International Federation of Consulting Engineers
The Global Voice of Consulting Engineers

/SOW2021
State of the World

Tackling the global water crisis

Actions today result in change tomorrow

/A FIDIC report

/Contents

/SOW2021

Foreword from the President and CEO

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The last State of the World report looked at establishing the value of water and discussed in detail how there are a wide range of factors that should be considered in establishing it. Amongst other things, the report reminded us that water is often undervalued and we are underinvesting if we are to achieve The UN water-related Sustainable Development Goals (SDGs). But increased investment is not enough – innovation is also needed to reduce costs in a sustainable manner.

Engineers can and should play a significant part in developing sustainable solutions to meet the incredibly complex and costly water needs we are all facing. As noted in the 2015 State of the World report, big-picture focus and proper planning will be essential in ensuring that the right projects are identified and that they are executed and maintained properly. While significant 'traditional hard infrastructure' will be necessary, natural and behavioural strategies must be part of the mix. The challenges are extraordinary but the engineering community, if given the resources, is up to leading the effort. After all, this is what we are trained to do.

To that extent, this report not only provides three recommendations focused on engaging industry, stakeholders and governments, it also highlights various projects that are demonstrating progress around the globe at this current point in time. That is not to say that things will not change, or projects improve, but we believe it is important to share information to learn from current best practices. It is only by understanding what we do today and with imagination and skill that we can achieve the potential of tomorrow.

Following Covid, the environment has once again been rising up the agenda, especially amongst the younger generations and such momentum should not be wasted. There is an increasing awareness amongst individuals that want to live more sustainably. This includes how water integrates into our lives, considers the items we consume and how such activities will be increasingly important as we drive towards net zero.

It is imperative that activities are considered as part of larger systems, catchments and coastal protection areas. Failure to do so will mean that communities and society will constantly be fighting to maintain the status quo, simply shifting problems rather than resolving them. If we are to move forward, solutions need to be innovative and consider not only mitigation but reduction and control at the source.

Policies, theory and discussion, however, can only take the sector so far. It is also important to develop, nurture and create the right environment for future projects but to do so it is important we understand what is happening now.

It is only through understanding these achievements that engineers can derive tomorrow's solutions moving us towards meeting the SDGs and climate goals.

As such, this report asks the whole sector to

- **Respect the importance of water.**
- **Renew efforts to meet SDG Goals.**
- **Rethink what approaches we need to take to sustainably achieve them.**

None of this will be easy. To be successful we will need to work with governments, stakeholders and importantly customers to rethink, engage and use their knowledge and expertise so we can hit the SDG goals. We have approximately 3,200 days or closer to approximately 2,000 with weekends, holidays, and lost time from Covid to deliver on this challenge. While time is not on our side, there are exciting opportunities for engineers to lead the quest for achieving the SDG goals and in so doing, make the world better for all of us.

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/Executive summary and recommendations

/SOW2021

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As noted in our first two State of the World reports, our infrastructure challenges are immense and it will take a concerted effort to resolve them. Every year, the world falls further behind and the gap between required and needed investment widens. It is likely that the COVID-19 pandemic and the increasing challenges related to climate change have increased our needs and exacerbated the 'investment gap problem'. The global water sector 'owns' an enormous amount of our infrastructure needs.

Our water challenges are appearing everywhere. Some of them have been with us for a very long time and many of these are getting worse. Others such as plastics and Perfluoroalkyl and polyfluoroalkyl substances (PFAS) are just now being understood. It suffices to say that despite the incredible innovative things engineers and the scientific community can do and have done, millions of our fellow global citizens still lack access to safe drinking water and adequate sanitation. The water sector it is fair to say is facing unprecedented challenges from all fronts.

As the first report in the State of the World series revealed, the economic circumstances could not be more challenging as we exit from the Covid crisis. In that report we noted that the global infrastructure investment needs were estimated to be $94 trillion between 2016 and 2040, which is 19% higher than current spending.[i] Then there is the additional pressure of not only meeting the investment needs of the current situation but ensuring that we meet the commitments of the SDGs. This is estimated to be between $5 trillion and $7 trillion a year.[ii] So, the additional pressure equates to potentially between $1 trillion and $3 trillion a year.

These numbers are large and while the engineering and scientific communities can do a lot to reduce them through innovation and proper planning, innovative financing from government, agencies, international funding institutions and the private sector will be required as well. We all need to work together to get the results we need to meet the SDG goals.

We believe that this report reinforces the recommendations from the previous State of the World publication entitled *Establishing the value of water - the business case for change*. There are a myriad of water issues we face and the innovative approaches engineers are implementing around the globe lead us to make three more recommendations which can be summarised by three words – **Respect, Renew and Rethink**.

FIDIC commits to take action to encourage everyone we interact with to respect the value of water and understand the importance of it to our survival. There are number of activities we have and will be implementing in this regard, including these State of the World reports.

FIDIC will encourage and assist the engineering and scientific community to build upon the many innovative approaches to addressing our water challenges being implemented around the globe and rethink how we can improve on them. This will include sharing lessons learned and knowledge via describing projects and approaches which have been successful in meeting complex multifaceted needs, reducing costs and conservation all in a sustainable manner.

FIDIC will encourage its members, partners and stakeholders to renew/revitalise efforts to invest adequately in addressing all of our water challenges so that the SDGs are met. Perhaps the growing awareness of climate change and the many visible water challenges we are facing will drive all of us to insist on more action.

The tasks at hand are challenging but they are creating opportunities for engineers and scientists to lead the world towards a better place. Let's all commit to doing our part in this regard.

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/Tackling the global water crisis and the world's water challenges

/SOW2021

/Tackling the global water crisis and the world's water challenges

The last State of the World report, *Establishing the value of water - the business case for change,* explored the importance of issues related to the value and pricing of water services.

This report made three recommendations which are worth repeating.

Recommendation 1: To increase the perception of value, to reduce waste and to ensure that critical water systems are available for future generations, FIDIC recommends that prices (rates/costs/prices) for water, wastewater, ecosystems and stormwater services be established with the assistance of qualified professionals. These should be sustainable enough so that they recover operational costs, allow for maintenance, rehabilitation and expansion to allow for adequate use by future generations, while also providing reasonable, perhaps subsidised charges for the poorest among us". In addition, policies should be put in place to encourage conservation.

Recommendation 2: To increase the perception of value, the understanding of the complexity of water issues and to reduce costs, FIDIC recommends that more stakeholders be involved in developing approaches to address water-related issues. More local community involvement and consideration of utilising total cost concepts like TOTEX, along with customer input, will help ensure that the right projects are developed to effectively address the right issues and that solving one problem does not cause another.

Recommendation 3: To truly embrace the SDGs and resolve the issues of those without access to safe drinking water and adequate sanitation, FIDIC recommends constructive dialogue with governments, the private sector and NGOs to identify and implement realistic solutions. FIDIC commits to be more proactive in working with governments, the private sector, international funding institutions, NGOs, the forthcoming COP26 conference and others in developing solutions to this vexing and insidious problem.

We believe that this report reinforces these recommendations. The further discussion of the myriad of water issues we face and the innovative approaches engineers are implementing around the globe lead us to make three more recommendations which can be summarised by three words – **Respect, Renew and Rethink**.

Going forward we must use policy and pricing mechanisms to meet a very important, delicate and critical balance, between providing services universally to meet the SDGs, while improving the livelihoods of our fellow global citizens.

In addition to describing a few more water challenges, this report looks at a number of practical projects and innovative activities that have been going on and/or should be considered to meet this challenge. Setting up the problem is to some extent the easy part, getting individuals and society to understand the scale of those issues and include consideration of them in their decisions and on the infrastructure they demand is the difficult challenge.

As was outlined in the previous State of the World report, millions of our fellow global citizens do not have reasonable access to clean water and/or sanitation, millions fall ill to water-borne diseases every year and some of them are deleteriously affected by these diseases for their entire life. At the same time, water-related global infrastructure needs are underfunded every year.

Over 30% of our population experiences some type of water scarcity and the global demand for water is expected to increase by 20% to 30% by 2050.

Some progress has been made but not enough to meet the SDGs. Adding to the challenge is that many of the issues we face today have been with us for some time, with marginal progress in addressing them, new issues are evolving and the post-COVID world will be different, but how the differences will effect our water challenges are not completely known at this time.

To put all of this in perspective, it is worthwhile to repeat the SDGs, as follows:

Goal 6 to ensure availability and sustainable management of water and sanitation for all contains the following targets:

- 6.1 - By 2030, achieve universal and equitable access to safe and affordable drinking water for all.
- 6.2 - By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.
- 6.3 - By 2030, improve water quality by reducing pollution, eliminating dumping and minimising release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.
- 6.4 - By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.
- 6.5 - By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.
- 6.6 - By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.
- 6a - By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and Programmemes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies.
- 6b - and strengthen the participation of local communities in improving water and sanitation management.

Goal 14 is to conserve and sustainably use the oceans, seas and marine resources for sustainable development and contains an equally ambitious set of targets:

- 14.1 - By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution.
- 14.2 - By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience and take action for their restoration in order to achieve healthy and productive oceans.
- 14.3 - Minimise and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels.
- 14.4 - By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics.
- 14.5 - By 2020, conserve at least 10% of coastal and marine areas, consistent with national and international law and based on the best available scientific information.
- 14.6 - By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognising that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organisation fisheries subsidies negotiation.
- 14.7 - By 2030, increase the economic benefits to small-Island developing states and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism.

- 14a - Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the *Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology*, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small-island developing states and least developed countries.
- 14b - Provide access for small-scale artisanal fishers to marine resources and markets.
- 14c - Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in United Nations Convention on the Law of the Sea (UNCLOS), which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of *The Future We Want*.

As noted before, meeting the SDGs is becoming more challenging due to climate change. Consider the following:

- By 2100, sea levels could rise one to four feet and an eight-foot rise cannot be ruled out by that time. The pH of our oceans has been relatively stable for millions of years at around 8.2. Since the industrial revolution, however, it has dropped to about 8.1. This sudden rate of acidification is unparalleled in 66 million years and has a long-term impact on marine life.
- Coral reefs are being damaged or destroyed by rising water temperature, ocean acidification, rising sea levels and a reduction of photosynthesis (light penetration). This is negatively impacting marine life (Life below water SDG 14) food supplies and tourism. They are also an important carbon sink. The reduction of the aforementioned would therefore mean potentially more pressure on rising greenhouse gas emissions into atmosphere, exacerbating climate changes.
- The World Water Institute estimates that one quarter of the world's population live in countries facing extreme water stress and there are more than 500 dead zones in our oceans due to untreated wastewater. Flooding problems due to increasingly intense storms are being exacerbated by the diminished ability of saltwater marshes and wetlands to mitigate the impact of storm surges. Damage to wetlands and saltwater marshes is also reducing the world's capacity to capture carbon before it is discharged to the atmosphere as a greenhouse gas.
- Glacier melting is causing flooding problems which is impacting property, agriculture and water quality in the short term. In the longer term, it will cause even more water scarcity.

There is a need to **rethink** our approach to meeting the SDGs, to encourage everyone to **respect** the importance of water and to understand the damage that has been done to this precious resource and to challenge all stakeholders to **renew** our focus on building a better and brighter future for all. FIDIC is committed to playing a key role in making all of this happen.

Communities and their interaction with water systems – adapting the way we live?

Water is essential for life. In addition, to keeping us alive, it is also required for other essentials like agriculture, sanitation, energy and as such it would be difficult to find a process or requirement for life that does not in some way involve water. Thus, we are compelled to adequately address the many challenges we face associated with it and in so doing, meet the SDGs.

Water and communities

Water Scarcity is one of the top five potential disasters in terms of impact in the World Economic Forum's *Global Risks Report* [iii]. It is now becoming more imperative than ever to act.

Water will be a major issue in the 21st century, as is highlighted in the FIDIC 2020-2021 State of the World series. At any given time, some geographies will have too much and others too little. Some areas will experience both phenomena at different times.

Several countries in all continents now have water shortages as well as, in some cases, deterioration of the quality of the supplies they do have. Climate change is exacerbating this situation via more intensive weather events, sea level rises and global warming.

Whilst of serious concern, this should not be a surprise. As reported in the 2015 State of the World report, in July 2010, the United Nations General Assembly recognised the right of every human being to have access to sufficient safe and affordable water for personal and domestic uses. While progress was made as part of the millennium development goals and the inclusion of water in the recent Sustainable Development Goals is welcome, more needs to be done.

Despite how intricately water is linked with our lives and livelihoods, water literacy amongst the global community is mixed at best. Few appreciate the true value of water—many take fresh water for granted and there is little understanding of the water footprint of the foods, goods and services that they consume. This is despite there being several websites available such as the Water Calculator[iv] and Water Footprint Network.[v]

Wastewater and communities

While long-term planning of wastewater management usually centres around assumed increased flows and loads proportional to planned future growth, consideration should also be given to situations of reduced flows, because of demand management measures implemented due to drought or longer-term water conservation Programmemes. Due to the effects of climate change, it can be expected that cities will be exposed to more precipitation extremes, more incidences of reduced rainfall, as well as more flood events. As such, there is already pressure on many city systems to reduce demand and improve their resilience to extreme climatic scenarios. Reducing water use could assist in managing such extremes and this potentially could reduce wastewater which would leave excess capacity of wastewater management systems to essentially function as emergency 'overflow' situations.

According to a recent South African Water Research Commission study on the effect of the 2017 drought experienced by City of Cape Town, South Africa,[vi] reduced water usage decreases water that flows into the wastewater transmission and treatment systems of the community, thereby decreasing the overall water volume, but not the waste load.

Since wastewater most often flows using gravity from the point of origin to the treatment plant, decreased flows travel more slowly than usual, allowing solids such as sand, plastics, rags and strings to fall to the bottom of the pipes and accumulate at pipe joints and in junction boxes, resulting in solids build-up and blockages in the system, causing corrosion of pipes.

Fat deposition may also be a significant problem, especially in areas where a high amount of industrial wastewater is discharged. For example, in Northern Ireland in 2020, the largest reported 'fatberg' was over 200 tonnes[vii]. Such deposits not only make wastewater systems less efficient but take considerable time and resource to remove. Blockages and slow-moving wastewater will result in decomposition of the components in sewage, especially in flat, low-lying areas, causing septic conditions and methane gas in the collection

system. This is not only a source of odours—overflowing manholes because of blockages are the cause of severe health and environmental risks and result in increased need for sewer cleaning and increased system corrosion. The wastewater's viscosity will increase and flushing of the system will not occur as easily and activities such as flushing put significant stress and velocity on the sewer network, which itself may then need further work to resolve.

Drought conditions are hard on underground pipes and concrete structures, as contracting soils cause cracks and breaks and wastewater with a higher concentration of solids may cause problems with fouling or ragging of pumps at pump stations routing sewage to treatment works. Without normal levels of outdoor irrigation or reduced groundwater levels, tree roots in search of water invade sewer pipes and grow there over time, resulting in additional blockage problems.

Wastewater treatment plants will have the same organic loading rates at a reduced water volume, leading to greater concentrations of ammonia, COD and total suspended solids in the raw influent, creating potential hydraulic, treatment and corrosion issues. The septic conditions in the sewer and deterioration of the inflow quality, if not properly managed, can upset the biological processes and result in a corresponding increase of pollutants in the final effluent. The potentially higher than normal concentrations of free and saline ammonia in the effluent may also interfere with disinfection and pose toxicity impacts on receiving waters.

Many wastewater treatment facilities also feed water to reuse plants that require predetermined effluent quality. Changes to the effluent quality from wastewater treatment plants may therefore impact the design of any proposed reclamation plants. The lower water use also means there is less wastewater available to recycle, which may impact of the overall water balance. Water reuse is likely to become more prevalent in many municipalities going forward, with some already having implemented this and some investigating the concept.

For example, the city of Cape Town and the town of Beaufort West have already implemented water reuse Programmemes, with Beaufort West having implemented direct potable reuse and the city of Cape Town using wastewater effluent for irrigation and industrial process water. Drought conditions may result in decreases in the base flow of the streams and rivers which receive the wastewater treatment plant effluent. Base flow is used to determine the effluent parameters required to be achieved by the wastewater treatment plant. Therefore, as the base flow decreases, effluent requirements will become more stringent and may require that the treatment plants install additional treatment facilities to meet the discharge requirements. There are also effluent parameters based on the mass load which can be discharged to the waterway. In this case if you reduce the flow, the concentration in the effluent needs to decrease to ensure the mass load is not exceeded.

The above demonstrates that there are many factors at play. Some result in an increased maintenance costs and additional capital investment (e.g., additional treatment capacity) for municipalities, without a comparative increase in revenue. Others could free up capacity and help existing systems to be more resilient and integrate with other infrastructure and societal needs. The vital consideration is that we need to better consider and integrate water systems, nature based solutions and biodiversity together across our infrastructure needs.

How will future communities interact with water systems? Will things change?

Smart and urban water and communities

Smart cities are no longer the wave of the future. They are here now and growing quickly as the internet of things (IoT) expands and impacts municipal services around the globe.

The smart city industry was projected to have been a $400bn market in 2020, with 600 cities worldwide. These cities are expected to generate 60% of the world's GDP by 2025, according to McKinsey research.[viii]

While global population surges, a dramatic relocation is occurring, drawing individuals from rural areas to urban hubs. It is still unknown if such trends will continue following the Covid-19 pandemic as there is early evidence individuals and households are reversing this trend, favouring remote working, less urban locations and greener spaces.

If trends do, however, return to the pre-pandemic trend, the drivers are likely to continue to be migration, economic opportunity and quality of life, bringing an estimated 70% of the global population to cities by the time we reach 10 billion human beings, according to the Population Reference Bureau.

This means literally millions more people inhabiting the same cities we live in today at a time where infrastructure networks like energy, transportation and water treatment and distribution are already stressed. We can also expect the emergence of an expanded global middle class, set to become prosperous consumers. To support this kind of population density, cities around the globe are going to require major improvements to infrastructure systems, both in terms of quality and efficiency of service delivery.

'Smart Water' is one of six components that define a smart city. The others include energy, mobility, buildings, public services and integration. The goal of these efforts is to make the city more sustainable and efficient, according to *Water World* and effectively improve quality of life. How water, energy, transport, people and technologies integrate within such communities and not just cities will be the focus of the next State of the World report.

As we update and invest in our water infrastructure with more internet-enabled tools and a wealth of data becomes available, it is vital that these networks communicate with one another. This will allow for not only the measurement of important indexes such as reservoir and groundwater supply and triage of infrastructure updates, but will improve efficiencies across water-related disciplines. This will of course involve sophisticated data management.

The discussion of using data and smart technology to enable more efficient and sustainable solutions is gaining traction but is by no means new. An article by Bruce Steward in 2008 mentions some areas where data management and IT systems will help in developing 'smarter systems', as follows:

- The development of instrumentation and measuring techniques that will improve the accuracy of water resources information, noting that this includes level, flow, quality, use, reuse, allocations, trades, etc.
- Ensuring that measurement techniques meet required standards.
- Ensuring that appropriate meta-data are collected, held and made readily available.
- Improving the access to and availability of streamflow information in real-time and in concert with other information about the resource and its use.
- Making appropriate use of satellite measurement techniques, while ensuring information on their accuracy and reliability is available, as well as being able to relate and express the observations from a variety of measurement techniques to each other and to agreed standards.
- Defining an internationally agreed standard water information exchange format through the development and evaluation of a conceptual model of water resources information, corresponding mark-up language.

Urban development is a huge opportunity to create resilient and liveable cities. The world will hopefully invest around US$90tn in infrastructure over the next 15 years. These investments are needed to replace ageing infrastructure in advanced economies and to accommodate growth and structural change in emerging markets and developing countries.[ix] This is a huge opportunity to make communities water smart and water efficient, to help ensure water for all.

Embracing water-smart cities

Urbanisation and the impact of climate change call for circular approaches to integrated water management in urban areas that consider water as a resource that is used and reused and not something to be used once and discharged to distant receiving waters. This includes managing water resources at the source as a complement to technological solutions. For example some cities such as New York are investing in protecting the watershed that supplies the city's drinking water as an alternative to investing in additional treatment facilities.

Such sustainable approaches are increasing the probability that future generations of urbanites will have access to clean freshwater and that built-up areas of cities with all their physical assets can successfully function despite a more extreme climate.

Fortunately, there are numerous examples of Programmemes of urban areas exhibiting the integrated resource management approach.

In Los Angeles with its exposure to snow melt and unpredictable rainfall—three inches one year, ten inches the next—water shortages are common, but so is (or more accurately, was) spring-time flooding. In the distant past, rain or snow melt would swell the often-dry Los Angeles River, allowing water to flow into surrounding wetlands on its way to the ocean. Prior to the city undertaking an innovative integrated resource management approach, the concrete-channeled river, designed to protect development, 'zipped' stormwater straight to the ocean.

For a city forced to import water, Los Angeles has rethought stormwater management by removing dams and concrete levees, so water can be captured via infiltration basins and constructed wetlands before it discharges to the ocean. It is part of their Green-Blue City of Los Angeles One Water Management Programme that has a goal to reduce imported water by 50%.

Another good example is the FIDIC award-winning Orange County California Groundwater Replenishment District. They treat their wastewater treatment plant effluent (which previously they released to the sea) with microfiltration, reverse osmosis, ultraviolet light and hydrogen peroxide to better than drinking water standards and then use it as a well injection system that serves as a barrier to saltwater intrusion (another danger of rising seas) and as a groundwater recharge system.

Water-sensitive urban design (WSUD) is a land planning and engineering design approach which integrates the urban water cycle, including stormwater, groundwater and wastewater management and water supply, into urban design to minimise environmental degradation and improve aesthetic and recreational appeal.

The WSUD terminology is prevalent in Australia and the Middle East but similar concepts exist across the globe, including low impact development in the US, sustainable urban drainage system (SuDS) in the UK. These concepts not only promote the smart use of water, but the resulting 'infrastructure' can support enhancement of green spaces, increased biodiversity and improved waterway health.

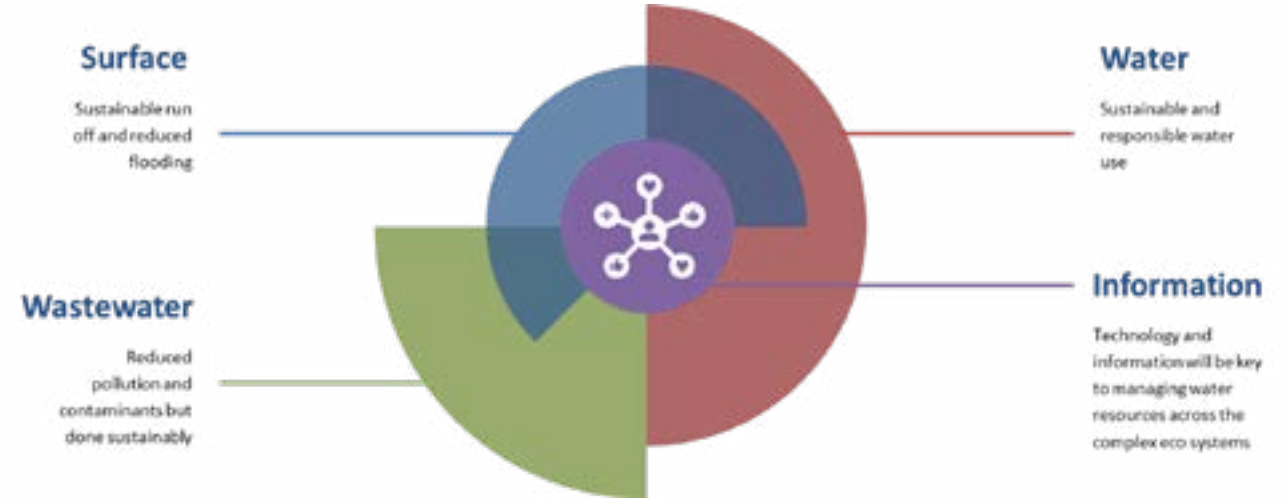
Many of our cities were designed years ago to drain rainwater and wastewater outside the city limits and to import water from rivers and well fields significant distances away. As noted above, communities around the world are changing this approach, consistent with the philosophy of considering water as a resource.

The potential benefit is that, by treating all types of water as a valuable resource, innovative approaches and opportunities arise, both directly in terms of preserving the freshwater resource and obtaining climate resilience and indirectly in terms of creating more liveable cities by linking the new water infrastructures to aesthetical and recreational benefits. The idea of the water-smart city approach is to exploit these opportunities in a smart way.[x]

This does not just mean plug in a computer and watch the data flow in. In fact, it also means being smarter about water use and as a recent piece by the University of Queensland describes "Keeping water where it falls"[xi]. This concept not only applies to storm waters to prevent flooding elsewhere but using water for cooling, energy and food production etc.

It is this kind of thinking that demonstrates a 'smart use' of water and 'smart water' as a concept as the two are intrinsically linked.

Smart communities, smarter water use and smarter water



To achieve the above the approach needs to integrate urban/rural planning and the urban/rural water cycle and makes a good business out of it for society. The concept includes integration of stormwater, groundwater, wastewater management and water supply to cope with societal challenges related to climate change, resource efficiency and energy transition, to minimise environmental degradation and to improve aesthetic and recreational appeal. This approach develops integrative strategies for ecological, economic, social and cultural sustainability.

This brings us back to the SDGs and the challenge of universal access to clean water which is a growing challenge for urban communities in the face of climate change. Ironically some relief to this pending crisis may occur since the Covid pandemic has challenged many perceptions of individuals just simply continuing to flock to urban environments.

Another urban challenge is that much water is lost before it reaches consumers' taps due to inefficient water management systems and aging infrastructure prone to leaks. Technological innovations offer hope for this sector, as smart water systems are designed to gather meaningful and actionable data about the flow, pressure and distribution of a city's water, which can be used to better serve customers and prevent losses. Developing newer and smarter products and services around smart water management is our best bet in reducing massive water losses in pipes and shrinking overall water consumption.

Smart technologies are highly efficient, interdisciplinary technologies that enable a step change in the water domain. Intelligent sensors and steering devices enable utilities to operate the infrastructure in a more flexible manner in changing urban settings. They can include, for example, process or information technologies at varied levels of technology readiness and also smart sensors form the backbone of the products and services within the smart water opportunity space. Smart sensors on pipes and other critical water management infrastructure can detect leaks, measure water-related data, including rainfall, pH, temperature, turbidity, flow, pressure and even contamination levels.

As IoT, smart sensors are Wi-Fi enabled, allowing data to be sent in real time to cloud storage. Therefore, to be truly effective, smart sensors are integrated with advanced software systems capable of handling and managing these large datasets in real time. In doing so, municipalities can utilise this data to improve service, stop leaks and boost efficiency.

Smart technologies also open new ways of encouraging and managing customer behaviours. For example, pricing and usage could be linked in a more efficient manner to encourage sustainable outcomes. Currently water systems are designed to meet peak demand, so pricing signals which promote some reduction of peak demand can also assist in making the most of existing infrastructure, reduce pressure on future investment needs and encourage sustainable behaviour.

But 'time of day' pricing to reduce peak demand should only be part of a wider set of upgrades and behaviour changes across the water network. For example, smart meters and customer platforms which identify high water usage (potential leaks) in near real time and alert customers via the app or SMS are changing behaviour and encouraging reductions in wastage. This allows action to be taken promptly rather than the customer only noticing when they get their quarterly water bill. This demonstrates that no solution will work unless it engages both the network providers and the end users.

Such lessons are not only important for developed nations updating systems but also for developing countries where systems in development and 'new' infrastructure should be developed in line with not only the SDGs, but meeting sustainability needs beyond the 2030 targets.

Thus, smart systems can be part of a cutting edge to the smart city environment in providing the needed water supply to every house. Overall objectives are to increase efficiency, (in terms of cost, energy and resources) of process and information technologies applied in the SMART Water priority areas.

Resilience is key

Much is being written about the need to develop resilient strategies to address the impacts of climate change on water related infrastructure. Engineers are designing armouring facilities (berms, levees, seawalls, inflatable dams, backflow preventers etc) and raising structures to deal with the anticipated impacts of climate change especially sea level rise.

Examples of these facilities are everywhere. For instance, at San Francisco Airport, any updated shoreline protection will need to account for not only rising seas but also the increasing frequency of 100-year storms. As a result, some barriers will be raised by almost three meters as seen in *San Francisco Prepares for Sea Level Rise on Several Fronts*[xii].

At the same time, many in the profession are expressing the need for better standards to address current and expected future impacts of climate change which include:

a) Harsher weather swings (acute floods, droughts, precipitation, heat waves and power outages).

b) Sea level rise which will intermittently and sometimes permanently damage water and wastewater systems near oceans as well as increase power costs related to pumping systems.

c) Increased saltwater intrusion into ground and surface waters in coastal areas especially in areas where groundwater aquifers already have been excessively drawn down.

d) Diminished raw water supplies of both surface and groundwater due to less rain and snow in some locations, earlier snowmelt and greater evaporation.

e) More combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) due to more severe storms and sea level rise.

f) Increased water demand due to greater water use for cooling during heat waves and for irrigation during droughts.

g) Increased temperatures which could increase algal blooms, the proliferation of invasive and nuisance species and invasive aquatic plants and animals including zebra and quagga mussels.

h) Increased raw water temperatures which can increase concentrations of organic matter and disinfection byproduct precursors.

i) Increased water temperatures which could influence biological treatment processes and possibly allow for lower bacteria populations in biological water reclamation facilities (a benefit); and

j) Lower raw water intakes, more severe rains and increased forest fires which could cause increased sediment thereby increasing treatment costs;[xiii]

These and other impacts of climate change are challenging us to develop innovative and cost-effective resilience strategies. For very good reason, engineers are generally risk averse and perform their best design work when the standards/codes for which they are designing are clear. While some modifications to standards are obvious, such as building codes requiring mechanical equipment and living quarters at higher elevations and better zoning rules to prevent development in areas prone to fires and/or flooding, other elements related to standards/codes are less clear because of uncertainty and risk. A recent article in *Civil Engineering*[xiv] summarised a discussion about the challenges engineers face related to sustainability and resilience.

The panellists highlighted the need for engineers to improve communication with their clients and expand dialogue to include all stakeholders about the criteria we should be using in addressing resilient infrastructure challenges. All parties should understand the risks involved with developing resilient water systems in a world where historical average temperatures, flood frequencies, droughts and sea level rise are not as useful in predicting future conditions as they once were. This is where countries are now looking at concepts such as adaptive planning so that systems can flex and respond to changing conditions and behaviours.

This is also where increasingly nature-based solutions for urban resilience are being utilised and built into the infrastructure solutions that are delivered. For example, the concept of 'sponge cities' where natural infrastructure is either maintained or restored to increase resilience to floods. This demonstrates how using multiple approaches and integrating their benefits with more traditional engineered solutions can have lots of co-benefits.

The American Society of Civil Engineers (ASCE's) committee on sustainability is planning on producing a report on climate safe infrastructure and anticipates publication of standards on sustainable infrastructure in 2021. The standards are likely to be performance-based rather than prescriptive and rightly so in this era of uncertainty.

In addition, the article mentions that ASCE and the Global Covenant of Mayors for Climate and Energy (which includes over 10,000 cities and local governments in 132 countries spanning six continents representing 10% of the global population) have formed a coalition to help cities around the world advance their plans toward becoming more resilient to the effects of climate change. The coalition will:

1. Identify, prioritise and better understand the gaps and barriers for the planning, design, construction, maintenance and operation of sustainable and resilient infrastructure.

2. Cultivate and unlock the full potential of untapped partnerships and investments to reduce the impacts of extreme weather events, create sustainable and resilient infrastructure and enable better decision-making and outcomes; and

3. Identify and outline practical plans of action and resources for implementing strategies that achieve realistic short-term goals and have measurable long-term effects.

It is expected that all this activity and similar initiatives will help engineers and their clients develop appropriately resilient facilities to address their current and expected future water related infrastructure needs and in so doing reasonably protect their systems from future climate change related events. Michaella Wittmann, HDR's director of sustainability and infrastructure, summarised our challenge well – "Engineers (need to) understand that the standards we designed to in the past need to be challenged and rewritten to address the changing climate and demands for today's infrastructure needs".

/SOW2021

Peter Macy
President
ROCKblue

Water systems will more often bring a community together than apart. It can create leaders.

In the developed world, most communities do not notice their water systems until a failure of water of quantify and/or quality. There is not a strong interaction between the community and the water system, except at the tap. There is less need to focus on those communities. Due to their own self interest, they will ensure the water service provider addresses their needs. Or they will raise their voices for external forces to help.

It's different in the developing world. Statistics help explain why. About two billion people, most in the developing world, live in water stressed communities (UN Social and Economic Council 2017). And by 2050 nearly 5.7 billion people, mostly from communities in the developing world, will face water scarcity (WWAP/UN-Water, 2018).

Hence, in the developing world, water is almost always on the community's mind. There exists a closer connection between the community and their water system. The community knows from where water is supposed to come. What it costs, when it is available or how long it takes to fetch it and its quality.

Communities in the developing world have different types of water systems. These include the very basic. Such as a lake, river or stream - often requiring time and danger to walk to these sources. One step up would be a water catchment combined with a small

pipe network. A more complex water system would be a (deep or shallow) well, sometimes with a pump. The more complicated, the more the community needs leadership and money. To support the water system. The next order of system complexity is communal water point or public kiosks (free or for a fee). This is an extension to a reticulated system. Where these occur, we often see small water vendors. They sell water in containers to individuals. The final level is the reticulated system. Including treatment, storage and distribution and pipes. Direct into people's homes or businesses. These are the most common systems found in the developing world. Of the different systems described above they often operate together to varying degrees. For example in an urban or peri-urban community some citizens will get their water from streams, lakes or rivers. Others will get their water from shallow wells. Some will stand in line getting water from kiosks. Or bought from water vendors. The wealthier will get their water through a pipe into their homes or businesses. For the most part, the more complex the water system, the less the community is engaged.

But, most communities in the developing world are helpless to effectuate changes if their water systems are inadequate. Water systems are managed by well-intentioned individuals. But, often without the requisite training and experience. Money to maintain, repair and expand water systems, is usually inadequate. Inadequate for salaries, equipment, parts and supplies. This leads to marginally functioning water systems. And yet communities have little influence or means to help improve the situation. The result is often poor quality water. And, consequentially, community members can become sick or die. This also impacts the community's economy.

For a community to effectuate improvements in their water system they need exceptional community leadership. But, as with anywhere, it's rare to find exceptional individuals. The other method is from external (outside the community) intervention. For the latter, while the intervention is there, the systems improve. The community benefits. But, it's all too common that once the intervention ceases, the water system inadequacies return. Not only does the suffering and deprivation resume, but a new challenge surfaces. That is frustration and despondency. More insidious is a fatalistic attitude. That the community has even less control of their destiny, when it comes to water, then they had before.

There is good news, especially for the less complex system. Water systems will more often bring a community together than apart. It can create leaders. And create community water committees, advocacy groups or other means of collaboration.

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/Oceans play an important mitigation of climate change

/SOW2021

/Oceans play an important role in climate mitigation

Oceans play a fundamental role in our planet. Covering over 70% of the planet's surface, they support the food we eat, the air we breathe and play a critical role in stabilising our climate. Environmental changes due to climate change impact our oceans - continued damage that prevents these ecosystems from operating in balance would cause significant issues for life going forward.

Oceans are the world's largest store of carbon, with an estimated 83% of the global carbon cycle circulated through marine waters [source: https://www.worldwildlife.org/stories/how-climate-change-relates-to-oceans]. The balance is changing however, as the quantity of carbon dioxide we produce is more than our oceans can handle. This leads to acidification of the oceans, with consequential impacts on marine organisms and biodiverisity.

A recent piece of analysis estimated that the atmospheric reservoir of carbon (mostly in the form of carbon dioxide) is about 750 gigatonnes of carbon (GtC), whereas the ocean capacity is nearer 40,000 GtC [xv]. This, demonstrates the importance of the oceans and water cycle in the storage of carbon and also the risk if oceans become saturated to the point where they no longer can perform a role in storing carbon emissions.

Oceans as a carbon store

Ever since the world was introduced to phrases such as global warming, greenhouse gases, climate change and the more recent climate emergency there has been a growing focus on reducing carbon emissions. There are various ways in which this can occur and it is likely that no one solution will provide the answer given the scale of the challenge ahead.

How do we relate our activity to such numbers when considering storage? What is the scale of the challenge we face? The IEA latest analysis [xvi] of CO_2 emissions reveals that emissions flattened in 2019 at around 33 gigatonnes (Gt). That is a very large number, so to provide some context to the scale of a gigatonne.

- 1Gt equals one billion or 1,000,000,000 metric tons.
- A metric ton is 1000kg.
- So, a gigatonne is 1,000,000,000,000 kg.

Again, these are significant numbers but are still hard to conceptualise, so to make some comparisons:

- The largest African elephants can reach 6,300kg [xvii] so in 2019 we released the equivalent of 158,730,158 (approximately 159m) elephants.
- Google defines a gigatonne as a unit of explosive power equivalent to one billion tons of TNT, so an 8.8-magnitude quake unleashed about 50 gigatons of energy [xviii]

Given the above, it is reasonable to deduce that the carbon challenge is therefore one of the largest issues the planet faces going forward and requires proactive action to limit the damage that is being caused. The oceans and the role they play within the carbon cycle is therefore something that we can not ignore or take for granted.

Climate change and changing weather

2021 hopefully concludes one of the worst pandemics in recent history, but despite reduced activity and the environmental improvements that occurred because of this it also continues to start the next decade as we left the last.

Up to 2020 there was a decade of exceptional global heat, retreating ice and record sea levels driven by greenhouse gas emissions from human activities. Average temperatures for the five-year (2015-2019) and ten-year (2010-2019) periods are almost certain to be the highest on record. This means that 2019 is on course to be the second or third warmest year on record, according to the World Meteorological Organisation.

The World Meteorological Organisation provisional statement on the *State of the Global Climate*, states that the global average temperature in 2019 (January to October) was about 1.1 degrees Celsius above the pre-industrial period. [xix]

/Oceans play an important role in climate mitigation

The weather varies, but climate change affects the frequencies at which particular weather occurs, including the frequencies of extremes, such as heavy storms, heat waves and droughts.

Increased frequentency in weather extremes will underlie the most serious physical and economic effects of climate change. Prudent programmes to adapt to current and future climate change must take these changing probabilities into account when making risk assessments and devising adaptation measures. [xx]

Extreme weather events, including floods and droughts, are increasing in frequency and intensity. They affect the operation of water supply, drainage and sewerage infrastructure and the functioning of wastewater treatment plants, thereby affecting the protection of public health. [xxi]

Climate change manifests itself primarily through changes in the water cycle. As climate changes, droughts, floods, melting glaciers, sea-level rise and storms intensify or alter, often with severe consequences. Climate change impacts have direct consequences for water security and conflict.

Water and weather, the delicate balance between evaporation and precipitation, is the primary cycle through which climate change is felt. As our climate changes, droughts, floods, melting glaciers, sea-level rise and storms intensify or alter, often with severe consequences.

Can carbon storage, mitigate and teach us something?

Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide. Such processes already occur in nature. CO_2 is captured and stored via rainforests and vegetation, rivers and oceans and soils and sediments. Whilst some things like vegetation can be developed in the short run, others like rainforests take thousands if not millions of years to develop.

For example, it is estimated that:

- reforestation (planting more trees) has the potential to capture between 0.5bn and 3.6bn metric tons per year at an estimated cost of capture between $5 to $50 per metric ton;
- Soil carbon can store up to 5bn metric tons per year with an estimated cost of capture between $0 and $100 per metric ton.[xxiii]

The most straightforward solution to the CO_2 problem, of course, would have been not to have emitted the CO_2 in the first place. The concept of carbon sequestration in nature has, however, provided inspiration for several companies and individuals to ask whether we can artificially replicate such methods of carbon storage.

The Global CCS Institute collates a database of various carbon capture and storage (CCS) projects across the globe. It shows there are a wide variety of projects including large scale schemes and states “these facilities are already capturing almost 40 million tonnes of CO_2 per annum and a total of 220 million tonnes of CO_2 has been safely injected underground to date.” [xxiv]

Below we discuss some of the options and technologies being used to capture carbon.

Carbon capture and storage (CCS) and/or carbon capture and utilisation (CCU)

CCS technologies can be fitted to coal or gas powerplants or industrial processes to capture carbon emissions and store them in various ways including in underground caverns.

Alternatively, there is carbon capture and utilisation (CCU) which still involves the capture of carbon but then utilises it to create useful materials such as alternative fuels, enhanced concrete etc.

Geological storage

As mentioned above, this generally forms part of wider CCS schemes. Geological storage is where existing geological caverns and formations are used to store captured carbon thus removing it from the atmosphere. Whilst such storage has been proven to work it is important that certain conditions are met to ensure that the captured carbon does not leak back into the surrounding environment or atmosphere.

One method of storing such carbon is to use the captured carbon to enhance oil recovery. This in theory reduces the carbon footprint of such activity but is not carbon neutral as the oil that is extracted is generally combusted and thus releases a greater degree of carbon than is stored as part of the enhanced recovery process.

Direct air capture

Direct air capture is the use of technology and chemical processes to capture carbon directly from the air. Whilst the technology holds some promise there are issues with scalability and cost. For example, the World Economic Forum recently highlighted a Swiss company called Climeworks which has constructed such a plant in Italy. The issue remains to be scale, however, as it can only capture up to 150 tons of carbon dioxide per year or the equivalent to taking just 32 cars off the road. [xxv]

Whilst the concept is interesting, the scalability of such technologies will be key if they are going to play a sufficient role in reducing carbon emissions in line with the challenge outlined above.

Biochar

Biochar can be created by providing an oxygen-free environment during the thermal degradation of biomass. In this process one of the materials acts as a CO_2 absorption material which can then be used as a soil conditioner to enhance agricultural production.

For example, a pilot gasification plant at Loganholme Wastewater Treatment Plant (WWTP) has demonstrated that improved biosolids management, reduced WWTP operating costs, improved energy efficiency and enhanced resource recovery and reuse can be achieved. In combination with solar panels, it is energy neutral, the gasification process destroys most if not all contaminants of concern and it sequesters the carbon into the biochar. [xxvi]

There are also negative consequences of using biochar. It also can also be a source for soil contaminants, reduce yields due to its water absorption and pose a risk to health if not understood and used correctly.

Despite the current interest in the climate emergency and ever improving CCS and CCU technologies, the concept has fallen down the political agenda. Whilst the current cost of carbon storage may be a driving factor in its limited application, the cost of not acting would be far greater and CCS and CCU technologies for a limited class of technological solutions may play a role in reducing CO_2 emissions to the atmosphere.

Given the scale of the challenge we face and that no one solution is going to solve the carbon problem it is important that governments, industry and individuals remain open to technologies such as CCS and CCU.

/SOW2021

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Respect, Renew, Rethink

Tackling the global water crisis will require innovative thinking, integration of disciplines and a holistic approach to water issues. Water is so integral to our lives and our livelihoods. Sustainable water management contributes to many of the UN Sustainable Development Goals. It is therefore vital that, as an industry, we understand, appreciate and tackle this very important challenge.

Water needs to be considered in its broadest sense. From the catchments and the rivers to the oceans and groundwater through to the urban collection and distribution systems. This means consiering, agricultural water, industrial water, urban water, environmental water, allocation of water, water reuse, water and wastewater treatment. All of these elements are part of the water equation and all aspects need careful consideration and management to ensure we are sustainably managing this critical resource. Increasingly, necessities of this challenge are causing a recourse to disruptive technologies and paradigm-shifts, such as applying innovative devices to generate water from ambient air moisture and cloud seeding to name a few.

Climate change is having a clear impact on water – the extremes of droughts and floods have been experienced in many countries, at severities and frequencies not seen before. These extremes threaten the security of water supplies in times of drought and also threaten homes and lives during flood events.

Coastal inundation due to sea level rise could displace 200 million people by 2100 as homes fall permanently below the high tide line1. That's just one lifetime away. The implications of such a change are enormous. Exacerbated coastal hazards are of course proven to be a direct consequence of the climate change which aside from sea level rise include but are not limited to the following major social, economic and environmental risks: falling water levels of great inland lakes and drying up of wetlands, more intense tropical storms with wider-reaching trajectories thus imperiling previously out of reach geographical locations, increased storm surges causing more severe coastal-flooding especially near some major cities, more energetic wave climates in most places worldwide impacting existing coastal and marine structures which were not initially designed to withstand such loads.

A successively more agitated sea-state, as is predicted to occur over the next few decades according to UNEP/IPCC predictions, is almost consensually expected to generate more significant morphological changes of the shorelines around the world leading to more severe coastal erosion. Moreover, an increased probability of occurrence of the so-called meteo-tsunami, which is caused by a sudden change in atmospheric pressure generating a rapid long-wave radially impacting all reachable near and far coasts, much like a more conventional tsunami caused by earthquakes and land-sides, can be devastating indeed for coastal communities and facilities which were not previously perceived to be in such a jeopardy and therefore are utterly unprotected against meteo-tsunami inundation and destructive loads.

As far as risks to marine bio-diversity are concerned, it can for instance be pointed out that a stark reality is faced in some land-locked regions of the globe like the Persian Gulf and the Gulf of Oman where fish are deprived of a water path to naturally migrate to cooler waters toward the north or south pole as the case may be depending on the hemisphere and therefore some species face certain extinction due to inevitable rising seawater temperatures. Of course, the above account is by no means an exhaustive list and many other perils related to climate change are worth noting like the loss of operational days at ports due to bad weather, both due lack of harbor tranquility and rain preventing handling of certain cargo like grains, disrupting global transport and reducing port revenues.

For many years, engineers have tried to 'manage' water – to tame rivers, build dams, protect coastal areas, pump and treat water and harness water for power. But we are increasingly understanding the power of nature and the variability of our climatic conditions (which is increasing). Now, adaptation and resilience are a key focus for water systems and solutions, integrating changes in climate into their design, asset management and investment.

There is recognition that we don't know what the future looks like, so planning for a range of scenarios and adopting solutions which can best adapt to this variability are preferred. All options need to be considered when planning water systems, including stormwater harvesting, water recycling and potable reuse. Clearly, solutions emphasising 'adaptive planning' are sought for and it may be strived to turn this sustainability quest into an historic opportunity for mankind by looking into multifaceted solutions whenever possible with added benefits. For example, using mariculture systems such as fish cages which have the potential to empower coastal communities can also be used to mitigate the impacts of depleted water bodies in the face of biodiversity threats by growing out more resilient species at sea to also cater to food security needs.

Currently, some design codes of coastal defence and breakwater structures are being revised with a view to apply circular economy principles which is expected to yield more sustainable solutions to work with nature in protecting from coastal hazards.

Generally, the full range of 'soft' and 'hard' coastal protection strategies against flooding considering all options including retreat and relocation are to be weighed properly in the context of a benefit/cost analysis before rushing to implementing a design. For example, aiming to reap the great rewards of the 'blue economy' by tapping into marine renewable energies at the same time as implementing coastal flood protection is becoming increasingly more achievable now that the technologies to harness wave and current energies into electricity are becoming more mature and some of such devices can be installed together with smarter structures for coastal protection.

As we see a broader consideration of sustainability in projects, new approaches to address water issues have emerged. Projects that are carbon neutral, projects that enhance the environment and support biodiversity and projects that close the loop through a circular economy approach. It feeds from a **respect** for the precious resources that is water, a **renew**ed focus on taking a holistic and collaborative approach to solving water issues and by **rethink**ing solutions to better prepare for climate change and to promote a sustainable future.

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/Polluting today will not preserve tomorrow

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/Polluting today will not preserve tomorrow

The problems associated with some of the world's largest cities still discharging untreated or inadequately treated sewage into waterways and oceans remain daunting due to the serious impact to downstream users and aquatic food supplies. Coastal eutrophication has grown exponentially over the last 40 years, with virtually no coastal areas (except for Antarctica) spared.

A significant part of this problem is not local. Much of the coastal eutrophication can be traced to the success of fertiliser applications to farmland (often far from the ocean) in increasing crop yields. The the reduction of the extent and duration of dead zones needs to be a significant priority both nationally and increasingly nand importantly globally.

Even success stories, such as the Deer Island wastewater treatment facility in Winthrop, Massachusetts, USA, credited correctly for cleaning up and restoring ecosystem services in the Boston inner harbour, required a deep-water effluent diffuser designed to, among other things, remove nitrate and other nutrients from the shallower harbour.

In another case, the Logan Water Partnership (Logan Water, Cardno, Downer and WSP) worked closely with the regulator to develop a solution which used wetlands and riparian restoration to minimise and offset nutrients to achieve zero net emissions of nutrients. The Cedar Grove Environmental Centre comprises an environmentally sustainable Wastewater Treatment Plant (WWTP), a Landcare nursery and training centre and a community recreation reserve. [xxvii] Again, the projects provided as part of this report continue to demonstrate the work that is going on across the globe to improve progress towards the SDGs.

Endocrine-disrupting compounds are also introduced into coastal ecosystems through sewage effluent, with unknown concentrations and effects on developing fishes, birds, marine mammals and invertebrate larvae. We expect greater societal and regulatory focus in these areas in the coming years.

Combined sewer overflow (CSO) systems are another troubling issue in coastal ecosystems. When CSOs dump directly into the coastal zone without benefit of a living shoreline or vegetated bed, bacterial contamination often skyrockets above levels that would permit shellfish harvesting or beach-going. CSO inputs also introduce organic pollutant contamination that accumulates in the food chain and in coastal sediments.

Many coastal cities have developed plans for CSO mitigation with newer designs incorporating holding facilities to dampen out flow peaks rather than bypassing the treatment plants and directly discharging to a sensitive coastal ecosystem.

There are again examples of such developments taking place, for example Urban Utilities in Cannery Creek (Queensland, Australia) worked with communities to solve a local wet weather overflow challenge.

One of the solutions for addressing wet weather issues was to utilise a complex effects-based planning operation, where overflows would be captured locally, screened and pumped via a rising main for discharge into a much larger neighbouring waterway following bioretention. Thus understanding, management, monitoring and action is key. The resulting effects-based solution better met the communities' liveability needs, creating greater social and environmental value at a much lower financial cost than a traditional sewer solution.

This again shows the importance of linking policies to solutions and solutions to meeting the goals policymakers have set. To do this engineers will continue to play a vital role in delivering such schemes.

It is imperative that activities are considered as part of larger catchment and coastal protection areas. Failure to do so will mean that communities and society will constantly be fighting to maintain status quo, simply shifting problems rather than resolving them. If we are to move forward, solutions need to be innovative and consider not only mitigation but reduction and control at source.

The damage from plastics and strategies to regain control

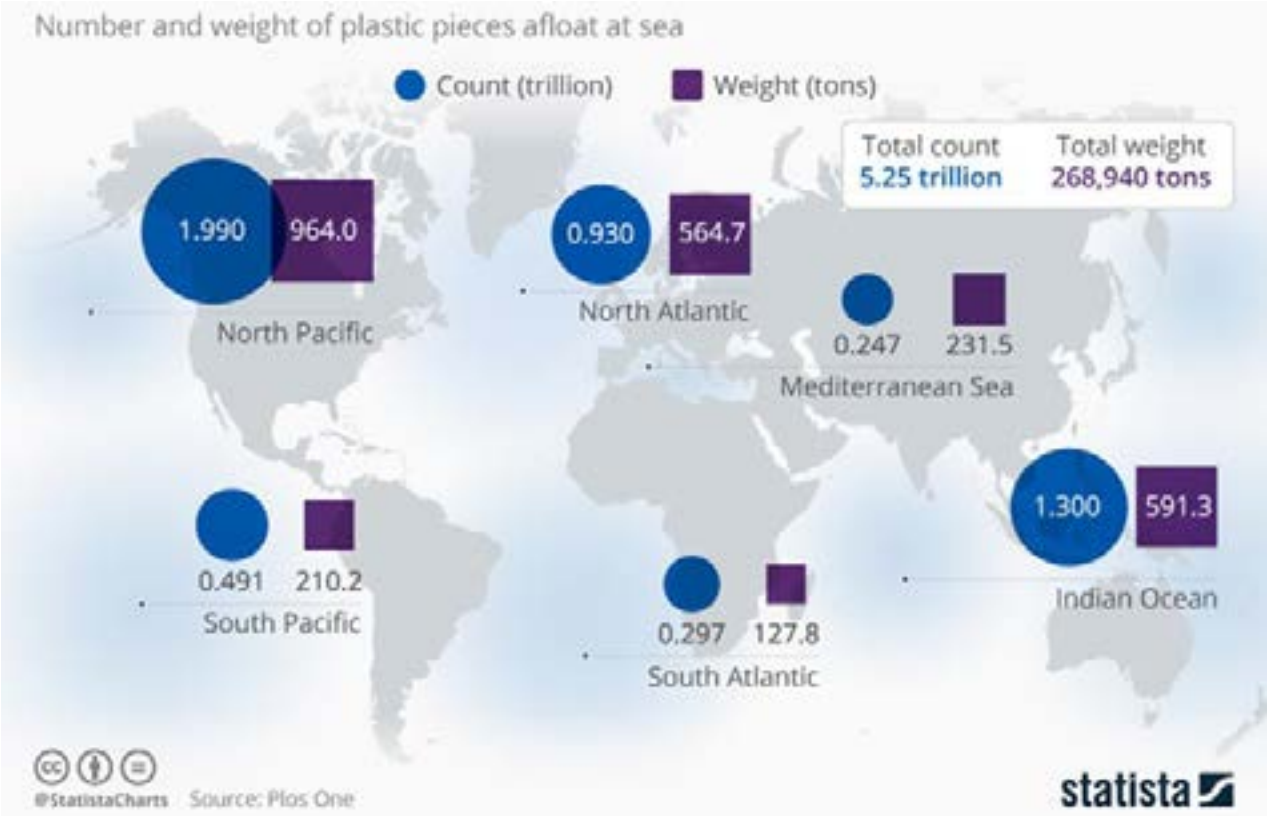
Plastic takes decades or even hundreds of years to decompose and poses a threat to our water supplies and water quality in a variety of ways. Plastic pollution from discarded water bottles, polystyrene coffee cups, grocery bags, synthetic clothing fibre and other waste breaks down into tiny bits of plastic no bigger than the full stop at the end of this sentence. Plastics also leech into the water, degrading the water quality with toxic compounds and end up harming human and animal health.

Because of its longevity, ubiquity and sheer volume, plastic debris is now emerging as a new, truly global challenge. (It is estimated that some plastic products will retain their original recognisable form 400 years after discharge into the ocean). Recent research has highlighted the urgency of preventing unmanaged plastic waste from reaching the ocean, a problem known as plastic-waste leakage. [xxviii]

Unless steps are taken to manage this waste properly, by 2025 the ocean could contain one ton of plastic for every three tons of finfish, an unthinkable outcome.

Solutions must be global. Plastic is the workhorse material of the modern economy. It often moves through global supply chains and supports global companies. While plastic products can have short useful lives, the longevity of plastic molecules themselves means that plastic waste travels far across borders and into our common high seas. We need a global approach to mitigating pollution from plastic waste—an approach that considers region-specific solutions that will prevent this waste from entering the ocean in the first place.

The world's oceans are infested with plastic



Source: Statista, Plus One [xxix]

According to the trade association PlasticsEurope, world plastic production grew from some 1.5m tonnes (about 1.7m tons) per year in 1950 to an estimated 275m tonnes by 2010 and 359m tonnes by 2018; between 4.8m and 12.7m tonnes are discarded into the oceans annually by countries with ocean coastlines.

Several solutions, mentioned in the McKinsey Center for Business and Environment report are most effective:

- Closing leakage points within the collection system by optimising transport systems to eliminate illegal dumping and closing or improving dump sites located near waterways.
- Increasing waste collection rates by expanding collection service, as plastic waste is more than twice as likely to leak into the ocean if it remains uncollected. Stopping the growth in absolute metric tons of leaked plastic would require that the weighted average collection rate in the five focus countries be doubled, from roughly 40% to nearly 80%.

- Using a variety of waste-to-fuel (e.g., gasification) or waste-to-energy (eg., incineration with energy recovery) technologies to treat waste in areas with high waste density. The choice of waste treatment should, of course, align with local priorities, local regulations and electricity tariffs. (Using these technologies does not preclude a portion of high residual-value plastics being recovered by the informal sector for recycling.)
- Pyrolysis also is an option in the medium term; if the cost structure for this technology improves by 25-35% over the next five years, it could become even more widely used as a substitute treatment option.
- Manually sorting high-value plastic waste and converting much of the remainder to refuse-derived fuel (RDF). This lever, which is specific to areas with low waste density, entails extracting for recycling the 20% of plastic waste that has high residual value and converting a substantial portion of the remaining 80% to refuse-derived fuel for use in the cement industry. This RDF could replace 3% of total coal consumption.

Whilst the above outlines a number of challenges and methods for reduction, we have seen some shift globally in other areas as well such as the reuse of plastics, reducing unnecessary plastic packaging, removing the use of plastic straws, returning to paper products (bags etc), whilst each one may only influence part of the overall issue combined the effect is significant and so it is important that such measures are not only encouraged but actively pursued.

Our relationship with the oceans needs to improve

The SDGs have started to attempt to bring to the attention of individuals and governments important issues that, of which there is some awareness, but are mostly hidden from people's day to day lives.

This always makes the challenge of gaining traction on change difficult as the problem is not always apparent, but it is vital we address this challenge.

Technologies are being developed to remove rubbish from the oceans and many engineering solutions have been designed to reduce coastal pollution pollutants yet more still needs to be done.

It is important to remember that the coastline now is not what it may be in 25, 75, 200 years' time. Cities, regions, in fact whole countries, could face the prospect of significant loss of property, infrastructure and life if sea levels rise to the extent predicted if we do not meet the SDGs.

To put the above in context and to consider how we can possibly survive as a sustainable species and planet if we fail to act, it is "estimated 50-80% of all life on earth is found under the ocean surface and the oceans contain 99% of the living space on the planet".[xxxi]

We therefore need to find innovative ways to connect populations with the importance of the oceans in water cycles, sustainability, weather etc together going forward. This again can be done using technology and innovations which provide clear warnings as to the behaviours that are damaging parts of the ecosystem that once lost will be extremely difficult to rebuild or replicate.

/SOW2021

Peter Guthrie
Professor of Engineering for Sustainable Development
at the University of Cambridge

New approaches are emerging but progress is slower than it should be and very poor in respect of sanitation which lags behind water supply in provision.

This follow-on report by FIDIC is a hugely welcome compilation of the opportunities to address the global water crisis. The contribution of engineers is elegantly described and there is full acceptance that this contribution can only be effective when set in the context of the wider political, economic, social and environmental dimensions. There are three key recommendations.

First, there is call to respect the value of water by setting prices at appropriate levels to encourage conservation and management. Of course this needs to respect the needs of those who cannot pay and acknowledge that much of the water cycle is beyond the scope of revenue and integrated management is critical to ensuring the whole system is considered. Second, the report recommends wide involvement in decision making around water management, embracing communities at all levels in the process.

There is a recognition that decisions around water need to remain cognisant of the wider system within which a water system is set and this demands extensive consultation and engagement. Third, the report recommends renewed and redoubled efforts to tackle the persistent problem of inadequate water supply and sanitation to many of the world's poorest people. New approaches are emerging but progress is slower than it should be and very poor in respect of sanitation which lags behind water supply in provision.

The mnemonic of Respect, Renew, Rethink is helpful in encouraging all engineers to come to the global issues of water in all its manifestations with a fresh approach and redoubled effort.

FIDIC plays a key role in the engineering world globally and this report adds significantly to the wider understanding of the vital contribution engineers can make in delivering on the sustainable development goals.

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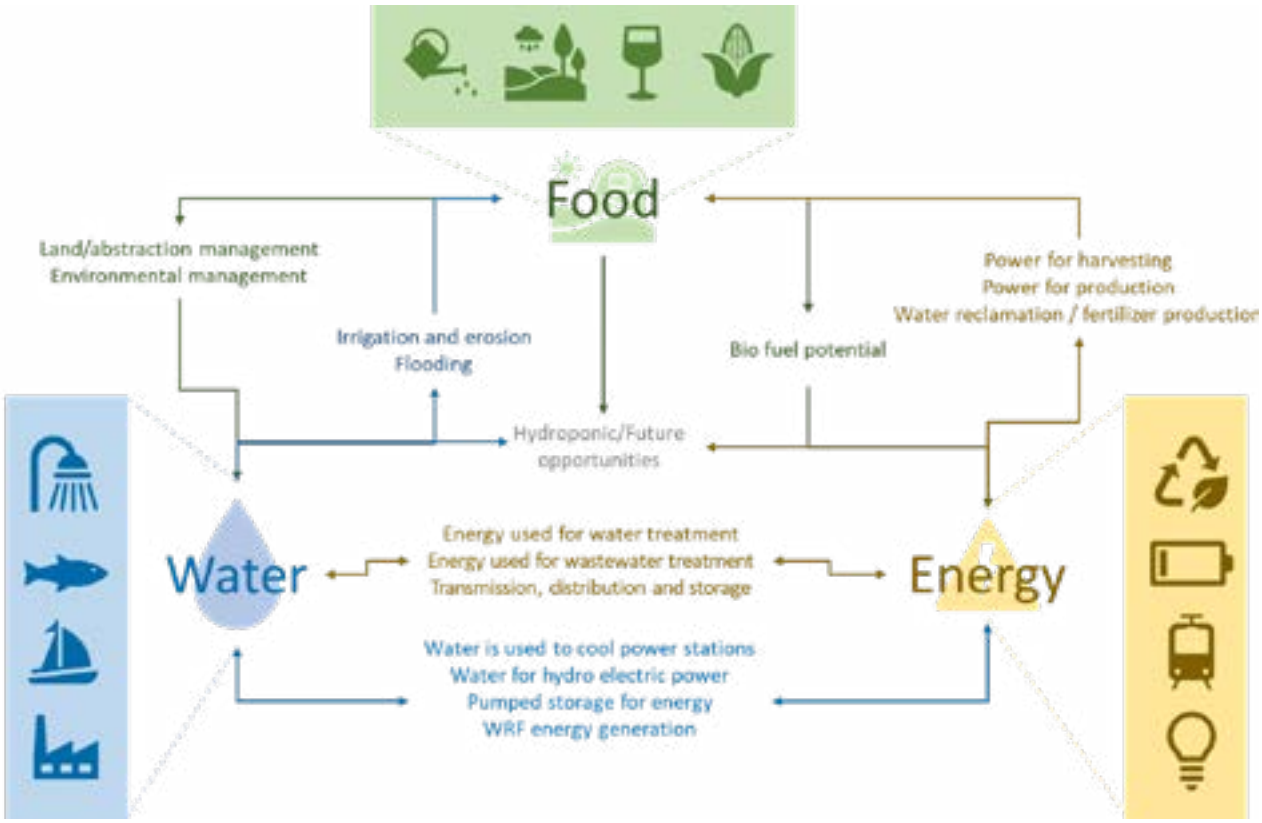
/Water for agriculture and industry

/SOW2021

A reminder of the food-energy-water nexus

As discussed in the last State of the World report *Establishing the value of water - the business case for change* there is an important task in recognising the food-energy-water nexus.

The graphical representation of this nexus that was shown in this report (and can be seen below) shows how, food, energy and water activities are all linked via a complex web of activities which to a large extent are dependent upon each other for success.



If we look more specifically at certain aspects of this nexus and how they are changing, we find that the shifts are not only generally towards more water usage but also that these interactions contain various degrees of inefficiency and waste, resulting in a sub-optimal outcome both in terms of resource utilisation and economic value.

Looking at energy and water, large amounts of one are generally required to produce and distribute large amounts of the other, be it water for cooling in power stations to produce electricity to distribute to a wide network of homes/business etc, or the electricity produced to power pumps and systems to move large volumes of water to homes/business etc. In addition, wastewater byproducts are more frequently being used to generate energy and fertiliser.

Looking at the food-water part of the equation, agriculture and water are strongly linked because 70% of the world's freshwater demand is associated with food production for consumption and this can be as high as 95% in developing countries.[xxxii]

The above demonstrates how future water and carbon scenarios will require a significant shift in the methods and types of food we grow/raise

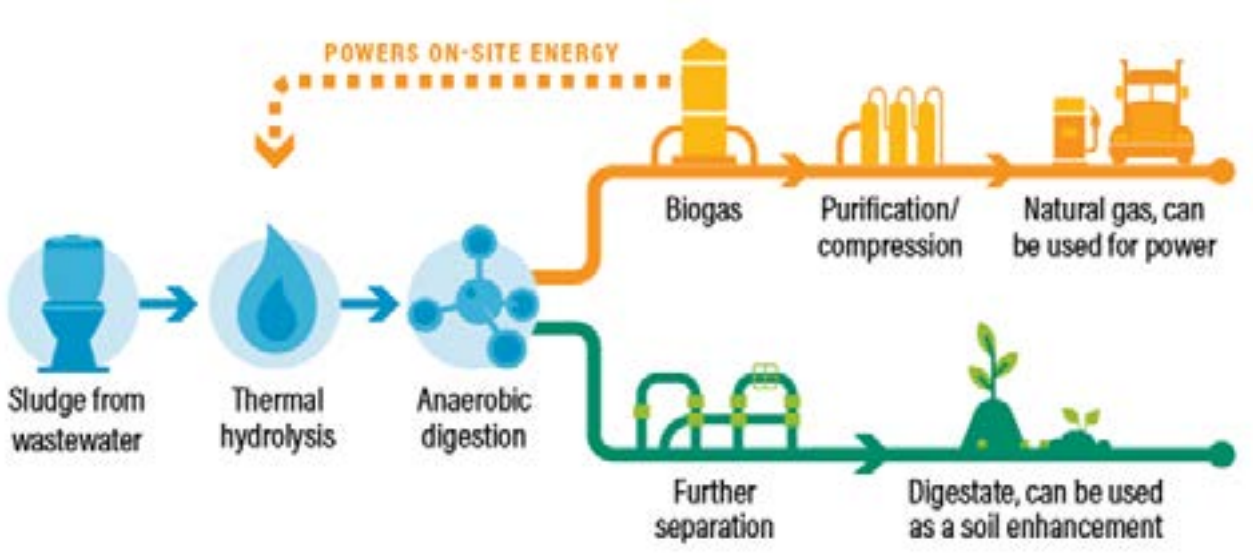
It is important, in this report that we therefore look at some of the innovations that are occurring to improve and make the interactions in this nexus more sustainable such as innovative approaches to water reclamation facilities.

How can we influence this nexus moving forward?

Examples of water reclamation facilities (WRFs) as energy producers

In direct connection to greater sustainability consistent with best water resources management practice, wastewater is now being considered more as a resource than as a waste—a resource for water, for plant nutrients and more recently for energy. The organic matter contained in wastewater from our sewage systems (commonly known as sludge) can become a valuable resource with sludge-to-energy systems.

Water reclamation facilities, energy and soil interactions



Source: World Resources Institute [xxxiii]

As wastewater treatment plants can use biogas generated from their own sludge to power their operations, it allows them to be energy self-sufficient.

In the European Union, through project PowerStep[xxxiv] belonging to EU Horizon 2020, efforts are underway to convert existing municipal wastewater treatment plants from net power consumers into energy neutral or even energy positive service providers, exploiting the chemical energy bound in the organic matter. Decreasing energy consumption and raising energy production at the same time, PowerStep converts wastewater treatment plants into real power producers, creating a circular economy.

For example, statista.com presents the primary energy production from sewage sludge gas in the European Union (EU) from 2013 to 2017 measured into tonne of oil equivalent (ktoe). At the level of the year 2017, 1.387 ktoe primary energy was produced from sewage sludge.

Likewise, Melbourne's growing population is placing greater strains on water and energy resources, so they are planning and adapting to this changing environment by building waste-to-energy facilities to process commercial food waste into clean, renewable energy. Turning food waste into energy helps reduce landfill and cut greenhouse gas emissions and reducing our energy costs helps to keep pressure off customers' water bills.[xxxv]

This again shows sustainability becoming a growing part of day-to-day project delivery and the sharing of such practices and developments will be important to meet the SDGs.

Wastewater treatment plants – conventional vs energy positive

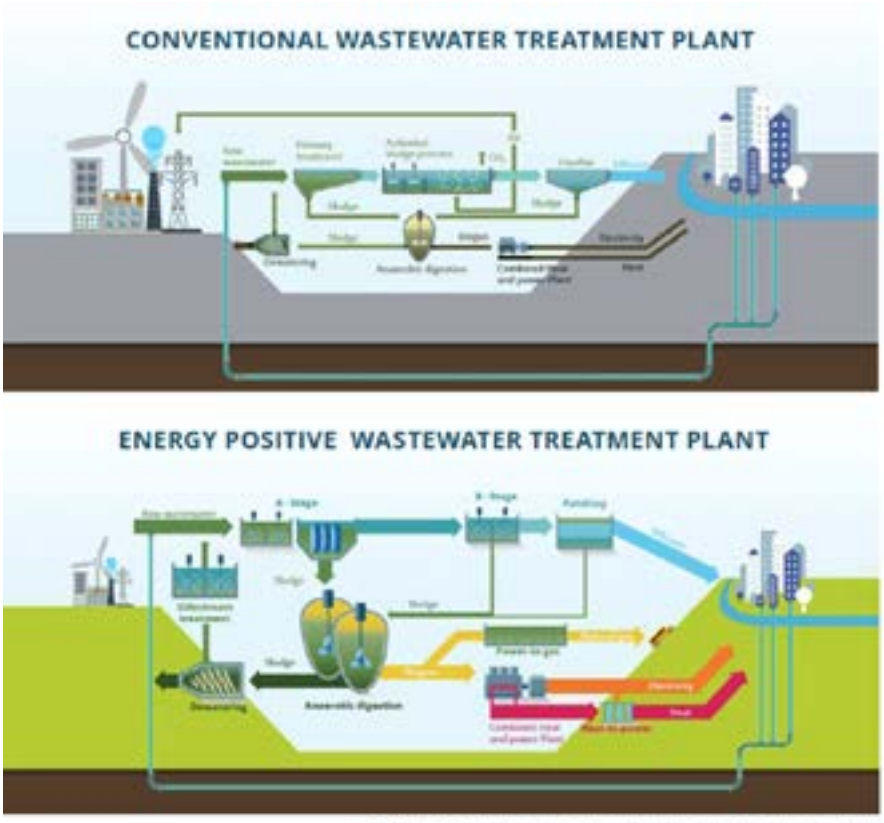


Figure 2: Conventional vs PowerStep wastewater treatment plants

Source: PowerStep[xxvi]

Sewage sludge disposal from urban wastewater treatment by treatment method

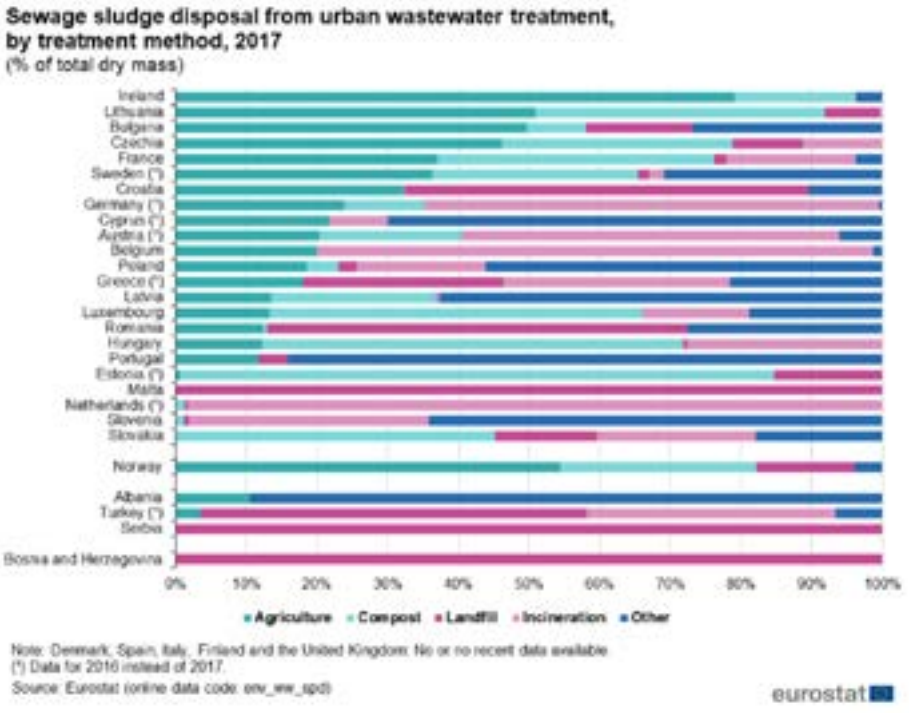


Figure 6: Sewage sludge disposal from urban wastewater treatment, by treatment method, 2017(% of total dry mass)Source: Eurostat (env_ww_spd)

Source: Eurostat

The nexus and how it integrates with biodiversity

The recent UK government *Economics of Biodiversity: The Dasgupta Review* clarifies that climate change and biodiversity losses are intimately related, yet the 2020 WWF Living Planet Index shows an average 68% fall in populations of mammals, birds, amphibians, reptiles and fish between 1970-2016 and the Intergovernmental Panel on Climate Change reports a continued rise in global greenhouse gas emissions.

The economic and financial value of infrastructure and urban development is substantial, but infrastructure construction contributes to carbon emissions and can negatively impact the environment and how we live. On the other hand, it also presents opportunities for increasing carbon sinks and biodiversity recovery.

The global race to achieving a healthy, resilient and net-zero future has highlighted the importance of integrating biodiversity and carbon sequestration into infrastructure development, including the siting, design and engineering of grey infrastructure and nature-based infrastructure solutions. Shifting global practice in response to this recognition will require close collaboration among scientists, conservation practitioners, policymakers and the engineering industry.

There are increasing moves to use the concept of natural capital in assessing future infrastructure decisions. These concepts, however, remain challenging when attempting to attract green investment from various stakeholders and investors.

Increasingly, countries are considering replacing traditional ‘concrete and hard solutions’ with ones that incorporate nature-based ones. This includes revitalising things such as wetlands, flood plain areas, marshes and mangroves etc within cities. These systems not only help to reduce peak flows but can also improve water quality, the quality of life of individuals and improve biodiversity systems.

It is positive to see countries embracing the need for change and recognise the financial and environmental challenges that the infrastructure sector should be addressing. Steps must be taken by governments, multilateral development banks, asset owners, investors and sovereign wealth funds towards increasing the availability of finance for sustainable infrastructure.

/SOW2021

Stuart Orr
Freshwater Practice Leader
WWF International

Climate change, overuse of freshwater resources and changing consumption patterns are just a few of the myriad forces putting freshwater systems increasingly at risk.

This report – a continuation of FIDIC's State of the World review of the challenges and opportunities associated with water resource management and water security – highlights the importance and interconnected nature of natural and engineered systems and points to some of the innovative solutions required to address the challenges facing the water sector and achieve the Sustainable Development Goals (particularly SDG 6). The insights from this and previous reports in the series underscore a simple but difficult set of truths; globally, the water sector is experiencing unprecedented challenges and pressures and there is an increased urgency to address them with innovative approaches.

Yet there is also reason to be optimistic. There is now a growing – but still not sufficiently realised – appreciation for the value of nature and natural systems in addressing these challenges. Increasingly, opportunities to protect, preserve and enhance aquatic and freshwater ecosystems, sustain livelihoods and meet the nutritional needs of a growing and changing population, will likely drive new financing and investment, enhance governance strategies for managing shared resources and bring new technologies to arrest and reverse the loss of nature and build a carbon-neutral and nature-positive economy and society.

Climate change, overuse of freshwater resources and changing consumption patterns are just a few of the myriad forces putting freshwater systems increasingly at risk. The past 20 years have seen the quickest rise in the earth's temperature since records began in 1880 and the consequences for the global water system are clear. The 2020 global Living Planet Report – WWF's landmark review which presents a comprehensive overview of the state of our natural world through the Living Planet Index – clearly outlines how humanity's increasing destruction of nature is having catastrophic impacts not only on wildlife populations but also on human health and all aspects of our lives. Serious declines in species population numbers are a measure of overall ecosystem health and the index suggests, simply, that we're fast approaching a tipping point. Consumption of freshwater is increasing by 1% per year in line with a growing population and the and the associated demands that correspond with a welcomed rise in living standards. There is an associated decline in the Living Planet Index for freshwater species of 4% per year, meaning that freshwater biodiversity is more imperiled than the terrestrial biome. In the 20th century, around two-thirds of all the world's remaining wetlands were drained, dammed and dyked and they are still disappearing three times faster than rainforests. The bottom line: despite the importance of water for life and health, with natural systems playing an essential role in freshwater regulation, these ecosystems have become threatened. Their disruption and destruction is costly and in many ways harms human health. Protecting freshwater cannot happen alone and will require new forms of collaboration between the public and private sectors and new tools and strategies.

Against this backdrop, WWF has developed an emergency recovery plan for freshwater; a six-point plan that prioritises solutions that are rooted in cutting edge science and have already proven successful in certain locations: letting rivers flow more naturally, reducing pollution, protecting critical wetland habitats, ending overfishing and unsustainable sand mining in rivers and lakes, controlling invasive species and safeguarding and restoring river connectivity through better planning of dams and other infrastructure. The engineering and conservation communities are well positioned today to work together on three facets of this plan: promoting nature-based solutions, engaging in better planning practices and bridging the financing gap.

1. **Nature-based solutions.** Nature can provide many of the solutions we need - from healthier floodplains that help prevent flooding of cities, mangroves that protect coastal communities from storm surges and wetlands that improve water quality. Nature-based solutions (NBS) are actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human wellbeing and biodiversity benefits. They are underpinned by benefits that flow from healthy ecosystems and target major challenges like climate change, disaster risk reduction, food and water security, health and are critical to economic development. NBS can also substitute for, or complement, more traditional engineered solutions. Engineered solutions generally provide a single benefit and often influence other resources and require continued maintenance and eventual replacement. In contrast, NBS provide the primary benefit and a range of co-benefits and often require less maintenance over time as they rely on the regenerative processes of nature. For example, levees and floodwalls provide a single benefit, impact river-floodplain ecosystems and require considerable long-term maintenance (much of the developed world now faces a considerable challenge of backlogged maintenance of levees). In contrast, NBS for flood management can reduce flood risk while benefiting water quality, nutrient sequestration, biodiversity and open space and require less maintenance over time.

2. **Integrated approached to planning.** The conservation and engineering communities - together with national and subnational governments and other sector stakeholders - can rethink and reshape the way infrastructure is designed and infrastructure services are delivered. Governments must continue to invest in institutions, infrastructure and information systems across sectors and link national planning to local decision-making. Such investments help satisfy often competing environmental, economic and social needs while preparing for the future. Planning at the system-scale can support more sustainable development options or pathways by quantifying how a group of projects perform as a system, examining the tradeoffs that are inherent in infrastructure development and selecting options that minimize harm and optimise benefits. More equitable and transparent regulations and allocations, a mix of natural and hard infrastructure and increased monitoring and data can all further help reduce delays and cost overruns due to projects with high social or environmental conflicts or risks, improve climate resiliency and reduce the risk of 'economic water shortage', the term applied when poor management or a lack of investment keeps a population from accessing an adequate water source.

3. **Developing a pipeline of bankable water projects.** Finally, the conservation, engineering and finance communities together can structure sustainable water projects and direct investments into priority landscapes and basins, moving beyond a project-based approach to water-related investment. With a better understanding of water risk and how to account for it when valuing investments, these entities can proactively engage with existing efforts and start to create offerings that finance NBS and support policy that lays the foundation for credible green investments.

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/What is next for global water systems?

/SOW2021

What is next for global water systems?

Having established the complexity of the systems within the water sector it is important that engineers constantly assess their approaches and learn from them. This will lead to more innovative and cost effective solutions to our water challenges. In so doing, we will increase the probability that we will help the world achieve the SDGs and do so in a way where it will still be a goal that is met 20, 50 or even 100 years later.

Such assessments and continuous learning should include asking questions such as the following

- **Why can't** everyone have access to clean water? This problem has gone on too long and can be solved with the proper application of technology, innovation, finance, training and governmental commitment.
- **Why can't** everyone have access to adequate sanitation? See above.
- **Why can't** we take advantage of current technology and provide for more mobil desalination plants which can be moved to serve remote communities on a rotating basis?
- **Why can't** we take advantage from current and evolving technology and have more pumps use less power, use more renewable energy, operate at peak efficiency more frequently or not be required at all?
- **Why can't** catchment areas be more effective at restoring wetlands and recharging aquifers?
- **Why can't** we use current and evolving technology to make products more water efficient?
- **Why can't** food production be less polluting and why can't we make better decisions on what to grow and where to grow it?
- **Why can't** we restore more marshes and wetlands and make them flourish?
- **Why can't** we use current and evolving technologies to produce energy less water?

The short answer is **WE CAN and WE NEED TO DO MORE**. All the above of course require investment and creative thinking and as the global body representing engineers it is FIDIC's job to ask not why we can't, but how can we!

FIDIC as part of this report is putting out a challenge to the sector - engineers, regulators, water companies etc - to improve knowledge sharing of innovative solutions, practices and regulations that help to improve the complex water cycle in which we live.

There needs to be a greater drive to increase the public awareness and to increase the respect for the water systems that provide for our food, water and energy requirements.

These systems are all interlinked and there is a danger that if actions are not taken to ensure approaches are sustainable, such systems will either deteriorate or, even worse, collapse.

/SOW2021

Eoin Cullinane
Senior Project Engineer
Nicholas O'Dwyer

With the publication of this report *Tackling the global water crisis – State of the world 2021* FIDIC has clearly set out the complex interconnected challenges which face the water sector in its broadest sense.

Taken together with the previous State of the World report *Establishing the value of water - the business case for change* the drivers for change in the way we interact with water and the importance of encouraging greater innovation into this sector are unambiguously expounded upon leaving us in no doubt of the challenges we face in addressing existing environmental concerns while at the same time facilitating future development.

These challenges are far-reaching, impacting on all regions of the world and across all economic sectors albeit with a predictably disproportionate impact on those who are already less fortunate. From the most developed countries (such as the regions in the

US which are currently experiencing unprecedented periods of drought) to the poorest (where for the three in ten people globally who are unable to regularly use soap and water to wash their hands at home, a lack of adequate water and sanitation negatively impacts the ability to follow the simplest of health guidelines) the issues raised in this report are relevant to engineers across the world.

The water sector provides an excellent example of the need for market driven innovation to deliver positive improvements in order to facilitate engineers who are at the forefront of tackling the problems we currently face in the development of resilient and sustainable infrastructure. Digital disruption in engineering and construction continues to open exciting opportunities for innovation and we as engineers must focus this progress on areas, such as the water sector, which currently lack in both investment and public attention. The recognised links between water, energy, food and climate which are highlighted again in this report further emphasise the need for a more sustainable approach to all aspects of water engineering.

The need for increased investment in the delivery of new water supply, sanitation and flood relief infrastructure is clear from this report as is the need for greater investment in the going operation and maintenance of existing systems. The benefits accruing from such investment is obvious given that the World Bank estimates the toll from floods and droughts over the last decade to include tens of thousands of deaths and more than a trillion dollars of property damage. Equally stark however is the cost of continuing to delay in remedying the impact of existing and in many cases outdated, urban infrastructure on the quality of our natural water environment. The ongoing COVID-19 pandemic has shown the ability of governments, public health bodies and industry across the world to collectively address major global health challenges. Given that the World Bank estimates that a lack of adequate safely managed sanitation impacts on 4.5 billion people worldwide and causes an estimated 1.6 million deaths each year, our role as engineers must be to ensure that as we build back better after the pandemic the issues facing the water sector are addressed in a similarly forthright manner.

I have spent the majority of my career to date working on water-related projects be it in water supply, wastewater collection and treatment, catchment hydrology and flood relief or the water-related aspects of highways and infrastructure projects and I have therefore witnessed first-hand many of the issues which have been outlined in this report. The difficulties the issues outlined in this report generate for engineers striving to deliver robust, resilient, sustainable and cost-effective design solutions and construction projects are obvious and at times greatly frustrating. However many opportunities for meaningful interventions also abound within the water sector which provides endless opportunities to deliver environmental improvements and facilitate future development are also palpable, whether that's through the improvement of water quality by removing plastics from our oceans or nitrogen rich agricultural runoff from our rivers, by providing safe reliable drinking water and sanitation, or protecting at risk communities from flooding. Based on my experience I believe that engaged and innovative engineers are key to addressing the myriad of challenges that continue to face the water sector and that groups like FIDIC's Future Leaders in particular have a crucial role to play in turning these challenges into opportunities for positive improvement.

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Project examples

Water supply

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Water supply

This FIDIC report has explored the challenges and discussed some of the ways the industry is trying to meet the challenges of meeting the sustainable development goals (SDGs) and climate goals. Policies, theory and discussion, however, can only take the sector so far towards making progress in meeting such targets. Yes, it is important to develop, nurture and create the right environment of tomorrow's projects but to do so it is important we understand what is happening now, what is being delivered on the ground.

It is only through understanding these achievements and potentially learning lessons or limitations that engineers can derive tomorrow's solutions moving us towards meeting the SDGs and climate goals.

Knowledge sharing and showcasing engineering projects and developments has always been something FIDIC has supported through its awards Programmeme, but it is increasingly important that such projects and their purpose be more closely linked to policy development and wider activity with stakeholders. This report is a step in that direction and we hope it engages a wider set of the industry on the importance of early and detailed engagement within policymaking and project development going forward to ensure we can achieve the best outcomes.

Lima Water Supply Project

Type of project: PPP to enhance the water supply network in Lima.

Large water treatment and supply project, envisioning the transfer of water from a dam complex in the Peruvian highlands into the Rimac River, the main potable water source in Lima.

Includes a new potable water treatment plant (5m^3/s) and a 167km-long water conduction and distribution network.

Only 50% of the Peruvian population has access to safely managed water services.

Lima, where a third of Peruvians live, is a semi-desert.

Organisation

IFC, as Government of Peru Consultant, hired to successfully structure and retender the project.

The service is funded by SECO through IFC's Sustainable Cities Programmeme.

Nacala (Mozambique) Water Supply Scheme

Nacala is a major port city in North Eastern Mozambique, with a current population of 225,000 people.

The Nacala water supply distribution system is supplied by two sources - a dam on the Muecula River some 30km south west of the city and two wellfields (Mpaco and Mutuzi) located on the eastern environs of the city. The recently completed water supply project provided for the upgrading of the existing groundwater sources together with new pumping facilities, transmission mains and an expansion of the existing distribution system. These works increased the supply capacity of the water supply system by 10,000 m^3/day to over 33,000m^3/day.

Client: Fundo de Investimento e Património do Abastecimento de Água (FIPAG), Mozambique.

The project provided for the construction of the following works:

- Development of 22 No. new borehole sources together with groundwater collection systems.
- 2 No. 200m^3 RC collection reservoir and 1 No. 100m^3 RC collection reservoir.
- 4 No. high lift pumping stations.
- Approximately 10km of 350mm and 17km of 200mm transmission mains.
- 2,000m^3 RC service reservoir and 250m^3 water tower.
- Extensive mechanical and electrical works.
- Approximately 115km of additional distribution pipework and 26,000 additional connections

Nicholas O'Dwyer completed the design, tender documents, contract administration and supervision on behalf of FIPAG (Fundo de Investimento e Património do Abastecimento de Água), a semi-state organisation responsible for the development and operation of water and sanitation facilities in major urban locations in Mozambique.

The construction works were completed in 2020.

Energy efficient design

Energy efficient design management was implemented to reduce the lifecycle energy consumption. Whole life cost assessments were completed to determine the most efficient water transmission system from the two wellfields, taking account of both operating cost of the pumping equipment and the capital cost of the transmission systems. New high lift pumping systems were provided at both wellfield sites and economically-sized transmission mains were provided to deliver water to the service reservoirs / distribution centres in Nacala.

Design and construction innovations

Poor ground conditions were encountered at some of the sites and special foundation details were provided. This included the need to design a foundation piling system for the new water tower at the Faita Reservoir site in Nacala. This was successfully achieved and the impressive wine glass-shaped water tower has become an attractive feature in the city skyline.

Water supply

A smart control and monitoring system is used to manage the delivery and distribution of water in the city. This ensures that appropriate levels of storage are maintained in the reservoirs at all times and economic levels of pumping capacity are activated to achieve a high level of service delivery.

Economic, employment and sustainability benefits

In recent years, the transport infrastructure on the Nacala region has undergone significant improvements through the development of both highway and rail corridors along with the redevelopment of a deep-water port and terminal and the completion in 2014 of an international airport. The recent completion of the expansion of the water supply system was therefore a critical parallel infrastructural requirement to support the development of the city and its environs. Nacala is now well on its way to becoming a very important transport and logistical hub on the east coast of Africa with strategic transportation links to all of Mozambique, Malawi, Zambia and Zimbabwe. The establishment of the Nacala Special Economic Zone (SEZ) has also played an important role and the critical improvements to the water supply system is now facilitating the development of both heavy and light industry in the region. This in turn is attracting new commercial entities to the region and creating greater market access for the small-scale agricultural producers in the region.

The spin-off in job creation terms is very substantial and the strategic manner in which the SEZ has been developed, together with the substantial investment in both water supply and transport infrastructure, will guarantee the long-term sustainability of the city and its environs.

Improved community health and wellbeing

The new water supply systems, which included a significant expansion of the water supply network and over 26,000 new water connections (including public standpipes), will significantly improve access to the rapidly growing population of the city and environs to a wholesome water supply, with all the attendant health benefits.

This project has supported existing local and regional jobs during the construction stage and is providing full-time permanent employment during operation and is supporting the continued social and economic growth of the region in terms of trade, tourism and industry. It is also enhancing the region's competitiveness in attracting inward investment and associated job creation.

Operational Programmeme Environment 2014-2020 (OPE 2014-2020)

Water supply services in Bulgaria generally meet the standards, but water losses are very high (60%) and the maintenance of water supply systems and facilities is insufficient.

Operational Programmeme Environment 2014-20 (OPE 2014-20) is one of Bulgaria's operational Programmemes developed pursuant to Europe 2020 – the EU strategy for smart, sustainable and inclusive growth.

Client: Ministry of environment and water of Bulgaria - Directorate General Operational Programmeme Environment

Investments under Priority Axis 1 Water are aimed at achieving compliance with Directive 91/271/EEC, Directive 98/83/EC, Directive 2013/51/EURATOM and Directive 2000/60/EC through construction of water supply and sewage infrastructure – financing is focused to the agglomerations of more than 10,000 population equivalents (PE). The projects are addressing one of the specific challenges: "improving wastewater treatment and drinking water quality and management, in a strategic and cost-efficient way."

OPE 2014-20 will contribute to the reduction of the greenhouse gas emissions in the country and thus it will support the achievement of Europe 2020's target for a 20% reduction in the greenhouse gas emissions compared to 1990 levels. Measures in this respect are envisaged for urban wastewater treatment, in particular construction/rehabilitation/reconstruction of wastewater treatment plant (WWTP) sludge treatment facilities and supply of the necessary equipment, including for existing WWTPs (according to the concept for treatment of sludge from UWWTP at national level), with priority on improving their quality parameters with a view to their subsequent use for energy purposes.

On 4 September 2018, the minister of finance approved tender documents for the water sector Programmeme "Environment 2014-2020" and Programmeme "Development of Rural Regions 2014-2020", using the FIDIC Red and Yellow Book 1999 General Conditions.

- 1.5bn euro are being invested in WSS infrastructure in Bulgaria under Priority Axis 1 Water, 77% EU co-financing.
- WSS operators and municipalities are employers in more than 30 FIDIC contracts for WSS infrastructure and WWTPs.
- 24% from the 1.5bn euro have been paid up to now.

SUSTAINABLE DEVELOPMENT GOALS

6 CLEAN WATER AND SANITATION

13 PROTECT THE PLANET

http://ope.moew.government.bg/files/useruploads/files/evaluation_plan_ope2014-2020_en.pdf

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Project examples

Water management

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Sustainable water management by reducing non-revenue water using innovative IoT device

Enhancing the efficiency of financial management by reducing water losses is a key to achieve sustainable water management as per SDG Target 6, «Ensure availability and sustainable management of water and sanitation for all.» Water utilities usually struggle to address high level of water losses in their distribution networks.

The water loss induces a high operational cost for the utility, as well as an additional investment in the water resources development, which is getting scarce due to the rapid growth of urban population.

In Rwanda, the non-revenue water (NRW) rate is extremely high at 41% and the resulting financial loss is estimated to be $7.9m per year. Reducing these water losses is the most critical issue for Rwanda's water utility (WASAC) to ensure a sustainable financial management. The main reasons for the existing high NRW are 1) High pressure at the water supply networks due to hilly terrain. 2) Lack of adequate pressure monitoring and control. and 3) low capacity of pipes (sub-standard construction for the distribution sub-mains and customer connections). Monitoring the pressure at the distribution network is necessary due to the existing complicated pipe networks which were expanded in an unplanned manner. It is essential to develop an inexpensive and handy pressure monitoring system because of the utility's limited budget.

To tackle the problem, Nihon Suido Consultants Co. (NSC), which is currently elaborating the new water supply master plan for the City of Kigali and its seven adjacent sectors, has worked with an entrepreneurial venture company SIRC Co. to make an innovative system for managing the pressure in the water supply network. They conducted a pilot study to identify the leakage points in the pipelines on a small pilot area (30 households) by using pressure meters with a SIRC IoT device. The SIRC has proprietary technologies that pertain to IoT-familiar chip and module that are retrofit (using existing analog water meter), easy (No electrical work required) and convenient (available to check by PC/Smart Phone). The device can read the numerical value indicated by the pointer remotely by simply attaching a magnet to the centre of the existing analogue meter pointer and replacing the cover on which rotation angle sensor module is installed. As its structure is simple, maintenance staff can easily install it by themselves without any specialised contractor. The data can be transmitted via Bluetooth low energy communication directly to the base station. This sensor module is driven by a coin battery and when communicating once every 11 seconds it can theoretically last for over one year. The pressure maps created by NSC have clearly shown the location with abnormal pressures, which can be a leakage point.

Following the successful completion of the experimental phase, the project is scheduled to be implemented under the demonstration phase funded by the Japan International Cooperation Agency (JICA) for testing whether it is feasible to monitor the water supply system's actual scale and do a sustainable local business.

SUSTAINABLE DEVELOPMENT GOALS

6 CLEAN WATER AND SANITATION

Pressure meter and water meter equipped with a SIRC device installed in Pilot Project (left), Checking Data by PC (right).

Water management

The use of ultrasonic prepaid water meter and web-based data acquisition technology for sustainable water supply management

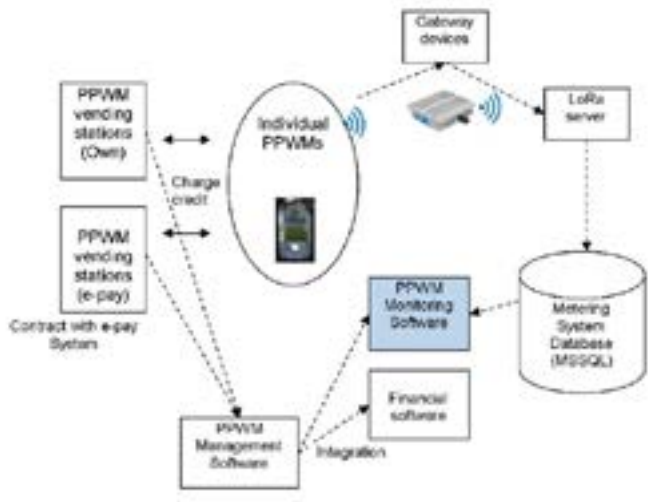
The United Nations' Sustainable Development Goal 6 calls for clean water and sanitation for all. Achieving this goal by 2030 is a challenge, especially for many low-and middle-income countries in Asia and Africa. Improving technical and managerial capacities of water utilities to manage their systems more efficiently and making them more resilient to the impact of the Covid-19 crisis would be crucial in achieving this goal. A case of how a prepaid water meter system coupled with a smart communication framework helps a city manage its water system more sustainably, supply water more equitably and cope with the impact of the Covid-19 crisis as well is presented here.

Meter selection

In a target city of a country in the Middle East area, intrusion of air into the piped supply is ubiquitous because of intermittent supply conditions. Measurement of trapped air by the water meters causes erratic and high water bills. To select a meter most suitable to local conditions and effective in terms of non-recording of trapped air, a detailed experiment was conducted. Among the three types of water meters (volumetric, velocity and ultrasonic) tested, an ultrasonic meter was selected as it does not measure trapped air, has no moving parts and the flow path is unobstructed. To address the problem of low revenue collection, the concept of a prepaid system was adopted and ultrasonic prepaid meters were decided to be used in the project. A total of about 3,000 ultrasonic prepaid water meters (PPWM) have been installed in the city. The PPWM system is based on the principle that a credit charged in advance exhausts as water is consumed based on a pre-Programmemed tariff rate. Every meter is operated by its own smart card and credits are loaded into these cards from vending stations or by e-pay systems. Prepaid meters are also Programmemed for reserve water to be used during emergency or fire cases. PPWM systems can also detect tampering with the device and supply can be cut off remotely.

Communication system with latest smart technology

The meters possess essential features of smart meters and are preloaded with LoRa (Long Range Radio) communication module. The metering system is integrated with the existing billing and collection system of the city. Several vending stations have been established from where customers can buy credits to recharge the meter. A LoRa based communication system as shown in Figure 1 has been setup by means of gateways (collectors) and cloud service of the meter provider which connects all prepaid meters and relays data to city's collection and billing system. By using this system, it is possible to read meters remotely and monitor water consumption, credit balance, battery and valve status, tampering attempt and so on. It is also possible to close and open the meters remotely.



A schematic of LoRa (IoT) based communication system using gateway devices and cloud server.

Benefits of the PPWM system in the context of SDG Goal 6 and the Covid-19 pandemic

- On the supply side, the PPWM system has reduced customers' debt and improved the revenue collection, maintaining better service and expanding the coverage. This system has also reduced meter reading, billing and collection costs and saved manpower hours are utilised to improve city's customer service activities. The PPWM thus contributes to achieving extended (universal) coverage and better (sustainable) water services by the utility.
- On the demand side, it helps customers manage their consumption, reduce unnecessary usage thereby saving water which can be used to supply non-coverage areas and/or compensate customers who receive inadequate water. There is a clear evidence that water use has become more equitable after PPWM was introduced. Customers with high consumption reduced their consumption whereas customers with zero/low consumption consumed more water.
- From the technological aspect, remote data acquisition is easier and more accurate and acquisition of various data on daily basis helps to improve customer service.
- The PPWM system has made a positive contribution to minimise the spread of Covid-19 by eliminating the need for face-to-face contact of customers with meter reading and billing staff.
- Water charge collection from PPWM customers has not decreased even during the Covid-19 crisis. However, it may be necessary to safeguard the provision of water services for vulnerable population who cannot afford to pay. In such cases the PPWM system can be Programmemed to provide either a certain amount of free water or a subsidy in the water tariffs.

Concluding remarks

PPWM system together with the innovative remote reading and data management framework contributes significantly to meet the targets set by SDG Goal 6 by improving revenue collection, reducing NRW, promoting equitable distribution, increasing the coverage and enabling an efficient and sustainable water supply system.

The PPWM (left) and gateway equipment

Chahnimeh to Zahedan water transmission pipeline project

Supply Zahedan potable water for year 2031 - Zahedan is one of the most populated and important centres in the east of Iran. It is the capital of Sistan and Balouchestan province with a sharp increase in population. Considering the climate and development conditions of the city, potable water demand calls for new water supplies and projects.

To emphasise water supply importance, the neighbourhood with countries offering inadequate healthcare and warm and dry air might be pointed as added reasons. The coverage population for the target year (2031) is equal to 790,000 and the needed water for delivery points with considering leakages of the distribution network is 55 million cubic meters per year.

Iranians have been successful in coping with natural limitations, establishing one of the world's oldest civilisations and sustaining life for thousands of years in a mostly arid to semi-arid region with limited water availability. This was done through the invention of ingenious water harvesting techniques, which made farming and food production feasible in a water-scarce region of the world in ancient times. Today Iran is facing unprecedented water problems. Despite diverse topography and climate variability of Iran, water supply systems are considered as one of the main solutions to provide safe water for everyone.

Mega water supply projects can have many advantages and disadvantages. In general, these projects providing access to clean water and sanitation systems, economic growth and industrial development, reduce gender inequalities, etc but also have disadvantages including the cost of construction and operation, energy consumption, causing changes in the ecosystem and climate of the project area and so on. Chahnimeh to Zahedan Water Transmission pipeline, which has been studied, constructed and operated for more than 20 years, is one of the water supply projects that according to the government policies and the selection of Zahedan as a centre and important city with more than 700,000 population, is put on the agenda. This project can be considered as an example of engineering and executive success and has advantages such as providing clean water to the city, improving sanitation system, reducing poverty, economic growth, industrial development, etc but disadvantages such as reducing the water level of the Hamoon Lake and agriculture of origin of the pipeline, energy consumptions and so on.

Considering the performance of the plan and comparing it with sustainable development goals can have significant results because sustainable development is a multifaceted subject and it is necessary to consider all sustainable development goals together, land use planning and study comprehensively before starting a project. Several factors make a project sustainable. In the Chahinemh to Zahedan water transmission pipeline project, sustainable development goals have been considered as much as possible for the consulting engineers of the project, but it cannot be fully assured that the project has been based on the sustainable development goals. It must be acknowledged that in the early stages of the project, there were no clear sustainability goals and still no clear sustainability goals as per the SDGs have been defined for the project.

Water management

This makes the project a good candidate for re-engineering. Re-engineering seeks to scrutinise and rethinks all aspects of a project with a different perspective and reflects its findings fundamentally in existing processes and plans to achieve major improvements in terms of efficiency and productivity. Chahnimeh to Zahedan water transmission pipeline in the south east of Iran is briefly described as follows.

The main components of plan

- Water intake structure and other relevant equipment with a capacity of 2,080 litre per second.
- Length of transfer line: 205 kilometres.
- Diameter of water transmission pipeline: 1,400 and 1,200 millimetres.
- Pumping stations include five stations. The height of pumping from Chahnimeh to Zahedan is 1,660 meters.
- Six storage reservoirs and regulating in direction of the line with a volume of 90,000 cubic meters.
- Cathodic protection, telemetry and remote control.
- Conventional drinking water treatment plant near Zahedan, with a capacity of 1,680 litres per second.

Kowsar-e-Yazd Water transfer project

Kowsar-e-Yazd institute has intended to carry out conceptual and basic design study of a seawater desalination plant and water transmission networks from Jask shores off Oman Sea to Yazd province to fulfill needs of desalinated water in certain industrial and agricultural domains.

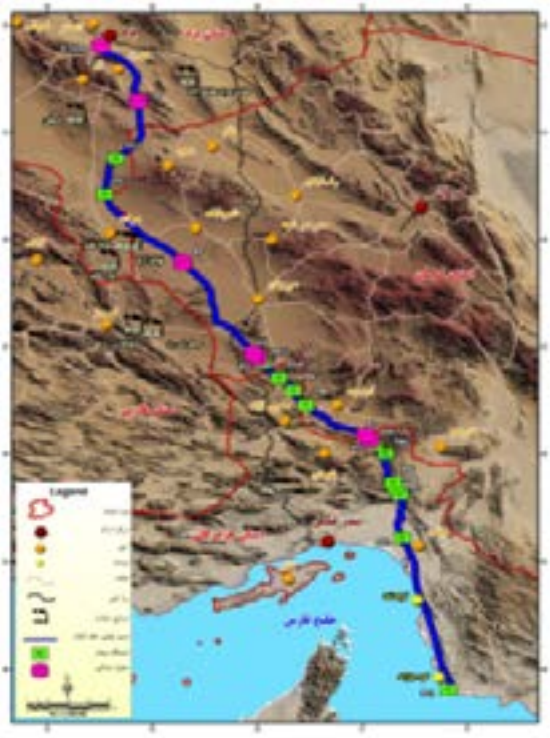
Yazd province is located in an arid and ultra-arid region of Iran with an annual precipitation rate of ~ 100mm. This rate of precipitation is almost 2.5 times less than Iran's average and 8 times less than global average of annual precipitation indicating a severe rate of water deficiencies. This has led authorities to seek alternative water supply schemes such as water transfer from other basins.

Early investigations indicated that by year 2045, Yazd province needs almost 530 million m^3 of freshwater to meet its industrial, agricultural and residential needs. As a result, to meet this water demand, a new project was kicked off to implement a water transfer pipeline from Oman Sea to Yazd province.

The project began by identifying best suitable location for constructing water desalination facilities by conducting a thorough feasibility and site locating studies. At this stage, several consideration were taking into account including technical, social, economic, environmental considerations. After selecting best suitable location, a conceptual and basic design stage was followed. An initial site plan was also envisaged to accommodate various elements inside the allocated site. The project aims at providing 160,000 m^3/day of desalinated in two separate phases. The project has been divided into two separate sectors: (1) a marine sector where conceptual and basic design of suction chamber, water withdrawal pipelines and intake structure will be carried out along with coastal desalination facilities and storage areas; and (2) an on-land sector which deals with buried pipelines and relating pumping stations.

SUSTAINABLE DEVELOPMENT GOALS

6 CLEAN WATER AND SANITATION



International Federation of Consulting Engineers
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Project examples

Waste and wastewater supply and treatment

SOW2021

Waste and wastewater supply and treatment

Kerry Central Water Supply Scheme

This €30m project to develop a new water treatment plant (WTP) for central Kerry will remove approximately 62,000 customers from the EPA's Remedial Action List and will ensure a sustainable, safe and secure drinking water supply to communities. These communities include Tralee, Killarney, Castleisland and Castlemaine, "Irelands tourism capital".

The new WTP is amongst the largest in the country and will provide over 50 million litres of drinking water every day. The Project also included:

- Upgrade of Intakes, including a hydroelectric power turbine.
- 15million litres of water storage (about six Olympic swimming pools)
- Process water treatment including recycling to conserve water and protect the environment.
- Pumping stations and pipelines

The project is located adjacent to Lough Guitane and the Finnow River, near Killarney Co. Kerry.

Nicholas O'Dwyer /Tobin completed the preliminary design, planning, tender documents, procurement, contract administration/supervision on behalf of Irish Water. Glan Agua undertook the role of Design Build Operate Contractor.

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- Process water treatment including recycling to conserve water and protect the environment.
- Pumping stations and pipelines.

The construction works were completed over a 24-month between 2016 and 2018.

Energy efficient design

Energy efficient design management was implemented to reduce the lifecycle energy consumption which included the upgrading of the existing Hydroelectric Power turbine. Following detailed investigations and analysis, including hydraulic modelling, a whole-lifecycle analysis was completed following consultation with the turbine supplier and the ESB. This analysis recommended the relocation of the existing turbine to improve energy efficiency.

Power generation capacity is approximately 943,257kWh per annum. The power generated is used on site and reduces the power requirements from the national grid by 22.8%. The whole-lifecycle analysis indicated a payback period of within three years in terms of the associated capital investment.

Design and construction innovations

A very challenging aspect of the project was the fast-track design and construction of the water treatment building in terms of the reinforced concrete operations, precast building and structural steel frame. The implementation of Level 2 BIM together with detailed consultations and Programmeming of supply chain partners was critical to allowing the completion of the building in a timely manner and facilitating significant off-site construction activities for a safer working environment.

Waste and wastewater supply and treatment

The plant is operated and maintained using mobile tablet technology - allowing operators, scientists and engineers to access the control interface from anywhere in the plant. Therefore, process adjustments can be monitored from the treatment area and maintenance activities can be monitored from the plant room, making the operation of the plant much more efficient.

Process design innovations

Traditionally, water treatment processes were designed to achieve the lowest possible turbidity and colour in the treated water. However, this is not a complete solution due to the high levels of natural organic matter often encountered, particularly in surface waters. The measurement of UV absorbance of the raw water and its use as a control parameter, in addition to turbidity and colour, allowed for enhanced automation of the coagulation process – the most essential step in surface water treatment. Kerry Central is one of the first plants in the country where this philosophy was implemented. This approach has since been widely accepted as best practice within the water treatment industry.

Environmental and sustainability benefits

Due to its sensitive location, the project involved significant environmental and sustainability works including the management and treatment of surface runoff, process water discharges and the development of compensatory habitats. Over 6,000m^3 of excavated material was also reused as ballast for the clear water tank to counteract uplift forces. The reuse of excavated spoil minimised off-site disposal, reduced construction traffic and had a positive impact on the project's carbon footprint.

Improved community health and wellbeing

The scheme was listed on the EPA's Remedial Action List (RAL) as having "Inadequate treatment for Cryptosporidium and elevated levels of THMs above the standard in the Drinking Water Regulations" affecting over 60,000 people and in excess of 1.1 million tourists annually. The new WTP produces drinking water meeting and exceeding the highest standards set out in the current EU Drinking Water Directive and their corresponding Irish regulations. Consequently, the communities of central Kerry now benefit from a safe, secure and reliable water supply, which will facilitate improved community health and wellbeing and the removal of the scheme from the EPA's RAL.

In everyday terms, consumers are reporting that their water "looks" much cleaner. This is as a result of the new WTP.

Employment and economic benefits

Killarney is "Ireland's tourism capital", receiving 1.1 million visitors annually, supporting 3,122 local jobs and generating €410m every year.

This project has supported existing local and regional jobs during the construction stage, is providing full-time permanent employment during operation and is supporting the continued social and economic growth of the region in terms of global tourism and other industries. It is also enhancing the region's competitiveness in attracting inward investment and associated job creation.

Waste and wastewater supply and treatment

Programmeme management and cost consulting services for provision of water and sanitation services to human settlements and schools in eThekwini municipality (Phase 3)

As a middle-income developing country, South Africa suffers unequal income distribution, with more than half (55.5%) of the population living below the upper-bound poverty line. eThekwini Municipality, the largest city in KwaZulu-Natal (KZN) province, is home to over 3.5-million people and approximately 200,000 informal households, some of which fall within the poorest communities in South Africa. Many of the densely populated informal settlements within eThekwini have little or no access to piped potable water and ablution facilities and as a result experience adverse health conditions.

In an effort to meet and address basic human needs for its informal residents, in January 2008 eThekwini water and sanitation department undertook a pilot project to provide ablution facilities to various informal communities within the municipality.

The pilot project, which was initially carried out on a small scale to assess its acceptance by the communities, was a great success. The approach proved to rapidly and effectively address the provision of water and sanitation services to the informal settlements concerned. Consequently, Phase 2 of the Programmeme commenced in 2012 on a larger scale to further address the municipality's sanitation backlog. Further to this, the Programmeme for the Provision of Water and Sanitation to Informal Settlements and Schools (Phase 3) commenced in August 2015.

The Phase 3 Programmeme deliverables included the construction of male and female ablution facilities, water and sewer bulk infrastructure, including reticulation mains, pump stations, rising mains, onsite treatment works and ancillary infrastructure that is aligned to future municipal development.

Project managing an R1.7-billion Programmeme.

SMEC South Africa's Management Services team was appointed by the eThekwini Water and Sanitation Department for the Phase 3 Programmeme management and overall governance and control, over a four-year period.

The overall Programmeme budget exceeded R1.7 billion and to date has delivered over 400 new and a further 825 refurbished ablution facilities. Nearly 52km of sewer pipes and over 38km of water pipes ranging from 22mm to 315mm have been laid. Significant bulk sanitation infrastructure projects have been implemented, including 4.2km of 900mm concrete pipe, together with three concrete pipe bridges spanning between 150-200m.

SMEC South Africa also implemented three onsite treatment plants ranging from 5ml to 10ml, as well as the construction of a 90 L/S bulk pump station. The location of the ablutions and particularly the associated infrastructure network and bulk services, are designed to prevent fruitless expenditure when future formal developments take place. The design is based on the FIDIC Red Book's Guidelines for Human Settlement Planning and Design Principles, together with customised project processes and procedures that were formulated by SMEC South Africa specifically for the Programmeme. Upon completion, the project had provided accessible and appropriate ablution facilities per 50-75 dwellings (approx.) and within a 200m walking radius.

Innovating through system integration

The Programmeme itself has also proved to be resilient when faced with challenging demographics, social elements, environmental considerations, difficult terrain, adverse geotechnical conditions and densely populated settlements.

SMEC South Africa efficiently managed these ever-evolving factors through the continual development of project processes, techniques and tools, such as the S12 financial tool which allowed for the processing of many payments certificates every month with minimal delays at month end and Noodles (NDLS) which

Waste and wastewater supply and treatment

integrates the S12 financial tool with design and construction data to allow for live dynamic monitoring, tracking and reporting. Through the implementation of these structured procedures, SMEC South Africa was able to ensure that the client received an accurate electronic record of new infrastructure and that new assets had been captured in the client's systems.

United Nations Sustainable Development Goals (SDG)

Under the management of SMEC South Africa, the project team (which comprised of four design consultants, 11 contractors and 40 emerging consultants and contractors) successfully contributed towards several the United Nations Sustainable Development Goals as highlighted below.

Ensure healthy lives and promote well-being for all at all ages (SDG Goal 3); and ensure availability and sustainable management of water and sanitation for all (SDG Goal 6)

Prior to the implementation of the Programmeme, a large majority of the informal residents that benefited from the new and revamped ablution facilities had little or no access to piped potable water and ablution facilities. In the absence of formal ablution facilities, community residents were required to make use of pit latrines or alike and either collect water from nearby rivers or from water tanks supplied by the municipality. The interrelated effects of poor water quality and inadequate human waste disposal posed an increased risk of disease transmission within each of the communities.

Since implementation of the ablution facilities in these areas, residents now have access to potable water and flushable toilets, which in turn has allowed for improved personal and community hygiene, access to potable water and a decreased risk of disease transmission.

Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all (SDG Goal 4)

In 2020, it was estimated that roughly 3,000 schools across South Africa only have pit latrines or other inappropriate sanitation facilities available for learners. These inadequate facilities not only pose a threat to learners from a hygiene standpoint, but also from a safety standpoint following several reports of learners drowning in school latrines.

The South African Department of Education (DoE) appointed eThekwini Water and Sanitation as an implementing agent to assist with providing numerous schools within eThekwini and Ilembe municipalities with adequate sanitation facilities. The DoE had issued numerous schools to the project team with the same contractual obligations related to the Programmeme works.

The school's portion of the Programmeme works, which was funded by the DoE, was successful in providing over 51 schools in the eThekwini and Ilembe municipalities with sanitation facilities and restoring dignity to thousands of South Africa's learners. In addition to schools, the Programmeme has also been successful in implementing similar services in hostels and housing projects scattered within the metropolitan.

Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all (SDG Goal 8)

The project team was committed to and has been successful in achieving South Africa's Contract Participation Goals (CPGs) by supporting social development and increased economic wealth throughout the Programmeme. This is evident through the support of local enterprises and services, employment of unskilled labour and the overall upliftment of the local community where dignity is restored and a sense of ownership is created by the introduction of the ablution facilities.

The Programmeme prides itself in local job creation of both a temporary and permanent nature. Job creation is strictly monitored and reported on in line with Expanded Public Works Programmeme requirements, where full time equivalent (FTE) jobs are reported on a monthly, quarterly and annual basis. The final figure for Phase 3 was 7,043 FTE jobs as at the end of January 2020 and since inception of construction works in February 2016. A total of 30,751 job opportunities were created during Phase 3.

Waste and wastewater supply and treatment

Furthermore, contractors were encouraged to utilise labour-intensive construction methods, systems and techniques where possible. Unskilled labour was to only be sourced from the local communities through the eThekwini community development officers and the local ward councillors, with the help of community liaison officers who are also employed by the contractors for the duration of the various ablution facility sites.

Operation and maintenance of the facilities does not form part of the Programmeme itself, however, caretakers from within the communities were permanently employed by the municipality's wastewater network branch at the handover stage of each ablution facility. The above factors give rise to increased local economic activities and social wellbeing.

The indirect social impact of the Programmeme cannot be ignored as the outputs of the project restored a sense of dignity within local communities. The informal settlement is more likely to encourage locals to improve on their current living conditions and local commerce. This is further enhanced by the construction phase where local security companies, materials, plant and equipment suppliers were supported through the contractors – an area that can lead to the development of small local economic hubs.

eThekwini Human Settlements housing projects that follow the required inclusion of complementary services (roads, storm water, electricity and waste removal services) further uplift the areas in general, eventually resulting in fully functional residential nodes for other service providers to compliment the services that have been installed by the Programmeme.

Luganda Pipe Bridge Pier - Formwork and concrete being poured for pier foundation.

Construction of the Luganda 900mm diameter pipeline laid in 2.5m trenches.

One of the various ablution facilities that formed part of the Phase 3 Programmeme.

Official opening ceremony for the completion of the ablution facility.

Solving small community drinking water challenges

Approximately six million Canadians are serviced by small drinking water systems, which are subject to 77% of the nation's boil water advisories. After working with communities struggling with these issues, WSP approached researchers at RES'EAU-WaterNET to investigate and pilot test an innovative organics removal process researched at the University of British Columbia and specifically created for small and remote communities.

The goal was to assess the viability of using a biologically enhanced ion exchange media to remove organics from surface water. This approach would require little to no chemical addition, minimise the production of harmful wastewater and reduce operator oversight by using natural biological processes. A groundbreaking treatment system, coined biological ion exchange (BIEX) was developed. It harnesses the source water's natural biological elements to provide treatment. By combining a new treatment technology and a collaborative project implementation approach, this work culminated in the world's first BIEX treatment plant and enabled the pilot community of Dzitl'lainli (Middle River), from the Tl'azt'en Nation in British Columbia, to lift its 14-year boil water advisory. Innovations developed and applied towards solving the water supply problems of the Middle River village can benefit numerous remote and small communities across Canada.

The project was supported and funded by Indigenous Services Canada and the technological advances WSP led will ultimately improve environmental conditions and sustainability, alongside citizens' lives, community and prosperity. For the juror, the simple and affordable solution proposed in this project was technically ingenious.

The BIEX system

Providing treatment for organics in small and remote communities has been an engineering challenge, as most conventional technologies include chemical treatment, mechanically complex and expensive filtration and residual treatment systems, or costly adsorption medias. Additionally, small and remote communities lack the luxury of finding alternative treatable source water and as such struggle with the social and economic consequences of living under a continual boil water advisory (BWA).

Middle River

In 2016, WSP worked collaboratively with researchers from RES'EAUWaterNET of UBC and supported by Indigenous Services Canada (ISC) to apply the research and to investigate and pilot test this innovative organics removal process in the remote village of Dzitl'lainli (Middle River) of the Tl'azt'en Nation. WSP's engineers, RES'EAU researchers, Indigenous Services Canada (ISC) and the First Nation's health authority (FNHA) conducted regular site visits to this remote village to meet with the residents and the operator to discuss their expectations, previous failed attempts at treating the water, alternative solutions and treatment goals. The goal was to assess the viability of using the BIEX technology. To remove organics from the surface water, which would require little to no chemical addition, minimise the production of harmful disinfection byproducts and reduce operator oversight and operation and maintenance costs. Extensive community engagement took place and the Tl'azt'en Nation enthusiastically collaborated in the development and testing of this breakthrough technology. The operator worked directly with the researchers to pilot test the BIEX technology on the source water at Middle River and was instrumental in the pilot system setup and operations. The team's efforts allowed the researchers to develop and demonstrate the treatment method at the pilot scale before advancing to a full-scale water treatment plant. With this innovative research, methodology and implementation, in 2018 WSP carried out the design for the world's first full-scale BIEX water treatment system for the community of Middle River. The water treatment system has allowed the long-standing boil water advisory to be lifted. Since the BWA was lifted, residents anticipate the improved conditions will encourage more people to stay in, or return to, the community, inspiring renewed connection with ancestral lands and a more thriving, vibrant community. Having safe drinking water at the tap also lays the foundation for the community to develop economically.

Waste and wastewater supply and treatment

Community Circle

Approach In conjunction with lab work, RES'EAU Water-NET pursued a new approach for the delivery of complex technical engineering projects focused on the end user rather than completing a "check box exercise"—this approach is termed Community Circle. The goal of the Community Circle is to involve all relevant parties of a project, from project inception to delivery, encouraging diverse perspectives and collaboration.

Broad reach

The novel BIEX treatment system provides an alternative for organics removal in drinking water. The removal of organics reduces the potential formation of regulated carcinogenic by-products, which can occur when chlorine reacts with organics and improves the efficacy of UV disinfection. With minimal generation of wastewater residuals and chemical consumption, the design makes the process more environmentally sustainable and reduces operational complexity. Innovations developed and applied towards solving the water supply problems of Middle River can benefit numerous remote and small communities across Canada. The goals of the technological advances with BIEX and the Community Circle® approach are to ultimately improve environmental conditions and sustainability—alongside citizens' lives and community prosperity. Earlier this year this project received the Lieutenants Governor's Award of Excellence at the 2019 ACEC-BC Awards for Engineering Excellence.

Waste and wastewater supply and treatment

Feng-shan Creek Wastewater Reuse Project

With the rapid urbanisation and industrialisation, domestic and industrial water consumption in Taiwan has been increasing constantly and sharply for the past several decades. Being the top 18th country in the world shortage of water resource and under the significant impact by unbalanced seasonal rainfall resulted from global climate change, the demand for developing new water resource in Taiwan becomes more imminent than ever. As urban wastewater has the advantages of stably produced daily amount and less affected by weather conditions, it was identified to be a reliable water resource for reducing the pressure of water supply through effective reuse treatment. Under the circumstance, the Feng-shan Creek Wastewater Reuse Project in Kaohsiung City was initiated by The construction and planning agency ministry of the Interior of Taiwan.

The project was delivered by the process of built-transfer-operate (BTO) which allows the private sector in the private-public partnership (PPP) to apply new and advanced technology to improve the operational efficiency without being restricted by general governmental procurement practice. Hsin Dar-CTCI business alliance, the company received the concession for this wastewater reuse plant from Kaohsiung city government, commissioned Moh and Associates, Inc. (MAA) to provide consultant services for all the design works throughout design and construction phases.

Project summary

Scope of this NT$2.5bn project includes construction of a new wastewater reuse plant, a 7.2km new pipeline for transmission and distribution of reclaimed water and upgrade of existing wastewater treatment facility for improving its nitrogen removal capabilities. To meet the water quality requirements of an industrial park, the wastewater is treated through a combined process of filtration, ultrafiltration (UF) and reverse osmosis (RO) membrane treatment. Figures 1 and 2 show the photos of the UF and RO facilities, respectively, in the plant. To meet the national discharge standards, the activated sludge process of the existing wastewater treatment facility is upgraded by the AO nitrogen removal process.

This wastewater reuse project was commenced in 2016. Supply of the reclaimed water for the Kaohsiung Linhai Industrial Park was started in 2018. Total supplied amount was 25,000 CMD in 2018 and quickly increased to 45,000 CMD in 2019. Today, one fifth of the daily water usage of the Linhai Industrial Park is provided from this wastewater reuse plant.

Significance of the project

Core of design for this project was sustainable energy-saving. Environmental conservation elements covering landscape, ecology, education and recreation were incorporated into the wastewater reuse plant, surrounding parks and river corridors which in turn constitute the Water Resource Environment Education Park as shown in Figure 3. As the first wastewater reuse plant built in Taiwan, this wastewater reuse plant adopts a variety of state-of-art wastewater treatment technologies with the performance of reliable and efficient treatment process, ease of operation and energy-saving carbon footprint reduction.

Immediate benefits brought about from this project include improving wastewater reuse efficiency, providing alternative water resources for nearby industrial parks and securing the water rights for the public and industrial use. Long-term benefits include raising public awareness for water conservation and environmental protection, strengthening climate change resilience, promoting sustainable growth, promoting Taiwan's wastewater business development and enhancing the robustness of Taiwan economy.

Kaliti wastewater treatment plant and sanitary sewer trunk mains

For years, Ethiopia's capital city of Addis Ababa had only a small%age of its area and population served with a piped sanitary sewer system. Rapid development and increased density resulted in numerous challenges, including increased risk for a major disease outbreak.

Morrison Hershfield, in collaboration with its partner ARMA Engineering PLC and client Addis Ababa Water and Sewerage Authority, discussed various treatment options during the preliminary design stage and created a decision matrix that established goals and evaluation criteria.

A new wastewater treatment plant was designed and constructed to meet the 100,000 m^3/d maximum demand and the existing trunk main was twinned, adding 18km of new pipe. The wastewater treatment plant process consists of an up-flow anaerobic sludge blanket front end, trickling filters, secondary clarifiers and chlorination/dichlorination for disinfection before disposal in the river. Morrison Hershfield provided innovative, cutting-edge treatment technology and training, resulting in a new, client-managed and operated system that improves the treatment process and sewage collection system and ultimately, the quality of life of over two million people.

The need for new technology

Rapid development and increased density in Addis Ababa resulted in numerous water resource problems. The existing lagoon treatment system was operating beyond its design capacity, resulting in less effective treatment with the potential of a release downstream of effluent that did not meet treatment standards. Under-capacity sewers were overflowing in the streets and into the city watercourses and streams. Local rivers were biologically 'dying' and turning into open sewers. All of this resulted in an extremely unhealthy situation, increasing the city's risk for a major disease outbreak. The World Bank and the government of Ethiopia entered into an agreement for loans to construct a new WWTP at the Kaliti lagoon site and expand the existing trunk main from the heart of the city to the treatment plant. The goal was to improve the standard of living in Addis Ababa by improving the overall level of sanitation and meet World Health Organisation guidelines for sewage treatment. The project included the design and construction of a WWTP sized for a maximum flow rate of 100,000 m^3 per day. The process consists of a UASB (Upflow Anaerobic Sludge Blanket) front end, trickling filters, secondary clarifiers and chlorination/ dichlorination for disinfection before disposal in the river. The UASB reactors collect the biogas from the digestion process which can be harvested for fuel to generate electricity. Biodegradable materials removed in the process can be given to the agricultural sector for natural fertilisers to be used in place of other products that may be more harmful to people and the environment. The catchment area to the plant was modelled and the construction of 18km of new sewer trunk mains was added. Geotechnical issues arose during construction because of hard rock in areas of the WWTP and the trunk main. Trunk main routing was redesigned to reduce the depth of the pipe installation.

Knowledge transfer

Morrison Hershfield provided innovative treatment technology and training to a country desperately requiring these resources, resulting in an improved level of quality to the treatment process and sewage collection system. The client was engaged in the decision-making process. Various WWTP treatment processes were discussed and a decision matrix was set up with them. Goals and evaluation criteria were developed during the preliminary design stage. The firm worked with local consulting partner ARMA Consulting to compile pipe routing options and oversee the surveying of key points of river crossings and locations of conflicts. ARMA completed the design drawings for the trunk main under Morrison Hershfield's guidance and review. Modelling of the catchment area was completed as part of the preliminary and design stages for the trunk main. The Morrison Hershfield modelling specialist met with the client's staff to demonstrate the new model and provide insight into new modelling software and techniques. Following the delivery of the final design report, Morrison Hershfield arranged and accompanied staff from AAWSA on a technical trip to Ghana and Brazil to tour existing WWTPs that had a similar process to the proposed Kaliti plant. The client was provided with background information on Canadian (Calgary and Edmonton) sewer bylaws, highlighting the advantages of establishing requirements and limits for industrial sewage to maintain a healthy treatment plant. Following

construction of the plant, the client was provided with performance testing results and commissioning and operational plans and reports along with coaching by Morrison Hershfield's process engineer on process and operational requirements.

Improved sanitation

The construction period was originally estimated to be 18 months but eventually took over three years. Construction delays resulted from complex government processes and approvals, custom approvals, weather delays and social issues. Morrison Hershfield worked with the client and contractors to ensure that import permits were requested in a timely manner and pressed follow up with the appropriate stakeholders. The goal of this project was to improve the standard of living in Addis Ababa by improving the overall level of sanitation. Morrison Hershfield assisted AAWSA with planning and managing the future expansion of its sewerage system in the Kaliti catchment area and expanding and improving the level of wastewater treatment serving the Kaliti Basin. Commissioning and performance testing for the WWTP at Kaliti was completed in mid-August 2018, with trunk main installation wrapping up in December 2018. Lab results during the performance testing showed that all effluent quality goals exceeded contract parameters. AAWSA is using this project as a model for other related construction projects. They have already begun projects to tie residential and industrial areas to the expanded trunk main.

Waste and wastewater supply and treatment

Kutahya wastewater treatment plant project, Turkey

Nicholas O'Dwyer provided design review construction supervision services for the upgrade to the existing wastewater treatment plant in Kutahya. The original plant had a design capacity of 202,000 p.e. with a maximum hydraulic capacity of 4,428m^3/hr.

The new Kütahya wastewater treatment plant is being designed and constructed as a biological nutrient removal (BNR) activated sludge plant with anaerobic stabilisation of sludge. Carbon, phosphorus and nitrogen removal are being incorporated in the process using a combination of biological and chemical means. The WwTP is designed and constructed to be resilient, sustainable and fully self-sufficient from an energy perspective. The biogas provides sufficient energy to power the plant.

The first stage of the treatment plant is designed to serve a population equivalent up to 358 850 p.e. in 2030 with the second stage serving up to 434 867 p.e. in 2045. The preliminary treatment and sludge processing units are designed for Stage 2 flows (120,868 m^3/d) while the biological treatment and secondary clarification are designed for Stage I flows and loads.

The plant is designed to treat a large industrial load from food processing and manufacturing facilities within the city. The existing process was severely overloaded and the quality of the discharge was having an adverse impact on water quality in Porsuk Creek (receiving water). The contract is being managed in accordance with FIDIC Conditions of Contract (Yellow Book) with all designs and submission requiring prior approval of the engineer before commencement of construction on site.

Nicholas O'Dwyer also provided capacity building (CB) and technical assistance (TA) for the water utility department and the PIU of the municipality. The studies and trainings provided by Nicholas O'Dwyer included TA and CB in administrative and financial issues, TA and CB in technical operation and maintenance, TA and CB with specific technical issues (SCADA, leak detection, NRW Programmeme, water resource protection plan, Sludge Management), Developing guidelines and procedures.

- Fully sustainable, resilient and automated sanitation process.
- The project removed the large-scale discharge of untreated sewage to the Porsuk creek – a strategic water body with potable water abstraction downstream.
- The project protects and restores the local water-related ecosystem.
- The improved effluent discharge affords protection to the downstream potable water abstraction source at Porsuk reservoir - previously impacted by the effluent discharge.
- Ensured that that the knowledge, skill and understanding of how to operate and maintain a modern, automated WwTP facility within the local workforce.
- Intensive training Programmeme for technical and operational management, administration and HR, financial and personnel management and institutional and organisational development.
- Developed the business case for establishing a fully autonomous and self-sufficient water utility department. Enable full and productive employment.
- Fully energy self-sufficient WwTP utilising energy generated from the biogas process.
- Pre-treatment of sludge using innovative Nipramox process required to reduce the elevated nitrogen content from unlined landfill site – the first process technology used in Turkey.
- Maximise low cost/low energy solar drying methodologies – capitalises on Kutahya's above average solar radiation.
- Underfloor heating provided by the biogas process.

Waste and wastewater supply and treatment

- Introduced climate adaption design requirements considering increased intensity storms, higher flooding contours for site selection, capable of withstanding natural disasters.
- Promoted renewable energy supplies using solar radiation and biogas.
- Promoted energy efficiency in all design aspects and equipment selection.
- All concrete batched locally, significantly reducing carbon emissions from transport.
- The project significantly reduced the elevated nitrogen levels and pollution discharging to the receiving Porsuk creek due to elevated inert particulate COD.
- Additional protection measures to critical water abstraction source downstream.
- Protects the local ecosystem.
- Improvements to the river channel promoting biodiversity and fish movement.

Main deliverables and outputs

- Contract management and supervision for construction of Kutahya WWTP.
- Construction Supervision (FIDIC).
- Institutional development/strengthening of the water utility department (WUD) in the municipality.
- Capacity building of WUD of municipality to enable the implementation of projects.
- Evaluation of WUD organisation and recommendation of improvements.
- Construction Supervision experience of comparable works for WWTP.
- Design review and engineering input.
- Project coordination and management with local municipality.
- Familiarity and understanding of Turkish construction contracts.
- Training and capacity building in the field of wastewater treatment design, management and operation.
- Management of FIDIC contract.

Cedar Grove Environmental Centre

Developing Logan City's newest wastewater treatment plant (WWTP) at Cedar Grove was challenging. The community was outraged and Queensland's environmental regulator imposed the strictest licence conditions in history.

However, Logan Water innovated and working with the regulator on policy and collaborated with the Cedar Grove Community Reference Group (CRG) and Economic Development Queensland (EDQ) to engineer a Queensland first.

Cedar Grove Environmental Centre features the state's first WWTP to benefit the environment through membrane bioreactor technology and constructed wetlands to achieve record low nutrient levels and offsetting remaining nutrients through catchment restoration. The site is also a centre for research and a community recreation reserve.

Cedar Grove Environmental Centre is inspiring - a project which began as a WWTP development and was reimagined as a 'gift' to the environment and community.

Logan Water collaborated with EDQ, the state's environmental regulator, the Cedar Grove CRG and other stakeholders to transform perceptions of the project and engineer a Queensland first. Cedar Grove Environmental Centre features the state's first WWTP to benefit the environment by:

- Using membrane bioreactor technology to produce low nutrient effluent.
- Further treating the water in constructed wetlands to achieve record low-nutrient levels (nitrogen of less than 1 milligram per litre and phosphorus of less than 0.5 milligram per litre).
- Offsetting any remaining nutrients through catchment restoration projects.

Logan Water extended these environmental features by:

- Reducing the environmental impacts of trunk pipeline construction by using horizontal directional drilling on long sections (up to 1.3km) to reduce vegetation clearing around waterways and koala habitat.
- Planting 34,000 native trees on 37ha of the Cedar Grove site to offset approved vegetation removal by developers across Logan. In total, 120,000 native trees and shrubs have been planted on site.
- Including a solar farm as part of the project to provide energy for WWTP operations.
- Integrating the effluent outfall pipeline in a fish ladder on Seqwater's weir on the Logan River to replace water released to maintain environmental flows. This preserves 3ml of water per day in the weir pool which is a future drinking water resource.
- Planning for the future reuse of recycled water from the WWTP for agricultural irrigation in the region.
- Initiating environmental research projects with Griffith University at Cedar Grove Environmental Centre.

The master plan prepared for Cedar Grove Environmental Centre by Logan Water in collaboration with the Cedar Grove CRG will see just 5% of the 204ha site used for hard infrastructure. The other 95% is dedicated to environmental and community uses.

The first stage of this 'non-functional scope' has been delivered and features a 2.5km walking trail to the Logan River, a Landcare nursery and training facility for disadvantaged people, picnic areas and shelters and community amenities.

Ultimately, a WWTP which was initially 'on the nose' for the community has become regarded as a precious, sustainable asset for current and future generations.

Waste and wastewater supply and treatment

Cedar Grove Environmental Centre is part of a changing Australian water industry in which utilities are striving for sustainable infrastructure. Council has committed to the UN Sustainable Development Goals and has a target of carbon neutrality for its operations by 2022.

Collaboration with EDQ and Queensland's environmental regulator helped to find a sustainable way to meet license conditions for the WWTP. Effluent management and treatment options were assessed using cost and non-cost (social, environmental, health and safety) criteria. This propelled the project from achieving 'zero harm' to net environmental and social benefits for the region. These will extend to future generations.

The WWTP combines an efficient membrane bioreactor (MBR) with the passive treatment of 7.27ha of constructed wetlands. A 150kW onsite solar farm provides baseload power.

Ultra-low nutrient effluent is released into the Logan River via a pipeline. Logan Water partnered with Seqwater to design the pipeline within a fish ladder at Cedar Grove weir. The infrastructure facilitates fish passage while replacing water that Seqwater ordinarily releases to maintain environmental flows. In turn, this preserves water in the weir pool which is a future drinking water resource.

To offset remaining nutrients in the effluent, Logan Water partnered with Healthy Land and Water to rehabilitate an eroded river bank upstream of the WWTP. This prevents 5,775 tonnes of sediment-laden runoff from entering the river annually.

Logan Water is now coordinating research with Griffith University to build industry knowledge on treatment wetlands and the impacts of catchment restoration on river water quality.

Biosolids gasification facility

Logan Water has pioneered Australia's first biosolids gasification facility to transform sewage sludge (biosolids) into renewable energy and a beneficial soil additive called biochar. The facility paves the way for Australia to take a more sustainable approach to managing its 2.3 million tonnes of dewatered biosolids produced each year (*Australian Water Association 2019*).

Research into the performance of the biosolids gasification demonstration plant showed that this solution is heat energy neutral and reduces the volume of biosolids for beneficial reuse by around 90%. It eliminates about 94% of persistent organic pollutants (POPs) like polyfluoroalkyl substances (PFAS) and 63% of micro- and nano-plastics in biosolids. The process does not harm the environment through air emissions and the resulting biochar contains bio-available nitrogen, phosphorus and potassium and increases the water holding capacity of soil. This helps plants to germinate and grow, making biochar suitable as a soil improver.

The innovative biosolids gasification process is relatively simple and can be replicated by utilities around the world.

Context

Logan City is one of Australia's fastest growing areas. The city's largest wastewater treatment plant (WWTP) at Loganholme is operated by Logan City Council's water business, Logan Water. The WWTP processes wastewater from around 300,000 people and produces 34,000 tonnes of biosolids annually.

Every day, six truckloads of biosolids are transported 300km to an agricultural area to be used as a soil additive. This is a major operating cost for Logan Water; about AU$1.8m per year or 30% of the operating costs for Loganholme WWTP. Transporting biosolids by truck can also adversely affect communities and the environment through increased traffic, fumes, odours and greenhouse gas emissions.

Biosolids management costs are increasing due to rising electricity prices and fossil fuel costs, population growth and tightening of government regulations associated with carbon reduction and the management of pollutants in soils.

In Australia, land application of biosolids is regulated by government. An emerging threat to land application is posed by organic micro-pollutants and persistent organic pollutants (POPs) in biosolids. POPs are chemicals that are toxic, non-biodegradable and accumulate in the food chain, biosolids and soils. They are not yet listed as contaminants in Australian regulations but this is likely to change. In Europe, 50% of biosolids do not meet POPs limits set for land application and Switzerland and Germany have banned land application.

Another emerging issue is the presence of micro- and nano-plastics in biosolids. These pollutants are shed during machine laundering of modern fabrics including active wear. The plastic microfibres enter the wastewater network, become enmeshed in biosolids and are not destroyed by wastewater treatment processes. They can enter the terrestrial food chain when biosolids are applied to land for agricultural production.

Project strategy

In 2018, Logan Water recognised the potential to change its approach to biosolids management to improve energy efficiency and resource recovery and reuse.

At Loganholme WWTP, biosolids are currently dewatered to around 13% dry solids content using belt presses. This means a lot of water is handled during the storage, transport and reuse of biosolids.

As part of this project, Logan Water hoped to produce a biochar with a dry solids content of 80-90%, significantly reducing handling costs. The biochar was also likely to be a marketable product.

Based on a study of biosolids management options, gasification was selected as the most cost-effective way to create a high quality biomass for beneficial reuse as biochar. As the solution could capture and reuse heat energy, Logan Water recognised the opportunity to apply for grant funding from ARENA. A 1MW solar array was also planned to provide additional energy.

Waste and wastewater supply and treatment

Project implementation

Logan Water worked with Australian gasification technology provider Pyrocal and engineering services provider Downer to develop its biosolids gasification facility. Existing technologies used for gasification of agricultural waste were adapted for biosolids.

The design features dewatering of biosolids in a centrifuge, drying it in a belt dryer and treating it at high temperatures in a gasifier.

Gasification converts biosolids into carbon monoxide, hydrogen and carbon dioxide when it reacts at high temperatures with a controlled amount of oxygen and/or steam. The resulting gas mixture is called biogas and is a fuel. The energy from gasification and combustion of biogas is a source of renewable energy in the form of heat, which is used to dry the biosolids.

Dried biosolids enter the gasifier and progress through the unit, with the material heated to 650°C under controlled oxygen conditions. A secondary air source is introduced to the thermal oxidiser to ensure complete combustion of the off-gas and maximum heat generation and recovery. After heat recovery, the cooler flue gases pass through a wet scrubber and filtration for emissions control and then to a discharge stack. The system produces biochar as the end product, treated air and a scrubbing liquid that is returned to the WWTP.

Rather than build a permanent gasification facility immediately, Logan Water constructed a demonstration plant to assess the following:

- reliability of the design and equipment.
- air emissions and compliance with regulations.
- quality of the biochar and confirm destruction of POPs and micro- and nano-plastics.
- heat balance for an integrated drying facility.
- operating costs including power and consumables.

The demonstration plant operated for 12 cycles over 450 hours and produced 170 tonnes of biochar. Testing of the plant design, operation and emissions was completed on site and the biochar was studied by university researchers.

Lessons learned from the trial, such as the need for chemical dosing for air emissions control and understanding particulates in the system, were applied to design of the full-scale biosolids gasification facility now under construction.

Logan Water's biosolids gasification facility is supporting council to meet its target of carbon neutrality for its operations by:

- recovering energy from waste.
- reducing energy consumption.
- sequestering carbon and binding heavy metals which reduces carbon emissions (initially by about 4,800 tonnes per year).
- destroying POPs by about 94% and micro- and nano-plastics by about 63%.
- avoiding harmful air emissions.
- complying with environmental regulations.

The facility will also save about AU$500,000 in WWTP operating costs each year and is expected to produce a marketable biochar.

The project has generated great interest in the global water industry, with other utilities encouraged by the positive results Logan Water has achieved.

Waste and wastewater supply and treatment

Waste to energy (anaerobic digestion) facility

As part of ensuring that it makes the most of its natural resources, Yarra Valley Water has built a waste to energy facility that processes commercial food waste into clean, renewable energy.

This was Victoria's first waste to energy facility, in Wollert to the north of Melbourne and it has been operating since May 2017.

Waste producers, such as markets or food manufacturers, deliver the equivalent of 33,000 tonnes of commercial food waste to the Wollert facility each year.

The facility sits next to Yarra Valley Water's Aurora sewage treatment plant and generates enough energy to power the facility and the sewage treatment plant. Excess energy is exported to the electricity grid.

Turning waste into energy benefits Victoria by helping to reduce landfill and cuts greenhouse gas emissions. By reducing energy costs, these facilities will also help to keep water bills lower.

Tackling the rising cost of energy for Victoria and the planet

Yarra Valley Water is Melbourne's largest retail water utility, providing essential water and sanitation services to more than two million people and 58,000 businesses. Many of these customers struggle with financial vulnerability and it is important that they are safeguarded against bill rises in the future, by Yarra Valley Water finding ways to reduce its own costs.

It is recognised that the impact on the community extends well beyond water services – it is seen as a proactive contributor to the health of the environment and the public served. The purpose – To support the health and wellbeing of customers and create a brighter future for communities and the natural environment – informs on dynamic thinking on this issue.

The Australian water sector is a heavy energy user – the supply, treatment and distribution of water is an energy-intensive process. For all businesses, one of the big challenges of the future is reducing reliance on non-renewable sources of energy.

Shared value: a project that solves several problems

During the millennium drought, Yarra Valley Water examined the need to augment its satellite sewage treatment plants to include recycled water provision. We were aware that this would drive up energy costs, and looked at several ways to offset these costs. Our initial assessment looked as several renewable energy sources – including traditional cogeneration systems, wind and solar – but we needed an economically viable solution for smaller-sized plants.

Another issue we sought to address was Victoria's vast and growing waste management problem. We produce more than two million tonnes of organic waste annually. Our solution was to construct a waste-to-energy plant next to our sewage and recycled water treatment plants in Melbourne's growing north. The site was chosen not only because it was adjacent to the treatment plants but also for its proximity to local food manufacturing, including the wholesale markets in Epping. Each day, our waste-to-energy facility repurposes 100 tonnes of food waste previously destined for landfill, processing it into biogas via anaerobic digestion.

Diverting 33,000 tons of organic waste annually from landfill into energy production delivers obvious environmental benefits. Organic waste in landfills is a major contributor to odour, leachate and vermin issues, the largest landfill-related environmental impacts. Actively diverting organic waste from landfill extends the lifetime of existing landfill sites, giving waste – by definition a product without a use – a useful purpose, according to the environmentally sound principles of reducing, reusing and recycling.

Yarra Valley Water's waste to energy facility is a bold step towards energy security - at full capacity, the facility will provide 25% of our annual electricity demand. In addition to reducing our reliance on the grid and

Waste and wastewater supply and treatment

safeguarding our energy security, the significant revenue and cost savings we receive from gate fees and the energy market reduce our costs.l In turn, this helps us combat the upward pressure on water prices for our customers.

A watertight business case

When the economics started to favour renewables, we decided the time was right to construct this ground-breaking organic waste to energy facility. Our decision was further sparked by a paradigm shift in our role as a processor of waste, not just sewage. We were already processing 75% of commercial and industrial waste by volume. We harnessed this expertise to consider how we could expand into other waste streams. Our research told us that this was achievable in both capacity and capability terms.

The waste-to-energy facility is completely self-sufficient and its success is such that a second facility is in the pipeline. There is demonstrable community, business and government demand for such a service. The new facility will be larger than the current one, providing greater environmental benefit and propelling us closer to our aim of being carbon positive by 2025. It will take advantage of the latest technological advances to treat a wider range of wastes, driving home the reliability and flexibility of waste to energy conversion. The second facility is expected to be operational in 2020.

An enduring gift to Victoria

Yarra Valley Water's waste-to-energy facility generates enough energy to power the facility and the neighbouring treatment plants. The surplus energy is exported to the grid, reducing Victoria's greenhouse gas emissions and Yarra Valley Water's reliance on traditional sources of electricity.

The outcomes of this project are tangible – they include reductions in waste going to landfill, greenhouse gas emissions and energy costs (for Yarra Valley Water and, by extension, our customers) and the establishment of a long-term sustainable energy source that remains resilient to supply and price shocks in the future.

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Project examples

Drainage and flooding

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Cork Lower Harbour Main Drainage Scheme, Ireland

The Cork Lower Harbour Main Drainage Scheme (Cork LHMDS) serves the population/industrial centres of Cobh, Carrigaline, Crosshaven, Passage West, Monkstown, Glenbrook, Ringaskiddy, Shanbally and Coolmore. The existing sewer network comprises mainly combined sewer systems. Wastewater from large areas is currently discharged following preliminary screening or untreated into the harbour.

Cork County Council

Nicholas O'Dwyer carried out all investigations, surveys and designs for the collection and transfer infrastructure including the sub marine crossing. Preliminary designs and detailed designs and bidding documents were prepared for the wastewater treatment plant, which was constructed using FIDIC Gold conditions of contract, one of the first such contracts to be used internationally. Nicholas O'Dwyer provided all the construction supervision and technical support for the collection contracts and the Design Build Operate contract. In total 20 resident engineering staff were provided across four separate contracts with significant contract administration and managerial support provided from Dublin HQ.

The project includes for the collection, transfer and treatment of wastewater from each of the population centres to a new state of the art wastewater treatment plant with an ultimate design capacity of 80,000 PE (54,000 m^3/d). The treatment process is based on the Nereda® technology and is the largest of its kind in Europe. Is utilises a modified granular activated sludge base on SBR technology and reduces the treatment volume by up to 50% compared to conventional systems.

The final effluent is discharged to Cork harbour via and existing submerged outfall. The scheme includes the construction of eight main pumping stations and approximately 57km of new/upgraded sewers (ranging from 225mm to 1,050mm), rehabilitation of existing trunk sewers and surface water separation where economically viable. Connection of flows from the eastern catchment requires design and construction of a sub-marine crossing of approximately 1km with twin 500mm rising mains.

- The project removed the large-scale discharge of untreated sewage to the lower harbour ensuring compliance with the Urban Wastewater Treatment Directive and protect several important European designated habitats and species.
- The project protects and restores the local water-related ecosystem.
- The project included the capacity building and training of local operations staff including the innovative WwTP Nereda® technology.
- Outreach Programmemes to local communities and schools to increase awareness/education.
- The project has innovation to its core and deliverables a resilient infrastructure for the existing WwTP operations capable of withstanding impacts of climate change.
- The project capitalises on sustainable smart technologies to reduce carbon emissions and operational costs – harnesses methane gas.
- The process stream requires a significantly reduced footprint thus saving of land costs and large-scale concrete structures.
- Introduced climate adaption design requirements considering increased sea levels, increased intensity storms, higher flooding contours for site selection, etc.
- Promoted renewable energy supplies.
- Promoted energy efficiency in all design aspects and equipment selection.
- Considered circular economy and end of life requirements for equipment and materials.
- The project significantly reduced the sewage pollution to the marine environment.
- The upgrade of pumping stations and networks introduced increased resilience thus reducing storm water overflow and emergency spillages to the marine environment.
- The nutrient reduction from the stringent wastewater Emission Limit Values (ELV's) significantly reduces the N and P discharge to the marine environment.

Drainage and flooding

Main deliverables and outputs:

- Design review.
- Options appraisal / feasibility studies.
- Development and calibration of hydro works network models.
- Preparation of contract documents (FIDIC Gold) for collection systems and treatment plant contracts.
- Design of collection and transfer infrastructure for project including sub marine crossing using horizontal directional drilling technology.
- Design and preparation of bidding documents - experience of comparable works for WWTP and sewer network design.
- Construction supervision experience of comparable works for WWTP and collection networks.
- Design and construction supervision of wastewater treatment infrastructure relating to marine and coastal engineering works.
- Management of FIDIC contract.
- Management of multiple contracts simultaneously with a large team of resident engineers for supervision of works.
- Detailed civil, process, mechanical and electrical designs for WWTPs.

Flood protection plans - Cities of Sullana and Talara (Peru)

Flood protection studies and corresponding pre-investment interventions design for cities of Sullana (200k inhabitants) and Talara (145k inhabitants), in the north of Peru.

ARCC – Autoridad Reconstrucción con Cambios

Services provided

- Basic complementary studies: topography, hydrology, risk assessment.
- Inventory of existing infrastructure of drainage and sewerage network in general.
- Development of the drainage plans.
- Pre-investment study of adopted solutions.

Squamish Integrated Flood Hazard Management Plan

In 2014, the district of Squamish retained Kerr Wood Leidal Associates Ltd. to lead a groundbreaking, three-year study to assess and mitigate an extensive range of overlapping flood hazards. The resulting Integrated flood hazard management plan looks beyond traditional floodplain mapping to systematically consider the interplay of physical, economic, social and environmental risks.

In 2014, the district retained KWL to complete a three-year assessment of its flood hazards from an integrated systems-based perspective. Mitigation strategies had to balance flood protection, community growth and environmental objectives. The resulting Integrated flood hazard management plan (IFHMP) represents a significant step forward for flood hazard management. Examining the district's intertwined hazards together allowed mitigation strategies to identify and avoid undesirable results. Also, rather than as well the integrated approach looked beyond traditional floodplain mapping to consider aspects of physical, economic, social and environmental risk. This required a multidisciplinary team of engineers, planners and environmental scientists.

The project produced several engineering innovations, including western Canada's most detailed floodplain-scale hydraulic model and a new first-principles approach for establishing sea dike design criteria. The IFHMP takes a comprehensive approach to incorporating future development and adopted European methods to highlight potential challenges for floodplain evacuation. As well, new geographic information system (GIS) tools can extrapolate results from a small number of dike breach models to ensure that planning maps capture the possibility of a dike breach at any location along a 20km dike.

The IFHMP began by reviewing over 170 past studies to confirm hazards, understand existing protections and identify policy gaps. Phase 2 explored coastal flood risk mitigation options. In Phase 3, KWL undertook dike breach and consequence modelling, prepared inundation maps and developed mitigation tools. Phase 4 consolidated the technical work and produced an official community plan update, a new floodplain bylaw and new development permit area guidelines. Based on community input, the IFHMP prioritized a new 7km sea dike around downtown Squamish. Design concepts reflected different community priorities at different locations along the dike. Urban densification can increase water levels during a dike breach event.

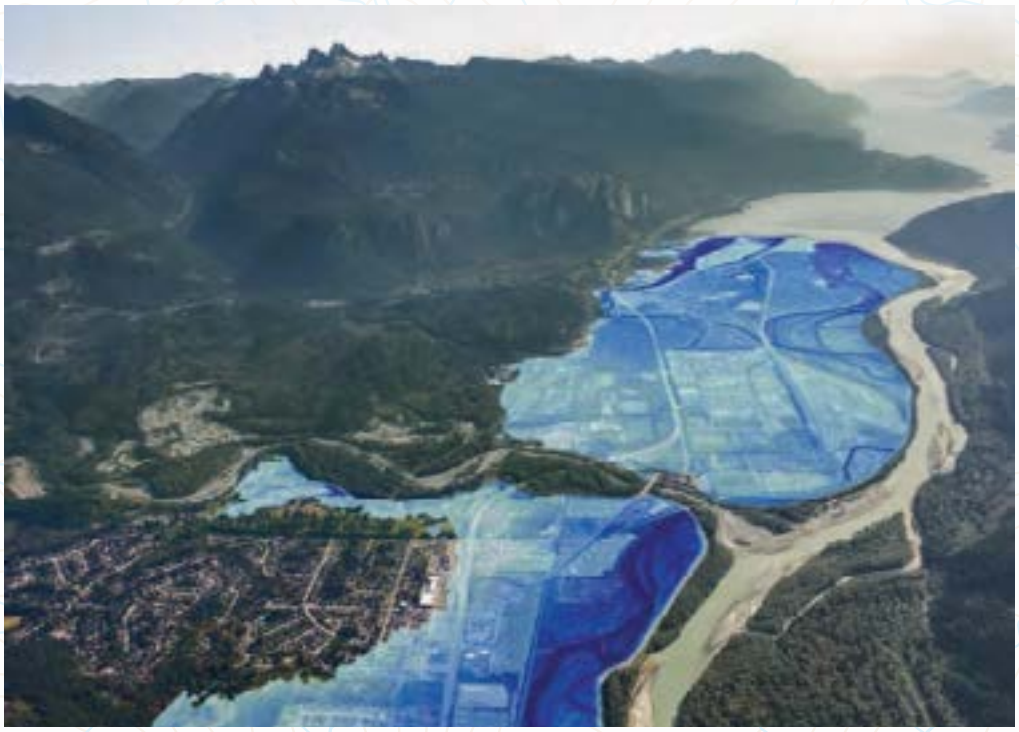
To address this challenge, KWL developed a detailed hydraulic model that represents mitigation and development on a lot-by-lot basis. Results confirm key behaviours like flow concentration along streets and water level increases caused by future development. The detailed model also confirmed that the 'bathtub effect' could be mitigated by intentionally breaching the sea dike at carefully selected locations. After producing a full suite of hazard maps, KWL completed a GIS-based assessment of social and economic consequences. The economic assessment used Natural Resources Canada's HAZUS-MH model, which showed that flood damages could exceed $450m and displace nearly 60% of the community's population. Results also indicate that a dike breach could damage or destroy as many as 1,400 buildings and generate nearly 40,000 tonnes of debris. The IFHMP expanded the traditional engineering role of designing flood protection to a broader one of building sustainable communities. For small communities like Squamish, benefit-cost analysis is the only sustainable way to justify long-range capital planning decisions involving large capital expenditures.

The IFHMP recommended some $80m in flood protection improvements and considered all possible measures to minimise the financial burden. The IFHMP's watershed and river management recommendations also focus on protecting primary floodway corridors and promoting sustainable land use throughout the watershed. The IFHMP also recommends continued advocacy for reforestation and other sustainable land use practices throughout the watershed. The district's objectives for the IFHMP were to reduce and share flood risk fairly, support development opportunities, promote sustainability and produce solutions that are achievable, realistic and supported by the local community. KWL met these objectives by preparing a detailed strategy that includes over 100 specific tools to manage flood risk. The strategy incorporates elements of protection (diking), accommodation (floodproofing and appropriate land use), avoiding new risks, managed retreat of key infrastructure and selectively accepting risk where it brings significant benefits for the community.

Drainage and flooding

The IFHMP identifies an array of mitigation choices that balance the need for flood protection with impacts to stakeholders, the community and the environment. The project's engineering innovations include Western Canada's most detailed floodplain-scale hydraulic model as well as a GIS-based method for generalising dike breach model results to account for all possible breach locations.

The project also takes an unprecedented comprehensive approach to incorporating future development and anticipated key aspects of the World Meteorological Organisation's 2017 guidelines for integrated flood management.



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The FIDIC board

As with all documents and research produced by FIDIC, the board plays a vital role in ensuring that quality, integrity and direction of such publications and as such we thank the board members for their contribution to this publication.

The secretariat

FIDIC is only possible because of the hard work of its team and this report would like to recognise the efforts of the individuals within the FIDIC secretariat that made this report possible. The FIDIC board will continue to support and endorse the actions of the secretariat to deliver for its members and the wider infrastructure sector.

Reviewers

FIDIC's research is important and covers a global stage so that research is peer reviewed by several independent individuals and a selected board member to help ensure its quality. FIDIC would therefore like to take this opportunity to thank:

- **William Howard**, President, FIDIC
- **Nelson Ogunshakin**, FIDIC CEO
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Contributors

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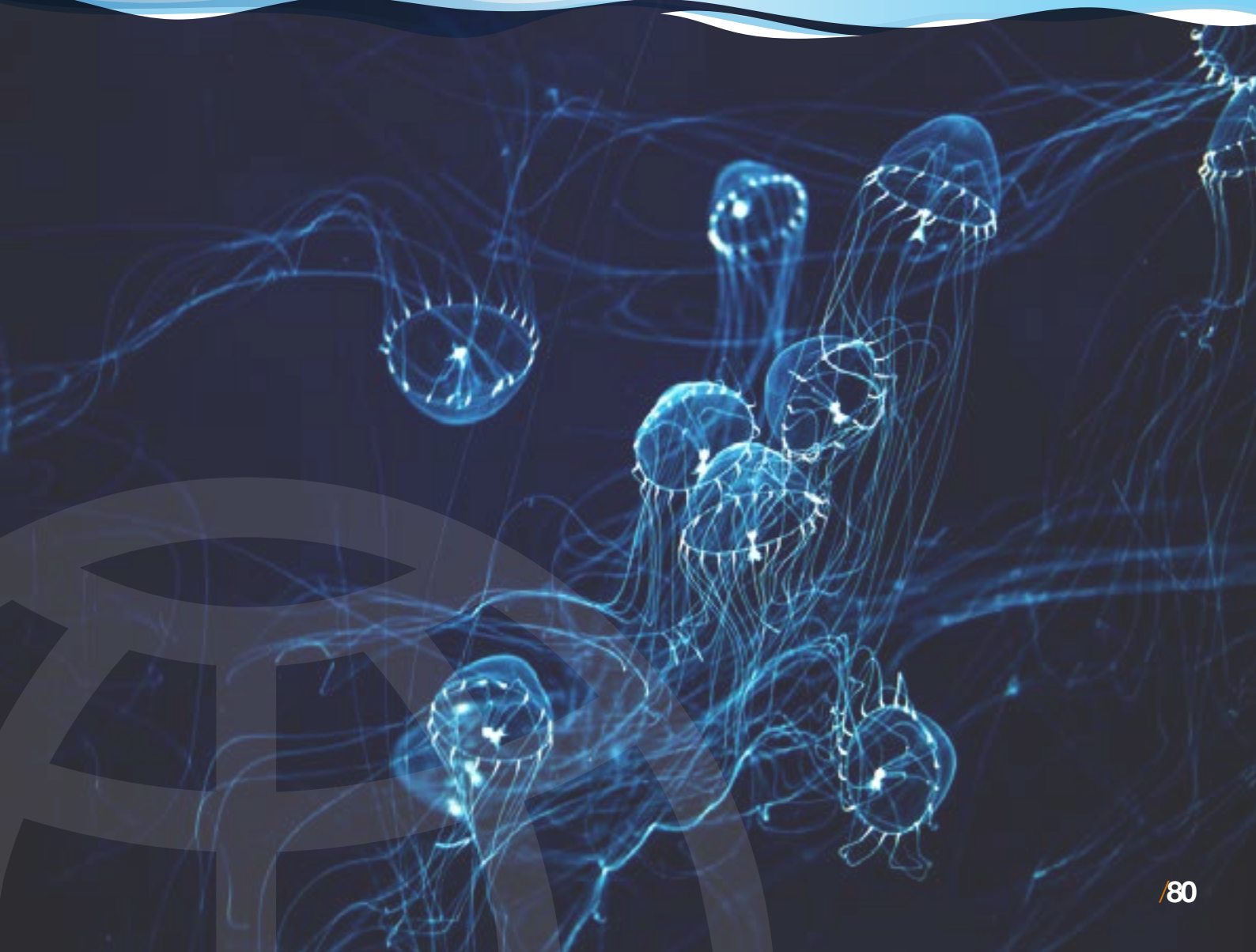
FIDIC's full partners

FIDIC partners are an important part of its presence and the effectiveness of the industry and help to ensure FIDIC can deliver services for the improvement of the industry. These partners go above and beyond to help support, promote and engage with FIDIC and we thank them for their support and continuing engagement.

UN environment programme

SIP



Thanking our member association partners

Finally, but by no means least, FIDIC is a product of its member associations without which FIDIC would not exist. Whilst all member associations can be found on the FIDIC website, in this and future *State of the World* reports we have engaged with FIDIC member associations on the detail of our work and we would like to thank the following member associations for their support for our research.

/About FIDIC

FIDIC, the International Federation of Consulting Engineers, is the global representative body for national associations of consulting engineers and represents over one million engineering professionals and 40,000 firms in more than 100 countries worldwide.

Founded in 1913, FIDIC is charged with promoting and implementing the consulting engineering industry's strategic goals on behalf of its member associations and to disseminate information and resources of interest to its members. Today, FIDIC membership covers over 100 countries of the world.

FIDIC, in the furtherance of its goals, publishes international standard forms of contracts for works and for clients, consultants, sub-consultants, joint ventures and representatives, together with related materials such as standard pre-qualification forms.

FIDIC also publishes business practice documents such as policy statements, position papers, guidelines, training manuals and training resource kits in the areas of management systems (quality management, risk management, business integrity management, environment management, sustainability) and business processes (consultant selection, quality-based selection, tendering, procurement, insurance, liability, technology transfer, capacity building).

FIDIC organises the annual FIDIC International Infrastructure Conference and an extensive Programmeme of seminars, capacity building workshops and training courses.

FIDIC 2020-2024 priorities

Lead the consulting and engineering industry visibly and effectively:

- Being the industry's credible global voice
- Providing the nexus for all stakeholders
- Facilitating improvement and growth in business
- Addressing global challenges

All of the above is for the benefit of society, FIDIC members and their member firms.

/Recent FIDIC policy documents

Establishing the value of water - State of the World 2020-2021

Water is vital to so many aspects of life, but investment into the infrastructure, environmental mitigations and resilience aspects of this sector for the wellbeing of humans, the environment, food production, energy etc are not sufficient.

This State of the world report therefore asks a very important question what the value of water is, is it valued incorrectly, how this will change and will this finally drive the investment required to meet the SDGs.

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Time to Tn-vest - State of the World 2020-2021

FIDIC as part of this report makes three recommendations for creating investment certainty, to create an SDG capital envelope and to reinvigorate efforts to truly shift to holistic and sustainable investment. These will help industry to move the industry forward and generate positive momentum.

It is therefore Time to Take The Trillion Task seriously, yes one T for every trillion that is estimated to be needed as a minimum to meet the SDG requirements. It is Time to Tn-vest

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FIDIC Strategic Plan 2020-2024

FIDICs has produced its new Strategic Plan for 2020-2024, it summarises FIDICs activity the results from the various appendices and the goals and approach from FIDIC going forward.

The plan includes a summary of the ten key areas identified and the five goals that FIDIC has set in these areas, including its ambition, targets and current performance.

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/Recent FIDIC policy documents

FIDIC Annual Report 2020

FIDIC's latest annual report was published in September 2020 and highlights the federation's work and activities during the financial year 2019-2020.

As well as a financial report, the annual report includes updates from the FIDIC president and chief executive and reports on the work of the various FIDIC committees.

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FIDIC MDB overview document

This briefing note has been written to assist both FIDIC member associations and their members in understanding the significance and opportunities available because of the partnership between Multilateral Development Banks and FIDIC.

This briefing note explores the scale of the infrastructure challenge governments, the private sector and multilateral development banks face and their role in infrastructure investment

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What the FIDIC-AfDB contracts agreement means for members

This briefing note has been written to assist both FIDIC member associations and their members in understanding the opportunities and processes that are in place as part of the agreement between FIDIC and the African Development Bank Group (AfDB).

It outlines the scale of project opportunities that are available via the AfDB and what kind of sectors and geographic regions they cover.

Importantly the document then provides details to members about how to access the AfDBs project pipeline and the processes and expectation the AfDB has for firm that wish to apply for its projects

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Disclaimer

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