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/SOW2021
State of the World

Establishing the value of water - the business case for change

Addressing the world's water challenges more aggressively

/A FIDIC report

Contents

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Foreword from the President and CEO

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Nelson and I welcome you to this second 2021 *State of the World* report entitled, *Establishing the value of water - the business case for change*.

The first report, *Time to $ Tn-vest*, published on 18 February 2021, focused primarily on the significant scale of the investment needed to meet the world's infrastructure requirements including meeting the United Nations Sustainable Development Goals (SDGs). While the first report mentioned strategies to raise the necessary funds, we also noted that engineers have the ability to reduce financing requirements through prudent use of their innovative skills.

This second report continues with such ambition, exploring and addressing the world's water challenges, the financial and social value we need to place on water and the business case for action. This report therefore builds upon the themes included in the Time to $ Tn-vest report as well as the 2015 *State of the World Report on Water Challenges*.

It is important that we clarify that for convenience, we use the term "water" in this report in the broadest sense to include all elements of the world's water resources including potable water, wastewater, stormwater and our oceans. This report also addresses the myriad of related water challenges due to climate change.

This report also touches on the impact of Covid-19 in the short and longer terms which, as noted in our first report, may well have created an increased awareness that global crises can occur. Hopefully, we can build on this awareness and make significant progress toward meeting infrastructure needs.

The world has changed dramatically in the past 12 months. Covid-19 has not only changed working patterns but has also reduced economic activity to lows never seen before. This will add to the challenge of financing infrastructure requirements.

While FIDIC will continue to address many issues in our future State of the World reports, the choice of "water" as the first 'technical' subject is appropriate due to its importance to human life, ranging from the billions of people without adequate basic drinking water and sanitation to the growing water scarcity problem throughout the world. All this also takes place in a world where the direct and indirect connection between climate change, environmental sustainability and water challenges is changing rapidly.

Since the FIDIC *2015 State of the World Report on Water Challenges* was published, some progress has been made but much more needs to be done. This report discusses how some of this progress is the result of more attention being paid to our water challenges which, in turn, are also developing due to goals set such as the United Nations Sustainable Development Goals which put in place clear targets for 2030, two of which (Goals 6 and 14) are directly concerned with water.

FIDIC and the infrastructure sector more widely needs to communicate more clearly the importance of all elements of water in our daily lives and if the investment required is to take place, the economic and social value may need to adjust. It should not be underestimated that the challenge of providing universal services in the water sector is not a small one and it will require government decision-makers and the public sector to invest more in solutions and for the private sector to also step up and invest to play its role.

This report is part of our effort to more broadly communicate 'state of the world' issues which engineers can help address. This report includes discussion of issues related to the value and pricing of water services, which going forward must meet a very important, delicate and critical balance, between providing services universally to meet the SDGs, improve livelihoods, food, energy, health etc as a necessity but

using policy and pricing mechanisms which allow significant investment to take place without pricing people, towns, areas or even regions out of vital services.

We also note issues related to the financial and social costs of our water challenges which are not routinely 'priced'.

Our next report will focus on innovative approaches which are occurring or should be considered in addressing our water challenges. These two reports, in combination with our first report on the scale of the investment challenge, will therefore hopefully help to establish a logical way forward to improve our progress in addressing our water challenges.

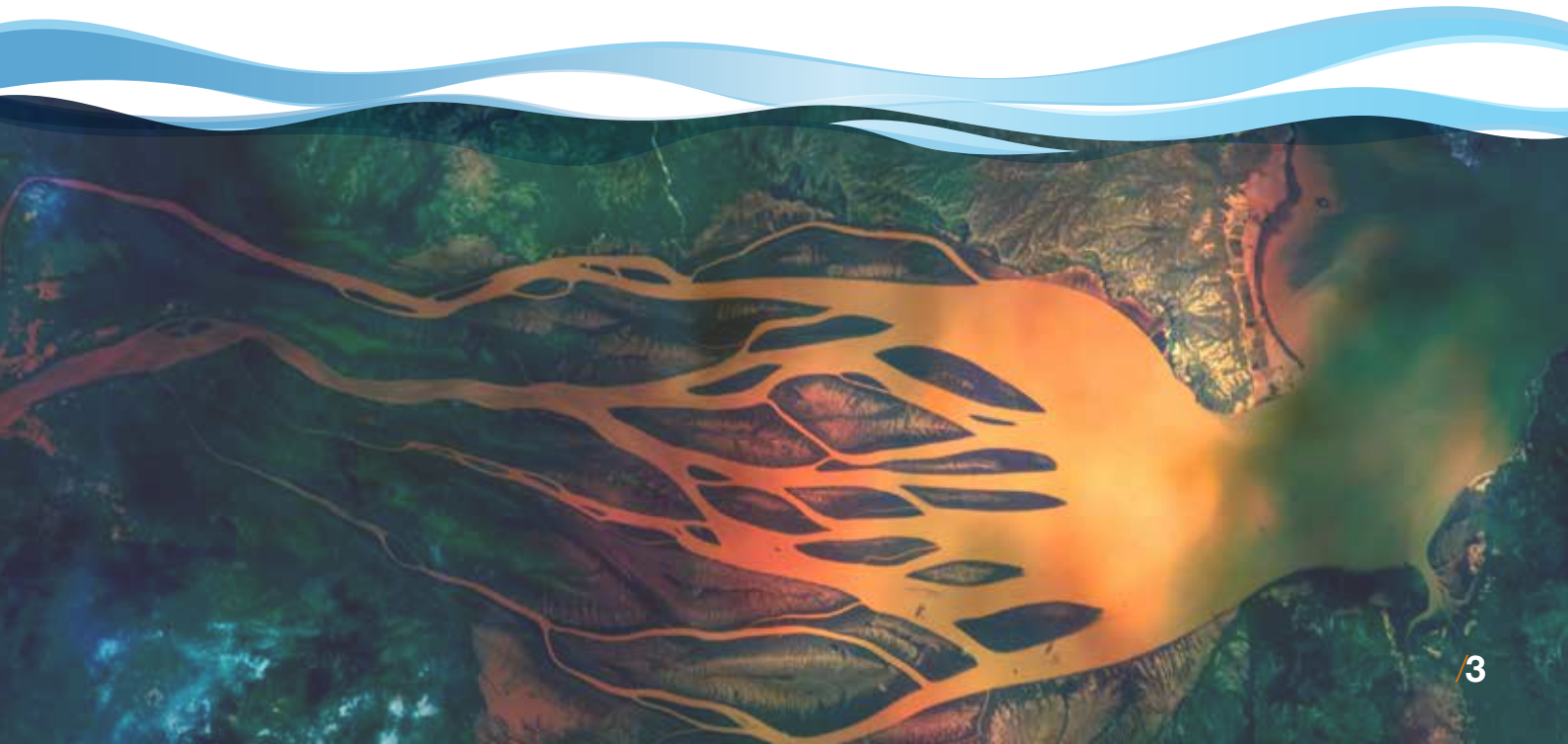
It is therefore my pleasure as the president of FIDIC along with our CEO, Nelson Ogunshakin, to present FIDIC's views on our water challenges especially the need to recognise how important it is to develop solutions more rapidly.

Whilst the entire sector, from financiers through to end consumers, will need to be engaged to deliver effective solutions to our water challenges, engineers will form a key part of successful investments. They will do so by ensuring that the right cost-effective projects are developed in the planning phase, timeframes are reasonable and quality is not compromised.

It is in the inception and planning phases of projects where the best engineering is often done. The cost of this phase is only a small fraction of the overall project cost, but it has enormous influence on the quality, whole lifecycle cost and outcomes.

Sustainable projects that consider the future will ensure that we develop infrastructure that is not only fit to provide for the current generation but for future ones as well.

The world therefore continues to face a myriad of complex and longstanding water challenges. It is imperative that all stakeholders commit to addressing them more vigorously. The engineering community can provide leadership in developing innovative solutions. As noted in FIDIC's 2015 report, this will not only involve technical strategies. Equally or perhaps more importantly, it will include appropriately involving all stakeholders in pursuing solutions to our water challenges.



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/Executive summary and recommendations

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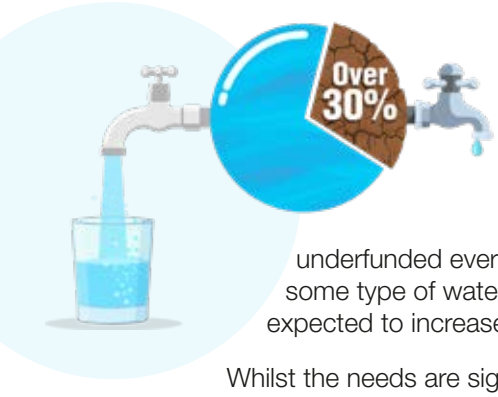
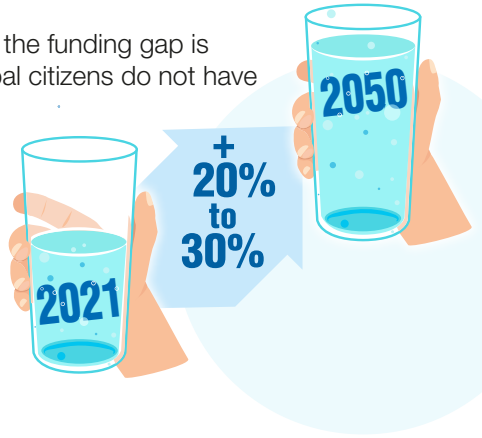
In this, the second 2021 FIDIC *State of the World* report, we build upon some of the challenges mentioned in the previous report, *Time to $Tn-vest*. There are two major themes in the document. The first theme addresses the need for the global community to establish a proper value on water so that water services are priced in a manner that meets the challenge of universal provision, sustainability and investment requirements. In doing so, the myriad of operations, maintenance and any asset expansion needs can be sustainably funded. The second theme is a reminder of the many serious water resources issues which have financial and social costs which are closely linked to climate change and/or global warming.

The first theme focuses on the expected increase in the global demand for water, the energy-food-water nexus and the challenges associated with properly charging for water and sanitation services to ensure that we properly fund entities providing these services so that current and future generations are properly served. We emphasise that this is not the case now and it will not be the case for future generations unless we act more aggressively.



We emphasise that the task associated with closing the funding gap is complex and multifaceted. 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.



Whilst the needs are significant, the challenges associated with charging enough for water services to finance them are complex as well. We discuss some of these ranging from affordability for the poorest among us to the inelasticity associated with some large users (such as energy production and agricultural practices). To satisfy the global needs, government assistance, involvement of the private sector, proper planning, innovative strategies and other approaches will be necessary.

The identification of new sources of sustainable funding as well as providing proper oversight of those funds particularly in the developing world is, in our view, an enormous critical success factor. To engage such funding on a significant scale it is therefore important that all parties across the infrastructure sector, including governments, be transparent and clear about the credentials they require and the standards they expect.

We must solve the funding problem soon because more challenges are on the way. Some of these challenges are delineated in the second theme explored in this report. Water-pricing policies should provide adequate incentives for customers to use water resources efficiently, and thereby contribute to environmental objectives.

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.

The American National Oceanic and Atmospheric Administration estimates that the average surface temperature of our oceans has risen by about 0.9 degrees ºC.

Plastics have benefited humans in many ways, but not without negative environmental consequences. The indiscriminate disposal of plastics, however, is having an increasing insidious impact on our waterways and drinking water. Concerns are increasing about microplastics and micro resins. They are being found in virtually all our oceans and are likely entering the food chain as they are being ingested by aquatic life and there is uncertainty about their impact.

There is also growing concern over the occurrence of contaminants of emerging concern (CECs) in the aquatic environment. New analytical techniques are constantly being developed to discover countless numbers of CECs in wastewater treatment plant effluents, surface and groundwater systems and even in drinking water.[xxxv],[xxxvi]

The emerging issues range across the entire range of water systems, one climate model predicts that the number of extreme rainstorms worldwide will double with each one-degree Celsius increase in global warming.[iv]

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 SDC 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.

Despite our ability to provide adequate treatment, it is estimated that 80% of wastewater is discharged without it. In addition, more than 80,000 synthetic organic chemicals, many of which are CECs mentioned previously, are used daily in domestic, commercial, or industrial applications[i]. These chemicals are designed to improve our quality of life in a number of ways by increasing the global rate of agricultural production (e.g., pesticides), protecting human and animal health (e.g., pharmaceuticals), improving hygiene (e.g., personal care products), or advancing industrial production (e.g., plasticisers). However, many of them are persistent and treatment of them is a challenge.

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.

Overuse of water sources, especially groundwater without adequate recharge, is already an issue, with piezometric surfaces/water tables being significantly depressed due to over-pumping. It is therefore not only an issue for future generations but also current ones, further use and pressure on such extraction will only serve to intensify the water scarcity problem for future generations.

FIDIC's 2015 report suggested that of the myriad of water challenges the world faces, the following four are most important:

1) Providing everyone access to clean water and sanitation.

2) Closing the demand-supply gap.

3) Planning for climate change including robust adaptation; and

4) Adequately investing in natural infrastructure (aging and new)

These challenges are still with us and we must work harder to properly address them. Our success in resolving our water challenges will, to a large degree, depend on the value individuals place on them as well as the level of importance more global citizens place on the threats to our environment from climate change. As these concerns grow, we should expect to see the political pressure for action to increase.

It is critical that we succeed if we are to avoid the many deleterious consequences of failure. As Dr James W. Patterson, President of the American Academy of Environmental Engineers and Scientists, stated "The scientific community is in agreement that the earth's rising temperatures are fuelling longer and hotter heat waves, more frequent droughts, more extreme rainfall events and more powerful hurricanes."[2]

This increasing global agreement about the water challenges we face may be creating an opportunity to involve more stakeholders in exploring solutions. In doing so, we must achieve the United Nations sustainable development goals, especially goal 6 and, to a degree, goal 14.

Currently, the global water challenges are numerous, complex and perhaps not well enough understood from a 'value' or 'cost' point of view. However, this may be changing for the better. Potential consequences of climate change, global warming and the associated water-related challenges are appearing more frequently in all elements of the media. A look at the references to this document is a testament to this. While some are from technical journals, others are from more commonly read non-technical periodicals.

Toward the end of the FIDIC *State of the World* report on water challenges, there was mention of the need for engineers and scientists to involve others in searching for solutions to our vexing problems.

Now, six years later, the need to involve more of our fellow citizens is even clearer. The Covid-19 pandemic has provided an opportunity to do so. The July 2020 issue of *Time* magazine "*One Last Chance*"[3] was largely dedicated to climate change. A portion of the article mentioned that the pandemic just may have contributed to the shift in collective thinking. A question from the article is worth repeating. "Will a newfound respect for science and a fear of future shocks lead us to finally wake up (i.e., to the climate change threats) or will the desire to return to normal overshadow the threats lurking just around the corner?"

Through constructive dialogue about the issues, involvement of all stakeholders, looking at the big picture and encouraging innovation, we can hopefully keep the right amount of attention on our water challenges. As difficult as they are, there are a lot of reasons for optimism. Our environment, while threatened, is resilient (the restoration of sea grass along portions of the east coast of the USA is just one example[4]) and with some help

from innovative engineers and scientists, we can meet the challenges we face and build a better world for future generations. We will discuss this more in the next report.

It is beneficial to provide some actionable recommendations related to the subject matter being discussed. Thus, for this report on *Establishing the Value of Water - the Business Case for Change*, FIDIC offers the following three recommendations.

1

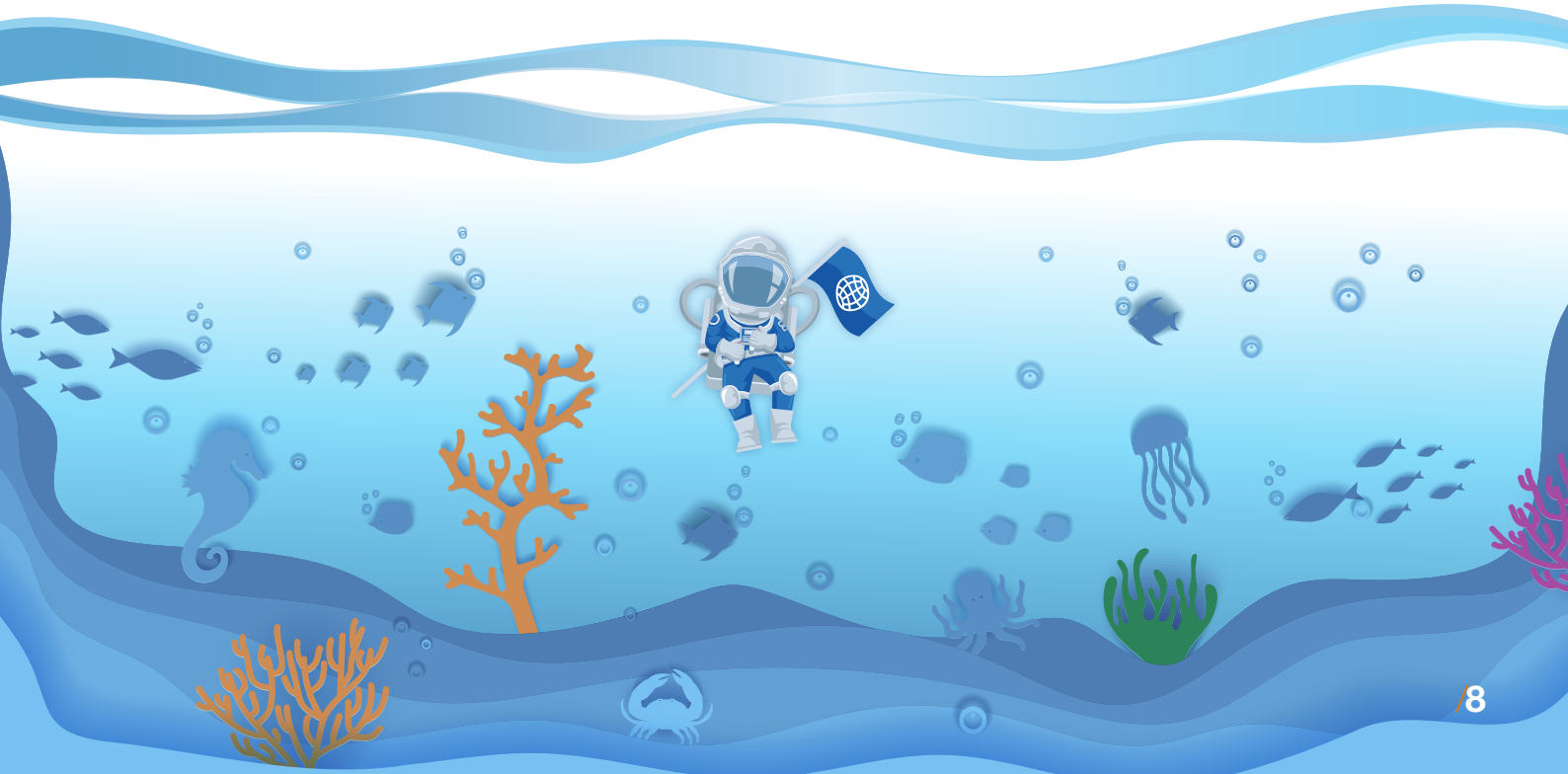
Recommendation 1: To increase the perception of value, to reduce waste and to ensure that critical water systems are available for future generations, FIDIC recommends that prices (i.e., rates/costs/prices) for water, wastewater, ecosystems and stormwater services be established with the assistance of qualified professionals and 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.

2

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.

3

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, COP and others in developing solutions to this vexing and insidious problem.



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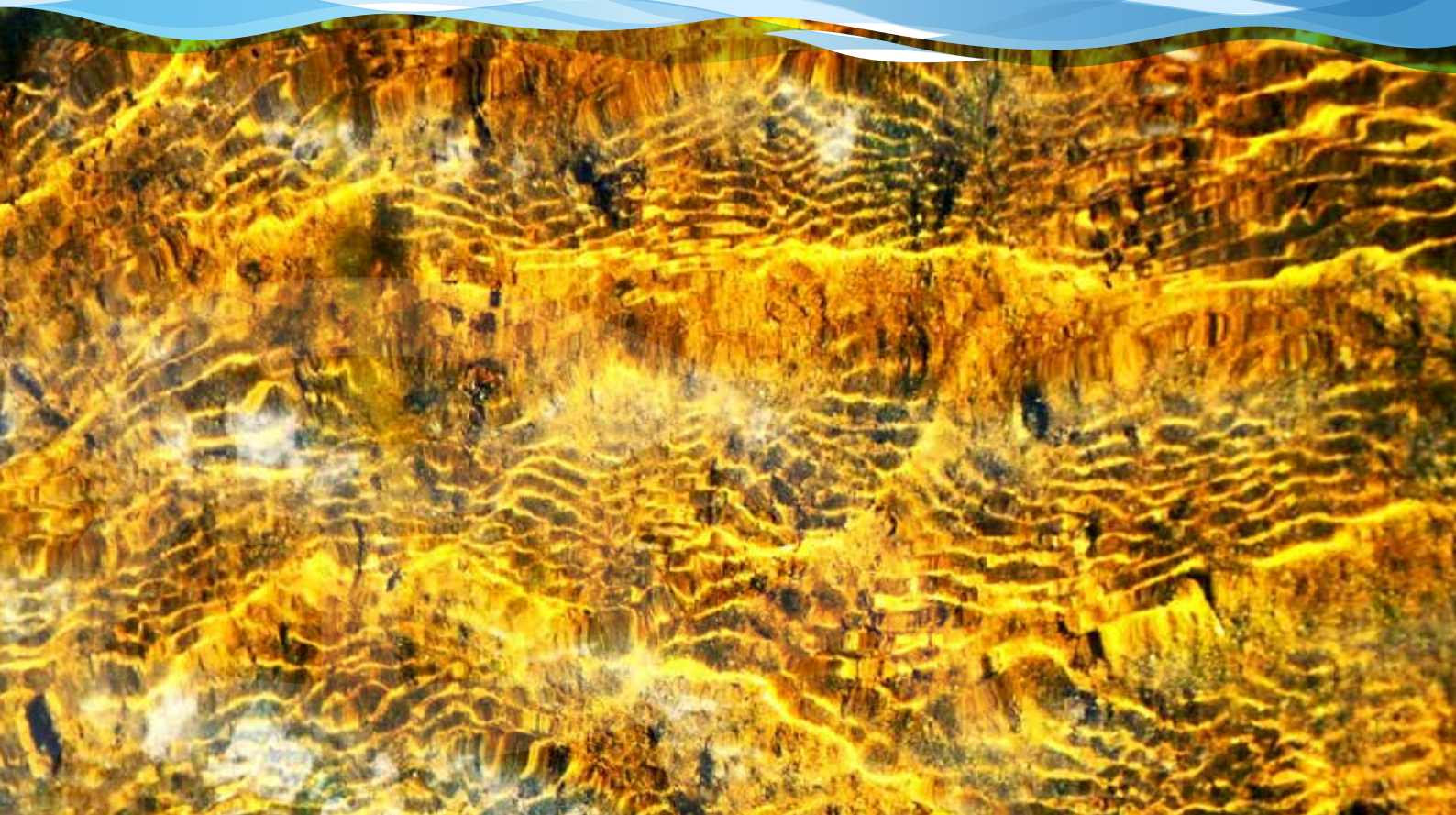


/Establishing the value of water

Water[5] services such as potable water delivery, wastewater disposal/treatment, and stormwater management are often under-priced or in some cases not priced at all. The costs of not having adequate water and sanitation are rarely calculated. Examples include the economic and social costs of sickness, death and reduced productivity caused by lack of adequate water and sanitation.

There are also elements of our water resource challenges that are not routinely priced, which are financially and/or socially costly. In addition, the complexities of them are not always understood, fully appreciated or valued.

For example, we know that over-pumping (mining) of groundwater aquifers with little or no recharge is an unsustainable practice with significant financial and social impact on future generations, but it is a practice that is still commonplace. Similarly, inefficient agricultural practices have significant financial, environmental and social costs that are rarely quantified or mitigated. Nevertheless, they are very significant considering that about 70% of the world's water demand is for agricultural use.

These factors contribute to the global community undervaluing the importance of the world's water. This report is intended to change this perception and in doing so increase the global community's understanding of the many water challenges we face and the importance of addressing them with more vigour.

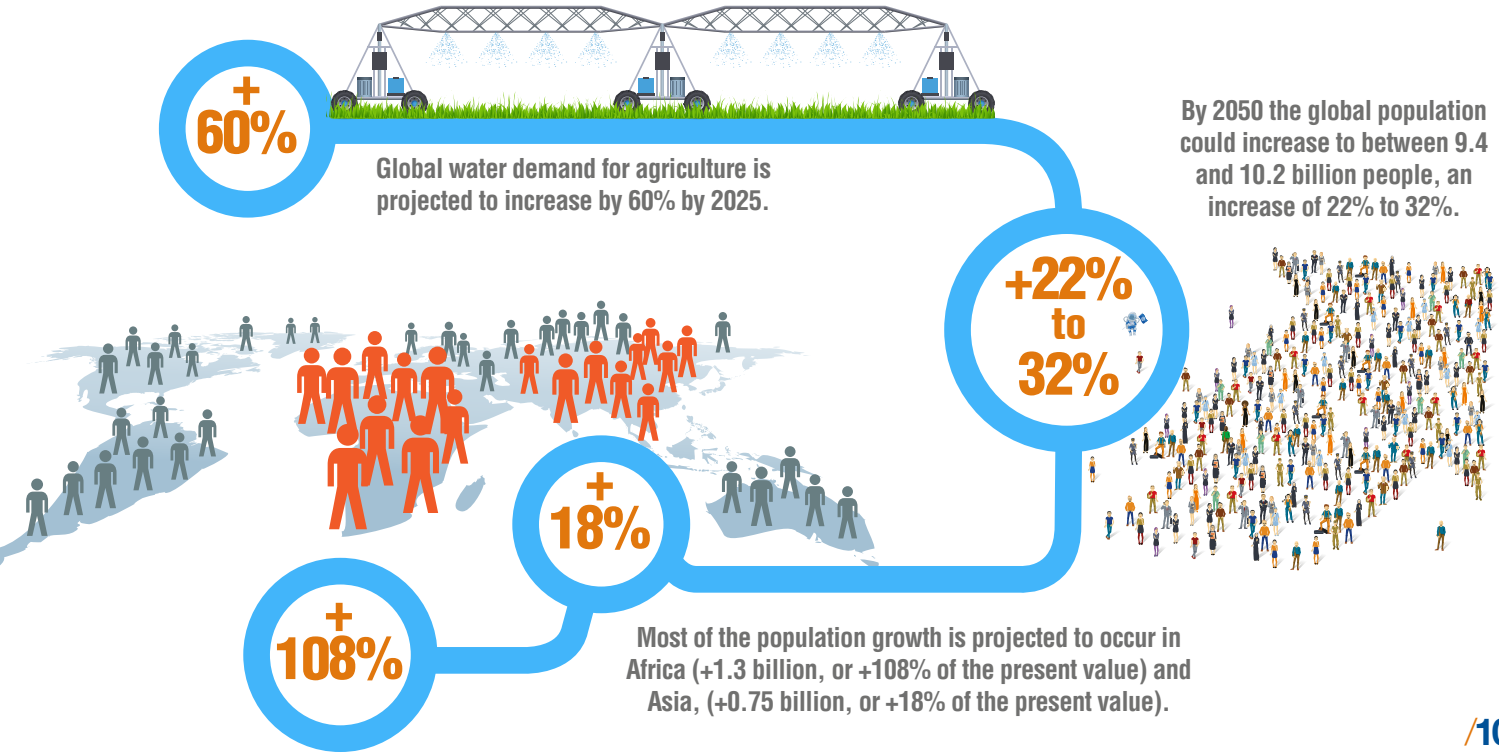
In areas of water stress and scarcity, the lack of access to adequate sanitation and the effects of pollution suggests that water issues should receive more attention, in an effort to make an economic case to generate investment and stimulate corrective action.

Conversely, in areas where water resources are abundant and there is reasonable access to sanitation and pollution control, the resource is often devalued, not fully appreciated or taken for granted, despite the important role it plays.

Global water demand

Increasing water demand follows population growth, economic development and changing consumption patterns. Global water demand (agriculture, industry, households, environmental flow) is estimated to have increased by 600% over the past 100 years[6], which is an annual incremental rate of 1.8%[7]. The present annual growth rate is less, at 1%, but this figure may be optimistic.[8]

Global water demand for all uses, presently about 4,600 km^3 per year, is forecast to increase by 20% to 30% by 2050, up to 5,500 to 6,000 km^3 per year. Some key items to consider within this are listed below:



This shows the potential scale of the issue and whilst these forecasts of future population and water demand are the best estimates available and there will be a degree of uncertainty, the direction of travel it would be fair to say is well established.[9]

Given the above, we can see that global water demand is expected to grow significantly over the next two decades, with changing technology for products, changing usage (green, blue and grey sources of water) and evolving demand profiles (agriculture, industry, households, environmental awareness) it will be important to monitor and understand such trends. It is, however, anticipated that agricultural demand will continue to be the largest component.

Prior to the Covid-19 pandemic, two-thirds of the world population was projected to live in cities. These projections of future population and water demand are the best estimates available although it is appreciated that such forecasts are uncertain.[10] It remains to be seen if this trend will continue in the post-Covid-19 world, especially in areas with good access to broadband where working remotely becomes more accepted.

Unfortunately, regardless of the accuracy of the projections, the current situation indicates that 2.7 billion people experience at least one month of water scarcity a year.[11]

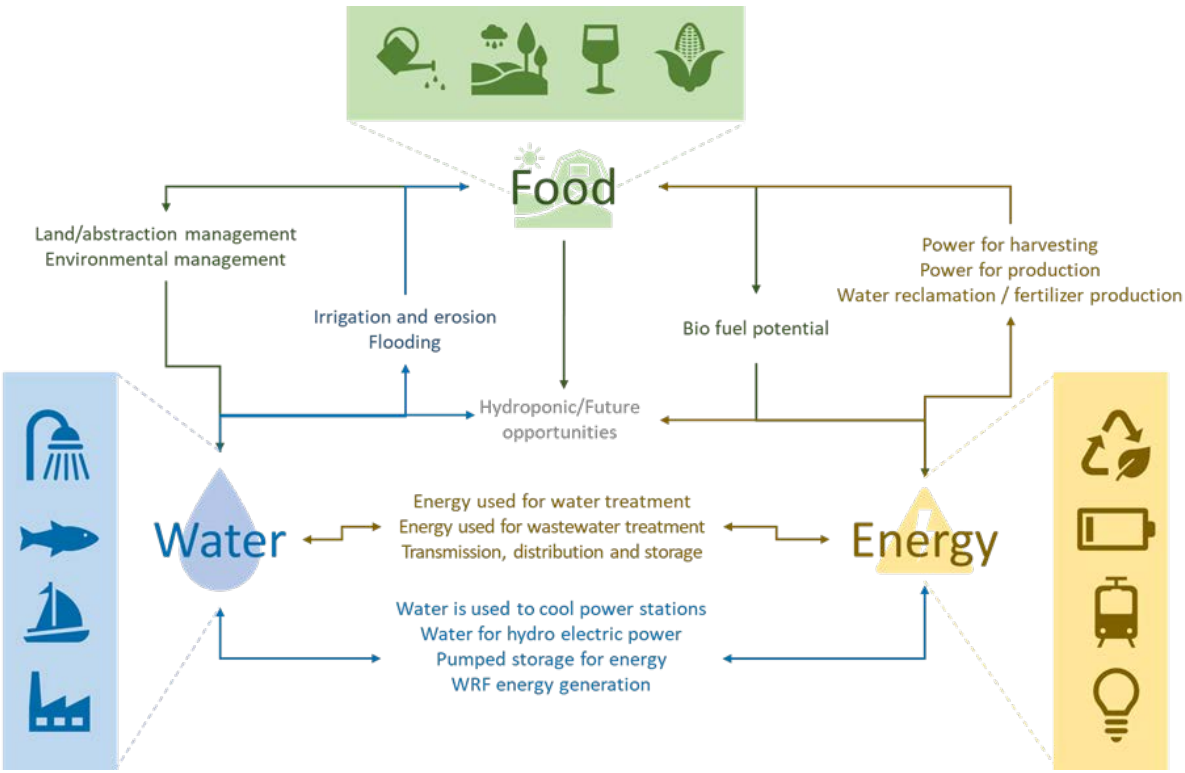
This leaves several fundamental questions. Who is going to pay for our water needs? How are we going to supply them? How do we ensure that solutions are sustainable? How do we establish the true value of water? All these questions lead us to continue to consider the food-energy-water nexus, which has likely become even more significant since FIDIC's 2015 report.

The food-energy-water nexus

As noted in the 2015 report, energy and food requirements contribute to the growing demand for water resources and therefore create an enormous impact on water challenges. Thus, we need to recognise the food-energy-water nexus.

The graphical representation of this nexus below shows how, food, energy and water activities are all linked via a complex web of activities which to a large extent are dependant upon each other for success.

Food-energy-water nexus



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 by-products 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.[12]

Growing populations, increased wealth and the need to provide energy and food to this growing global population, results in increasing the demands for both.

A paper published by the World Bank in 2017[13] explored economic growth, convergence (the phenomenon of per capita income in poorer countries increasing faster than that of wealthier countries) and food demand/supply, considering the global population rising to nine billion by 2050 (approximately 7.4 billion currently). It was found that accounting for higher production costs associated with dietary upgrading and increased demand growth per capita is likely to be a more important driver of food demand than population growth. It states:

"Using the middle-ground International Institute for Applied Systems Analysis Shared Socioeconomic Pathway projections to 2050, which assume continued income convergence, the paper finds that the increase in food demand (102%) would be roughly a third greater than without convergence (78%). Since the impact of convergence on the supply side is much more muted, convergence puts upward pressure on world food prices, partially offsetting a baseline trend toward falling world food prices to 2050."

Equally, at the same time, China and Africa, which account for approximately a third of the world's population, are increasingly linked, as China invests heavily in securing food and mineral resources, all of which will require the use of or investment in energy assets,[ix] most of which require fresh water. The loss of such supplies and the economic and social impact on human life and food production would be significant.

This demonstrates how the rate of growth, especially in China and India, is driving increased demand for meat, eggs, and dairy, boosting pressure to grow more corn and soybeans to feed more cattle, pigs, and chickens.

The problem is compounded across the globe by an increasing demand for water intensive foods in our diets and inefficiency or behavioural traits. For example:

In sub-Saharan Africa food losses add up to $4bn annually and the majority of food loss happens between harvest and the point of sale - very little is wasted by consumers after purchase.[5] Whereas, in more developed countries a larger proportion is due to food waste. In the USA for example, food loss and waste account for between 30-40% of the food supply.[6]

As noted in FIDIC's 2015 *State of the World* report, the demand for meat has tripled in the last 40 years and the demand for eggs is up seven-fold. The water footprint for beef is estimated at 15,400 litres per kilogram. The water footprint for one egg is 200 litres. Thus, pressure is occurring broadly across a wide source of food sources. This pressure will likely continue going forward.

As is demonstrated by the above, the relationship between food, water and energy is significant and it is important to understand how all three interact.

Going forward, improvement in drop-per-crop values, less waste, better decisions on what to grow and where to grow it, indirect water reuse including rainwater harvesting, grey water and recycled water for activities that do not require potable quality, could all reduce agricultural water demand per unit of food.

The key is having an integrated and holistic approach to how water is treated and used for its optimal outcome given the economic and environmental cost of doing so. Without such activities we are risking increased water stress along with the associated economic and public health impacts.

When a scarce resource is bought and sold in a market, the price per unit will increase as scarcity increases, either because of greater demand or lesser supply. However, because significant political, societal, and individual driven factors, the most important of which is it's importance to the health and wellbeing of our global population, influence the price of water, the market price cannot often be used as a bellwether of scarcity or value. This means the price of water may not be sending the right signals to water resource users and managers.

To paraphrase that economic proverb: "Diamonds are rare and expensive, water less so and comparatively cheap but you cannot drink, bath, grow crops etc. using diamonds!!"

Establishing value - potential economic losses in the water sector

It is beneficial to look at pricing practices for water services, since there often is room for improvement and since under-pricing such services negatively impacts the perception of value, potentially leading to a shortage of available funds to meet operation, maintenance and appropriate expansion needs.

Many water systems around the globe are managed under various regulatory regimes and yet often large amounts of water are wasted whilst water stress and scarcity are increasing. Whilst it is important that core infrastructure is built and managed in an incremental, interdependent and holistic way to avoid duplication of expensive assets, there is a case to be made for infrastructure to be delivered where direct consumer benefit is either improved or could be delivered faster and better outside of inflexible regulatory regimes.

Those entities responsible for pricing potable water and sanitation services are faced with a dilemma. They need to develop pricing structures that ensure access to all while also providing adequate funds to operate their facilities effectively and allow for operation, maintenance, and expansion as appropriate. Fortunately, to assist professionals in establishing water rates, many regulatory agencies have provided guidance regarding affordability, often reflected as a percentage of income.

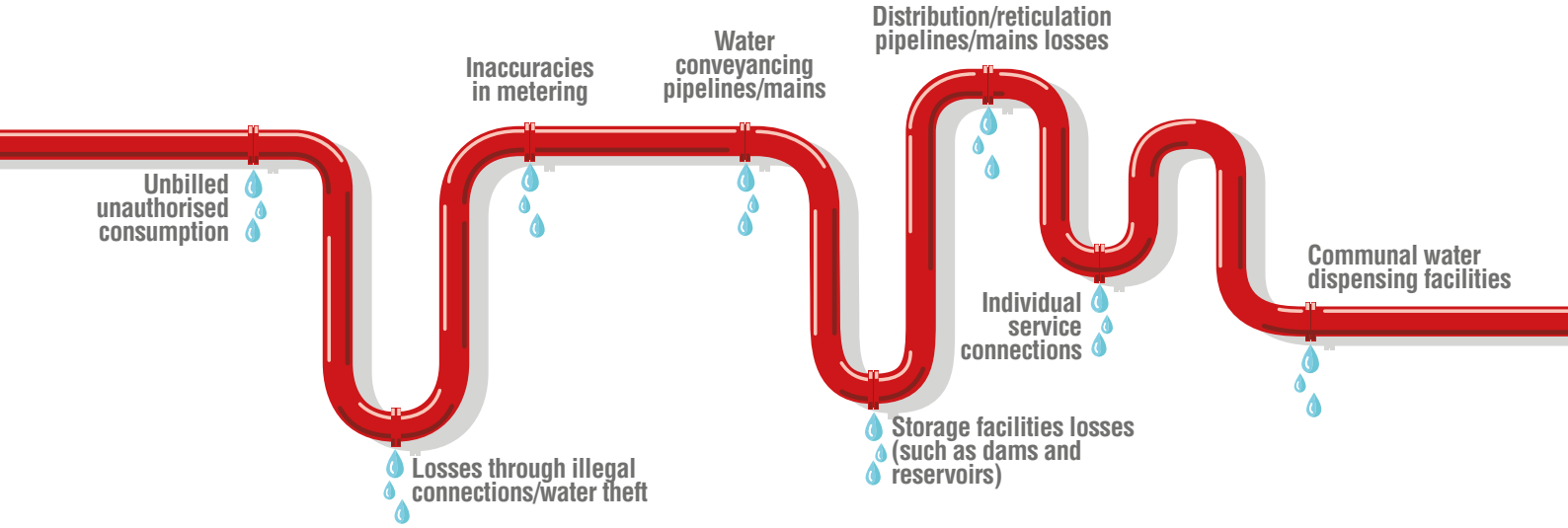
For example, in the USA, charges for water and wastewater services should be no greater than 4.5% of household income. Such guidance also recommended parameters for the cost of service, maintenance, risk (such as the risk of droughts), rehabilitation and/or expansion needs. These can be quite helpful in addressing the need to provide reasonable service access to everyone while collecting sustainable revenue.[17]

There are many examples of "cost of service and/or rate studies" being conducted around the world annually. Many water and wastewater utilities either by law/regulation or by practice depend on them to establish charging practices. The most sustainable rate structures include reasonable amounts for operation, maintenance, rehabilitation and/or expansions of the asset in the future.

Decisions related to the pricing of water services are becoming more complex since these activities are often influenced by the regulatory environment and the nature of the entity providing the service (municipality, public or semi-public commission, public or semi-public authority, private company, public-private partnership, franchise, etc.). Whilst models vary across the world, the requirements of the emerging countries and developed countries broadly fall into the need of infrastructure to begin with or, alternatively, the issue of replacing existing infrastructure and avoiding a potential cliff-edge.

The considerations in whole lifecycle costing are aptly demonstrated on water infrastructure projects where the tariff charges to consumers are driven by a complex set of factors that need to balance a high level of service, quality (for health and safety reasons) and demand in the volume of water required and conveying the resource to where it is required.

Non-revenue water (water that has been produced and is lost before it reaches the customer) is a key[18] driver in the pricing conversation. Losses can equate to a significant amount of water production through:



In developing countries, losses also occur but water and behaviour around its use will be much more focused on utilisation and reducing wasteful usage given the need for water to stretch further. As has been discussed, however, whist water loses will be minimised once used for growing crops etc, there are then significant losses as a significant proportion of food does not make it to consumption.

The above demonstrates that whilst the water losses occur in different ways, what does this inefficiency mean for pricing, investment etc, and the wider understanding of the value of water? For example, once used to grow crops (that are never consumed or wasted) or for in the production of energy for homes (where we don't use the most efficient appliances), do consumers see these losses not only in terms of the value of the food or energy lost but also in terms of the loss of value of the water used to produce it? This can seen both in terms of its monetary value or opportunity cost (what else could we have used the resource for?).

To understand rate setting decision-making and the complexities of determining the social value of water, we can look at the example of Latin America and the Caribbean. Almost 90% of the water utilities surveyed in a recent study by the Inter-American Development Bank (IDB) had adopted an increasing block tariff scheme.[19] Under this scheme the price of water increases as each consumption block is exceeded with the objective of penalising excessive water use.

This model has offered multiple benefits but is not without its drawbacks. The IDB report notes low-price elasticity in drinking water demands, so that schemes that penalise high consumption are not always effective in ensuring optimal use. A social problem to be considered is that households with fewer resources are often those with the greatest number of cohabitants and, therefore, are the ones that require a greater volume of water to meet their basic needs.

There is also a high use of cross-subsidies in the region. This strategy consists of raising the price for higher-income users to be able to charge less to users with lower incomes, without incurring losses. In other words, through cross-subsidisation, wealthier consumers indirectly finance those with lower salaries.

While appropriate tariff structures must continue to play an important role, there are other measures to be taken. The IDB report emphasises that to achieve economic sufficiency of water systems, i.e. to obtain revenues to cover all costs, it is essential to reduce the levels of non-revenue water. Efforts must be devoted to operational aspects such as reducing leaks in the systems, limiting water consumed illegally or improving the levels of micro-metering of consumption.

The European Union introduced a disruptive approach in 2000 through the Water Framework Directive (WFD). This legal instrument included a wide range of economic concepts aimed at improving water resources management with the objective of achieving good ecological status of all water bodies.

Specifically, Article 9 of the WFD requires member states to take account, not only of the principle of recovery of the costs of water services, including environmental and resource costs (ERC), but also of the use of water pricing as an instrument of environmental policy. Water-pricing policies should provide adequate incentives for customers to use water resources efficiently, and thereby contribute to the environmental objectives of the directive.

The 20 years of WFD implementation have probably produced ups and downs. Quantification of ERCs has proven to be a complex task. It is a difficult concept to put into practice. A clear case is the non-consumptive water use, for example, for hydroelectric power generation or for cooling thermal or nuclear plants. These uses are rarely subjected to a detailed economic analysis, even though some of them alter the water regime of rivers and have a significant negative impact on ecosystems.

Some water uses have a low-price elasticity and, therefore, pricing instruments are less efficient. This is the case of the agricultural sector in water-scarce areas which are, paradoxically, the places where savings are most needed and where agricultural water demand can account for 80% of total demand. It has been found[20] that in water-stressed regions where irrigation modernisation programmes have already produced water savings, increases in the price of water have little effect on generating greater savings and, on the contrary, have a significant effect on farmers' incomes. It should, however be noted that price elasticity is to some extent relative across the various global nations and so whilst in theory it is a universal concept it can not be treated as such when discussing specific targets or circumstances.

Consequently, the European Environment Agency (2017)[21] formulated the statement that "water demand management strategies need to find the right mix of pricing and non-pricing instruments". Water tariffs are an important instrument for efficient management. In addition, they must be accompanied by governance instruments such as developing and implementing rigorous river basin management plans, limiting surface and

groundwater withdrawals with technical and scientific criteria, promoting good agricultural practices aimed at environmental compliance, establishing prohibitions and regulations to restrict the discharge of pollutants, encouraging the adoption of new technologies, promoting water rights markets where possible and improving monitoring and control.

While pricing water services can be complex and progress has been made, more needs to be done. The *United Nations Global Analysis and Assessment of Sanitation and Drinking Water 2017* noted that while countries have increased their budgets for water, sanitation, and hygiene at an average annual rate of about 4.9% over the last three years, 80% of countries have reported the increase is still insufficient to meet nationally defined targets for those services.

The above does not truly begin to represent the complexity of the water issue or the pricing mechanisms which could drive both investment and behaviour. The rationale behind this statement is that the above mostly considers the delivery of water at the highest quality (consumable) for the purposes of all uses. In reality, however, not all water has to be of drinkable/consumable quality and infrastructure could be developed to provide services using various grades of water.

In this connection there are many examples in both the developing and developed world of using utilise grey water systems for flushing toilets etc. or purple pipes and systems (recycled water) could not be used for irrigation and industrial purposes.

However, despite the above mentioned activity, reuse concepts have generally been under-utilised in the planning and development of water systems. Whilst economically there is an argument not to 'replicate' infrastructure to ensure economies of scale that are consistent with a natural monopoly, having infrastructure where you can provide water without the need of extensive treatment to get it to the grade of drinkable water is economically efficient, even though the market may not price it as such currently.[22]

This is specifically relevant for new systems as retrofitting is more difficult and expensive. Developing countries for example could learn from the mistakes of developed countries and the path they followed, where systems were built decades ago without a true appreciation of climate change, sustainability and use issues and the actual need for treatment.

If the infrastructure sector is to have a chance of meeting the SDGs it will not be done by simply repeating past trends and project profiles over and over. The sector and governments have to operate in the new space of a collaborative approach including well informed owners focused on an outcomes-based approach using skilled professionals such as engineers, economists and financiers.

Therefore, to meet the ambitious UN SDG targets, which aim for universal access to safely managed water and sanitation services and wider by 2030 (SDG Goal 6 and 14), countries need to use financial resources more efficiently as well as increase efforts to identify new sources of sustainable funding. This includes not only government and investors, but also companies undertaking their own environmentally and socially responsible corporate investments in their water systems.

The complexity of water systems is by its nature complex, the value of environmental systems is not often included in the price of water, leading to a trade-off between direct and indirect ecosystem services (e.g. between drinking water and instream flows for fish reproduction). The value of water in situ needs to be balanced against the value of water extracted for other uses.

The magnitude of the water challenge

It should, however, not be underestimated that the above is by no means the full extent of what needs to be done to meet the SDGs. Success will involve:

- Planning and following those plans (e.g. master plan).
- Required utility performance improvement planning.
- Analysis of staff capacity and if insufficient to rectify the capacity issues.

- Greater access to capital finance and adequate fiduciary controls over loans and grants.
- Durable approaches vs short-term fixes.
- Reductions in non-revenue water.
- Increases in female leaders in the sector.

The task is therefore not only about provision but all the aspects that connect into such activity. This demonstrates that this task is nothing short of a complex project on a global scale.

The identification of new sources of sustainable funding as well as providing proper oversight of those funds particularly in the developing world is, in our view, an enormous critical success factor. To engage such funding on a significant scale it is therefore important that all parties across the infrastructure sector including governments be transparent and clear about the credentials they require and the standards they expect.

As noted in FIDIC's 2015 *State of the World* report, the Organisation for Cooperative and Economic Development (OCED) estimated that $17.5 trillion was required for all water infrastructure needs by 2030, which is approximately 2% of the world's GDP. Another estimate developed via recent research by the World Water Institute group indicated that ensuring water for our societies by 2030 could cost just 1% of the world's GDP – about 29 cents per person per day from 2015 to 2030[23]. Regardless of the differences between these estimates, everyone should agree that the financial needs are large and are not currently being met.

The gap in funding is compounded by the fact that many facilities are approaching or have already exceeded their useful life and new facilities are needed to meet new requirements and/or expansion needs. These infrastructure needs include untreated or inadequately treated wastewater, combined sewer overflows, stormwater runoff, inadequate distribution/transmission systems, deteriorating watersheds and people without reasonable access to drinking water and sanitation.

According to the American Water Works Association, the top five issues mentioned by water utilities in their state of the industry report are renewal and replacement of aging infrastructure, financing capital improvements, long term water supply availability, public understanding of the value of water systems and services and watershed/source water protection.

The above, however, is not true of the entire globe. There are many countries where the replacement of aging infrastructure is not an issue because the actual development of infrastructure in the first place is the significant step that needs to be taken. Such infrastructure needs to be financed and built to provide clean water and wastewater services if we are to meet the SDGs.

It would be fair to say that if such developments do not occur there is no chance of meeting the SDGs and the infrastructure community would have failed. Water provision and all the targets that have been agreed are not just a developed world problem in 'upgrading' infrastructure, they are a social and human problem for so many countries around the world that need infrastructure.

Given the above and considering a more sustainable future, some targeted capital improvements while expensive now, could decrease or put in place systems where operational and environmental costs in the future are lower and more efficient.

When considering rehabilitation projects, engineers should evaluate techniques to provide additional services by the facility being renovated such as on-site energy generation. Such approaches are also being embraced by various regulators across the globe that are now shifting regulator regimes from capital intensive approaches to that of TOTEX (Total Expenditure), where the lifetime costs and essentially the elephant in the room is also considered.

Solutions to our water challenges are, of course, not simple and the decisions we have to make are complex. For example, Singapore has at its disposal desalination to support its drinking water supply. This is, however, very energy intensive and requires new technologies and innovation to become more sustainable in the future.[24] Fortunately, desalination and similar advanced treatment processes are becoming more cost effective.

Singapore also has schemes in place to collect and reuse water[25] where the NEWater process recycles treated water into high-grade reclaimed water. Today, there are five NEWater plants supplying up to 40% of Singapore's current water needs. By 2060, NEWater is expected to meet up to 55% of Singapore's future water demand. This is in addition to the treated water which it already imports from Malaysia

There are similar new and innovative ways being developed across the globe to address complex water issues some of which are still in their infancy. They are linking customer value and the environment with projects that can be delivered effectively. This is important since whilst regulatory regimes create certainty, they can disincentivise innovation as repetition, certainty and stability is favoured over such activity.

For example, in the United Kingdom, the regulator as part of its latest PR19 price control[26] has introduced a mechanism called Direct Procurement for Customers.[27] This mechanism allows companies to submit projects directly to the regulator which sit outside of their regulatory asset base (RAB) which is assessed every 5 years.

The approach to these projects is based on the HM Treasury 5 case business model and a TOTEX approach so that investments not only consider up front capital costs but also operational and maintenance costs alongside environmental and social benefits.

As such, this means projects can be delivered with private companies where the business case and benefit to customers can be demonstrated helping to minimise the swings in investment that occur under RAB models. This is an example of not only linking projects back to customer expectations but also reinforcing the value of water.

Similar steps towards greater innovation are also occurring worldwide. In Mexico, for example, there is a mechanism known as "Unsolicited Proposal" through which a private company can present to the government a proposal for the development of innovative and impactful infrastructure projects, to be executed under a PPP modality. This type of resource is employed mainly to promote energy, water and sanitation, transportation, and telecommunication projects.[28]

FIDIC, therefore, recommends that such mechanisms and the importance of customers should underpin the delivery of water, wastewater and environmental projects to a greater extent going forward.

This can be achieved through various methods. For example, in Melbourne, water retailers established a citizens' jury to help find a balance between price and a service which is fair for everyone. They provided a key input into their price submission to the regulator. Similarly, in the UK the implemented customer challenge groups are included as a mandatory part of companies' water and investment plans.

Such mechanisms help to bolster and create a value for water that will help to drive investment decisions that are also sustainable for years to come.

Considering the complexities associated with rate setting and the magnitude of our water challenges, FIDIC recommends that prices (i.e., rates/costs/prices) for water, wastewater, ecosystems and stormwater services be established with the assistance of qualified professionals and 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.

This would mean that projects would actively utilise strategies which consider a broad range of issues including:

- Minimising non-revenue water.
- Consideration of all elements of water, wastewater and stormwater as a resource and for beneficiation from waste.
- Use of resource efficient appliances, circular economy.
- Net zero and zero discharge initiatives.

These would all be driven by a better appreciation of the value of the water services.

/SOW2021

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

The value of water invested in products and food needs to be given far greater attention.

This report by FIDIC is the latest in a long series of important contributions to the global state of infrastructure. The report highlights the contribution that engineers can make against the background of the climate emergency and the imperatives of the sustainable development goals. Perhaps most importantly, there is recognition of the critical need for holistic engineering expertise to be deployed at the earliest stages of project identification and even before that, of programme inception, leading to projects that are more fully integrated with the spectrum of needs from technical and financial to social and environmental. Such comprehensive approaches are needed to meet the challenges not least in the water sector.

This drive for engineers to be more involved in the preliminary and strategic decision-making process leads to a need to rethink not just what it is to be an engineer, but also what education and training engineers need to receive. Engineers cannot fulfil their

wider role unless they are trained and educated more broadly to cover issues of governance, finance, social responsibility and environmental awareness.

Engagement with local communities is an important part of what needs to be done to broaden the base decision-making around the provision of water services. Additionally, the value of water invested in products and food needs to be given far greater attention (the concept of virtual water may be useful). Air miles have entered the public consciousness; a similar concept needs to developed for water embodied in goods and foods.

There needs to be clearer distinction between water that is needed but not consumed (such as a high proportion of cooling water in power stations) and water that is consumed in one location for the benefit of another location (such as food production).

Even by taking an integrated approach to water across the water/food/energy spectrum and looking at all aspects of water (green/blue/grey), there remains the challenge of holistically addressing how water is used, what for, and by whom.

A huge proportion of food grown in Africa is lost before consumption and even more shockingly much of the food delivered in richer countries is wasted. So the challenge for water charging may lie more in the charging of the products derived from water use than the charging for the water only at the point of abstraction.

In addition to the excellent elements in the report related to the value of and charging for water, we need to reinforce the benefits of not using water, driving down demand.

One aspect that a future report might address is a consideration of water quality where in many countries piped water is almost all of potable standard, whereas only a fraction needs to be treated to such demanding standards. There is real potential for dual supply systems to be greatly expanded internationally.

The report touches on the challenges of transboundary issues of water management both as blue water in rivers and as green water in transboundary aquifers. The issue of reducing mountain glaciers in the headwaters of some of the world's greatest rivers is acknowledged as a problem of immense proportions.

By preparing this report, FIDIC has once again fulfilled its role as a leading voice in global infrastructure.

/SOW2021

Natalie Muir
General Manager
- Water & Environment
Cardno

Reimagining our water future

Water supports life itself, it supports human health, our wellbeing and of course, it is vital for the environment. But what is the true value of water? Can you even place a value on something so precious?

Across society, water is valued very differently – where water is scarce, it tends to be more highly valued, conserved and appreciated. Where water is more plentiful (or where it seems more plentiful), it is often taken for granted, wasted and even hidden. Do our communities understand the real value of water? We need to shift the paradigm to ensure it is valued and managed in a manner that is sustainable, now and in the context of increasing demand and increased climate variability.

Value is one thing – cost is another. The cost of treating and distributing water and collecting and treating wastewater is not insignificant. Goal 1 under SDG6 sets a target that, “by 2030, achieve universal and equitable access to safe and affordable drinking water for all”. This means that the necessary infrastructure needs to be provided at a cost that is affordable to the people that it services.

This cost is not always proportionate. Those in regional and remote communities, indigenous communities and developing nations have less capacity to pay than their city counterparts, yet the challenges of water security are often greater and may require a higher investment to resolve.

Water and sanitation are viewed as basic human rights, yet 2.2 billion do not have access to safely managed drinking water, and 4.2 billion people lack safely managed sanitation.

In cities and towns that do have access to a safely managed supply, water security is a significant issue, with many facing a looming water crisis. “Day Zero” in Cape Town was narrowly avoided as the “city was just 90 days away from turning off the taps”. Chennai, India’s sixth-largest city, hit Day Zero in 2019. In Australia, some rural towns have had to truck in water for an extended period to secure their supplies. Climate variability is likely to mean that water security issues will only increase.

Significant investment is required to achieve SDG6. This investment is in addition to the costs of maintaining and operating existing infrastructure, a large proportion of which is coming to the end of its useful life and requires renewal or replacement.

It is our role as consulting engineers to work with governments, regulators, and water agencies to solve this conundrum – how do we provide water for all at a price that is affordable to all?

As an industry, solving this puzzle will mean ensuring that all options are on the table when developing sustainable water solutions (including alternative water sources such as stormwater and potable recycling). It will draw on our innovation and our ingenuity to ensure that fit for purpose solutions are developed that ensure the long-term sustainability of communities.

There are already some great examples of sustainable water practices and solutions across the world, from high technology treatment solutions, to green infrastructure, biomimicry and also programmes supporting basic water and sanitation in developing nations. But there is still much to be done.

The UN *Sustainable Development Goals Report 2020*, notes that “unless rates of progress increase substantially, Goal 6 targets will not be met by 2030”. Access to water, sanitation and hygiene has become even more important during the Covid-19 pandemic to help contain the spread of the virus. To progress the SDG6 goals, improvements in agricultural water productivity are needed, transboundary cooperation is needed and funding commitments need to increase.

Water is also intrinsically linked to so many of the other goals – poverty (goal 1), zero hunger (goal 2), quality education (goal 4), gender equality (goal 5), affordable and clean energy (goal 7), sustainable cities (goal 11), responsible consumption and production (goal 12), climate action (goal 13), life below water (goal 14), and life on land (goal 15). It is therefore imperative that we truly understand the value of water and the investment required to provide affordable water and sanitation for all. This *State of the World* report outlines the challenge.

The challenge is huge. Partnerships are critical (goal 17). It will require continued innovation and technological advancement from the engineering community.

Together, we can reimagine our water future.

International Federation of Consulting Engineers
The Global Voice of Consulting Engineers

Water challenges which are not routinely priced, but which have large financial and social costs

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Water challenges which are not routinely priced, but which have large financial and social costs

Many of the world's potable water challenges are often a mismatch between water demand, water supply and the need to maintain public health. The causes of this mismatch are many and include but are not limited to:

- Rapid population growth, particularly in cities and informal settlements of the developing world.
- Ageing and deteriorating infrastructure.
- Lack of access to capital finance.
- Non-durable investments, requiring repeat and similar investments not far into the future.
- Insufficient human capacity.
- Lack of organisational and individual accountability.
- Poor planning and adherence to plans.
- Lack of fiduciary oversight of loans and grants.

It should be noted that lack of adequate sanitation or sufficient stormwater management can be caused at least in part by the above as well. The good news is that, except for population growth, all of the above can be addressed. There are workable solutions to each 'cause' and many organisations working on these solutions, with varying degrees of success.

Help for those without reasonable access to drinking water and sanitation

For many years, various entities have noted the insidious problem of millions of our fellow global citizens without reasonable access to drinking water and/or sanitation. While some progress has been made, the problem is a growing concern, exacerbated by the Covid-19 pandemic and the subsequent economic downturn that has ravaged informal segments of various economies that remain the lifeblood of these vulnerable communities. It is therefore important that decisive action is taken to resolve this situation as soon as possible.

1) Governments should commit to eliminating the problem of so many people not having access to adequate drinking water and twice as many lacking adequate sanitation.

2) Governments should commit to eliminating water-borne diseases that impact millions of people, especially children every year.

To do the above, stakeholders must ensure that they understand the magnitude of the problems and the risk that climate change will exacerbate both. This report discusses the business case for improvements and increased sustainability, but much of the theory around the business case for sustainability is based on the experiences of existing water systems.

As mentioned above, there is a large proportion of the globe where infrastructure is needed to meet the SDGs as a starting point. That is a very different business case. Governments and societies across the globe need to create a desire to address the issues raised as part of the SDGs to meet basic human needs (drinking water and sanitation).

The rationale behind such important commitments becomes clear when you look at some of the statistics below.

Over two billion people live in areas having excess water stress.[29]

By 2050 nearly 5.7 billion people will face water scarcity.[30]

In 2015 there were 667 million urban residents without 'at least basic' provision of sanitation – an increase of over 100 million people since 2000.[31]

1.4 million children die every year due to preventable diarrheal disease.[32]

1.8 billion people drink contaminated water.[33]

Every $1 invested in improved water and sanitation yields a social return of between $4 and $12.[34]

Water challenges which are not routinely priced, but which have large financial and social costs

The developing world therefore faces a very different set of issues to that of developed countries where there is existing infrastructure, and as such just applying the economic and business case of the past will not be sufficient.

For example, where institutions and systems are less developed the world has seen individuals and households in societies effectively turn themselves into mini utilities, providing these services to the extent that they can afford. To some extent, whilst coordination and centralised systems are needed, embracing such change, such as the change that occurred with the advent of the likes of Uber, would help to enable the delivery of water and wastewater services.

This model whilst very different from the model that was rolled out in developing countries should not be underestimated and it is the role of engineers and professionals to assist the development of such models to ensure that they not only help to supply the needs of those in need but also can be as sustainable as possible.

This would help because there is a direct link between hygiene and the fight against Covid-19. Inadequate supply and interruption to supply of water and sanitation services have a detrimental impact on communities, particularly those in informal settlements and slums, so our systems need inherent resilience. Solutions to these problems include reviewing our infrastructure system through the lens of mitigation and adaptation to climate change.

This includes the use of more robust and sustainable materials, construction and operational methods and embracing nature-based solutions where we design for working with nature instead of contrary to how nature works and the adoption of innovative financing mechanisms to deliver water despite the weak business case for such.

Ocean challenges and extreme weather

It is estimated that sea levels have risen about eight inches since 1900 and three Inches since 1993. By 2100 sea levels could rise one to four feet and an eight-foot rise cannot be ruled out by that time[35]. We are already seeing evidence of the impacts of sea level rise such as 'sunny day flooding' discussed later in this report.

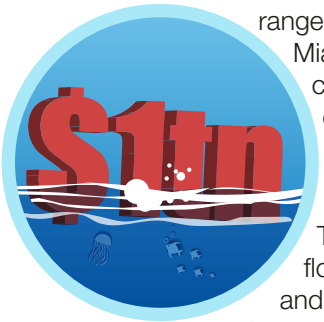
The pH of our oceans has been relatively stable for millions of years at around 8.2. Since the industrial revolution, however, it has dropped to about 8.1. This sudden rate of acidification is unparalleled in 66 million years and has a long-term impact on marine life. For example, crustaceans are experiencing a softening of their shells due to ocean acidification.).

Water challenges which are not routinely priced, but which have large financial and social costs

The last 115 years have been the warmest in history. The American National Oceanic and Atmospheric Administration estimates that the average surface temperature of our oceans has risen by about 0.9 degrees ºC. According to NASA[36], 2020 tied with 2016 as the hottest year on record for the planet. Ocean warming is impacting wildlife as well. For example, hake and herring are migrating out of the rapidly warming Gulf of Maine, eliminating a food source for several birds native to the area.

In recent years we have seen an increase in the frequency of extreme weather events globally. Extreme weather events affect water supply and sanitation systems. Availability of water and an excess of water after extreme weather events ultimately affect the price of water and the cost of infrastructure to address these challenges.

According to the United Nations, "Globally, the market value of marine and coastal resources and industries is estimated at $3 trillion per year or about 5% of the world's GDP, and an estimated 63% of global ecosystem services are provided by marine and coastal systems."[37]



As noted in FIDIC's 2015 report, due in part to projected sea level rise, the potential economic losses in 2050 if an extreme weather event overwhelmed protective structures around some coastal cities could range from $95bn in Ho Chi Minh City, Vietnam to $250m in Guangzhou, China, to more than $275bn in Miami, Florida, USA.[38] It is sobering to note that 40% of the world's population live within 100 miles of a coast. Indeed on a global scale, by 2050, without upgrading protective systems, damages to coastal communities due to flooding and storms could approach $1tn.[39] In the United States, the Federal Emergency Management Agency expects the number of flood insurance policies to increase in the future as well as the loss per policy[40].

The OECD estimates that by 2070, 150 million people and $35tn in property will be at risk of coastal flooding[41]. "In the coming decades, the World Bank predicts rising seas could invade major river deltas and generate salinity intrusion that will impact some of the world's richest agricultural land".[42] Property damage and deleterious impact on wildlife and the environment will be significant.

Several island nations such as the Maldives are extremely concerned about sea level rise which has the potential of inundating much (possibly all) of their land. Sea level rise and global warming is subjecting them to escalating tides, cyclones, flooding, damaged crops, and health concerns. The consequences could include economic loss and population migration.

Research published on migration and climate change in Latin America and the Caribbean[43] mentioned that studies from Saldaña-Zorrilla and Sandberg (2009) measured the influence of floods, storms, hurricanes, droughts and frosts on migratory phenomena in Mexico from 1990 to 2000. The results of their multivariable analyses show that, all other things being equal, an increase of 10% in the frequency of natural disasters results in an increase of 5–13% in migration, depending on the affected region.

Other studies[44, 45] confirm that, in the Chiapas region, Hurricane Mitch (1998) and Hurricane Stan (2005) were triggers among economically vulnerable populations for the decision to migrate. Wrathall's[46] offers a refinement of this result, affirming that, among vulnerable populations, the most economically disadvantaged often resort to migrating within their country".[47]

Plastics

Plastics have benefited humans in many ways, but not without negative environmental consequences. The indiscriminate disposal of plastics is having an increasing insidious impact on our waterways and drinking water.

In addition to the obvious floating and clogging problems caused by this disposal, plastic breaks down over many years into microplastic which is being ingested by aquatic creatures (thereby impacting the food chain) and end up in drinking water supply systems and even in bottled water. In fact, recent research by the WHO suggests that microplastics can be found in 90% of bottled water.[48]

Concerns are increasing about microplastics and micro resins. They are being found in virtually all our oceans and as noted above, they are likely entering the food chain as they are being ingested by aquatic life. There is uncertainty about their impact on health.

Water challenges which are not routinely priced, but which have large financial and social costs

The infamous 'Great Pacific Garbage Patch', which contains carelessly disposed floating debris consolidated by ocean currents and other phenomena, is perhaps the most well-known and certainly the most visible example of the plastics problem. Microplastics are prevalent in the 'patch'. They may also be settling below the surface perhaps exacerbating the food chain entry problem.[49]

As the issue of microplastics continues to evolve, the AWWA's emerging water quality issues committee is committed to disseminating the most relevant and up-to-date information to build institutional knowledge of this important topic throughout the water industry.[50]

Other oceanic and fresh water impacts due to climate change

The World Meteorological Organisation secretary general Petteri Taais has stated that: "If we do not take urgent climate action now, then we are heading for a temperature increase of more than three degrees Celsius by the end of the century, with even more harmful impacts on human wellbeing. We are nowhere near on track to meet the Paris Agreement target."

One climate model predicts that the number of extreme rainstorms worldwide will double with each one-degree Celsius increase in global warming[51].

Some predict a possible lack of Arctic Ocean ice in "future Septembers" after 2040.

Coral reefs are being damaged or destroyed by bleaching, rising sea levels, reduction of photosynthesis (light penetration) which are negatively impacting marine life (Life below water SDC 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. An article in the *Maui News*[52] addressed the many benefits of coral reefs, as follows:

"Beneath the ocean's waves, coral reefs reign as ancient, complex and living ecosystems that are often called the rainforests of the sea. Like tropical rainforests, coral reefs provide life and habitats for an array of plants and animals.

"The underwater seascape (hosts) schools of colourful reef fish, coral colonies with parrotfish … and eels slithering in and out of sight.

"Coral reefs are believed to be the world's most biodiverse ecosystem, even more so than tropical rainforests, but both are cornerstones to our planet's health. Approximately 6% of the world's land surface is covered by rainforests with more than 50% of plant, animal and insect species living within these ecosystems. In comparison, less than 1% of the world's marine environment is occupied by coral reefs, yet these ecosystems provide homes to over 25% of known marine species."

Water challenges which are not routinely priced, but which have large financial and social costs

Around the world, many of the largest, most colourful coral gardens have gone "tombstone grey".[53] The worst bleaching on record was triggered in 2014 by ocean warming and acidification caused by greenhouse gases[54] and then exacerbated by El Nino in 2015.[55]

The United Nations Office of Disaster Risk Reduction released a report[56] after COP1 in November 2015 which stated that between 1995 and 2015 flooding accounted for 47% of all weather-related disasters, an estimated 600,000 people lost their lives and 4.1 billion people were injured, left homeless, or in need of emergency assistance because of weather related activities and the economic losses of 36% of weather-related disasters are estimated at $1.89 trillion.

The World Water Institute estimates that one quarter of the world's population live in countries facing extreme water stress; and there are over 500 dead zones in our oceans due to untreated wastewater. Scientific America reported the top ten climate stories of 2019[57] as:

1) Second warmest year, warmest month, and warmest decade on record globally.
2) India's wettest monsoon in 25 years replenishes reservoirs but kills 1750 people.
3) Near record melting of Arctic sea ice.
4) The long-feared permafrost carbon bomb may be exploding, says NOAA.
5) Near record melting of the Greenland ice sheet contributes 20% of global sea level rise.
6) Second strongest Atlantic hurricane on record-Dorian- ravages the Bahamas'
7) Tropical cyclone Idai kills 964 people – the southern hemisphere's third deadliest tropical cyclone on record.
8) Australia's apocalyptic fire season
9) Typhoon Hagibis – Japan's second most expensive typhoon in history ($15bn), and
10) Flooding from the wettest year in US history costs over $15bn

A vicious cycle is perpetuated as these climatic factors increase pressure on the ability of countries to raise capital for infrastructure development as these uncertainties increase project risk, the cost of insurance and the cost of finance. Ultimately, they impact the determination of tariffs for services that are limited by the affordability of consumers to pay for them.

Wetlands, mudflats and seagrass

The substantial value to our wellbeing provided by wetlands and saltwater marshes was discussed in FIDIC's 2015 report and, for the most part, will not be repeated here. As noted above, sea level rise and global warming are having an increasing impact on shoreline communities, wetlands, and saltwater marshes. This is exacerbating flooding problems due to increasingly intense storms and the diminished ability of saltwater marshes and wetlands to mitigate the impact of storm surges and flooding. It is also reducing the world's capacity to capture carbon before it is discharged to the atmosphere as a greenhouse gas.

Research about the coastal zone of Quang Nam province in Vietnam[58] describes the benefits of coastal dunes, mangroves and other natural ecosystems provide around the world.

In the coastal zone of Quang Nam province in Central Vietnam, natural ecosystems such as coastal dunes and mangroves can serve as natural buffers against typhoons, storm surges, waves, and even small tsunamis and protect the shoreline from coastal erosion and sea level rise.

Apart from these protective ecosystem services, intact dune and mangrove ecosystems perform various other regulating services, such as carbon storage and sequestration and groundwater protection, as well as a variety of provisioning and cultural services. Moreover, they support a high biological diversity, which forms the basis for secure livelihoods of coastal communities. However, important ecosystem functions and services have already been lost or diminished due to overexploitation and a lack of integrated coastal management.

Water challenges which are not routinely priced, but which have large financial and social costs

Water quality issues including contaminants of emerging concern

This issue is very much one of two halves. For those that don't have the infrastructural facilities in place, especially in the developing world, the importance of putting in place infrastructure to treat water and wastewater is a significant and life-threatening issue. Whereas, in countries where infrastructure is in place the United Nations and others have noted the very high percentage (perhaps 80%) of wastewater discharges to the world's waterways with inadequate treatment or no treatment at all.

Considering the vast and advanced technologies that exist to combat these problems, there are two substantive issues. Where infrastructure doesn't exist how do we ensure it is there to meet the SDGs and where it does exist it needs to be operated/maintained/invested in a sustainable manner. The gap in infrastructure spending requirements vs actual expenditures implies that in some instances the latter is not the case. Addressing both of these problems more effectively needs to be prioritised.

FIDIC's 2015 report mentioned the enormous challenge of natural and manmade contaminants in our waterways and wastewater streams. At the time, we stated that the US EPA had identified over 87,000 contaminants of emerging concern. Since that time, more concerns have emerged, such as polyfluoroalkyl substances (PFSAs) and microbeads.

As noted above, more than 80,000 synthetic organic chemicals are used daily in domestic, commercial, or industrial applications[i]. These chemicals are designed to improve our quality of life in a number of ways by increasing the global rate of agricultural production (e.g., pesticides), protecting human and animal health (e.g., pharmaceuticals), improving hygiene (e.g., personal care products), or advancing industrial production (e.g., plasticisers).

The lifecycle of these chemicals, however, often results in their accumulation in the environment, with many of the more polar chemicals now known to occur globally in surface and groundwater resources.[ii] Further, once in the environment, these chemicals can undergo a variety of photocatalytic, chemical, or biological transformations that yield a suite of transformation products.[iii] Collectively, these parent chemicals and their transformation products are classified as chemicals of emerging concern (CECs).

The occurrence of CECs in water resources is predicated on the notion that exposure to them poses a significant risk to aquatic ecosystem or human health. Despite this, toxicological data are limited relative to the large number of CECs known to occur in the environment. The reason for concern with respect to exposure to these chemicals is supported by the following examples.

First, a large number of CECs are designed to be bioactive chemicals (e.g., pesticides, pharmaceuticals) targeting specific biological receptors. It is not unreasonable to assume that these types of CECs have biological effects.

Second, although individual CECs are generally reported to occur at very low concentrations (of the order of µg/L or lower) in the aquatic environment,[iv] the emerging view is that complex mixtures of environmentally relevant concentrations of CECs can lead to developmental or genotoxic effects.[v]

Third, for the small subset of chemicals that have been rigorously studied with respect to toxicity, there have been reports of significant developmental, reproductive, endocrine disrupting, and other chronic health effects. [vi],[vii],[viii] [ix], [x]

Finally, there is a growing body of evidence that shows that chemical or biological transformation of a parent CEC does not always abate the risk associated with the parent chemical[xi]. There are many examples of transformations that result in transformation products that are as or more toxic than the parent CEC[xii],[xiii].

Drinking water and wastewater treatment processes developed for the removal of CECs focus on either the targeted removal of a specific CEC or the untargeted removal of multiple CECs with diverse chemical structures. Targeted removal of a specific CEC is often more practical for wastewater or drinking water utilities experiencing the occurrence of a specific CEC with excessive frequency, in excessive concentrations, or one that is known to pose a significant risk to aquatic ecosystem or human health.

In this case, a specific physical, chemical, or biological treatment process could be designed and optimised based on the physicochemical properties of the target CEC. For example, drinking water utilities faced with per- and polyfluoroalkyl substances (PFASs) in their source water are more frequently turning to activated carbon adsorption to remove PFAS during drinking water treatment.[xiv]

Research on the most beneficial approaches to the treatment of CECs is ongoing. At present, it generally appears that the best options have been identified as advanced oxidation or powdered activated carbon followed by ultrafiltration.[xxxii] These techniques have been adapted at wastewater treatment plants in Switzerland to meet recent surface water quality standards targeting broad groups of CECs.[xxxiii],[xxxiv]

There is growing concern over the occurrence of CECs in the aquatic environment. New analytical techniques are constantly being developed to discover countless numbers of CECs in wastewater treatment plant effluents, surface and groundwater systems and even in drinking water.[xxxv],[xxxvi]

In addition to the groups of CECs this report has discussed, there is emerging interest in microplastics,[xxxvii] natural toxins formed by algae blooms,[xxxviii] and new types of disinfection byproducts formed from unconventional disinfectants or source waters impacted by anthropogenic activities.[xxxix],[xl]

Water Supply/Scarcity

Water scarcity is reportedly now one of the top five potential disasters in terms of impact in the World Economic Forum's *Global Risk Report*. The World Economic Forum's fifth most significant risk globally is a water crisis. Unfortunately, this risk is increasingly coming to fruition.

As noted earlier, the City of Chennai, India, experienced a "Day Zero" recently due to drought, population growth and deterioration of their water supply. Drinking water was transported to the city via rail, then distributed in the city by tanker trucks to people who often waited hours for the trucks to arrive[59]. Cape Town, South Africa, came close to a "Day Zero" a couple of years ago signalling what is the start of worrying levels of water scarcity and quality concerns across the water-stressed southern African country.

In addition to the obvious impacts of the lack of potable water, Cape Town experienced challenges with their wastewater collection, wastewater treatment facilities and reuse systems. Heavier wastewater loads and reduced flows caused problems in their sewerage system and impacted the ability of their treatment plants (wastewater and reuse plants) to treat stronger waste streams.

It is notable that the water scarcity problem is more severe from a sustainability standpoint due to the overuse of supplies, especially the over pumping of groundwater. The unsustainable practice of the over pumping (i.e., mining) of groundwater aquifers is impacting 40% of our population. Therefore, conjunctive use of surface and groundwater resources) and better operational practices that minimise vulnerability is key. For example, a study on "*Effect of Hedging-Integrated Rule Curves on the Performance of the Pong Reservoir (India) During Scenario-Neutral Climate Change Perturbations*" evaluated the effects of improved,

hedging-integrated reservoir rule curves which are used for managing reservoir operation on the current and climate-change-perturbed future performance and found that the historic vulnerability reduced from 61% (no hedging) to 20% (with hedging)[60].

As noted in the UN SDG targets, the overuse of surface and groundwater supplies calls for more transboundary water agreements between countries, many of whom have conflicting and varied political interests.

As noted earlier in this report, wasteful agricultural practices (growing water intense crops in arid environments, monoculture, inefficient irrigation practices, poor water retention in soils, over watering etc.) are contributing to water scarcity. The problem is compounded by an increasing demand for water intensive foods in our diets.

According to the International Water Management Institute, 25% of the world's population and 33% of the population in developing countries live in regions experiencing severe water scarcity.

Glacier and ice melting

An increase in air and sea temperature and subsequent melting of glaciers is contributing in the short term to increased frequency of storms, severe weather events, floods, and pollution (sediment, minerals etc.). In the long term, raw water supply shortages will impact local economies and, in some cases, lead to the need for population shifts, the latter of which we are already experiencing in some countries due to uninhabitable and unserviceable land. The American Water Works Association estimates that more than 20% of the world's population are affected in one way or another by the melting of glaciers.

Thirty four percent of the world's rice and 17% of the world's soybeans, both of which are highly water intensive crops, are grown in Asia. In addition, 15% of the world's cotton is grown in the area. Many of the rivers which supply the water to grow these crops depend in part on glaciers which melt in warm weather and build up during cold weather.

The glaciers in this region have not been in equilibrium for some time and are now experiencing net melting at an increasing rate. As this situation evolves, crop reductions, intercountry disputes, population shifts and economic damage is possible in many of the countries involved some of which are already poor.[61]

As mentioned above, melting glaciers can impact water quality/pollution problems as well. For example, the reduction of snowmelt and the receding of glaciers in Peru have exposed highly mineralised rock creating acidified streams during precipitation events.[62] Similar events are also occurring in the Himalayas where it is estimated that two-thirds of glacier ice will be lost by 2100 if climate targets aren't met.[63]

Yet another mountain melting problem has surfaced as well. A few years ago, two avalanches in Tibet which travelled great distances at high speeds (up to 300 km per hour) were at least partially caused by climate change as well as the topography and underlying soils. A Dr Andreas Kaab stated that "he hoped that (studying these incidents) would be a wake-up call for people living near mountain glaciers."[64]

The lack of public awareness on the impacts of melting glaciers and the consequences several thousands of kilometres away is a major contributing factor to the level of apathy that exists in the protection of water resources and the fight against climate change.[65]

Only recently, disaster struck Uttarakhand's Chamoli district on 7 February 2021 in the form of an avalanche and deluge, after a portion of the Nanda Devi glacier broke off. The sudden flood in the middle of the day triggered widespread panic and large-scale devastation in the high mountain areas.[66]

Social and health issues due to ice melting in colder climates

There are also major climate change-driven global warming challenges related to ice melting in the southern and northern extremities of our planet. They contribute to global warming and sea level rise.

Recently, the temperature in Antarctica reached slightly more than 18 degrees Celsius, which is the highest temperature ever recorded there. It is reported that the largest glacier in the world (Totten in East Antarctica) is melting from above and below. More water flows to the sea from this glacier than anywhere else in East Antarctica. Its entire catchment is larger than the state of California. If all this ice were to melt and end up in the ocean (which is not currently predicted to occur), sea levels could rise by three meters.[67]

Ice melting is causing local social disruptions as well. For example, communities in Greenland depend on ice sheets to support the dog sleds they use to interact with adjacent villages. Ocean warming is reducing the number of months each year that such interactions are even possible.[68]

Thawing of permafrost is also a problem. Arctic permafrost is thawing much faster than expected, reshaping the land and releasing carbon gases that could speed up climate change. Researchers now suspect that for everyone degree rise in the earth's temperature, permafrost may release the equivalent of four to six years' worth of coal, oil and natural gas emissions.

Globally, permafrost holds up to 1,600 giga tons of carbon, nearly twice what is in the atmosphere.

The (thawing) of permafrost could pump billions of additional tons of methane and carbon dioxide into the atmosphere.[69] It should be noted that methane is much more intense greenhouse gas than carbon dioxide. Ice melting in tundras is exposing us to spores and micro-organisms to which the human population has not been exposed to for thousands of years. Will our immune systems be able to handle such exposure?

According to an article in *National Geographic* "The Arctic is warming faster than any other place on earth. Snow and ice reflect most incoming light, but open water is less reflective so it absorbs more heat. More melting causes more open water, a feedback loop that leads to even more warming."[70]

Tidal flooding (and climate change)

Tidal flooding, also known as 'sunny day flooding', is the temporary inundation of low-lying areas during exceptionally high tide events, such as at full and new moons.

Astronomical alignments are not the only factor affecting the height of tides. High-tide flood frequencies vary year-to-year due to large-scale changes in weather and ocean circulation patterns, such as in the El Niño Southern Oscillation. During the El Niño phase, high-tide flood frequencies on the US west and east coasts were amplified above local trends at about half of the locations examined in a recent study.[i]

When coastal storms coincide with high tides, the depth and extent of coastal flooding can increase dramatically. Even relatively weak winds blowing toward land during high-tide events can push huge volumes of water inland. Rainfall can also add a substantial volume of water to these high-tide floods.

As global sea level rises because of climate change, so will the frequency and depth of high-tide flooding. Multi-century sea level records and climate models indicate an acceleration of sea level rise, but no 20th century acceleration has previously been detected. This acceleration is an important confirmation of climate change simulations which previously did not observe such a situation. If this acceleration remained constant between 1990 to 2100 the rise would range from 280 to 340 mm[ii], .

Engineers, therefore, face a serious challenge when this phenomenon can inhibit natural gravity-based drainage systems in low-lying areas. This happens when the sea reaches levels that are below visible inundation of the surface, but which are high enough to incapacitate the lower drainage or sewer system. Thus, even normal rainfall or storm surge events can cause issues such as flooded streets, homes and closing roads. To help alleviate this, engineering solutions based on control elements located at the outlet of drainage systems have been used since historical times.

Closing thought

The water challenges we face are complex, diverse and alarming. It seems that we are falling behind in addressing them. So, we need to pick up the pace as the consequences of not adequately addressing them will be severe.

/SOW2021

Jeshika Ramchund
Lead Engineer – Developments
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Solving the business case for tomorrow's water issues will require tomorrow's engineers today

Amid incredible technological development, some of the biggest challenges that face our generation and our planet today are rather basic and the solutions are comprised of several smaller fundamental changes rather through a few grand gestures. Enshrined in the United Nation's Sustainable Development Goals, SDG 6, Clean Water and Sanitation, underpins a simple yet life sustaining resource that is often overlooked and significantly undervalued.

The challenges are wide and varied:

- Poor and marginalised communities.
- Women who are disproportionately impacted by a lack of access to water.
- Water stress.
- Vulnerable communities dealing with the extremities of flood and drought events.

- the planning of infrastructure.
- Creating resilient designs.
- Implementation of water resources.
- Water infrastructure projects developed in an unintegrated manner.
- Underpinning projects with the principles of sustainability.

It is fair to say, there is not a singular problem so no silver bullet solution can solve this.

This report on *Establishing the value of water - the business case for change* is a sobering reality on the complexities of the issues surrounding water as a limited and threatened resource. The challenges, however, also create opportunities. In this 'decade of action', access to water, development of sustainable water infrastructure, circularity and the integration of technology and nature-based solutions are the armour with which consulting engineers and the engineering profession can tackle these challenges head on. Whilst the picture may look grim, what are the roles and where are the opportunities for engineers? Everywhere.

What sets today's engineers apart from tomorrow's truly sustainability-led engineering? Today, too often there is the willingness and ability to deliver to their client exactly what they were paid to do, within the agreed time and to the planned budget. Tomorrow's sustainability-led engineers would do all of this, but with the environment and the end users' long-term use of the system and affordability at the heart of the solution. We can envision a future where we lead the integration and synergy of grey infrastructure into green infrastructure for optimum balanced benefit.

We need adequate commitment for the requisite skills and enhancement of existing skillsets to realise these ambitions - skills that are scaled appropriately with a balance of expertise that looks inward, a depth of technical specialisation, complemented by the 'big picture' professionals, visionary connectors who are able to match problems to solutions for poorly defined problems and break down silo mentality.

Future Leaders play a critical role in this space. I'm certain that when Albert Einstein said that we cannot solve our problems with the same thinking we used when we created them, he had climate change, its impacts and the creativity and innovation that each new generation brings to the world in mind. The greatest opportunity for consulting engineers is to lead the charge of a multi-faceted renaissance of our sector and to reaffirm the commitments to achieving these complex goals pertaining to water as a start. By enhancing the body of knowledge of integrating technology, nature-based solutions and infrastructure development, a blueprint will emerge for truly sustainable development.

The advent of Day Zero, the day in which there is zero water available, is a reality that faces several catchments across many countries. In his bestselling book *The Third Industrial Revolution*, Jeremy Rifkin advocated for rebranding "climate change" as "water change" so that people may understand firstly, how a changing climate affects our water and secondly to connect how changing water affects our lives, health and environment. Water advocacy is an incremental process and the first step starts with each of us in our homes, our communities, businesses and through our projects.

We explored in *Time to $Tn-vest!* that the need for the Time To Take The Trillion Task seriously is immediate. In this report, the business case for change and to address the world's water challenges more aggressively is undeniable and undoubtedly the best way to improve the state of the world.

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Reviewers

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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 programme 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

FIDIC State of the World report, Time to $Tn-vest

FIDIC's first 2021 State of the World report recommends a renewed and massive global effort to improve infrastructure spending to meet the investment challenge facing the world which would amount to a doubling of current infrastructure investment to at least $7 trillion. If the investment is not made and/or if the need is not lowered through innovation, FIDIC says, then meeting the UN's sustainable development goals (SDGs) and making a full economic recovery from the Covid pandemic will be placed in jeopardy.

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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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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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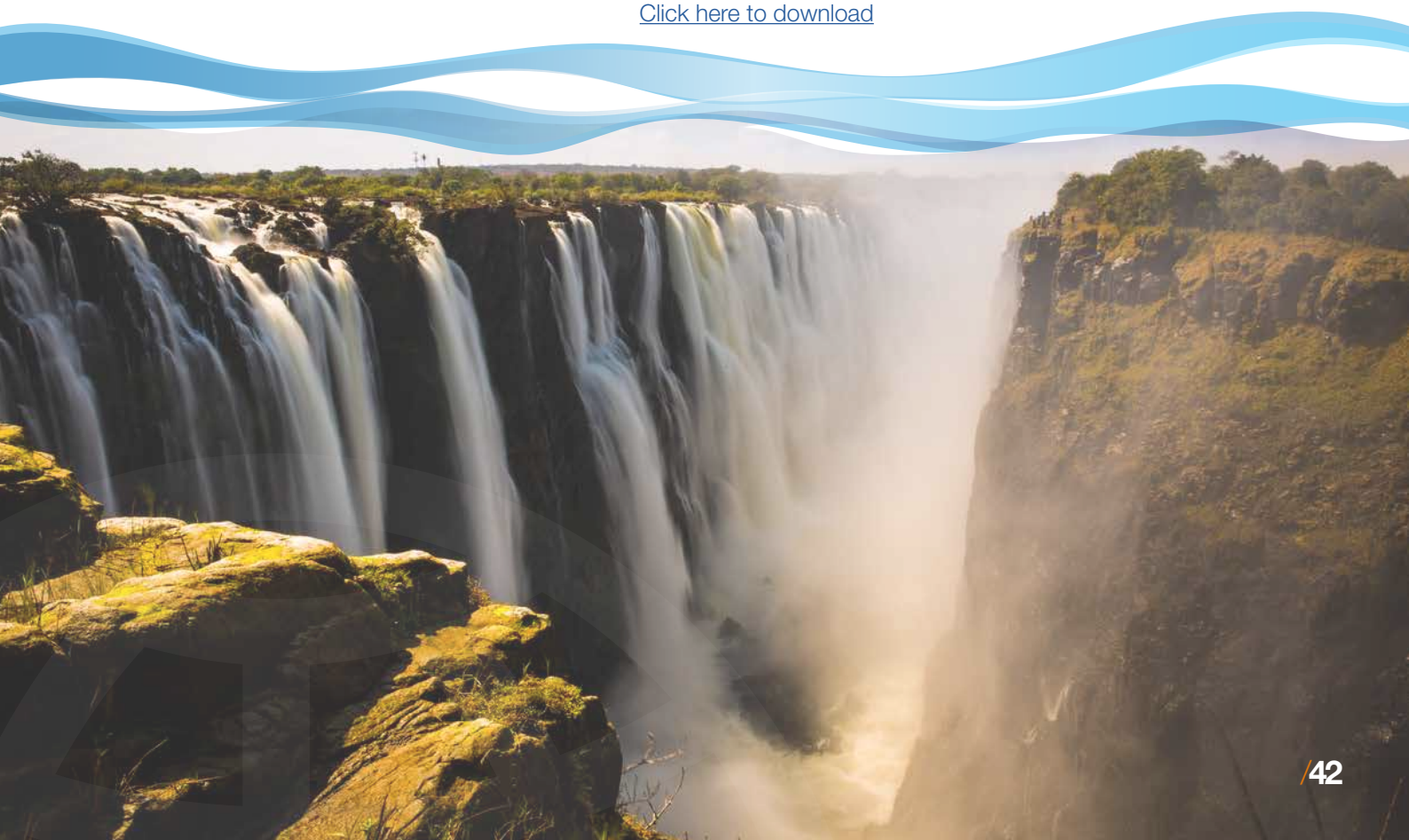

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Endnotes

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