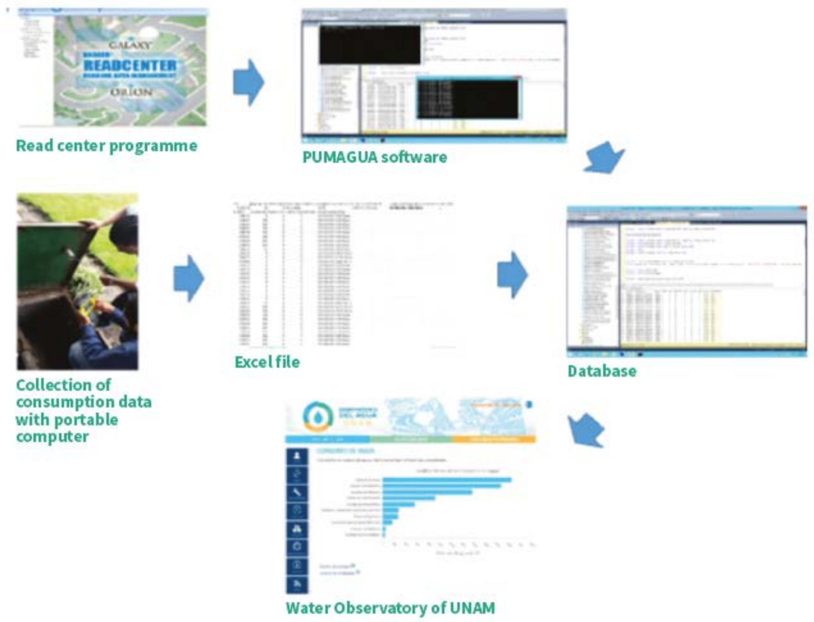


Figure 9: Integration of real-time information to PUMAGUA database and Water Observatory

In order to produce these results, PUMAGUA has made use of SWM technology, in particular, remote water consumption measurement and water quality assessment tools. The Program created UNAM's Observatory of Water, a digital real-time platform that includes water quantity and quality data, and social participation, in order to respond promptly to any eventuality and to actively interact with the university community. In addition to the implementation of the program at UNAM, PUMAGUA has extended its activities to trial smart water projects in another university campus and also in low-income housing in Mexico City.

Throughout the PUMAGUA program several lessons were learned, including 1) SWM can build trust in water users (in our case, in the university community); 2) smart technology still requires a lot of time and effort to manage and maintain, especially in the beginning stages of a project; and 3) as technology changes so quickly, it is essential to have the financial resources to afford the acquisition of technology upgrades, as well as the human capabilities to manage the updates. As a result of sharing our results and lessons from the PUMAGUA program we hope that other programs will be able to leapfrog some of the challenges we have faced, and also can achieve some of the great successes we have accomplished.

Moving forward, our intentions are to update the SWM technology, particularly, regarding water consumption measurement. We will also try to use this kind of technology for other purposes, such as measuring soil moisture, in order to determine the need for watering gardens. PUMAGUA has become a model for water management and use and has been extended to other universities, institutions, and localities. The use of SWM technology has been of the utmost importance to achieve this.

SMART WATER MANAGEMENT
CASE STUDY REPORT - EXECUTIVE SUMMARY

Small-scale agriculture productivity and efficient irrigation in Southern Africa

In essence, the key point argued and illustrated in this chapter is that *SWM technologies need to be implemented in conjunction with smart governance and learning processes (a two-pronged approach).* Small-scale communal irrigation schemes in Africa have not realised returns on investment. They are often under-performing and characterized by poor market integration, low capacity to invest in crop production, low yields, difficulties paying for water, or lack of willingness to participate in system maintenance. The end result is unsustainable utilisation of resources, failed infrastructure, inefficient use of water and land and increased conflict over access to these resources.

Figure 10: a) ChameleonTM soil moisture sensors and reader b) Farmer demonstrating the use of the Chameleon reader at Kiwere scheme

Transitioning these complex systems into profitable, equitable and economically sustainable schemes requires investment not only in smart technologies but also in the farmers, institutions and building the value-chain network.

The project features a two-pronged approach consisting of two complementary entry points to transition small-scale irrigation schemes towards long-term sustainability:

- SWM technologies monitor soil moisture and nutrients and facilitate farmer learning about irrigation water management to increase yield.
- Agricultural Innovation Platforms (AIPs), bring key stakeholders together to develop solutions to turn increased yield into increased profitability.

Both prongs of this approach are essential. The soil monitoring tools are sophisticated but simple-to-use SWM technologies that support a farmer-centred learning system. The AIP draws from systems thinking, it promotes learning process by bringing together stakeholders with a shared interest, builds capacity and networks, and facilitates a dialogue to identify critical barriers and appropriating hard and soft technologies to improve profitability.

The AIP identifies ‘stepping stone’ solutions to support ongoing learning and problem solving. The AIP facilitation ensures that the information generated by the tools is used to develop a deeper understanding of the water-nutrient dynamics, which allows farmers to make more informed decisions about water and nutrient management and engage in farm level experimentation. This results in critical behaviour and practice change leading to improved yields and profitability.

The project outcomes described in this case study draw mainly from a survey of project participants—a baseline survey conducted in 2014 and an end of phase one survey in 2017—as well as ongoing focus groups and field observations by the project officers working with the farmers on both elements of the two-pronged approach. Overall, the irrigators engaged actively with the SWM technologies and the AIPs. Many farmers have experienced significant yield and income increases resulting in increased food security and prosperity. **The time saved through reduced irrigation frequency has been invested in further improving yields and/or diversifying income streams: by establishing and engaging in small businesses and other non-farm income earning activities.** The irrigation schemes have experienced significant water savings resulting in an increase in supply that has been especially beneficial for down-stream users and has improved reliability during periods of scarcity. The improved profitability and reliability of supply has reduced conflicts, both among irrigators and within households, and resulted in an increased willingness to engage in collective action such as system maintenance, fee payment and fence building. The outcomes presented are the preliminary analysis of the changes reported in the surveys and further evaluation of both the outcomes and the research approach are ongoing.

Stormwater SmartGrids, Canada

Cities around the world are committing to sustainable stormwater management, by increasing permeable surfaces through water sensitive urban design (such as bioswales, raingardens and permeable paving) or investing in stormwater harvesting to collect and retain large volumes of stormwater. These approaches help to reduce pollutants entering sewers and subsequently urban waterways. At the individual property or residential household level, rain tanks have similarly been promoted to collect rainwater runoff. However, property based rain harvesting faces the same problem as land based infiltration systems – how to ensure there is sufficient reserve capacity to reduce stormwater overflow, when the system is already storing a previous rain event. Households do not typically install sufficient capacity to undertake the sophisticated storage and release operations of commercial facilities’ automation systems. As residential rain harvesting has relied on operation and maintenance by the property owner, municipal water utilities have been reluctant to incorporate it into urban water design.

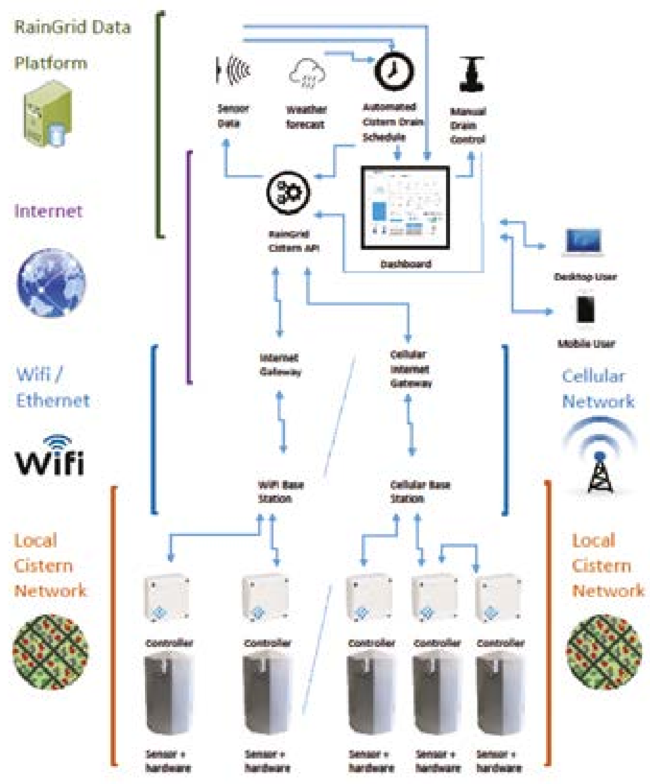


Figure 11: RainGrid Stormwater Smartgrid Architecture

To address this issue the RainGrid Stormwater Smartgrid in Canada was developed to apply real-time weather artificial intelligence (AI) management and internet of things (IoT) automation to passive residential-scale stormwater cisterns. The purpose of the AI is to determine how much rainfall will runoff from household roofs given the predicted rainfall and rooftop area, while the IoT automated cistern captures, filters and stores it in a suitably sized cistern. Thereafter the water is available for use in the household and garden as 1) recycled water, 2) groundwater recharge or 3) timed discharge into the sewerage system, by means of electrically actuated valves controlled by the IoT, until the next predicted rainfall.

A Stormwater Smartgrid operational data dashboard, specific to each property, visualizes the AI micro-climate rainfall data while on-board sensors calculate temperature, barometric pressure and rooftop runoff retained in the cistern. Extrapolating from these data sets we are also able to determine consumer behaviour regarding potable water demand offset, and potential flood and drought conditions in real-time, providing an exciting big data insight into community based rainfall patterns and property owner behaviours for utility operators. As the average household (or ‘lot level’) rooftop in Canada represents 40-60% of gross impermeable surfaces of the property, and residential rooftops represent an average of 47-56% of gross urban impermeable area, households offer an important but unmet opportunity for intelligent, climate resilience stormwater management. **An average yearly rainfall of approximately 780mm in Canada over a typical roof size of 250m^2 yields 195,000 litres of water that can be captured and either reused or returned to the groundwater or sewerage system.** Therefore by automating the operation of household rainwater cisterns, we can both achieve reliable, measurable and effective stormwater management as close to where the rain falls as possible (truly local source control), and increase access to carbon neutral water for environmental and domestic uses.

Beyond addressing stormwater challenges, the Stormwater Smartgrid also opens up the opportunity to generate highly granular (lot-level), optimally effective real-time microclimate data visualization and analytics. AI capacity to determine on a property by property basis when the next rainfall is likely to come, and to consequently empty cisterns to provide appropriate storage to ensure practically zero stormwater runoff from the rooftops that constitute the majority of urban impermeable area. This local climate data and distributed infrastructure should be extremely valuable for water utilities and municipalities.

This case study demonstrates the potential for the adoption of Stormwater Smartgrid technology to empower individual property owners to engage in and act on a shared community basis to ultimately make a significant difference to stormwater management in urban areas. It also shows the barriers that have been faced to date to implement this type of technology on a large scale. These barriers include: 1) the need to reach a 40% voluntary participation threshold to have a measurable impact on the municipal stormwater system; 2) the need for a stronger business case to ensure utilities are comfortable adopting household smart stormwater technologies; and 3) the need to perfect cost-effective internet communications to ensure year round operation reliability. It is hoped that by sharing this case study, others interested in smart technology for urban stormwater/water management capture and use will gain an understanding of the challenges faced, and the potential for moving forward.

Smart Water For Europe

The Smart Water for Europe (SW4EU) Project was developed to contribute to the European Innovation Platform (EIP) Water by accelerating demonstration and thereby deployment of innovative smart water network technology solutions for upgrading the reliability, efficiency, quality control, sustainability and resiliency of metropolitan drinking water supply services. Its outcome is expected to support significant improvements of the utility's capacity to respond to societal challenges and increasing public concerns, while enhancing European SME's competitiveness and effectively promoting economic growth in the emerging sector of Sensing, Information and Communication Technology (SICT) for smart water network applications. Furthermore, the project intent is to bring together the SICT industry experts and water operators to accelerate acceptance of innovations and accelerate their market penetration.

While the technology to implement SWM is readily available, there are several hurdles that currently impede the successful implementation of SWM for water distribution networks. Typical to the case of industrial innovation these include lack of: 1) integrated and open solutions to meet industry's standards; 2) ability to comply with all users' requirements; 3) validated demonstration cases for water utilities to implement future projects; 4) business intelligence awareness with an industry's motivation to change traditional water management approaches; and 5) political and regulatory support to address public water security and sustainability concerns.

To address these barriers, the SW4EU Project objectives were to develop and demonstrate integrated SWM solutions for water distribution networks across four demonstration sites (in the Netherlands, Spain, the United Kingdom and France). The water challenges addressed as part of this project include: water quality management (focused on early bio-contamination detection), leak detection and management, energy optimization and customer interaction, as those issues have been identified as the areas of greatest concern and interest for water distribution networks in Europe.

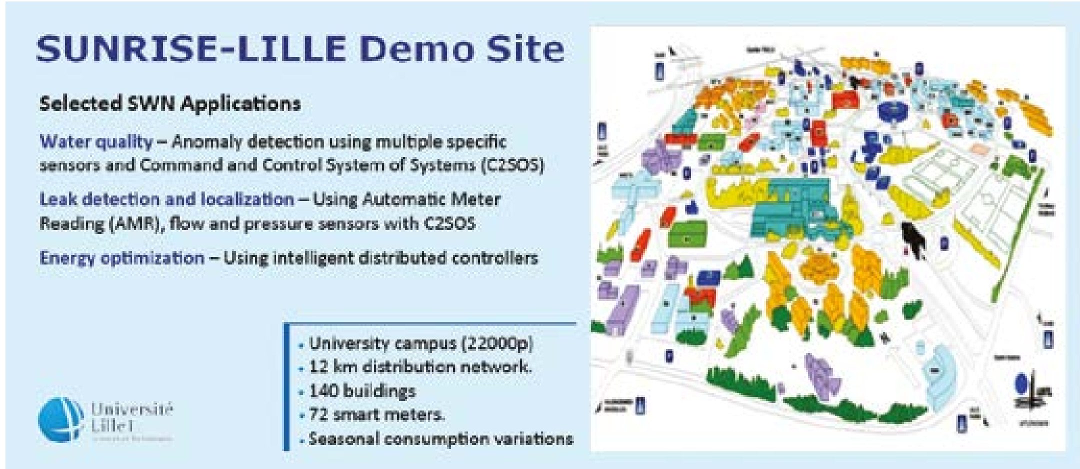


Figure 12: Overview of one of the four demonstration sites (Lille, France)

This case study provides an overview of the SICT solutions developed and/or demonstrated through the SW4EU project, along with lessons learned and recommendations for their integration in the selected applications towards preventive water systems management. **These applications have been selected due to their high potential for creating business cases of substantial savings and improvement of resource efficiency.** It is expected that sharing the outcome of this case study will contribute to engage water utilities and policy makers in accelerating their deployment and thereby support the competitiveness of European SICT SMEs.

VIII. Links to the Sustainable Development Goals (SDGs)

As part of developing a stronger understanding of how SWM can assist with moving towards the global aim of sustainable development, it was important to assess how each of the projects presented within this report can assist with achieving the Sustainable Development Goals (SDGs). Beyond the expected links to SDG 6 (Clean Water and Sanitation) and SDG 11 (Sustainable Cities and Communities), the analysis of these SWM projects has shown the breadth of targets that can be assisted through the use of SWM, in areas of poverty, hunger, gender equality, reducing inequalities and climate action.

The following table highlights the targets that the ten SWM projects within this report contribute to. With the continued success of SWM implementation around the world, it is expected that SWM will continue to provide an even greater contribution to reaching the SDGs in the future.

Table 3: SWM links to the Sustainable Development Goals (SDGs)

SDG	Links to Smart Water Management
1. No poverty	**Target 1.4 – Supporting equal rights to economic resources, natural resources and new technology** through introducing smart soil moisture monitors to assist farmers in increasing irrigation efficiency leading to increased crop productivity, income and improved land management (Africa) **Target 1.5 – Building resilience to climate related extreme events** through adopting flood and drought planning using satellite data across transboundary basins (FDMT) and smart integrated water resource management for national river basins (K-HIT) **Target 1B – Supporting policy frameworks based on pro-poor and gender sensitive development** through supporting community capacity and decision-making opportunities for women in farming (Africa)
2. Zero hunger	**Target 2.3 – Increasing agricultural productivity and incomes of small-scale food producers** through increased irrigation efficiency and reduced nutrient loss using smart soil monitors and Agricultural Innovation Platforms (Africa) **Target 2.4 – Moving towards sustainable food production and resilient practices** through increasing farmers' awareness of sustainable water management and irrigation (China and Africa) and reduced fertilizer use (Africa) and water reuse for aquaculture (see Uganda text box in report)
3. Good health and well-being	**Target 3.9 – Reducing the number of deaths and illness from water pollution and contamination** through improving water quality for drinking purposes (Mexico, France, Paju)
4. Quality education	**Target 4.4 – Increasing the number of youth and adults who have relevant skills including technical and vocational skills for employment, decent jobs and entrepreneurship** through job creation in the field of SWM technology development and implementation (Seosan), capacity building in design for water professionals (France), and technical capacity building for youth and adults in the use of SWM technology and implementation (Africa and FDMT).
5. Gender equality	**Target 5.5 – Increasing women's participation and equal opportunities for leadership at all levels of decision-making** through increasing awareness and knowledge-sharing using real-time data leading to better decision-making opportunities for women (Africa)
6. Clean water and sanitation	**Target 6.1 – Achieving universal and equitable access to safe and affordable drinking water for all** through increasing awareness and receptivity to drinking tap water through knowledge-sharing using real-time data (Paju, Mexico). **Target 6.2 – Achieving access to adequate and equitable sanitation and hygiene for all** through ensuring efficient treatment of sanitation using real-time monitoring and automated treatment (France and Mexico). **Target 6.3 – Improving water quality by reducing pollution** through monitoring and filtering contaminants using real-time sensors and treatment (Paju, Mexico, France, SW4EU and Canada). **Target 6.4 – Substantially increasing water-use efficiency** through improved irrigation efficiency (Africa), reduced leakages (Paju, Mexico and SW4EU), reduced consumption (Seosan, China, Mexico and SW4EU), capture and reuse of rainwater (Canada) and increased storage capacity (K-HIT). **Target 6.5 – Implement integrated water resources management at all levels** through integrated river basin and dam management (K-HIT), sanitation and water management network integration (France), transboundary flood and drought management and planning using satellite data (FDMT) and Agricultural Innovation Platforms for integrating governance (Africa). **Target 6.6 – Protect and restore water-related ecosystems** through reduced pollutant loads in wastewater through smart monitoring and treatment, restoring ecosystems and fish populations (France), and reduced stormwater pollution reaching waterways through smart cisterns (Canada). **Target 6A – Expand international cooperation and capacity building to support developing countries** through supporting transboundary basin agencies with flood and drought planning and management using satellite data (FDMT) and replicating successful SWM projects in developing countries (e.g. Seosan project replication in Indonesia) **Target 6B – Strengthening the participation of local communities in improving water and sanitation management** through involving local stakeholders from the beginning of the project (Africa, FDMT and Mexico) and learning from community experiences (China).
7. Affordable and clean energy	**Target 7.3 – Doubling the global rate of improvement in energy efficiency** through energy optimization (SW4EU) and increasing water efficiency, thereby reducing energy intensive processes (Paju, Seosan, Mexico, France, SW4EU and Canada).
8. Decent work and economic growth	**Target 8.1 – Sustaining per capita growth in accordance with national circumstances** through increased job opportunities in research and development, project management and construction (Paju Smart City). **Target 8.2 – Achieving higher levels of economic productivity through diversification, technological upgrading and innovation** through supporting research and development in SWM technology (France and Paju Smart City). **Target 8.5 – Achieving full and productive employment and decent work for all women and men, including for young people and persons with disabilities** through increasing capacity building and reducing the time required for low skilled tasks (e.g. irrigation), thereby increasing the time available for further education and employment opportunities for women and youth in particular (Africa) **Target 8.6 – Substantially reduce the proportion of youth not in employment, education or training** through capacity building and further education (Africa).

9. Industry, innovation and infrastructure	**Target 9.1 – Developing quality, reliable, resilient infrastructure to support economic development** through integrating SWM technologies to traditional infrastructure to improve accuracy and reliability (K-HIT, France and Mexico) **Target 9.4 – Upgrading infrastructure for resource efficiency** through leak detection and water consumption monitoring (Paju Smart City, Mexico and SW4EU).
10. Reducing inequalities	**Target 10.1 – Providing support and income growth for the bottom 40% of the population** through improving agricultural techniques (e.g. efficient irrigation, higher value crops and improve market integration) to increase crop productivity and income (Africa) **Target 10.2 – Empowering and promoting social, economic and political inclusion for all** through providing data to all water users and enabling local stakeholders to be involved in decision-making (Paju Smart City, Africa and China) **Target 10.3 – Promoting opportunities for women and youth** through increased education opportunities, increased decision-making and increased high skilled employment (Africa).
11. Sustainable cities and communities	**Target 11.4 – Strengthening efforts to protect and safeguard the world's cultural and natural heritage** through reducing the impact of natural disasters such as droughts and floods (K-HIT and FDMT). **Target 11.5 – Significantly reducing the number of deaths and numbers of people affected by disasters, including water-related disasters** through integrated operational water management (K-HIT) and future planning for floods and droughts using satellite data and weather predictions (FDMT). **Target 11A – Supporting positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning** through transboundary planning with local basin authorities using satellite data (FDMT). **Target 11B – Substantially increasing the number of cities and human settlements adopting and implementing integrated policies and plans towards resource efficiency, adaptation to climate change and resilience to disasters** through planning (FDMT), increased resource efficiency (China, SW4EU, Mexico) and local storage of water (Canada).
12. Responsible consumption and production	**Target 12.2 – Achieving the sustainable management and efficient use of natural resources** through efficient water use (China), leak reduction (Paju, Mexico, SW4EU), energy optimization (see SW4EU and China) and reduced reagent consumption (France). **Target 12.8 – Ensuring that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature** through increased community engagement and knowledge dissemination using real-time data and results (Paju, Mexico, SW4EU and China).

13. Climate action	**Target 13.1 – Strengthening resilience and adaptive capacity to climate-related hazards and natural disasters in all countries** through optimizing infrastructure to manage crisis situations (France), reducing pressure on centralised infrastructure in the case of flooding (Canada) and by integrating SWM into adaptive planning and forecasting (FDMT). **Target 13.2 – Integrating climate change measures into national policies, strategies and planning** using data and forecasting to integrate plans for future flood and drought events at a national and transboundary level (FDMT). **Target 13.3 – Improving education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning** through increasing community awareness of the importance of water and their role in its management (Paju, Mexico, SW4EU) **Target 13B – Promoting mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island states** through increasing awareness using real-time data on water consumption and access and future challenges (Mexico and FDMT).
14. Life below water	**Target 14.1 – Preventing and significantly reducing marine pollution of all kinds, in particular from land-based activities, including nutrient pollution** through reducing non-point source pollution (e.g. fertilizer in Africa; stormwater contaminants in Canada); and treating wastewater before returning it to the waterways (France).
15. Life on land	**Target 15.3 – Combating desertification, restoring degraded land and soil, included land affected by drought and floods** through flood and drought planning tools (FDMT) and integrated operational flood and drought management (K-HIT) **Target 15.5 – Taking urgent and significant action to reduce the degradation of natural habitats, halting the loss of biodiversity** through integrated flood and drought management (K-HIT).
16. Peace, justice and strong institutions	**Target 16.6 – Developing effective, accountable and transparent institutions at all levels** through increasing access to data for all water users (Paju Smart City and Mexico) **Target 16.7 – Ensuring responsive, inclusive, participatory and representative decision-making at all levels** through providing a forum for water users to contribute their ideas and access information and real-time data (Africa, Paju Smart City, Mexico, SW4EU, Canada)
17. Partnerships for the Goals	**Target 17.6 – Enhancing regional and international cooperation on and access to science, technology and innovation and enhance knowledge-sharing** through collaborations between local and international agencies (FDMT, Africa, China) and capacity building for local workers (Paju Smart City, Africa and FDMT). **Target 17.7- Promoting the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms** through enhancing knowledge-sharing through partnerships (K-HIT, Mexico, France and China).

VIII. Conclusions and next steps

The SWM projects included within this report have shown the considerable potential for SWM to assist with numerous water challenges, across various scales, geographic locations and developing and developed regions while also creating social, economic, environmental and governance benefits. These projects have also demonstrated the enormous potential for SWM to assist with achieving the SDGs, across a number of goals and targets.

While it is important to recognise that each project is set within its own context, the overarching lessons that have emerged as part of this report highlight the similarities between case studies to show how SWM can be successfully implemented around the world, and what challenges there are still to face.

As SWM is still an emerging field these projects demonstrate the untapped potential of what can be achieved using innovative SWM technology and solutions. As the field progresses and technologies evolve, the potential for SWM adoption across all contexts will continue to grow, leading to increased opportunities for both developed and developing regions, and innovative solutions for our current water challenges.

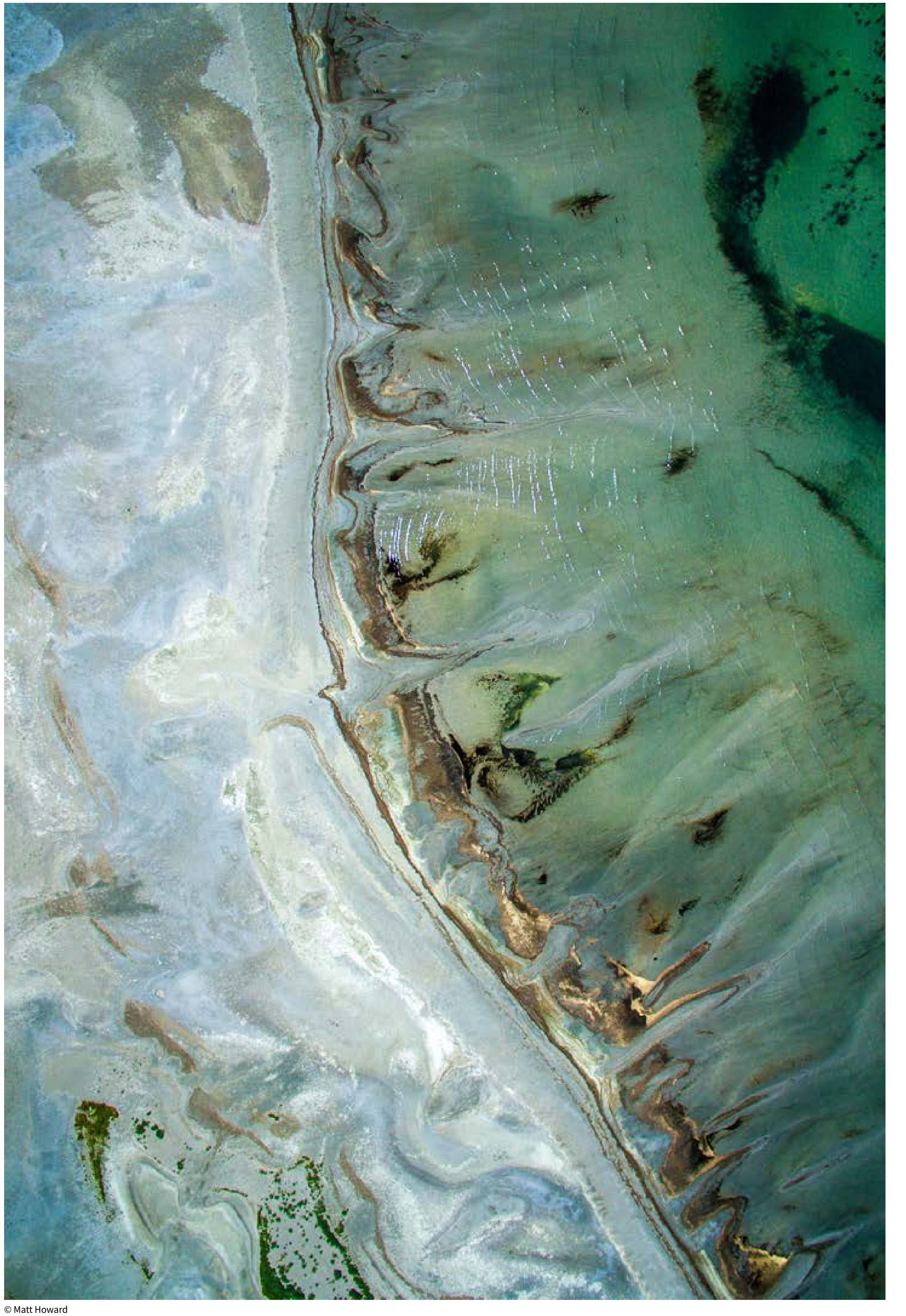
In order to continue learning from these case studies, it is important to follow them on their journey to see how challenges are addressed as the technology evolves, and what impact introducing SWM continues to have in their region. This is important when trying to scale up or down, or transfer existing SWM solutions to new locations, baring in mind the adaption necessary to the local context and challenges.

It will also be interesting to see how SWM technology and solutions can move from the research and development stage to the testing stage and finally to market. In other words, how SWM can become self-sustaining without reliance on initial government support in the early phases.

At this stage, many of these projects have shown the potential for SWM technology to successfully resolve water challenges. It is important to now build and develop the business cases for adopting, scaling and transferring these solutions. This is why the monitoring and measuring SWM benefits must continue. The next phase of research would be aimed at capital investors to help them see the benefits and potential of SWM, leading to increased possibilities for future investment.

Now that a wider number of smart tools are on the market, integrated smart networks will start to emerge, and with them increasing opportunities for sustainable cities and regions to integrate their various smart infrastructure, such as smart energy grids. While retrofitting existing cities is possible, the opportunity offered by urbanization and the creation of new cities and suburbs means that these new urban environments offer the greatest potential for smart technology integration.

This report demonstrates how far SWM has already come in a short time and the considerable benefits it can provide in both developed and developing regions, especially when coupled with strong policy support and community engagement. It also explores some of the constraints and barriers encountered to date. In the end, however, it is certain that SWM has nearly unlimited potential to contribute to the realization of the goals of integrated water resource management and sustainable development through smarter management of water.



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K-water (the Korean Water Resources Corporation)
is the governmental agency for comprehensive water resource development in the Republic of Korea, with a large pool of practical engineering expertise regarding water resources that has been championing Smart Water Management for the past decade.

IWRA (the International Water Resources Association)
are a non-profit, non-governmental, educational organisation established in 1971, providing a global knowledge based forum for bridging disciplines and geographies by connecting professionals, students, individuals, corporations and institutions concerned with the sustainable use of the world's water resources.

Published by K-water
200 Sintanjin-ro, Daedeok-gu, Deajeon, Korea, 34350

Printed in Korea.

This publication was prepared by K-water and IWRA in collaboration with various research institutes, water utilities, universities, government agencies, non-government organisations and other experts in Smart Water Management. It was made possible thanks to the financial support of K-water.

K-water website: www.kwater.or.kr
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