

London's wastewater future.

London 2100: The case for change.



Joseph Bazalgette created a sewer system which he originally sized for London's needs of the time - he then doubled it to anticipate the future beyond. These are the qualities that I admire.

Norman Foster

London 2100: The case for change

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Introduction

Londoners have benefited from the foresight of the Victorian architects of the capital's sewer system. Built to serve a population of four million, at a time when the capital was home to two and a half million people, it still forms the backbone of the system today. But London's wastewater services now face 21st century challenges.

Rapid population growth and changing weather patterns are placing an increasing pressure on our ageing infrastructure, while we strive to meet tighter environmental standards. It is up to us to enable London's growth; provide our customers with an affordable, reliable service - whatever the weather - and protect the natural environment on which the capital relies.

But the scale of these challenges means we need to think differently about the future, and look far beyond the conventional five-year price review cycles of the water sector. London's wastewater system is immense and complex, and significant changes will take time to achieve.

This word cloud illustrates the main themes that London 2100 is addressing.



A much longer-term approach is needed to manage risks and embrace opportunities for innovation, which is why we are now considering time horizons of 25 and 80 years in a way that reflects water resource planning. We call this new approach London 2100.

The legacy of London's 19th century engineers has served us well, but we need to develop a network fit for the 21st century and beyond. This is our first step in setting out the challenges we face, and how we will approach them - we hope you will work with us to develop the answers.

The purpose of this booklet is to set out how the environment we operate in is set to change, and why we need to plan wastewater services differently. As one of many organisations with a role to play in ensuring London's position as a great place to live and work, we want this to be the starting point for conversations with others who have an interest in future-proofing London.



What do London's wastewater services look like?

8 wastewater treatment works within the M25 serve 99% of the GLA population

153^{gWh} renewable energy in total from wastewater assets

Some London Sewers are over 150 years old

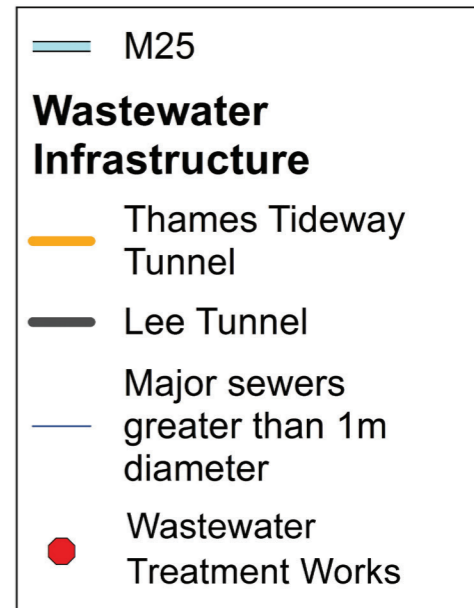
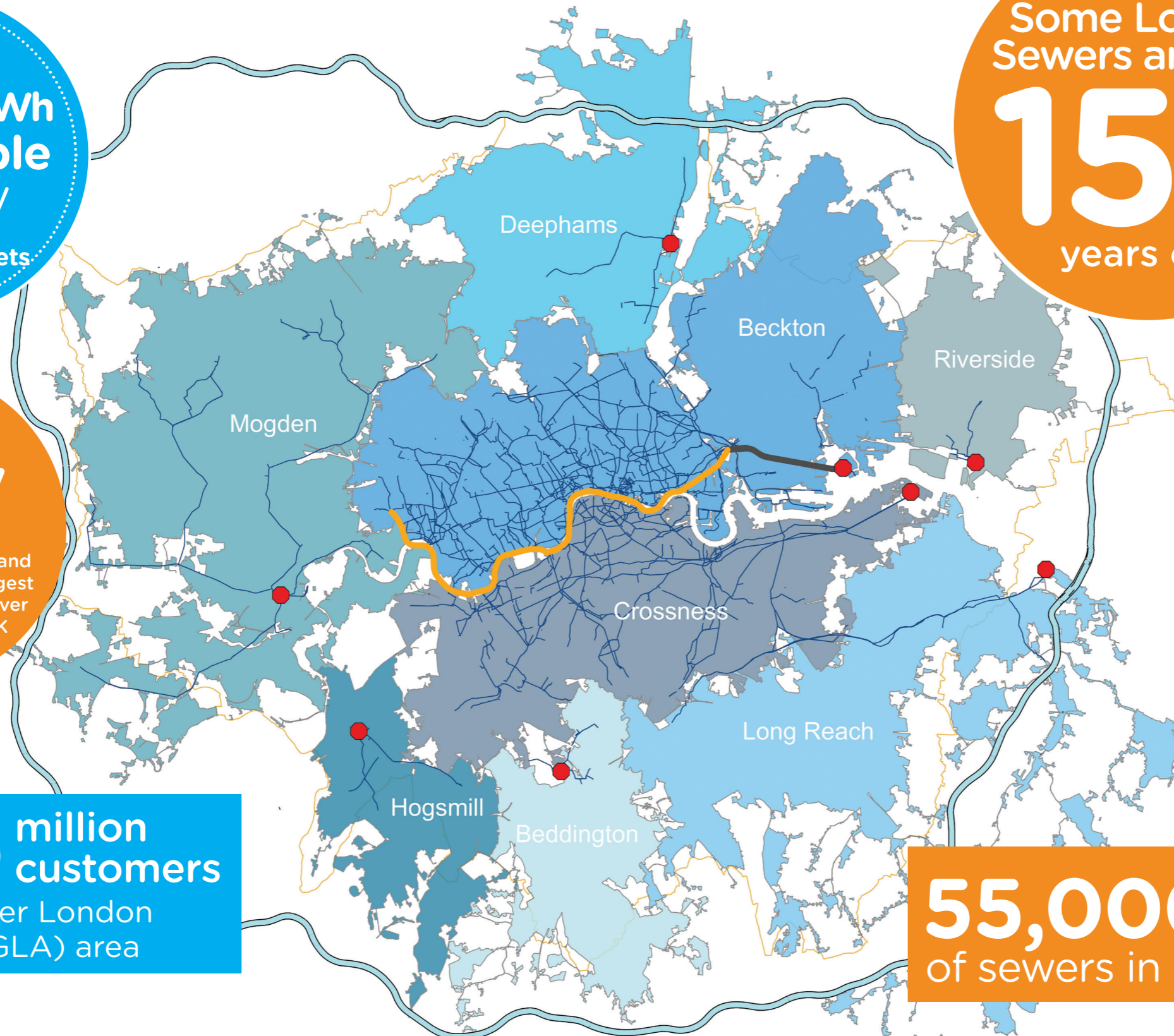
On average per day We are one of the best value providers

Thames Tideway Tunnel

15 miles long, 7m wide and upto 65m deep the biggest infrastructure project ever undertaken by the UK water industry

8.75 million customers in the Greater London Authority (GLA) area

55,000km of sewers in London



What can we learn from the past?

At the beginning of the 1850s London had no effective sewer system.

After 'The Great Stink' in 1858, legislation enabled construction of a sewer system which collected wastewater from central London and took it to Beckton.

Growing population after World War I resulted in hundreds of small local wastewater treatment works and increasing pollution of the river, which deteriorated further after World War II. In the 1950s the River Thames was so polluted it could not support aquatic life, but due to process improvements from the 1960s to current times, there has been a significant turnaround. In 2010, the River Thames won the Theiss International Riverprize which celebrates outstanding achievement in river management and restorations.

Much of London's sewer network, however, is "combined" - which means it handles both sewage and large amounts of surface water. The Thames Tideway Tunnel scheme is being constructed to intercept overflows of untreated sewage and clean up the River Thames.

History shows us that when wastewater strategy has changed it has made London a better place to live. Change has often happened in response to crisis: London 2100 is an opportunity to change our wastewater strategy before we reach crisis point.



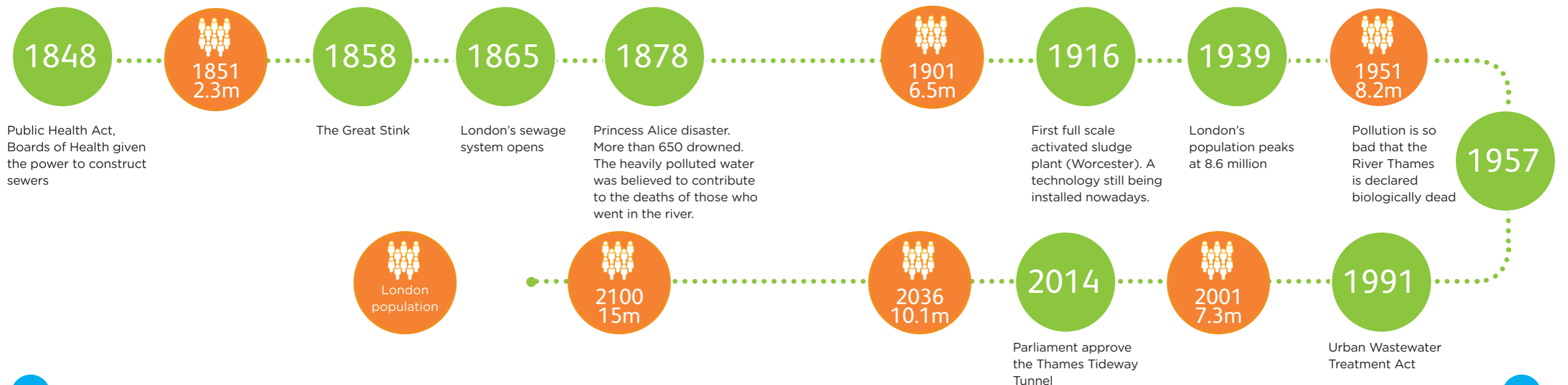
How does the wastewater sector compare?

If we look at sectors such as communications, medicine, transport, or computing, the pace of technological change over the last 80 years has been phenomenal.

Communication technology has changed from black phones and manual switchboards, to fibre optics and smart phones, some with more computing power than a 1980s supercomputer. The capabilities of computing technology is currently doubling in less than 5 years, and the rate of change is increasing almost exponentially.

In the wastewater sector, although some significant developments and improvements have been made, we are essentially using a 100-year-old technology to treat sewage.

So let's now fast forward to 2100 and imagine what the world could look like.



What could the future look like?

We can't predict exactly what London will be like in 2100 but here are 10 things being discussed today which could become everyday reality during the 21st century.

We need to consider how these, and other changes, could impact individuals' lifestyles and London's wastewater services.

1

Society will be using new materials and applying nanotechnology. Materials such as graphene, titanium foam and artificial spider silk could revolutionise our world, with applications in bio-medical science, computing and consumer devices. Desalination and direct reuse of wastewater could be commonplace because of nanotechnology.

2

Our diet will be different. People may be eating much less meat and the meat that we do eat could be grown from stem cells in a lab, reducing the amount of land and water required to produce it.

3

People will be healthier and could live longer. New materials, genetic engineering and personalised medicine could mean we live longer. According to the Office National Statistics, approximately 35% of people in the UK are expected to live to 100 by 2112.

4

3D printing will be commonplace. 3D printers could be in our homes and businesses, revolutionising the way we manufacture, obtain and consume products and services.

5

We will live in an augmented world Everyday objects will be connected through the Internet of Things and devices such as intelligent contact lenses could be implanted in our bodies, meaning that we live in a permanently augmented world.

6

Specialist micro-organisms will be generated to treat waste So-called 'smart bugs' could be genetically engineered to provide super-efficient, highly focused treatment of our waste products and to optimise the extraction of energy and recovery of resources.

7

Autonomous technology will transform the city. Passengers could travel and goods will be moved by vehicles run by computers. Utility networks will be integrated and could be operated and maintained by predictive Artificial Intelligence technology.

8

Robots will take over the service industry. Robots are likely to replace workers in sectors which involve routine and repetitive tasks, including hospitality, retail, entertainment, utilities operation and maintenance and even health and medical care.

9

Londoners will live in vertical communities and the city will be greener. People could live, work and play high above ground level and new buildings in London could provide the substrate for vertical forests.

10

London will be a champion of the circular economy. Our use of energy and resources will be extremely efficient. London could be a carbon neutral city and even a net exporter of energy.



Challenges and opportunities

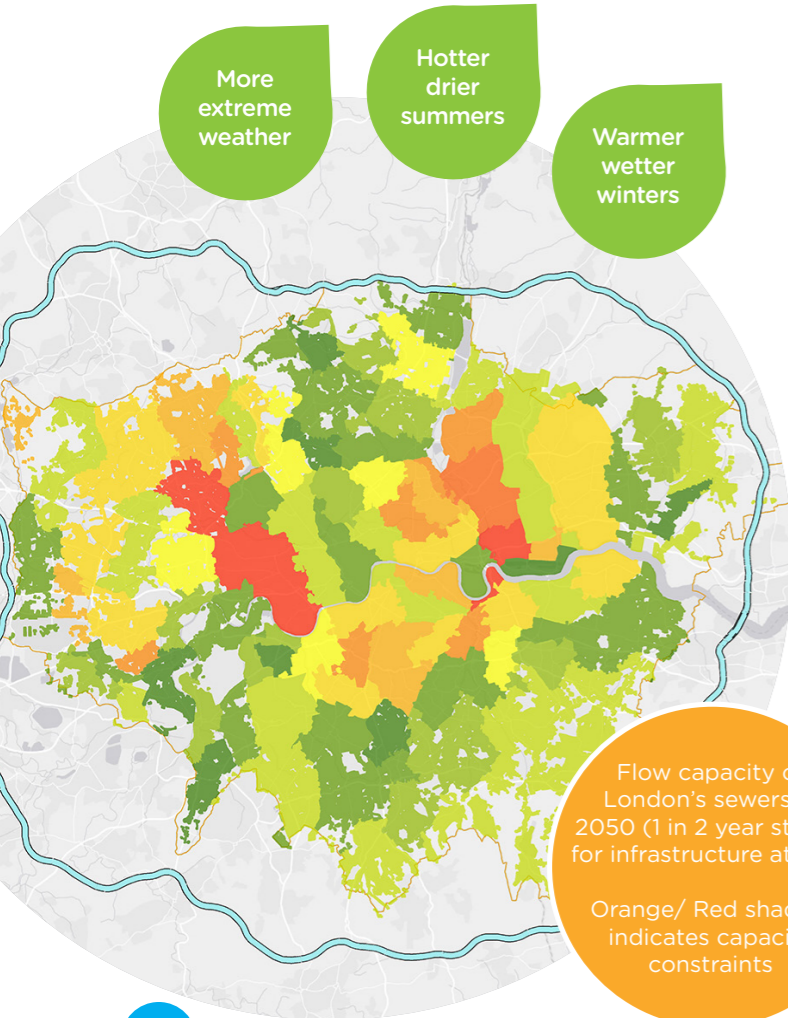


Now that we have reviewed the past and taken a glimpse of the future, we turn our attention to the specific challenges and opportunities that London's wastewater services face.

Climate change

Over the next 25 years, we are likely to see wetter, warmer winters and hotter drier summers in London. By 2100, the picture becomes highly uncertain, forecasts show up to an 8% rise on summer mean temperature and more than a 50% rise in winter rainfall compared to today. The potential for disruptive events also increases as 'tipping points' are passed.

We know that climate change could put London's wastewater systems at more frequent and more severe risk of flooding. There could also be an impact on the performance and condition of London's wastewater assets because of changes in sewer flows, water quality, ground conditions, the sensitivity of receiving water courses and the demand for sludge recycling. Increases in temperature could affect the efficiency of treatment works.



Flow capacity of London's sewers in 2050 (1 in 2 year storm) for infrastructure at 2017
Orange/ Red shading indicates capacity constraints

Social change and customer expectations

London's wastewater strategy must reflect what customers want now and in the future. Society's response to transformational change depends on values: some people favour sustainable solutions whilst others see infrastructure as a question of economics.

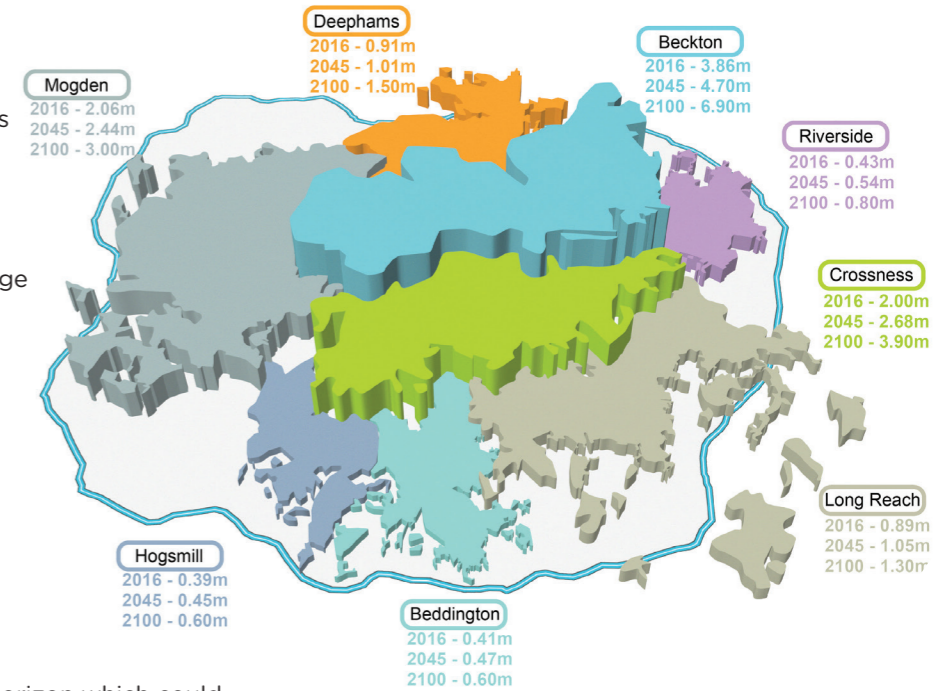
Customers could become more active in wastewater services, transitioning from "consumers" to "prosumers" (producing outputs from their own wastewater) with increasing control. Customer preferences could create demand for new services such as home bio-energy appliances and nanotechnology for local wastewater treatment. Despite these changing preferences; maintaining reliable service, preventing households from flooding and receiving value for money are likely to remain key priorities.



Demographic change

History has seen London's population fall as well as rise. The London Plan envisages London's population growing from 8.75 million to 10.1 million in 2036 and one estimate puts the city's population at 15 million by 2100. Such change is being driven by migration but also natural change (births and deaths).

The challenge for wastewater planners is not simply the increase in flows that this population growth represents, but the distribution of growth relative to the remaining capacity at existing treatment works.

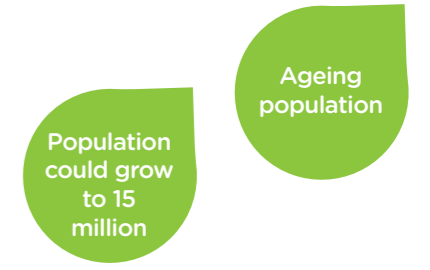


Note: numbers shown are "population equivalents" making allowance for trade flows.

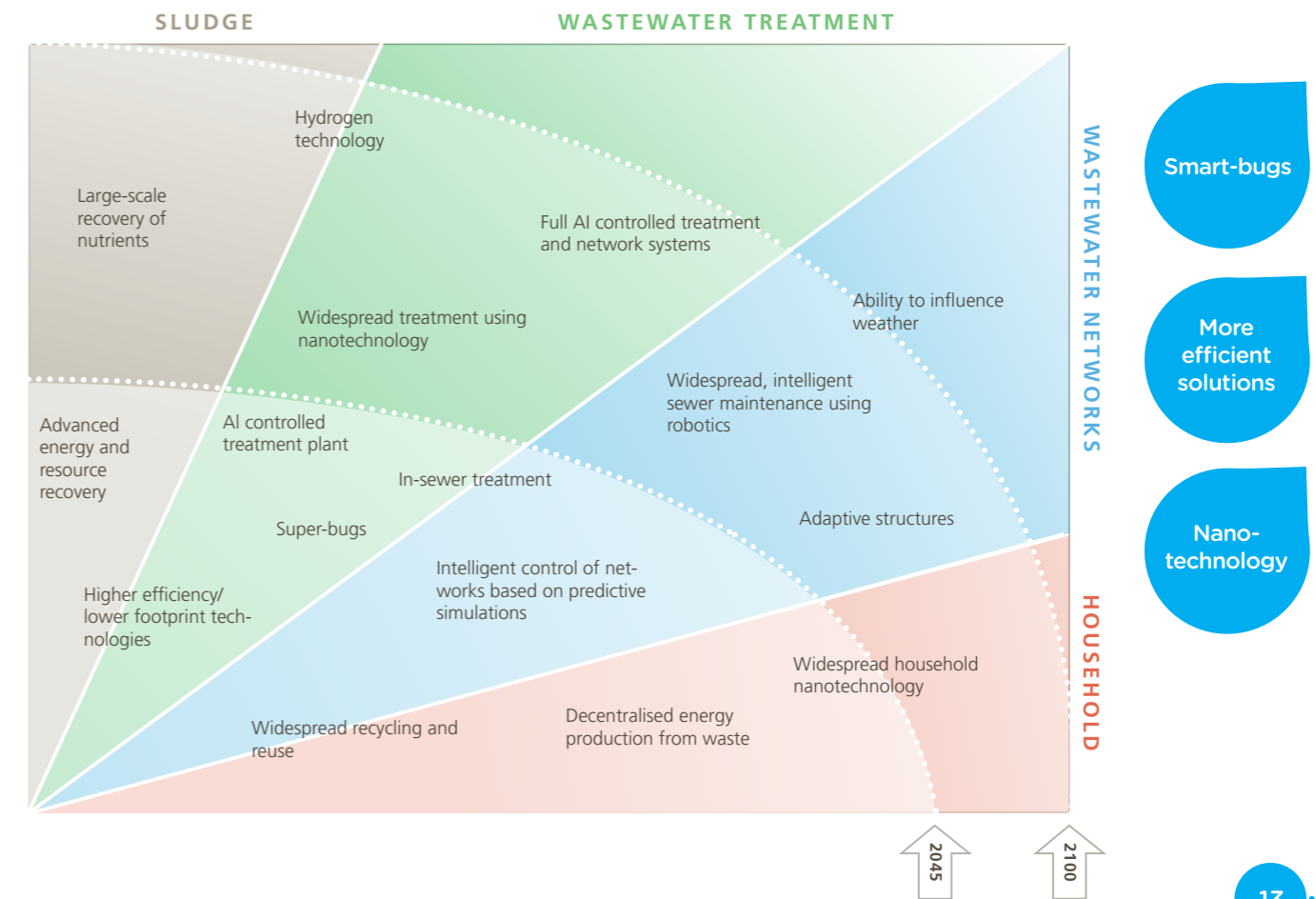
Technological change

A range of new technologies are on the horizon which could revolutionise wastewater services. These include: nanotechnology, graphene and smart-bugs. The challenge for London 2100 is to move towards technologies that can tackle London's specific challenges within the time period available.

We have an opportunity to choose more efficient technologies that maximise wastewater services whilst minimising resource use (including land), and exploiting options for energy generation and resource recovery.



Wastewater technology on the horizon



Challenges and opportunities cont.

Ageing network and sustainable drainage

Many of London's sewers are over 100 years old and are increasingly at risk of blockages, collapse and groundwater infiltration. As most of London's sewers carry surface water as well as foul drainage, development and urban creep (which increase the impermeable area) are putting an additional burden on the system, exacerbated by increasing rainfall intensity due to climate change. Floods with a likelihood of occurring once every 30 years today, could occur as frequently as once every 10 years by 2100.

The Thames Tideway Tunnel is a major investment to intercept overflows and improve river water quality. New infrastructure is not the only solution and opportunities to capture stormwater before it enters the sewage system will be key, using sustainable drainage systems (SuDS). SuDS measures to offset over 30% of impermeable areas could be required in future. This could be achieved at a local level (e.g. on-street rain-gardens) and household level (stormwater and grey water recycling). However, to be effective, SuDS approaches require strong and sustained stakeholder collaboration.

Increase flood risk

Local and household sustainable drainage

Old sewers are deteriorating

Workforce

The UK is facing a significant skills shortage in science technology, engineering and mathematics (STEM) subjects. In addition, the workforce is aging.

The effects of these challenges could be particularly acute in the wastewater sector which relies on scientific and technical skills and experience.

Technology could offer a partial solution to some workforce challenges: increasing automation and advances in digital technologies, robotics, Virtual Reality (VR) and Augmented Reality (AR) and materials science could change labour requirements, leading to an increase in demand for skills such as software development and coding.

Technology may also reduce the size of the workforce, replacing many professional roles in the future. We may still need more skilled maintenance and high level decision making but mid-level support services could become squeezed.

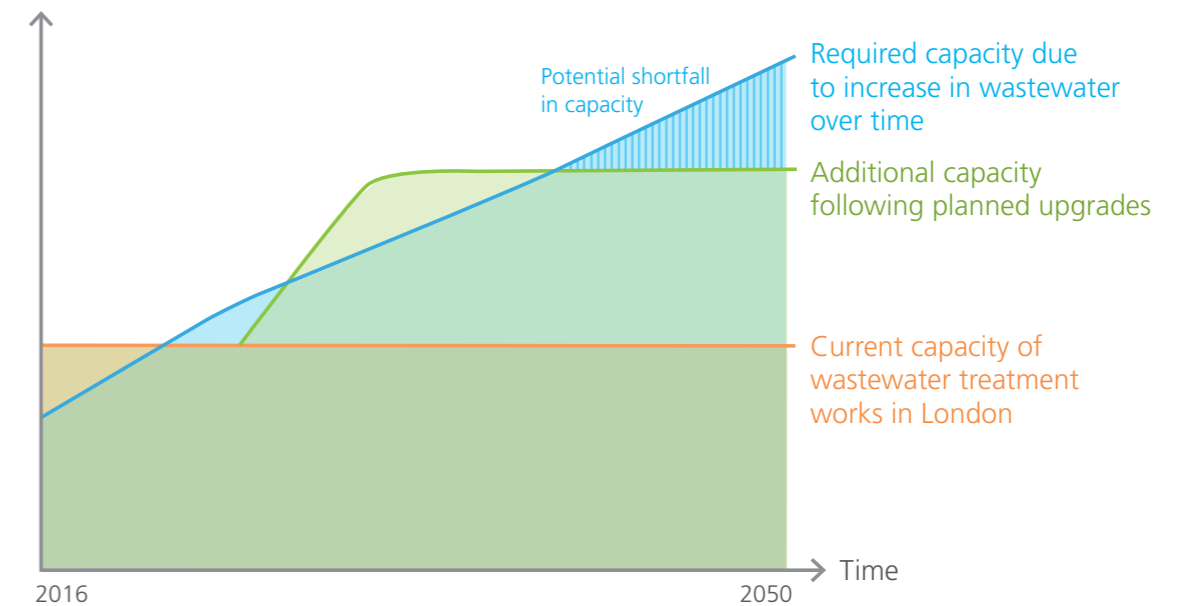
Pressure on wastewater treatment

Most of London's wastewater treatment works were constructed in the early 1900s although additional capacity has since been retrofitted to extend their life span. Despite these efforts, between 65% and 85% of civil assets at all but two of London's major treatment works will have exceeded their engineering lives by 2045.

Some critical processes are fast reaching their capacity; by 2040, London's wastewater treatment works will have insufficient capacity to handle the flow from the population.

Works at capacity

Amount of wastewater that can be treated (capacity)



Ageing workforce

Technology could help



Environmental Legislation

In recent decades, increasingly stringent environmental requirements for wastewater and effluent have been introduced and the Water Framework Directive (WFD) requires water-bodies to meet "good status" by 2027. One of the biggest challenges the industry currently faces is maintaining compliance with tightening phosphorous standards and future legislation dealing with micro-pollutants could have a significant impact on wastewater treatment requirements.

Much of our environmental legislation is based on European Directives so that the ongoing uncertainty relating to Brexit make it difficult to be confident what the future may hold. Current European environmental legislation appears only likely to get tougher and to date UK government have committed to no diminution on current standards when we are governed solely by domestic law. However, the final conditions of Brexit

Catchment management

may look rather different. For the moment the focus is on catchment management and innovative solutions as the mechanisms to meet increasingly stringent standards. Irrespective of the need for compliance with regulations, without developing the additional capacity to meet these standards we would run the risk of causing environmental damage.

Micro - Pollutants

Tightening standards

Challenges and opportunities cont.

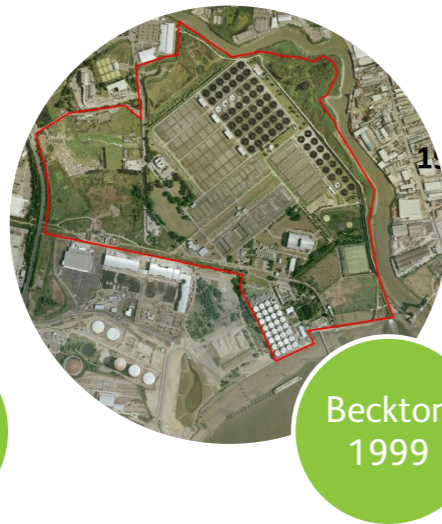
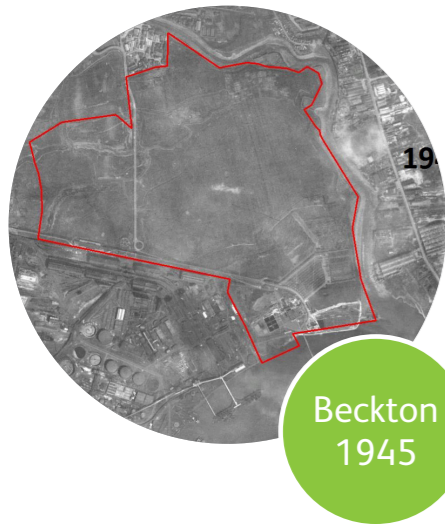
Pressure on land

London's treatment works were originally built away from communities but are now surrounded as the city has grown, with little land left to expand (see below images for how Beckton has developed since 1945). Growth, together with the establishment of the green belt, has meant that land values have increased rapidly. For example, the average house price around Beckton - formerly an industrial wasteland - has increased by 500% over the past 20 years.

The lack of land, coupled with increasing population (and therefore wastewater flows), presents a significant challenge as land at existing treatment works is severely constrained. In addition, the close proximity of housing presents challenges in terms of odour nuisance.

No space to expand

Odour



Competition and market reform

The Government is promoting new markets to encourage cost-efficiency and innovation in a sector that has been dominated by monopolies and regulation. Reform of the sludge market, to make it more competitive, is already underway.

Fast forward 20-25 years and there could be radical reform with expansion to treatment competition alongside water abstraction and resources trading. It is possible we will see total de-regulation, multi-sector utilities, a national water network and vibrant markets in bio-resources. There may be more community-based, decentralised activities, where consumers take more control of their wastewater.

More competitive services

Multi-utilities

Decentralised systems

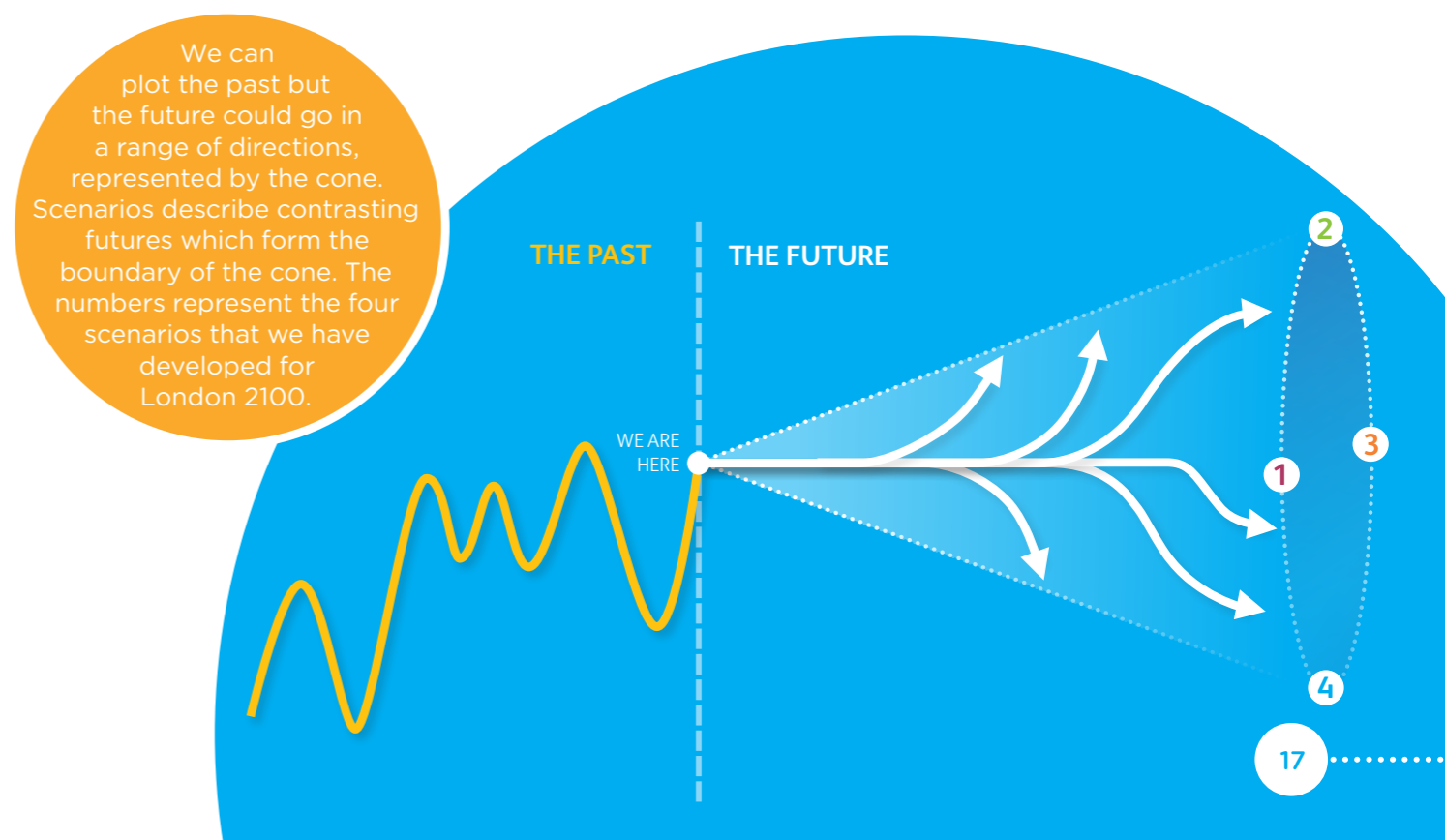
Scenario planning for the future

The future of wastewater services could develop in many directions. Whilst we cannot predict exactly how the future will develop, scenario planning provides a disciplined method for forecasting how social, economic, political, technological and environmental drivers could interact.

Using scenarios, we can uncover evidence in the here and now that enables us to set a direction and develop options that integrate new technologies and create resilience, whatever future may emerge. In other words, we can use scenario planning to help deliver wastewater services that are future-proofed against whatever shocks may lie ahead.

There are similarities between how other organisations have developed their scenarios and the approach we outline on the next page. Many scenarios are constructed around dimensions of social-economic change. For example, National Grid's Future Energy Scenarios are based around the level of prosperity and society's level of green ambition (similar to societal attitude in our scenarios). Sydney Water's Future of Urban Water scenarios explore change in the degree of centralisation of systems and the level of integration of utilities.

Other utilities around the world are using a similar approach to inform their investment plans. For example, scenario planning has been used to inform the planning of urban water systems in Sydney and energy infrastructure investment strategy in the UK.



Scenario planning for the future cont.

To explore what wastewater services could look like in 2100, we have created four scenarios or future worlds, using a foresight engineering framework. Here four future worlds are formulated, guided by axes representing two key drivers. This exercise is designed to be thought provoking, broadening the mind on a range of future possibilities.

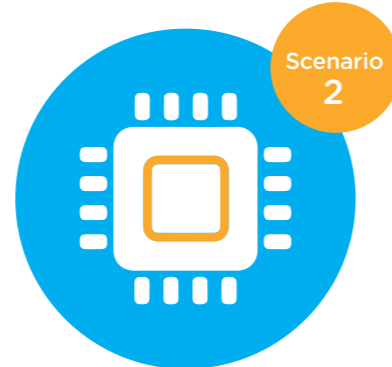
Landscape for innovation

Buoyant economy and rapid pace of change

Think Big



Technology Utopia



Societal attitude
Disengaged

Societal attitude
Engaged

Flush and forget



Reality Bites



Landscape for innovation

Stagnant market and slow pace of change

Key drivers:

- **Societal attitude** – this axis describes how engaged society is in wastewater services, wider sustainability and environmental issues: from a highly engaged, green society to a totally disengaged society that cares little for the environment.
- **Landscape for innovation** – this axis describes the precursors required for innovation and technological change, from a buoyant economy and rapid advances in technology to a stagnant economy where there is little change.

Scenario
1

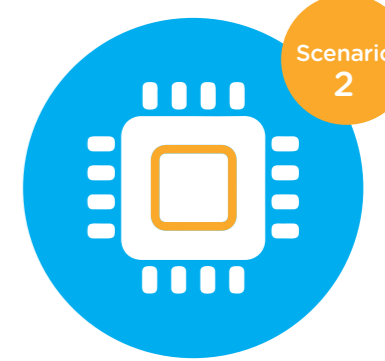


Think big

Advances in technology enable centralised wastewater treatment to continue

Advances in low-footprint technology as well as available finance mean that wastewater is treated at hyper-efficient, centralised treatment works. Greater flows can be treated in a smaller space, with the products used for large-scale energy generation. Customers are not very interested in wastewater and expect utilities and local authorities to adapt to climate change, resulting in development of large scale SuDS to reduce flood risk in London. Utilities are regulated by a central body, focusing on environmental quality. Customers are predominantly materialist consumers with the environment low on their list of priorities.

Scenario
2



Technology utopia

People care deeply about the environment and water, waste and energy services are integrated at a local scale

Technology leaps have resulted in significant changes in provision of wastewater services. Resources and carbon are managed prudently and a circular economy is well established. All 'waste' has value and technology enables significant energy generation and resource recovery from sludge. Wastewater treatment happens mainly at a community scale and the products are traded in vibrant markets. Regulation is minimal as inefficiency and environmental damage are socially unacceptable. London is a vibrant megacity and an attractive place to live. Customers care about the future and trust technology to solve future challenges.

Scenario
4



Flush and forget

Utilities are squeezed between rising customer expectations and slow technological change

London's population declines as the cost of living is high and remote working is normal. Lower flows mean that centralised wastewater treatment remains possible. Slow technological change means that there has been no wholesale overhaul of wastewater assets although their running is optimised relative to age. Service failures occur and customer relations are generally poor. Regulation is the main driver of change, focusing on reliability and keeping bills low. Utility affordability is a key political issue. Customers are struggling with managing today and give little thought to the future.

Scenario
3



Reality bites

People have a choice of utility providers at a range of scales

Competition in the utility sector is well developed and customers can choose bundles of water, wastewater and energy services from a range of providers, including community scale services. Technology has been slow to develop and wastewater treatment processes have changed little but greater localisation in response to the pressure for land means that there are more, smaller treatment facilities across London. Customers are heavily involved in regulation and are empowered to reward success and penalise failure.

What can we learn from other cities?

London is not alone in facing challenges due to population growth and climate change. Here we look at three other cities to see what we can learn from their approach.

Rotterdam

The threat of flooding from sea level rise and extreme rainfall has led the city to pioneer approaches to urban water management.

Massive underground storage facilities are there to relieve pressure on the city's sewers during heavy rainfall. An underground car park near the Museumpark is the largest water storage facility in the Netherlands, with capacity for 10,000 m³ of water. Rotterdam's water plazas are public spaces set lower than ground level which fill with water during heavy rainfall and then drain slowly back into the sewer system once the storm is over. During dry weather, the water plazas operate like any public squares with landscaping, seating and space for public events.

Singapore

Singapore provides an excellent example of an integrated approach to water and wastewater management. The city has a significant water scarcity and has historically imported water from Malaysia. This, coupled with an expected doubling of water demand by 2060, has driven Singapore's Water Agency to take a different approach. As well as optimising surface water resources, the city re-claims water from wastewater treatment, purified using advanced membrane technologies and ultra-violet disinfection. A 48-km-long used water superhighway conveys used water to five water reclamation plants. Presently Singapore's NEWater plants meet up to 40% of the nation's water needs. By 2060, NEWater is expected to meet up to 55% of Singapore's water demand.

Sydney

Sydney Water is addressing risks to water supply from climate change and population growth by diversifying supply, including recycling treated wastewater and storm- water harvesting.

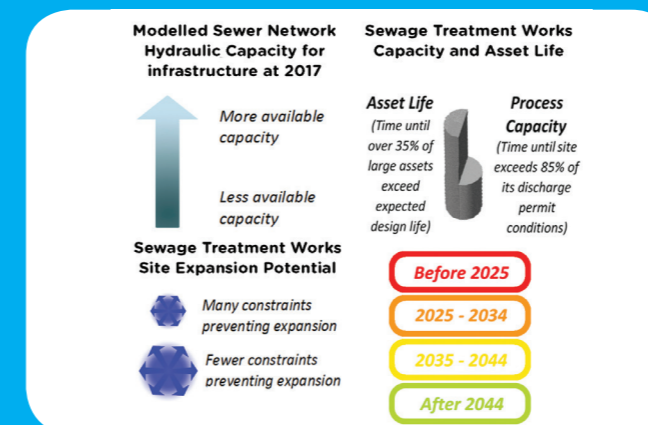
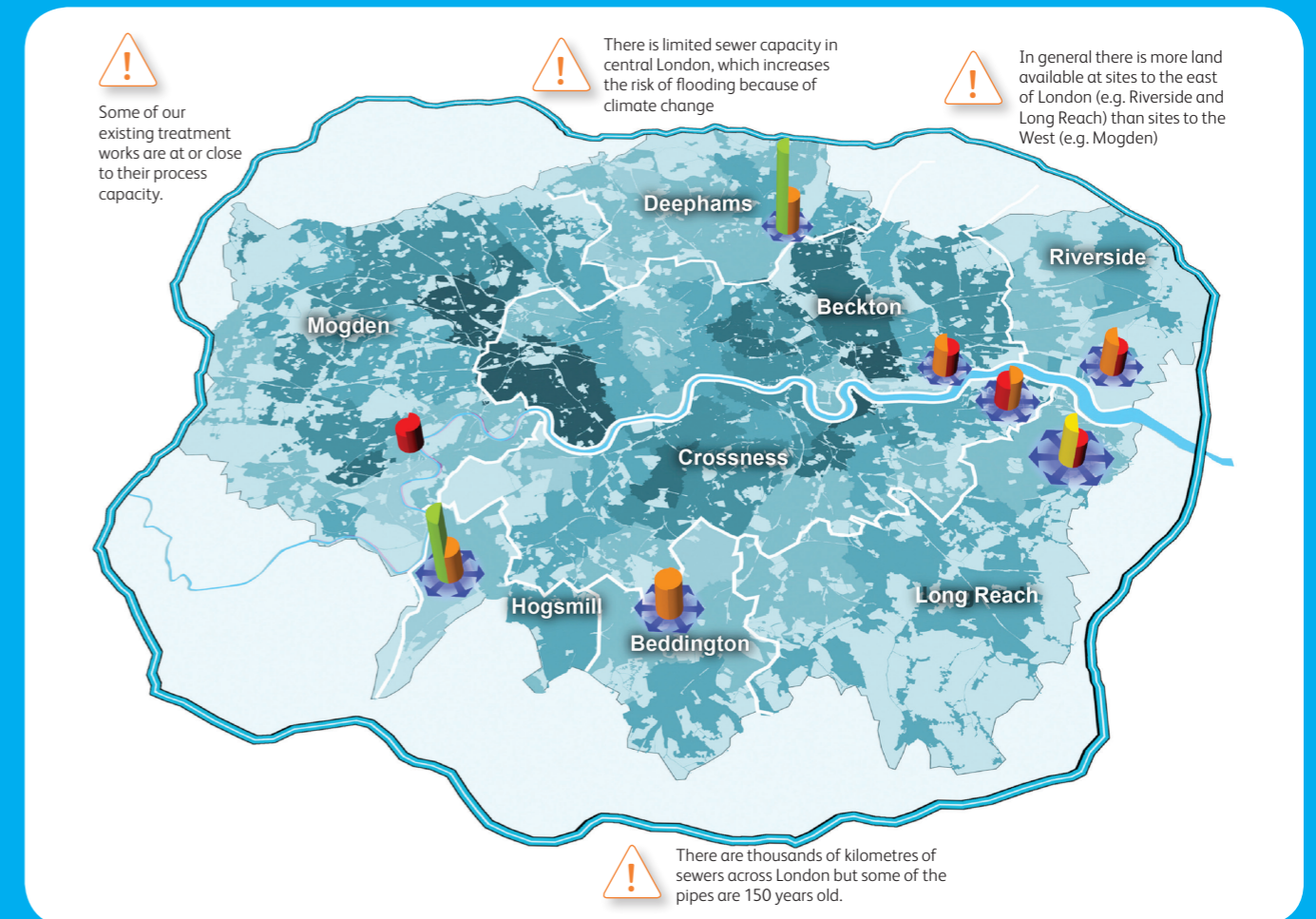
Wastewater is extracted from the sewer network and treated to produce recycled water, a process known as "sewer mining". Wastewater is treated locally at small treatment plants and the recycled water is used for toilet flushing, some industrial operations and to irrigate sports fields and golf courses.

There are around 70 stormwater harvesting projects across the Sydney region. Storm water is collected and used to water parks and gardens and flush public toilets. Together, these projects collect over 1.3 billion litres of water each year. This is about the same as 520 Olympic swimming pools.



The case for change

In the past, when faced with increasing flows or treatment requirements, we have extended or upgraded our existing wastewater treatment works and associated infrastructure. The scale of long-term challenges faced means we have to take a different path. The map below sets out some of these factors in a geographical context.



The map shows that there are a number of existing sites with limited spare capacity and little room for expansion: most notably Mogden in the west of London and Beckton in the east. Process intensification such as the recent upgrades at our Deepphams works can provide medium-term solutions, but these will not address long-term challenges. This, coupled with an increase in flood risk in central London, demonstrates why we need to think differently about wastewater services in London.

Our approach

The challenge for London 2100 is clear: how do we plan effective, efficient and resilient wastewater services in London in the face of a highly uncertain future?

One approach that lends itself to problems that are complex, long term and uncertain is adaptive pathways.

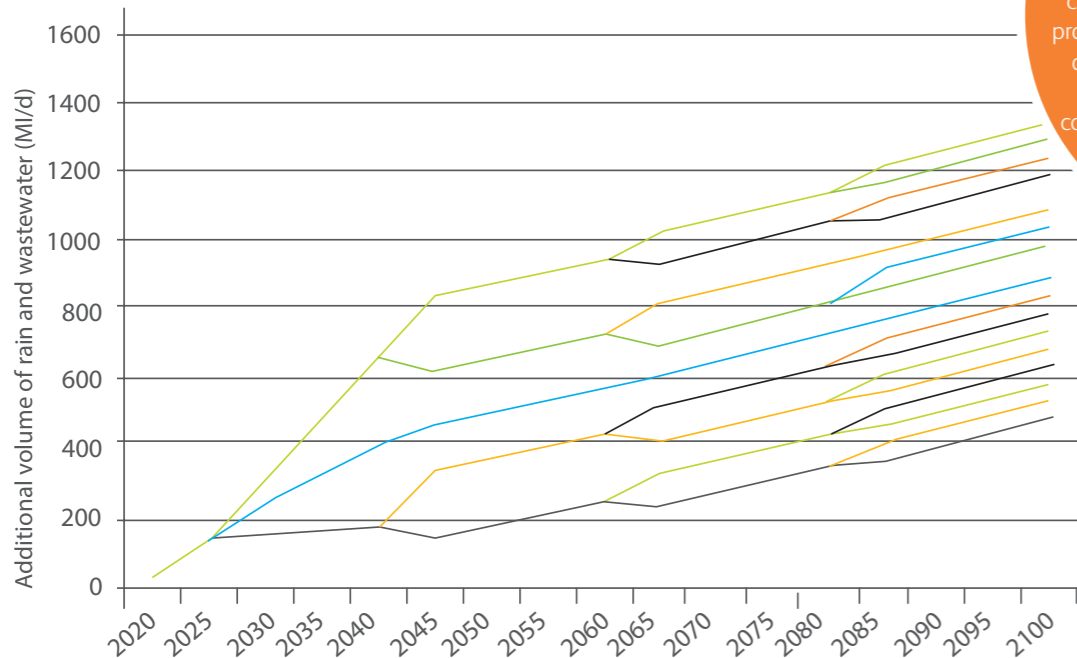
Adaptive pathways means a framework that enable routes or pathways to be established based on socio-economic and environmental data that map an array of interventions to a changing world. The pathways are dynamic, changing with feedback from appropriate monitoring data.

This approach is widely adopted in flood risk management to take account of uncertainty over climate change, classically represented by the Thames Estuary 2100 plan (TE2100). TE2100 uses sea level data

to determine when and what type of intervention is necessary to manage tidal flood risk until the end of the century and beyond.

Our first steps towards developing an adaptive framework for London 2100 are to look at future worlds, forecast data and draw up long lists of potential interventions. This work is currently underway.

The diagram on the opposite page provides an illustration of different interventions we could take. The arrows depict starting points for developing solutions to the wastewater challenges in London - some traditional practices, some more unconventional. The adjacent text describes the challenges associated with these pathways. A combination of these approaches will be used in defining the optimum way forward.



Innovative process technologies
 Innovative technologies are emerging which could allow us to treat greater flows in a smaller area at our treatment works. Waiting for an “innovation leap”, however, could be risky and requires the rate of technology change to keep up with the demands from population increase and other factors.

Business as Usual
 Expanding existing wastewater works using conventional technology requires a significant amount of land to be available adjacent to the site. For example, if we expanded Mogden to accommodate the anticipated population in 2100, the site may need to be as much as 50% bigger.

Localisation
 Breakthroughs in nanotechnology could allow more and more wastewater treatment to be undertaken at a local household level (as well as energy generation and resource recovery). If these breakthroughs happened at a sufficient pace, this could help offset the increasing demands at our wastewater treatment works.



Big infrastructure
 Big infrastructure (new treatment works or super-sewers) could be part of the answer if we can mitigate cost, land, and carbon impact whilst ensuring adaptability to technology changes.

Catchment management
 Catchment management approaches sustainable resource management from a catchment perspective ultimately leading to a “smarter catchment”. For wastewater services, this could mean restoring natural flood storage by installing sustainable drainage systems or delivering projects on a local scale with local communities. In all cases, a high degree of stakeholder collaboration is required.

London 2100 is an opportunity to change the way we think about wastewater services. We have to do this now because:

- There is very little land left to expand existing treatment works or build new ones.
- More conventional approaches will require substantial additional land to meet the challenges faced.
- Exciting new technologies are on the horizon which could replace traditional approaches.
- London’s natural environment is precious and we must nurture it.
- We need to keep up with our customers’ changing expectations and behaviours.
- Our services must remain resilient and affordable.

