Building utility resilience to climate shocks: *Lessons from global case studies*

Addendum: Case Studies

Case studies

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8. Copenhagen: Cloudburst Solutions
9. Northumbrian Water: Collaborative Flood Alleviation
10. United Utilities: Improving Operational Response and Recovery

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Case Study 1:
Copenhagen Metro: Integrating climate adaptation

Country: Denmark
City: Copenhagen

CLIMATE SHOCK:

- Extreme rainfall (flooding)
- Storm surge / coastal inundation
- Extreme weather (wind, hail etc)
- Extreme temperature (heat / cold)
- Fire

SECTOR:

- Transport
- Water
- Electricity
- Stormwater
- Wastewater
- Housing / Buildings

ENTITY:

- Private
- Utility
- Council
- State

TYPE OF INITIATIVE:

- Strategy/Policy
- Planning
- Implementation / Construction
- Operational
- Pilot

ENABLERS:

- Strong Leadership
- Regulations
- Economics
- Engagement & Expectations
- Collaboration & Co-benefits
- Knowledge & Experience

RESILIENCE OUTCOME:

- Robustness
- Flexibility
- Preparedness

Heslop E & Mukheibir P, 2022 Building utility resilience to climate shocks: Lessons from global case studies. Water Services Association of Australia

SUMMARY

An approach of continually reviewing climate shock impact predictions and updating design requirements accordingly so metro routes can be safeguarded against flooding from extreme rainfall and storm surges.

BACKGROUND / DESCRIPTION:

Copenhagen metro opened in 2002 and currently has 39 stations and 38km of track. It operates around the clock and services about 360,000 passengers per day. M1 and M2 are the original routes, M3 was completed in 2019 and M4 is partially complete with planned works to be complete in 2024. The underground part of the metro system is 20 - 30 m below mean sea level, making safeguarding against flooding crucial.

The metro is operated by Metroselskabet, a publicly owned company that is jointly owned by the municipalities of Copenhagen (50%) and Frederiksberg (8%), and the central government Ministry of Transport (42%). The O&M of the metro system is contracted to a private company.

CASE STUDY 1:
Copenhagen Metro: Integrating climate adaptation

CLIMATE RISK PROFILE

According to the 2014 Danish Meteorological Institute report on future climate, Denmark is expected to experience more winter precipitation, along with more frequent and more extreme weather events (based on using CMIP5 climate models (Coupled Model Intercomparison Project Phase 5) based on the United Nations IPCC AR5). The combination of sea level rise and changing wind patterns, will likely lead to increased storm surge heights. The report modelled 50 and 100 years into the future with all four IPCC Representative Concentration Pathways (RCPs) from AR5 (i.e. RCP2.6, RCP4.5, RCP6.0 and RCP8.5) to gain an understanding of the full range of possible climate futures from optimistic to more pessimistic. These impacts will lead to a higher risk of flooding within Copenhagen and its metro.

Metroselskabet uses this climate data, and reports that describe local weather (e.g. rain intensity), to undertake flood simulations that predict the impact of rain or storm surge events, and therefore to set design requirements.

CASE STUDY 1:
Copenhagen Metro: Integrating climate adaptation

NATURE OF THE RESPONSE:

In line with Metroselskabet's current design requirements, all four metro lines have been upgraded or newly built to be resilient to the changing climate based on these climate risk profiles - the following has been implemented:

- The metro stations along M1 and M2 lines were upgraded in 2019 to protect against the expected highest water level from a 1:2,000 year flood event cause by extreme rainfall (cloudbursts).
- The M3 and M4 lines were built to an even higher standard of climate resilience. Each station was individually mapped and modelled to protect against the expected highest water level from a 1:10,000-year flood event caused by extreme rainfall and storm surges.
- Metroselskabet has implemented a wide variety of flood protection measures to meet current design requirements, for example:
- All underground stations have pumping capacity, so if the tunnel is flooded, the water will be automatically pumped away.
- The technique rooms have waterproof outer doors.
- All electrical and mechanical installations are waterproof.
- To prevent rainwater ingress and therefore flooding in the metro stations, two design techniques were used to ensure all openings into the underground were at least 2.3 m above the present mean sea level (as determined by the hydraulic modelling): aprons around entrances were raised or steps up to the entrance were added before going down into the metro.
- For the sections of metro that are above-ground and exposed to sea waves, waterproof walls (which are combination of concrete and gabion walls) have been installed to protect against storm surges.

Metroselskabet's flood protection measures aim to make the following infrastructure resilient to heavy rainfall and storm surges: entrance, stairs, tunnel ventilation, ramp, technique room, shaft, elevator, and control and maintenance centre.

THE ENABLING FACTORS THAT MADE THIS INTERVENTION HAPPEN:

Strong leadership: Metroselskabet has been working with climate change adaptation since 1993, and this consistent leadership has developed into a comprehensive integrated approach that incorporates robust design requirements into metro upgrades and new build projects to protect the metro system. This strong and consistent leadership makes it clear that climate adaptation must be incorporated into all projects and keeps adaptation costs efficient as typically only minor cost adjustments are required during project design and implementation.

Metroselskabet has also aligned it's plans with the City of Copenhagen's climate adaptation plan. This shows leadership at the city-level and supports the leadership initiatives within Metroselskabet.

Regulations: Metroselskabet has been supported on a national and European level to deliver a climate resilient metro system. European railway companies see the benefit of being integrated into national adaptation plans and contributing towards their governments' commitment to deliver on the Paris agreement and Sustainable Development Goal 13: Climate Action as it supports reliable and cost-efficient transport services by embedding resilience to extreme weather and climate change into the railway organisation.

On a national level, for example, the construction of the M3 metro line was able to commence through an Act passed by the national parliament in June 2007, that set out how the metro would be constructed and funded. The metro expansion was agreed to between the municipalities of Copenhagen and Frederiksberg and national ministers. Collaboration between these stakeholders was key to the project being approved and this enabling legislation being passed.

On a European level, transport by rail is governed by several European Union (EU) Regulations and Directives. The main strategic document of the EU is the White Paper on Transport, which states that EU funding is only available to infrastructure projects that are resilient to the possible impact of climate change (as well as minimise environmental impact and improves the safety and security of users). The European Commission also has organisations such as EC DG MOVE that provides policy support for adaptation activities in the areas of mobility and transport.

Engagement & Expectations: Metroselskabet considered broader societal impacts of a reduced or closed metro service into consideration, noting that it would not only impact society, but cause reputational damage and affect meeting Metroselskabet's operation reliability target of 98%.

Collaboration and Co-benefits: Metroselskabet acknowledge that protecting the metro system against climate shocks via metro-related infrastructure measures alone is not financially or practically feasible, and recognise that a city-wide approach is more appropriate, particularly in socio-economic terms. Metroselskabet is in ongoing dialogue with the City of Copenhagen (co-owner of Metroselskabet) about plans to install sluices and dams to protect the city.
Importantly, the City of Copenhagen has a climate adaptation plan for the whole city, which explains the level of stormwater the urban environment can handle, as well as describes a series of projects to protect urban elements from cloudbursts and flooding as the climate changes. Metroselskabet has aligned its flood modelling and measures with this city-wide adaptation plan, as measures implemented for the metro system are dependent on the protection measures for Greater Copenhagen.

CASE STUDY 1:
Copenhagen Metro:
Integrating climate adaptation

Knowledge and experience: the success of the project depended on bringing in external expertise, including:

- high levels of climate change literacy within Metroselskabet
- design and construction by companies specialising in transport.
- consultancies (Ramboll, Cowi, Arup and Systra) providing design support via assessments, feasibility studies and cost-benefit analysis.
- research institutions supporting with expert advice; and
- inputs provided from weather forecasting and early warning systems (e.g. ZAMG in Austria).

APPROACH / MOTIVATION / JUSTIFICATION:

Integrating climate adaptation measures into Copenhagen metro to protect against climate shocks (cloudbursts and storm surges) was justified using several key reasons:

- Due to the long lifespan of the infrastructure and low flexibility of its operations to disturbances, it makes commercial sense for Metroselskabet to protect against extreme weather impacts.
- Reduce the risk of severe damage to metro infrastructure that would cause extensive repair costs.
- Reduce the risk of societal impacts and reputational damage from reduced or closed operation. Disruption of metro operation for an extended period would also affect meeting Metroselskabet's operation reliability target of 98%.
- Managing safety risk to human lives, which Metroselskabet has a robust internal safety policy that must be met, which in short states:

  o The safety level shall be as good as at similar metro systems.
  o Risk assessments shall be carried out using a quantified risk acceptance criteria established using the ALARP principle (As Low As Reasonably Practicable).
  o Applicable codes and standards shall be used, such as the European standard EN50126 called RAMS (Reliability Availability Maintainability and Safety).

The implementation of climate-proofing measures was financed by the owners of Metroselskabet and funding is included both in the construction and operating budgets.

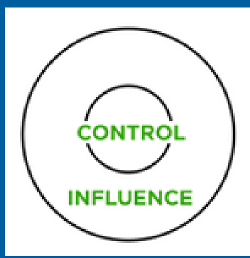
CASE STUDY 1:
Copenhagen Metro:
Integrating climate adaptation

OUTCOME: BENEFITS

The main benefit of climate-proofing measures is the prevention of damages to metro infrastructure and equipment, operation breakdowns and related financial losses associated with climate change induced events, in particular flooding.

Potential transferable actions for Australian and New Zealand utilities: e.g.

- Embed climate adaptation into water utilities' internal infrastructure delivery and asset management processes, ensuring integration of climate risk identification and adaptation within the business rather than regarding it as an optional or a separate stream of activity. (C)
- Determine the level of service water and wastewater customers expect during a climate shock event, to support climate adaptation decision making. (C)
- Improve the levels of climate change risk knowledge within water utilities. (C)
- Identify where to influence climate adaptation measures that impact a greater geographic area (e.g. precinct, town, or city) and reduce the climate adaptation requirements the water utility needs to undertake on their assets (rather than only protecting the utility's assets in isolation). This will require working with government and key partners. (C&I)



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Case Study 2:
Brisbane Airport:
The New Parallel Runway

Country: Australia
City: Brisbane

CLIMATE SHOCK:

Extreme rainfall (flooding)
Storm surge / coastal inundation
Extreme weather (wind, hail etc)
Extreme temperature (heat / cold)
Fire

SECTOR:

Transport
Water
Electricity
Stormwater
Wastewater
Housing / Buildings

ENTITY:

Private
Utility
Council
State

TYPE OF INITIATIVE:

Strategy/Policy
Planning
Implementation / Construction
Operational

ENABLERS:

Strong Leadership
Regulations
Economics
Engagement & Expectations
Collaboration & Co-benefits
Knowledge & Experience

RESILIENCE OUTCOME:

Robustness
Flexibility
Preparedness

Heslop E & Mukheibir P, 2022 Building utility resilience to climate shocks: Lessons from global case studies. Water Services Association of Australia

SUMMARY

Construction of a new parallel runway with an elevated runway, stormwater drainage, and a sea wall to protect against future climate induced increases in rainfall intensity, local flooding and severe inundation from storm tides.

BACKGROUND / DESCRIPTION:

Brisbane Airport is the third busiest airport in Australia, located in a sub-tropical, low lying estuarine environment, close to Moreton Bay.

The airport is owned and operated by the Brisbane Airport Corporation (BAC) which is 80% Australian-owned, principally by superannuation funds. To cope with the growing number of flights, preliminary planning for a new parallel runway (NPR) commenced in 2005 with a construction period of 2012 – 2020. The 2-year defect and liability period will be complete mid-2022.

The BAC has a statutory requirement under the Airports Act 1976 to provide a Master Plan every 5 years that is an essential part of BAC's medium and long-term planning, and the NPR project was incorporated into this process.

CASE STUDY 2:
Brisbane Airport:
The New Parallel Runway

CLIMATE RISK PROFILE

Due to climate change, the site of the new parallel runway is likely to be subject to more intense rainfall causing local/regional flooding, increased cyclonic activity and more severe inundation during storm tides. To ensure NPR could remain operational even during a combination of these events, for example, elevated storm tide occurring concurrently with heavy rainfall, BAC considered the worst-case scenarios.

The design team drew upon design frequency curves obtained from the Queensland Climate Change and Community Vulnerability to Tropical Cyclones (2004) report. The design of storm tide levels was derived representing the combined effect of tide level, storm surge effect and wave propagation. A 1% Average Exceedance Probability (AEP) design storm tide level for the Airport precinct consisted of:

- Current storm surge level of 1.5 m Australian Height Datum (AHD)
- Climate change increase of 400 mm (including 300mm sea level rise and increased cyclone frequency); and
- Wave set up freeboard of 500 mm

This resulted in a design storm tide level of 2.4 m Australian Height Datum (AHD) or 3.53 m Airport Datum (AD) for a 1% AEP storm surge event being adopted for preliminary design of the NPR.

To further assure the proposed runway height would provide protection against future climate shocks, in 2009, the Antarctic Climate and Ecosystems Collaborative Research Centre (ACE CRC) was engaged to evaluate the runway height specifications using the latest climate and sea level data available. Using a customised sea level calculator (CANUTE), the ACE CRC suggested a runway design level of 4.1 m AHD (or 5.23 AD) as 'strongly precautionary'.

CASE STUDY 2:
Brisbane Airport:
The New Parallel Runway

NATURE OF THE RESPONSE:

Brisbane Airport Corporation delivered a new runway, parallel and interconnected to the existing infrastructure that was fit for purpose for the historic and predicted severity and frequency of climate shocks.

The NPR's main objective was to be able to continually operate over its projected lifespan, and this was achieved by the following:

1. Runway level of RL 5.2 m (AD)
2. New underground stormwater pipe system to convey rainfall into tidal channels and reduce flooding.
3. A new seawall to protect against storm surges.

An extensive flood modelling study was completed to inform the final runway elevation and drainage system but also to determine the impacts the construction of the runway would have on existing flood.

The original runway used open channels to convey stormwater from the site, and this has shown to be a risk to safety and airport operation, because open channels can be filled by incoming tides and storm surges, reducing the system's capacity to convey water offsite if heavy rainfall occurs at the same time, for example, during cyclonic activity.

For the new runway, BAC decided to invest ~50M in an underground piped stormwater system. Climate adaptation drove this outcome because a piped systems' full capacity during storm tide events can be retained.

The high runway level also had the added benefit of improving the capacity and operation of the stormwater system. This is because the invert level of the pipes was raised (meaning a greater system capacity) and the gradient of the system was increased (meaning faster flow of water out of the system).

There were no operational or administrative controls used to manage climate risk. Infrastructure was considered the best approach, as it had the required operational outcome, for example, a sea wall so the airport can still operate during storm surges.

CASE STUDY 2:
Brisbane Airport:
The New Parallel Runway

THE ENABLING FACTORS THAT MADE THIS INTERVENTION HAPPEN:

Strong leadership: This case study reflects the strong leadership within Brisbane Airport Corporation to incorporate considerations of climate change impacts in the decision-making process throughout the project life. BAC had clear operational goals of delivering a runway with minimal disruptions to service and this enabled the approval of capital costs associated with mitigating risks from climate shocks.

Leadership was also shown during the construction phase of the project. With a 'one team' approach used for the contractors and consultants engaged by BAC. There was focus placed on the relationship of the entities, not just contractual. For example, A project leadership team was established that met for the "betterment of the project" set up a "team charter" had surveys one-on-one with people every 3 months to check everyone was following the one team charter. There were also incentives for individuals and companies that were seen as going beyond, and not just meeting the contract requirements.

Another leadership enabler at BAC was the clear strategies and plans in place, which supported climate adaptation being embedded into the NPR project's planning and delivery.

Engagement: Stakeholder engagement for the new runway was conducted over 22 months using varied engagement channels and activities. The process involved engagement with a range of stakeholders, including local community environment groups, scientific organisations and traditional owners, with value placed on tapping into the knowledge of the local area to achieve minimal impact on community and the environmental. Lots of research was completed during this time, for example, into turtles, migratory whales, dugongs, sea grass. Issues raised were included and addressed through the Environmental Impact Statement and Major Development Plan processes.

Knowledge and experience: There was a cultural alignment throughout BAC on addressing climate risks from the board, senior management, to project team. The project team was able to build organisational knowledge by developing an understanding of what was working well or not working at the existing runway by talking with the operations and maintenance teams. A lot of this information from the existing system was built into the design. Understanding how to address climate risks in new assets was not just from predictive modelling. The BAC project team also sought information from other big runway projects, looked at case studies and lessons learned and identified what was applicable to the NPR project. BAC also has an Environment Strategy and Climate Change Risk Assessment Register to help adapt to the changing climate and to ensure appropriate mitigation measures are implemented over time (e.g., continual review of sea level risk allowance predictions).

MOTIVATION / JUSTIFICATION:

In 1997, shareholders acquired Brisbane airport for $1.4 Billion and 8 years later, the project team went to the board with a business case for a new runway estimated to cost $1.3B. With such a large investment on critical infrastructure planned to last 100 years, the board was focused on ensuring the asset would be resilient to risks that impacted on operational reliability, including climate shocks.

The cost of climate adaptation was not separated from the broader project, the decision to implement climate adaptation measures was driven by 'business as usual' risk management to ensure operational reliability of the NPR as well as operational compatibility with the existing infrastructure levels.

The operational drivers are inherently economic drivers too, meaning the cost associated with mitigating operational risks from climate shocks is justified by the economic benefits of reduced service disruptions.

The NPR business case also justified implementing a higher runway level than the modelled climate change requirements to achieve operational compatibility with the existing runway infrastructure.

From BAC's perspective, the cost of good design and the additional outlay of funds is justified by the confidence that all future climate change impacts have been considered and there will be no need to upgrade the runway for some time.

CASE STUDY 2:
Brisbane Airport:
The New Parallel Runway

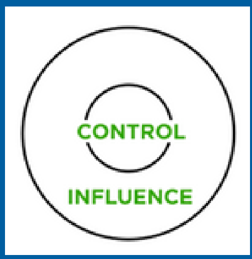
OUTCOME: BENEFITS

The outcomes of the study show that with the runway and drainage in place there will be some increases in the flood levels in the 1 in 100 year flood event which are confined to airport land and part of Nudgee Golf course. Parts of Nudgee Golf Course are already flooded in a 1 in 100 year event and the New Parallel Runway will result in a small increase to the existing flood level. Planning for predicted impacts and exceeding minimum regulatory requirements alleviates pressure of additional construction for the next 50 - 60 years.

After the severe weather event in February 2022, which created severe flooding in Brisbane and along the east coast of Australia, the NPR had no operational impacts compared the original runway where part of the taxiway system went underwater for a couple of days.

Potential transferable actions for Australian and New Zealand utilities: e.g.

- Long term view of project requirements for addressing climate shocks is considered in strategies and from project identification to delivery. (C)
- Incorporating the cost of climate adaptation into the cost of delivering an operationally reliable asset versus the risk and cost of failure. (C)
- Consider climate shocks as a project risk to be mitigated for the life of the asset through the business case process. (C)
- Engage with local stakeholders (e.g. local community groups) for support in improved understanding and management of climate shocks. (C)
- Build organisational knowledge by talking with the O&M teams to understand what was is working well or not working at existing assets. (C)
- Consider a team-focused approach for contractors and consultants engaged by water utilities to deliver climate adaptation. (C)



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WATER SERVICES ASSOCIATION OF AUSTRALIA

UTS Institute for Sustainable Futures

Case Study 3:
UK: Flood mitigation of electricity substations

Country: United Kingdom
City: central southern England and the north of Scotland

CLIMATE SHOCK:

- Extreme rainfall (flooding)
- Storm surge / coastal inundation
- Extreme weather (wind, hail etc)
- Extreme temperature (heat / cold)
- Fire

SECTOR:

- Transport
- Water
- Electricity
- Stormwater
- Wastewater
- Housing / Buildings

ENTITY:

- Private
- Utility
- Council
- State

TYPE OF INITIATIVE:

- Strategy/Policy
- Planning
- Implementation / Construction
- Operational

ENABLERS:

- Strong Leadership
- Regulations
- Economics
- Engagement & Expectations
- Collaboration & Co-benefits
- Knowledge & Experience

RESILIENCE OUTCOME:

- Robustness
- Flexibility
- Preparedness

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SUMMARY

Protection of electrical substations using a national standard to assess current and future flood risk, estimate costs and select protection measures.

BACKGROUND / DESCRIPTION:

Scottish & Southern Electricity Networks (SSEN) is a distribution network operator responsible for over 3.8 million homes and businesses across parts of England and Scotland. They manage electricity networks which comprise of overhead lines, underground cables and substations. Substations transform voltage and supply electricity to large numbers of customers, anywhere from 5,000 to 500,000 per substation.

Major floods in 2005 and 2007 resulted in critical electricity substations losing supply and highlighted their vulnerability. In response to these disaster events, a national task group was established to develop a consistent sector-wide approach to flood resilience, as at this time no industry standard for flood risk and mitigation to prevent loss of supply existed.

The task group was comprised of representatives from network operators, Government, and the industry regulator (OFGEM), who developed a national approach to flood risk assessment and protection to provide comprehensive guidance on the following:

- standards of resilience
- how to take account of increasing risk due to climate change

- methods of assessing the likelihood and impact of flooding
- measures to reduce flood risk
- cost-benefit analysis of measures.

The guidance is documented as a national standard titled 'Engineering Technical Report 138 – Electricity Substation Resilience to Flooding' (ETR138) through the Energy Networks Association.

CLIMATE RISK PROFILE

SSEN's substations are likely to be impacted by river, flash, and sea flooding because of increased winter rainfall, increased rainstorms, and tidal surges. These climate shocks can have a significant impact on substations leading to loss of supply in the network.

Data from UK Met Office's Climate Projections was used to model climate impacts for the UK's electricity network under a high emission scenario until the end of the century (corresponding to the IPCC SRES A1FI scenario). The Met office's data has been updated overtime (in 2002, 2009 and 2018) as new data has become available, and any changes to climate projections the new data brings has been incorporated into ETR138 and SSEN's flood mitigation program.

CASE STUDY 3:
UK: Flood mitigation of electricity substations

NATURE OF THE RESPONSE:

Since 2008, SSEN have been undertaking a long-term programme of works to improve substation resilience to flooding, including predicted climate impacts. This programme was agreed to by the industry regulator when allowances were set as part of the regulatory control periods; and is planned to be completed by 2023.
The flood resilience programme used the industry standard ETR138 to assess the flood risk and design flood defence measures. The key steps of SSEN's flood resilience programme are summarised below:

Step 1: Assessment of flood risk
Flood risk assessments were undertaken for all grid and primary substations to identify those at risk of flooding. As per ETR138, the following data was collected to undertake the assessment:

1. the likelihood of flooding in any one year (from rivers or the sea)
2. the potential depth of flood water
3. information about historic flooding
4. existence and condition of flood defence scheme
5. whether the site is in an area where the Environment Agency provides flood warnings
6. the time required to activate flood protection measures.
7. societal risk – number of customers and number of critical / vulnerable customers

The UK's Environmental Agency's flood risk maps was the data set applied to the ESRI mapping system to evaluate substations requiring flood protection based on the resilience levels set out in ETR138 (see table below). These standards are considered the default, but can be raised or lowered if an analysis of the costs and benefits suggests that is appropriate. Benefits include fewer disruptions to customers, lower regulator penalties and less reputational damage.

CASE STUDY 3:
UK: Flood mitigation of electricity substations

Prioritisation of the default levels for substation resilience (Issue 3 ETR138)

Substation Type	Flood Resilience Level
Grid Substations (132kV) And Primary Substations (33kV) (>10,000 unrecoverable connections)	Protection against the level of flooding that may occur within a 1:1,000-year flood contour for fluvial, pluvial and coastal flooding.
Primary Substations (33kV) (<10,000 unrecoverable connections)	Protection against the level of flooding that may occur within a 1:100 year fluvial and pluvial flood contour (1:200 in Scotland) and within the 1:200 contour for coastal flooding throughout GB.
Distribution Substations (11kV)	Not normally protected but may require protection in certain circumstances.

Step 2: Design and implementation of flood defence measures
SSEN considered a variety of flood prevention measures, including:

- a flood wall or embankment constructed around the site perimeter, designed to protect the entire site.
- building only protection. Barriers erected around individual plant and equipment items; or raising the level of plant items and equipment above predicted flood levels.
- a combination of these solutions to achieve the required level of flood protection.

Importantly, the resilience work is proposed to continue at SSEN with a further programme of work proposed for the next regulatory control period.

CASE STUDY 3:
UK: Flood mitigation of electricity substations

THE ENABLING FACTORS THAT MADE THIS INTERVENTION HAPPEN:

Regulatory Environment: The UK Climate Change Act 2008 requires SSEN to regularly report on what activities are being undertaken to adapt to climate change. This requirement has helped to drive SSEN's climate adaptation responses.

The Flood Risk Regulation 2009, requires the UK Environment Agency to prepare and publish flood risk information, including maps and management plans, on a six-year cycle. This is useful data for companies like SSEN to support the assessment of their flood risk and provide a consistent national approach.

Further, Ofgem introduced the Interruptions Incentive Scheme in April 2002. Under this scheme distribution companies are set a target for the number of interruptions each year that last over three minutes, and the total length of those interruptions. If they beat these targets they are rewarded and conversely, they are penalised if they do not achieve the targets.

Collaboration: The establishment of a task group and development of an industry standard was critical to enabling SSEN to develop and gain funding approval from OFGEM for a flood resilience programme. The industry standard (ETR138), which incorporated increasing flood risk due to climate change, was accepted by the Energy Emergencies Executive Committee (E3C), a partnership between government, the regulator OFGEM and industry for coordination of resilience planning across the energy industry.

Economics: Acceptance by E3C ensured all key stakeholders supported the flood resilience approach, meaning the inclusion of a flood resilience programme in SSEN's periodic price control review was expected and the approach followed an agreed national standard making the method and resilience levels to meet clear for SSEN and OFGEM.

Knowledge and Experience: A key enabler of the decision to protect electrical substations across the UK was direct experiences in climate shock events that resulted in substation failures.

CASE STUDY 3:
UK: Flood mitigation of electricity substations

APPROACH / MOTIVATION / JUSTIFICATION:

The national sector-wide approach to improving flood resilience of substations to an agreed standard has provided SSEN with clear justification to proceed with substation flood mitigation activities. The new ETR138 standard requires SSEN to raise their substation protection level to meet the agreed standards. As government and the regulator OFGEM were involved from the start, SSEN's business plans which follow this approach have been approved through the price control process (known as RIIO (Revenue = Incentives + Innovation + Outputs)).

Prevention of flooding at substations saves direct costs on repairs and customer compensation and saves large costs that would fall on the community if lengthy and widespread power cuts were to occur.

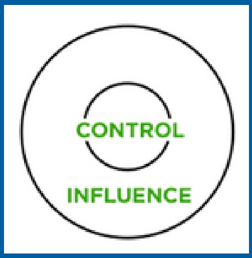
OUTCOME: BENEFITS

- SSEN now has a clear programme to raise substation flood protection levels to a national standard.
- The government has been clear about the standard of protection of this vital service.
- There is consistency for all distribution network operator across UK - customers in different areas enjoy the same standards of protection.
- Resilience measures take account of climate change, so will be robust in the foreseeable future.

CASE STUDY 3:
UK: Flood mitigation of electricity substations

Potential transferable actions for Australian and New Zealand utilities: e.g.

- Consider advocating for a sector-wide approach to assessing and designing resilience measures for climate shocks, with key industry, government, and regulatory stakeholders' part of a "task force", possibly with WSAA. (I)
- Advocate for any industry standards developed to make allowances for climate change to handle uncertainty about future risk, and keep standards under review, updating to take account of new information. (I)
- Consider jointly examining the current assessment of impacts and adaption options with the relevant state/territory pricing regulator, with the aim of agreeing a way forward that will be considered as part of the next round of pricing review, to overcome net present value issues when developing a business case. (C&I)



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Case Study 4:
Santiago:
Adapting to high turbidity

Country: Chile
City: Santiago

WATER SERVICES ASSOCIATION OF AUSTRALIA

UTS Institute for Sustainable Futures

CLIMATE SHOCK:

- Extreme rainfall (flooding)
- Storm surge / coastal inundation
- Extreme weather (wind, hail etc)
- Extreme temperature (heat / cold)
- Fire

SECTOR:

- Transport
- Water
- Electricity
- Stormwater
- Wastewater
- Housing / Buildings

ENTITY:

- Private
- Utility
- Council
- State

TYPE OF INITIATIVE:

- Strategy/Policy
- Planning
- Implementation / Construction
- Operational
- Pilot

ENABLERS:

- Strong Leadership
- Regulations
- Economics
- Engagement & Expectations
- Collaboration & Co-benefits
- Knowledge & Experience

RESILIENCE OUTCOME:

- Robustness
- Flexibility
- Preparedness

Heslop E & Mukheibir P, 2022 Building utility resilience to climate shocks: Lessons from global case studies. Water Services Association of Australia

SUMMARY

A utility constructed standby storage infrastructure to provide flexibility to overcome the poor quality of the source water due to increased turbidity.

BACKGROUND / DESCRIPTION:

The city of Santiago, Chile, has about 7 million inhabitants and produces about 40% of Chile's gross domestic product. The private water utility, Aguas Andinas, produces 80% of the city's drinking water. Since 2008, the city has been affected by high-turbidity events in the Maipo River, the main source of water, located in the southeast of Santiago. This poor quality water has resulted in severe disruptions to the supply of water to the city in recent years.

CASE STUDY 4:
Santiago:
Adapting to high turbidity

CLIMATE RISK PROFILE

The cause of the high-turbidity events are associated with high-levels of soil erosion in the Andean zone where the Maipo River headwaters are located. A greater area is exposed to erosion when there is heavy rains instead of snow precipitation. This phenomenon is plausibly associated with increase in global temperatures due to climate change, and likely to increase in future.

As a result of the river's high level of turbidity, Aguas Andinas has had to temporarily interrupt the production of drinking water at its primary drinking water plants, Las Vizcachas and La Florida. In some events, water turbidity has reached more than 380,000 NTU, with 3,000 NTU being the maximum possible turbidity treatable in their water production plants.

Three high-turbidity events (April 2016, February 2017, April 2017) caused several hours of service interruption. The duration of the February 2017 event exceeded 48 hours, affecting more than 1,400,000 homes (customers). In the cases of April 2016 and April 2017, 1,000,000 and 1,400,000 customers were left without service for longer than 12 hours, respectively.

CASE STUDY 4:
Santiago:
Adapting to high turbidity

NATURE OF THE RESPONSE:

In 2014 Aguas Andinas commissioned a 5 km long pipeline that allows water to be drawn from the reservoir directly to the plant for treatment, even if the plant inlet is closed due to the turbidity of the river. Together with the construction of tanks with a capacity of 0.225 GL and wells with a production capacity of 300 L/s, made it possible to increase the buffer capacity to 9 hours, during which time the turbidity levels would improve. However, due to the increase in turbidity and further outages, as described above, the construction of a further 1.5 GL storage (the Pirque Mega Ponds) for natural, untreated water (raw water) was approved, thus increasing supply autonomy to 34 hours from 2020 (this is however would not have completely avoided the disruptions in Feb 2017).

The approval of this response was beyond the normal required planning process and has required the planners to consider the uncertainty of future heavy storm events in order to anticipate the occurrence of high turbidity and reduce the risk of service outages.

Since the frequency of turbidity events is projected to increase over time, further works are proposed to avoid supply disruptions due to increased frequency of turbidity events and ensure up to 2 days' worth of autonomous water storage by either increasing raw water storages (cheapest option), wastewater recycling, or inter-connecting existing storage.

CASE STUDY 4:
Santiago:
Adapting to high turbidity

THE ENABLING FACTORS THAT MADE THIS INTERVENTION HAPPEN:

Regulations: Every five years tariff structures are submitted to Superintendencia de Servicios Sanitarios (SISS), an autonomous organization of the Chilean Government, controlled by the Public Works Ministry. SISS is responsible for controlling the tariffs, levels of service and investment of the water utilities. While, the utility is regulated to deliver a minimum level of service 24/7, the utility did not incur any penalties for the disrupted service in 2016 and 2017. Aguas Andinas argued that the turbidity events were an act of God, and not something that was foreseeable at that time. However, with knowledge that these events do occur and the projected further increase in turbidity events meant that Aguas Andinas needed to plan for managing these events to meet their regulatory obligations, or risk non-compliance and penalties.

Engagement and expectations: The major driver for the utility to ensure a security of supply is one of **reputation**, and to not learn and respond from historic events was a reputational risk. As a private company, they cannot afford to have their name tarnished in fear of losing their concession to supply water to Santiago in future. They have an obligation to their shareholders to make sure they turn a profit and maintain their concession to supply water.

Economics: The investment of A$200 M since 2014 is approximately A$35 per person served, which when translated to an increase in the tariff across the large customer base, it amounts to a relatively small increase for ensuring the continuity of supply and managing the risk. This argument was accepted by the regulator.

Knowledge and experience: The adaptive and iterative planning approach since 2014 has allowed the utility to learn its way forward based on historical lessons learnt. The utility was willing to accept the climate change science as it related to increased warming temperatures and changing rainfall patterns, as supported by the evidence of recent historical experiences. They were able to motivate for the investment in infrastructure that provides the flexibility to cope with increasing water quality issues caused by heavy rainfall events in the upper reaches of the catchment. The company is currently looking at further options to build in flexibility to cope with future increases in turbidity events.

CASE STUDY 4:
Santiago:
Adapting to high turbidity

APPROACH:

The disruptions to the water services were not due to a shortage of water per se, but rather poor quality water that is beyond the treatment capacity of the current treatment infrastructure. Transfer agreements between the agriculture sector located on the Maipo river and the utility has meant that Santiago has not experienced water shortages during a drought and therefore demand restrictions in recent times. As a private company, the utility has no legal, political leverage or social contract with its customers to impose restrictions, and the expectation from customers is for water to be delivered 24/7. Therefore, Aguas Andinas embarked on new infrastructure investments to ensure that there would no disruptions due to increased incidences of turbidity. With a population of over 7 million, the impact on prices due to these investments is considered minimal and will be accepted by SISS.

OUTCOME: BENEFITS

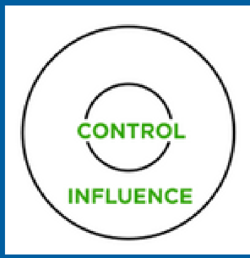
By building additional offline storages, Aquas Andinas has been able to ensure the continuity of supply and service to its customers, as prescribed in the operating licence, during periods of poor source water quality. This storage buffer has been insufficient to cope with the recent 2022 droughts however.

Through increasing the autonomous offline storage by an additional 34 hours, the utility is able continue to operate its treatment facilities during high turbidity events, and can resume river extraction once the water quality had resumed to acceptable levels.

CASE STUDY 4:
Santiago:
Adapting to high turbidity

Potential transferable actions for Australian and New Zealand utilities: e.g.

- Plan and implement infrastructure investments to avoid disruptions to water services, and ensure water security 24/7 based on climate science and projected rates of soil erosion (or flooding) in raw water catchments. (C)
- Survey customers to establish the level of service expected during increased cases of turbidity. (C & I)
- Demonstrate to the regulator that investment is needed to maintain a reliable supply to customers, and avoid frequent restrictions due to intermittent high turbidity. This will require collaboration with any associated bulk water supply authority or similar. (C & I)



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Case Study 5:

Cape Town: Stormwater management

Country: South Africa
City: Cape Town

CLIMATE SHOCK:

- **Extreme rainfall (flooding)**
- **Storm surge / coastal inundation**
- Extreme weather (wind, hail etc)
- Extreme temperature (heat / cold)
- Fire

SECTOR:

- Transport
- Water
- Electricity
- **Stormwater**
- Wastewater
- Housing / Buildings

ENTITY:

- Private
- Utility
- **Council**
- State

TYPE OF INITIATIVE:

- Strategy/Policy
- **Planning**
- Implementation / Construction
- Operational
- Pilot

ENABLERS:

- **Strong Leadership**
- Regulations
- Economics
- Engagement & Expectations
- **Collaboration & Co-benefits**
- **Knowledge & Experience**

RESILIENCE OUTCOME:

- **Robustness**
- Flexibility
- Preparedness

BARRIERS:

- **Temporal issues**
- **Tension between knowledge and decision-making**

Heslop E & Mukheibir P, 2022 Building utility resilience to climate shocks: Lessons from global case studies. Water Services Association of Australia

SUMMARY

Incorporating climate science in decisions-making aimed at reducing the risks and impacts of flooding due to increased rainfall intensity and sea level rise.

BACKGROUND / DESCRIPTION:

Cape Town's stormwater system comprises a complex and extensive network of natural and engineered features, which are owned by the City of Cape Town Municipality and managed by the Stormwater Branch. The coverage, age and quality of the current system assets varies considerably across the city, which gives rise to difficult decisions when weighing up relative costs and benefits associated with maintaining and upgrading existing infrastructure and expanding the network to under-serviced areas (due to the historical legacy of inequality). The rainfall patterns vary considerably across the western cape peninsula, both spatially and between years. The many small catchments, together with short-duration and high-intensity rainfall events results in periodic flooding associated with damage to property and infrastructure and the disruption of movement, economic activities and important services.

CASE STUDY 5:
Cape Town:
Stormwater management

CLIMATE RISK PROFILE

Using statistically downscaled climate data derived from five global climate models (GCMs), forced with one emissions scenario, hydrological attributes of the Cape Town sub-catchments were simulated. It was recommended to increase design rainfall intensity by 15 per cent.

Focusing on the Salt River catchment, the estimated sea level rise for climate scenarios for 2035 and 2050 were fed into the flood modelling, and this resulted in a predicted upper increase in maximum high-tide water levels from +1,90 m to +2,57 m above mean sea level (MSL) for the 1:20-year return period and from +2,01 m to +2,70 m MSL for the 1:100-year return period by the year 2060 (downscaled from 10 GCMs). These increases in water levels resulted in the potential for significantly increased flooding and damage.

CASE STUDY 5:
Cape Town:
Stormwater management

NATURE OF THE RESPONSE:

The rainfall and sea-level rise projections developed in the Salt River pilot were incorporated in subsequent modelling and master-planning of the other eastern catchments in 2013. The process was put in place for the remaining regions to be modelled and master plans developed using the same methodology. However, shortages in funding, changes in staffing, and organisational restructuring have caused these initiatives to be postponed.

Based on results from the Salt River pilot study, a number of climate risk reduction (or adaptation) measures have been promoted, which include:

- supporting and commissioning further research on flood risk assessment and preparedness;
- improving policy implementation to regulate urban development in vulnerable areas;
- adjusting the timing and intensity of stormwater maintenance activities;
- communicating to other stakeholders on the potential impacts of climate change, how the City is responding and what more is needed.

However, implementation has been slow to materialise, requiring additional resourcing, collaboration with other departments and external stakeholders, and, most importantly, political will to go down this path.

CASE STUDY 5:
Cape Town:
Stormwater management

THE ENABLING FACTORS THAT MADE THIS INTERVENTION HAPPEN:

Strong leadership: Leadership on climate change was demonstrated at the department level with the City's Environmental Resource Management Department commissioning the development of the Energy and Climate Change Strategy, the preparation of a Climate Adaptation Plan of Action, and a Global Climate Change Sea-Level Rise Risk Assessment for the CCT (between 2005-2008). These processes opened up dialogue and debate within the CCT's planning departments about the extent of local risks posed by climate change and the nature and suitability of proposed responses to stormwater and flooding. However, the engagements remained largely within the technical realm, and out of the political public domains, largely due to a lack of senior leadership (as opposed to that shown by the department).

Organisational knowledge: On the advice of a consultant in 2006, the Stormwater Branch identified the need to include climate change in the modelling of the catchments as a basis for detailed planning to manage and operate existing stormwater infrastructure assets and prioritise the acquisition and construction of new assets. Through the piloting of the Salt River catchment, the City's ability and knowledge to plan future provision and upgrade of stormwater infrastructure, determine service levels, improve development control and undertake scenario planning associated with urban densification, climate change and maintenance regimens was enhanced.

Collaboration and co-benefits: The intersection between the work of the Stormwater Branch, the Environmental Resource Management Department, the Western Cape Government, two universities and five consulting companies has given rise to the changes made to the analysis approach.

THE BARRIERS THAT CHALLENGED THE INTERVENTION:

Temporal challenge: Hampered by long lead times (more than 10 years, and still ongoing) to build the knowledge base and lay the planning and policy groundwork to enable the detailed design, selection and implementation of adaptation measures. Also the Day Zero drought distracted attention and funding.

Complex relationship between knowledge and decision-making: The decisions made were all driven and made by officials in the city administration and not by the elected officials. The complex nature of the scientific knowledge underpinning the decisions requires considerable technical expertise to interrogate and assimilate the range of results, while accounting for numerous possible scenarios with extensive spatial heterogeneity at the local scale. The implications are potentially far-reaching with regard to the development of the city and the allocation of public resources. The poor engagement with the political dimension of the decision-making process has undermined collaborative, integrated and inclusive decision-making. The scientific knowledge has not had the opportunity to influence the views of the political decision makers.

CASE STUDY 5:
Cape Town:
Stormwater management

APPROACH:

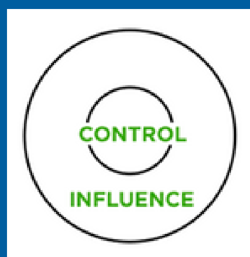
The implementation of the Salt River pilot study provided a **learning opportunity** for the Stormwater Branch to build its knowledge on how the impacts of climate change could be incorporated into the catchment modelling, asset planning and maintenance regimes in order to ensure resilience to flooding in future. The learnings from this initiative led to the future climate change impacts being specified for inclusion in subsequent catchment management planning processes.

OUTCOME:

The application of this approach has revealed that the conceptual framework has engaged poorly with the politics of decision-making. This has resulted in the improved analytical process not being progress to other catchments, nor the projected impacts due to climate change being incorporated in political decisions about land use zoning and spending on anticipatory stormwater infrastructure.

Potential transferable actions for Australian and New Zealand utilities: e.g.

- Ensure climate adaptation policy positions are developed first, to give support to people within the organisation with the knowledge and motivation to deliver on climate adaptation. (C)
- Strengthening the coordination and collaboration between multiple actors with a stake in city-wide climate adaptation. (I)
- Combining the technical expertise required to deal with the complex and evolving knowledge base with the political (and economic) expertise to address contested trade-offs and value-based judgements that underpin these decisions, with stakeholders and regulators. (C & I)



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WATER SERVICES ASSOCIATION OF AUSTRALIA

UTS Institute for Sustainable Futures

Case Study 6:
Victoria: Healthy Homes program

Country: Australia
City: Melbourne

CLIMATE SHOCK:

Extreme rainfall (flooding)
Storm surge / coastal inundation
Extreme weather (wind, hail etc)
Extreme temperature (heat / cold)
Fire

SECTOR:

Transport
Water
Electricity
Stormwater
Wastewater
Housing / Buildings

ENTITY:

Private
Utility
Council
State

TYPE OF INITIATIVE:

Strategy/Policy
Planning
Implementation / Construction
Operational
Pilot

ENABLERS:

Strong Leadership
Regulations
Economics
Engagement & Expectations
Collaboration & Co-benefits
Knowledge & Experience

RESILIENCE OUTCOME:

Robustness
Flexibility
Preparedness

Heslop E & Mukheibir P, 2022 Building utility resilience to climate shocks: Lessons from global case studies. Water Services Association of Australia

SUMMARY

Assessed the benefits of energy upgrades aimed at minimising the impacts of extreme weather (cold) on households using cost consequence analysis.

BACKGROUND / DESCRIPTION:

The Victorian Healthy Homes Program (VHHP) is a Victorian Government home energy efficiency program. It provides up to 1000 free home energy upgrades to Victorians who live with complex healthcare needs and have low incomes, in Melbourne's western suburbs and the Goulburn Valley. The program aims to improve indoor winter temperatures and reduce household energy bills. The impact on thermal comfort, wellbeing, health, energy use and costs to society of the home energy upgrades for vulnerable households were assessed through a randomised controlled trial.

CASE STUDY 6:
Victoria:
Healthy Homes program

CLIMATE RISK PROFILE

The average daily minimum and maximum winter temperatures are 5.4oC-13.2oC respectively in Melbourne, and 3.4oC-and 3.3oC respectively in Shepperton. Days over 35oC in Melbourne currently average 8 per year.

By 2070, average annual temperature for Melbourne is projected to rise by 2.6°C (2.1–3.1°C), and for Shepperton it projected to increase by between 0.6-1.1oC. Average number of hot days in Melbourne are expected to double.

CASE STUDY 6:
Victoria:
Healthy Homes program

NATURE OF THE RESPONSE:

The VHHP was implemented over a three-year period commencing in 2018, and has a staggered parallel group randomised controlled trial (RCT) design, where households were randomly assigned to one of two study groups. All households received the home upgrade (the range of upgrades available included ceiling and underfloor insulation, draught sealing external doors, space heating which can include reverse cycle air conditioning or replacement of gas heater, upgrades to lighting, and internal window coverings). The intervention group received the upgrade prior to winter and the control group received the upgrade after winter.

The primary outcome measured was average difference in temperature in the home between the intervention and control groups over winter. The secondary outcomes measured included the improvement in quality of life, reduction in gas and electricity consumption (and therefore a reduction in GHG emissions), and reduction in health service utilisation and costs.

The economic evaluation analysed both outcomes and cost data from the primary and secondary outcomes in the intervention and control groups. The economic evaluation undertaken included both a cost-consequence analysis (CCA) and a cost-effectiveness analysis (CEA).

CCA is a form of economic evaluation where disaggregated costs and a range of outcomes are presented to allow the decision maker to form their own opinion on relevance and relative importance of attributes to their decision-making context. The benefits are not aggregated into one monetised score, as would be the case for cost benefit analysis.

CEA compares an intervention to another intervention (or the status quo) by estimating how much it costs to gain a unit of a health outcome (like temperature, cold days avoided). It is always comparative and so we are exploring the incremental change in both costs and the relevant outcomes.

CASE STUDY 6:
Victoria:
Healthy Homes program

THE ENABLING FACTORS THAT MADE THIS INTERVENTION HAPPEN:

Strong leadership: The initial and primary motivation for the pilot study was to demonstrate the health (and energy cost saving) benefits of providing thermal improvements to lower-socio economic homes. Sustainability Victoria demonstrated leadership and set up the large pilot study (1000 homes) to assess the impact on thermal comfort, wellbeing, health, energy use and costs to society of the program, with a view to rolling it out more broadly across Victoria if the outcomes were positive, most notably whether improving residential energy efficiency reduces negative health outcomes.

Economics: The post intervention economic analysis considered both the monetised and non-monetised costs and benefits of the intervention, which included social and environmental aspects. Specifically a range of specific financial, indoor environmental, and health outcomes were considered, such as: average daily temperature within the home; quality adjusted life years; exposure to cold conditions; health care use and costs; Household energy costs; to list a few. The cost consequences analysis method allowed these outcomes to be assessed individually without needing to monetise them.

APPROACH:

The most interesting and relevant part of this case example, is that the **CCA** approach was adopted to demonstrate the benefits against a list of standalone objectives.

CCA is an approach that has mostly been used for assessing arrange of health outcomes due to a specific investment. The CCA approach avoids the need to monetise the outcomes (as would be the case for a cost benefit analysis) nor does it depend on a multi-criteria analysis (MCA) approach (where the outcomes are weighted by relevance) to bring the scores to a single assessment score. CCA is deliberately designed to allow the decision maker to form their own opinion on the relevance and relative importance of the outcomes and their magnitude of improvement.

In essence, this method reveals the social and health benefits of an intervention without comparing it to another intervention. It is not used for comparative assessments. Having established that the intervention does indeed deliver benefits, the aim is then to deliver them as cost effectively as possible.

WATER SERVICES
ASSOCIATION OF AUSTRALIA

CASE STUDY 6:
Victoria:
Healthy Homes program

OUTCOME: BENEFITS

The home upgrades had a positive impact on mean indoor temperature over winter by 0.33oC.

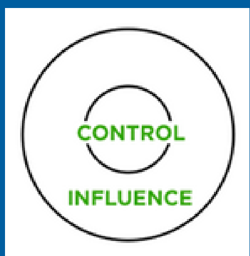
The economic analysis for the Healthy Homes program was able to demonstrate that there were both health and energy savings using the CCA method. This method demonstrated that an investment of around $4700 per home resulted in a 10% reduction in Medicare services. This investment also led to significant positive impacts on quality of life measured by the SF-36 mental health component score which showed an improvement in the intervention group of 1.5 points compared to the control group, and a reduction in absence from usual activities over winter.

The CEA further revealed that the number of cold nights avoided was the most cost effective outcome.

[SF-36: The Short Form 36 Health Survey Questionnaire (SF-36) is used to indicate the health status of particular populations, to help with service planning and to measure the impact of clinical and social interventions. It is a 36 item scale, measured across eight domains of health status: physical functioning; physical role limitations; bodily pain; general health perceptions; energy/vitality; social functioning; emotional role limitations]

Potential transferable actions for Australian and New Zealand utilities: e.g.

- Consider using the Cost Consequence Analysis approach for assessing the costs and benefits of an intervention, and avoid monetising the outcomes, assigning weights to the indicators and/or summing the scores using MCA. This approach could be especially useful for assessing outcomes associated with investments aimed at delivering liveability objectives, such as local cooling and green open space. (C & I)
- Consider multiple benefits from adaptation responses e.g. community benefits as well as infrastructure resilience. (C)



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Case Study 7:
New York City: Wastewater Resiliency Plan

Country: USA
City: New York City

CLIMATE SHOCK:

- Extreme rainfall (flooding)
- Storm surge / coastal inundation
- Extreme weather (wind, hail etc)
- Extreme temperature (heat / cold)
- Fire

SECTOR:

- Transport
- Water
- Electricity
- Stormwater
- Wastewater
- Housing / Buildings

ENTITY:

- Private
- Utility
- Council
- State

TYPE OF INITIATIVE:

- Strategy/Policy
- Planning
- Implementation / Construction
- Operational
- Pilot

ENABLERS:

- Strong Leadership
- Regulations
- Economics
- Engagement & Expectations
- Collaboration & Co-benefits
- Knowledge & Experience

RESILIENCE OUTCOME:

- Robustness
- Flexibility
- Preparedness

Heslop E & Mukheibir P, 2022 Building utility resilience to climate shocks: Lessons from global case studies. Water Services Association of Australia

SUMMARY

The New York City Department of Environmental Protection has developed a Wastewater Resiliency Plan to protect wastewater treatment plants and pump stations against the climate shocks of flooding and storm surges.

BACKGROUND / DESCRIPTION:

The New York City Department of Environmental Protection (NYCDEP) owns and operates one of the largest wastewater collection and treatment systems in the world, with 14 wastewater treatment plants (WWTPs) and 96 pumping stations that convey stormwater and wastewater (in combination in some networks).

Many of the plants and pumping stations are low-lying and located close to the waterfront. This creates challenges that were evident during Hurricane Sandy in 2012, when a storm surge caused extensive flooding and resulted in over $95 million in damage at 10 wastewater treatment plants and 42 pumping stations; millions of gallons of untreated and partially treated wastewater spilled into the harbour.

Hurricane Sandy became a major tipping point for New York City resilience planning under Mayor Michael Bloomberg with many city-wide strategies released that supported and proactive climate adaptation. One such strategy, A Stronger, More Resilient New York, committed the City to harden its wastewater treatment plants and pumping stations, which is why the NYC Wastewater Resiliency Plan was developed.

CASE STUDY 7:
New York City:
Wastewater Resiliency Plan

CLIMATE RISK PROFILE

Climate studies predict that NYC is likely to have more frequent and large surge events that will be exacerbated by sea level rise in the future. Previous wastewater facility designs typically provided protection against the highest historically recorded water height of nearby water bodies. However, the new surge records set by Sandy and projected future sea level rise led to a new **"critical flood elevation"** design standard being determined by NYCDEP (its calculation is explained in the following section).

Future sea level rise estimates were based on the high end projections by the New York City Panel on Climate Change (NPCC), which was convened by Mayor Michael Bloomberg in response to Hurricane Sandy. The NPCC modelled projections across RCPs 4.5 and 8.5 for 35 GCMs.

CASE STUDY 7:
New York City:
Wastewater Resiliency Plan

NATURE OF THE RESPONSE:

NYCDEP proactively assessed the resiliency of its wastewater infrastructure using the NYC Wastewater Resiliency Plan, which contains a framework of three major modules that analyse: future climate, infrastructure risk and then adaptation needs.

Module one calculated the **critical flood elevation** by using Federal Emergency Management Agency's (FEMAs) 100-year advisory base flood elevation online maps (which provide flood levels for specific local conditions, e.g. topography) plus an additional 30 inches to account for sea level rise into the 2050s, based on climate projection data from NPCC. The year 2050 was chosen to be consistent with DEP capital planning programs.

Module two was a comprehensive **risk analysis**, which determined that all 14 WWTPs and 60% of the 96 pumping stations were at risk of flood damage. This risk analysis was completed through site visits, analysis of facility blueprints, and interviews with facility personnel. Information about conditions during Hurricane Sandy also helped pinpoint specific risks and operational challenges. The existing elevations of infrastructure were then compared to the **critical flood elevation** to determine what was potentially at risk.

Cost estimates for the replacement of at-risk equipment under emergency conditions, cleaning of facilities, and temporary power and pumping were developed, and then used as a metric to inform the prioritization of risks.

Module three involved the selection of **six adaption strategies** (based on an extensive global literature review) that would best protect at-risk wastewater infrastructure from storm surges. These adaption strategies are listed below and include a range of strategies such as response measures, building robustness, and designing out risk (in increasing order of protection level).

1. providing backup power generation to pumping stations where feasible (no protection of equipment, but assists with regaining service).
2. emergency response of temporary sandbagging before an event.
3. sealing buildings or control rooms with watertight windows and doors.
4. constructing a static barrier across doors and other access ways.
5. floodproofing equipment, such as making pumps submersible, and placing electrical equipment in watertight casings.
6. elevating equipment above critical flood elevation.

As well as protection measures, other options being considered in response to storm surges and sea level rise, include relocation of the city's emergency pumping stations, system modifications, and increasing pumping capacities.

WATER SERVICES ASSOCIATION OF AUSTRALIA

CASE STUDY 7: New York City: Wastewater Resiliency Plan

THE ENABLING FACTORS THAT MADE THIS INTERVENTION HAPPEN:

Strong leadership: New York City, through the Mayor's Office, has had a strong focus on strategic planning to envision a sustainable and resilient city. First released in 2007, the plan (currently titled *OneNYC 2050: Building a Strong and Fair City*) has been reviewed and updated numerous times and most recently in 2019. This strategic planning has provided guidance and support to the many city agencies delivering services to the people of NYC. For example, the plan was updated after Hurricane Sandy in 2013 (titled *A Stronger, More Resilient New York*) committing to the hardening of wastewater infrastructure, which triggered the development of the *NYC Wastewater Resiliency Plan* and provided funding support to help achieve this.

Another great example of leadership is the Mayor's Office of Resiliency in New York City recently formulated new Design Guidelines for Climate Resiliency "to incorporate forward-looking climate change data in the design of City capital projects". The guideline includes, for example, a toolkit for a resilient design process, risk assessment methodology, and benefit-cost analysis methodology.

Economics: A Triple Bottom Line Analysis, which considers financial, social and environmental consequences, was completed during the infrastructure risk analysis (Module two) to guide adaptation decision-making and prioritisation for NYCDEC.

Environmental and social costs of flood damage were analysed from a qualitative perspective. WWTPs level of impact was determined based on proximity to bathing beaches. Pumping stations were prioritised based on metrics such as historical flooding frequency, proximity to beaches and sensitive waterbodies, tributary area population, facility size, number of critical facilities (hospitals, schools, etc.) potentially affected by failure, as well as operational metrics – whether the facility is scheduled for improvements in DEP's 10-year capital plan.

Collaboration and Co-benefits: NYC's strategic planning approach has also used successful participatory approaches that brought 25 city agencies together to envision common goals for the future. As part of these plans, pro-active design guidelines, zoning regulations, urban greening, and infrastructural projects that promote sustainability are being developed.

Knowledge and experience: A key enabler of the NYC Wastewater Resiliency Plan was the experiences during Hurricane Sandy, which resulted in major damage to and pollution from the city's WWTPs and sewer pump stations.

CASE STUDY 7:
New York City: Wastewater Resiliency Plan

APPROACH:

The NYC Wastewater Resiliency Plan is a model for a proactive approach to hardening wastewater infrastructure so the systems continue to operate during floods or storms, even as the climate changes.

NYCDEP has started protecting its wastewater treatment facilities by implementing the six adaptation measures as part of repairs and other planned capital improvements. The improvements have been prioritised based on level of risk at the facility, level of service to the community, and whether the facility has other planned capital improvements or were at the end of equipment life spans.

Investing $315-$426 million in a strategic mix of protective measures has been estimated to save New York City $1.1-$1.76 billion in damage costs avoided plus save $2.5 billion in emergency response costs avoided over the next 50 years; reducing the risk to NYC's wastewater infrastructure by 85 percent. These estimates provide strong support for implementing protective measures as they will likely save the city more money compared to the cost of repairs and disaster relief over time. [1,11,6]

Several federal funding sources became available for areas impacted by Hurricane Sandy, for example, funding to repair damaged facilities, and funding to strengthen long-term resilience for wastewater (and drinking water) treatment facilities.

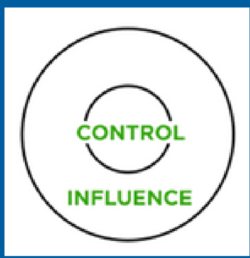
CASE STUDY 7:
New York City: Wastewater Resiliency Plan

OUTCOME: BENEFITS

The NYC Wastewater Resiliency Plan has saved millions of dollars in avoided costs and strengthened wastewater infrastructure to be resilient against climate shocks of storm surge and flooding into the 2050s and hopefully beyond.

Potential transferable actions for Australian and New Zealand utilities: e.g.

- Proactively undertake resiliency and adaptation planning so risks from climate shocks are understood and there is an agreed approach of how to balance risk and adaptation needs for capital projects. (C)
- Develop climate adaptation plans for areas at-risk to climate shocks, with ready-to-implement projects that can be either incorporated into planned asset upgrades/renewals or actioned when funding opportunities become available (e.g. after a climate shock event). (C)
- Revise engineering design standards to accommodate anticipated increases in sea level and storm surges. (C&I)
- Refine emergency response plans to improve disaster preparedness and recovery based on risk assessment and feedback from operating staff. (C)
- Undertake strategic planning to envision a resilient participatory approaches that bring together key stakeholders to agree on common goals for the future. (C)
- Consider a Triple Bottom Line Analysis to infrastructure risk analysis (Module two) to guide adaptation selection and prioritisation (and compare against "do nothing" costs of repairs and disaster relief). (C&I)



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Case Study 8:
Copenhagen: Cloudburst Solutions

Country: Denmark
City: Copenhagen

CLIMATE SHOCK:

- **Extreme rainfall (flooding)**
- Storm surge / coastal inundation
- Extreme weather (wind, hail etc)
- Extreme temperature (heat / cold)
- Fire

SECTOR:

- Transport
- Water
- Electricity
- **Stormwater**
- Wastewater
- Housing / Buildings

ENTITY:

- Private
- Utility
- **Council**
- State

TYPE OF INITIATIVE:

- Strategy/Policy
- **Planning**
- **Implementation / Construction**
- Operational
- Pilot

ENABLERS:

- Strong Leadership
- Regulations
- **Economics**
- Engagement & Expectations
- **Collaboration & Co-benefits**
- **Knowledge & Experience**

RESILIENCE OUTCOME:

- **Robustness**
- Flexibility
- Preparedness

Heslop E & Mukheibir P, 2022 Building utility resilience to climate shocks: Lessons from global case studies. Water Services Association of Australia

SUMMARY

The management of stormwater impacts with adaptive solutions that provides the city with robust flooding prevention measures during heavy downpours.

BACKGROUND / DESCRIPTION:

The city of Copenhagen is vulnerable to flooding from increasing precipitation because of its built-up environment and century-old underground wastewater system, which collects rainwater and is made to withstand only 1 in 10-year rainfall events. In July 2011, the city was hit by a devastating cloudburst, where 150mm in less than three hours of rainwater flooded cellars, streets, and major roads. This set the political impetus to change national legislation to focus on adaptation strategies. In the same year, the city council unveiled the Climate Adaptation Plan that combines surface and sewer-based, solutions and strategies to retain and drain water.

CASE STUDY 8:
Copenhagen: Cloudburst Solutions

CLIMATE RISK PROFILE

A primary challenge for Copenhagen in light of climate change, is the occurrence of more and heavier downpours in the future. While rain events are expected to decrease, overall precipitation is expected to increase, meaning more intense rain events and subsequent flooding. Using the IPCC projections under the A2 scenario (broadly comparable to RCP 8.5), the Danish Meteorological Institute projects that by 2100 there will be 25-55% more precipitation in the winter months, with decreasing events in the summer by 0-40%, and the intensity of heavy rainfall could rise by 20-50%. The intensity of rain with a 10 year return is projected to increase by around 30% by 2100, which would overwhelm existing sewage and runoff systems.

Using MIKE URBAN, a mathematical runoff model, to analyse existing conditions and project the impact of climate change on floods in Copenhagen, multiple scenarios were assessed using the timescales 2010 (as the baseline), 2060 and 2110 and looking at the frequency of the future flood events and implementing different climate adaptation measures.

CASE STUDY 8:
Copenhagen:
Cloudburst Solutions

NATURE OF THE RESPONSE:

In response, the city produced a comprehensive Adaptation Plan (2011) and the Cloudburst Plan (2012), and allocated budget for adaptation measures. The main adaptation actions comprised separating surface water (rainwater) from the underground wastewater system (making the city resilient to 1 in 100 year rains); refitting urban spaces to create rainwater channels along selected roads, leading to the lakes and/or the sea; 'greening' and 'blueing' public spaces for local retention of water; climate proofing buildings and transport infrastructure; and generally integrating adaptation concerns into other policy areas, including community regeneration.

The objective of the Cloudburst Management Plan is to reduce the impacts of flooding due to intense rains. The plan builds on a detailed socio-economic assessment to ascertain whether cloudburst and stormwater management can pay off for society as a whole. Previously, sewer overflows was allowed to ground level once every 10 years. With the new management plan, sewer discharge will still be only allowed to reach ground level once every 10 years, but average water levels will only be allowed to exceed ground level by 10 cm once every 100 years (except in areas designated for flood control).

CASE STUDY 8:
Copenhagen:
Cloudburst Solutions

THE ENABLING FACTORS THAT MADE THIS INTERVENTION HAPPEN:

Stakeholder collaboration: The Cloudburst Management Plan was a collaboration between the City of Copenhagen, Copenhagen Energy, the City of Frederiksberg, and the Frederiksberg utility company. The Adaptation and Cloudburst Plans and accompanying measures aim to establish the co-sharing of actions and benefits. The majority of relevant information is available at the city homepage for free. The city administration has also included HOFOR (the regional water company), and invited local business, clean tech companies, and property developers to develop local solutions as a way to concurrently stimulate green growth and make use of local business expertise.

Economics: There will be a net economic benefit due to this initiative. It will cost A$ 2.5 billion at 2015 prices to construct the combined solution. An economic assessment of the costs of damage to Copenhagen if nothing is done to adapt the current runoff and sewage system is estimated around A$ 3.5 billion over 100 years. Up to A$ 500M of this sum has already been "used up" in the recent major rainfall events.

The part of the combined solution concerned solely with managing water can be financed through the water charges, which will increase cover these costs. It has been estimated that the water charge of a household consuming 110 kL of water per year would increase by an average of A$ 180 / year.

Knowledge and Experience: A key enabler of Copenhagen's plans for climate adaptation and cloudburst management was the experience of a major cloudburst event in 2011 that made building resilience against future cloudburst events a top priority.

APPROACH

The financial justification for the approach is provided above – the economic argument speaks for itself. Through the collaborative approach, the costs and benefits were shared across agencies and the community as a whole.

A detailed socio-economic Cost-Benefit Analysis (CBA) tested two masterplan options. The option with the highest percentage of Blue-Green solutions and also the least additional infrastructural pipe improvements created a potential savings 50% greater than Conventional solutions alone. Additional qualitative social benefits, such as health, environmental, and urban spatial quality improvements resulting from the enhancements would potentially push this number even higher. It is estimated that the urban space improvements with recreational value will increase property prices in Copenhagen of just under A$ 300M. The upgrading of urban spaces can also increase revenue from property tax due to a significant increase in the value of those properties that are adjacent to the parks. Over 100 years, this extra revenue will amount to a value in present-day prices of A$ 200M. The number of new full-time equivalents employees will be around 15,000 for the construction activities, which will generate tax revenues of around A$ 400M.

CASE STUDY 8:
Copenhagen: Cloudburst Solutions

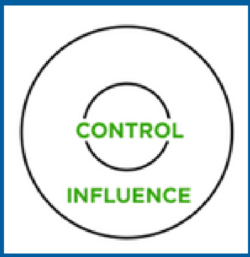
OUTCOME: BENEFITS

This approach integrated technical disciplines, moving away from isolated thinking. A common vision aligned engineers, hydraulic experts, GIS and information technologists, architects, planners, biologists, economists, communication specialists, and landscape architects with local citizens, investors and politicians. The 'Cloudburst Toolkit' was developed as a palette of multi-functional, flexible elements. The process outlines how hotspots can be identified, transferring strategic planning to human-scale experiences as a model for how other cities can mitigate Cloudbursts and daily rain events.

In December 2015, a list of 300 adaptation actions to be implemented over the next 20 years was endorsed by the City Council. Adaptation policies and actions have been integrated with the city development based on strong green growth, liveable public spaces; and a growing attention to using nature-based solutions while also building adaptation knowledge and skills in the local administration.

Potential transferable actions for Australian and New Zealand utilities: e.g.

- Building partnerships between local governments and utilities to share the costs and benefits of implementing a program of adaptation actions. (C)
- A cost-benefits analysis that included socio-economic outcomes can provide a compelling justification for implementing adaptation measures that benefits a wide sector of the community. (C & I)



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WATER SERVICES
ASSOCIATION OF AUSTRALIA

UTS Institute for Sustainable Futures

Case Study 9:
Northumbrian Water: Collaborative Flood Alleviation

Country: England
City: Brunton Park, Gosforth, Newcastle

CLIMATE SHOCK:

- Extreme rainfall (flooding)
- Storm surge / coastal inundation
- Extreme weather (wind, hail etc)
- Extreme temperature (heat / cold)
- Fire

SECTOR:

- Transport
- Water
- Electricity
- Stormwater
- Wastewater
- Housing / Buildings

ENTITY:

- Private
- Utility
- Council
- State

TYPE OF INITIATIVE:

- Strategy/Policy
- Planning
- Implementation / Construction
- Operational
- Pilot

ENABLERS:

- Strong Leadership
- Regulations
- Economics
- Engagement & Expectations
- Collaboration & Co-benefits
- Knowledge & Experience

RESILIENCE OUTCOME:

- Robustness
- Flexibility
- Preparedness

Heslop E & Mukheibir P, 2022 Building utility resilience to climate shocks: Lessons from global case studies. Water Services Association of Australia

SUMMARY

Three key stakeholders used a collaborative and sustainable approach to reduce flooding risk for residents living in Brunton Park.

BACKGROUND / DESCRIPTION:

Brunton Park is a large residential area of some 900 properties in Gosforth, within the City of Newcastle, England. The area generally falls toward the Ouseburn River and is constrained by a freeway to the west, main road to the east and the Ouseburn River to the south.

Brunton Park has a history of flooding because of urban creep in the local area and developments in the Ouseburn River catchment. A total of 62 properties were at risk of sewer flooding whilst 74 properties were at risk from surface water flooding.

The stakeholders involved in this collaborative project at Brunton Park are Northumbrian Water (NW), Environment Agency (EA), and Newcastle City Council (NCC). NW is a company that provides water and sewerage services in several English counties. EA is a non-departmental public body responsible to the Defra Secretary of State that protects communities from the risk of flooding and manages water resources. NCC is the local government authority for the city and metropolitan borough of Newcastle upon Tyne.

FLOOD RISK PROFILE

A hydraulic model (InfoWorks CS) was built to analyse the causes of sewer and surface water flooding. The model was verified using flow monitors and rain gauges, and through extensive manhole, topographical, CCTV and sonar survey work. The model was merged with the Environment Agency's river model to identify the options to reduce the risk of flooding. It is not clear if climate predictions were taken into consideration. Integrated catchment modelling (ICM) software was then used to present the preferred option using 1D and 2D aspects. The chosen design provided a 1:200-year level protection from surface water flooding.

CASE STUDY 9:
Northumbrian Water: Collaborative Flood Alleviation

NATURE OF THE RESPONSE:

NW and EA entered a formal partnership to develop and deliver the flood alleviation scheme, with NCC as the Lead Local Flood Authority. The three partners agreed to maximise the social and environmental benefits of the scheme by using water sensitive urban design (WSUD) elements (known as SuDS (sustainable urban drainage system) solutions in the United Kingdom) to reduce surface water flooding from catchment runoff.

In summary, the scheme involved the following elements:

- WSUD elements to reduce surface water and fluvial flooding:
  - Installation of 400m length of new river channel to divert flow from the Ouseburn River.
  - Modifying the current section of Ouseburn River channel and a new storage basin to store more than seven million litres of surface water.
- Constructing 650m of flood defences (earth embankment and a reinforced concrete / brick clad wall) to reduce fluvial flooding.
- Modifications to the sewerage system to reduce sewer flooding:
  - Upsizing and construction of 2km of foul and surface water sewers.
  - Construction of an off-line pumped return foul sewage storage tank, valve chambers and above ground control panel and kiosk.
- Tree planting and habitat establishment for local wildlife

THE ENABLING FACTORS THAT MADE THIS INTERVENTION HAPPEN:

Engagement: Stakeholder engagement was a key enabler in achieving the sustainable WSUD approach to flood management. Communicating the vision of the project as broadly and early as possible helped to gain community support. For example, in advance of the planning application submission, NW held a customer information session and issued a joint press release with EA for the media. This meant the project was publicised more broadly through regional television stations and local written press.

Another important aspect of the engagement process was listening and taking onboard feedback from consultations with residents, businesses, and councillors. This resulted in adjustments to the original proposal and meant the final design for the scheme received local stakeholder backing.

Collaboration: The collaborative approach between the three organisations enabled a holistic, sustainable, and efficient approach to flood risk management and it worked well due to a number of factors, including:

- The formal partnership between NW and EA to develop and deliver the scheme was overseen by a project board including representatives from the three key stakeholders.
- Both NW and EA worked together to align their different funding sources and contract procurement processes to achieve the required outcomes for both parties.
- There was a collaborative agreement which included the financial and non-financial contributions of each party, definition of roles and responsibilities, review processes to ensure project objectives were met and a process to manage any disputes.
- With the roles and responsibilities clear, NW led and project managed the joint scheme through the design and construction phases, and will retain responsibility for the maintenance of the WSUD elements (i.e. channel and basin).
- EA retained their own project manager during the design and construction phases for the financial and technical aspects associated with the fluvial flood defences.

Note: This project was the first time EA allowed a third party to deliver a main river solution in the United Kingdom.

WATER SERVICES
ASSOCIATION OF AUSTRALIA

CASE STUDY 9:
Northumbrian Water:
Collaborative Flood Alleviation

APPROACH:

It was determined that the community would be best served by a collaborative approach with NW, EA and NCC working together to deliver a WSUD-focused solution to reduce the risk of property flooding from both public sewers, and surface water and direct fluvial flooding. [1]

The total cost of the scheme was £7.2M comprising the following funding elements:

- Northumbrian Water - £5.742M
- Environment Agency - £1.358M
- City of Newcastle - £100K

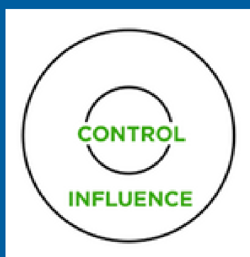
NW funded the sewer flooding capital programme whilst the EA secured a fixed allocation of funding through Local Levy and National Flood and Coastal Defence Grant in Aid.

OUTCOME: BENEFITS

In removing the risk of predicted flooding to over 100 properties in Brunton Park, the partners have collaboratively delivered a sustainable flood mitigating solution which is functional and complementary to the local landscape and ecology. The WSUD elements of a new river channel and storage basin, plus planting of new trees has created valuable habitat for wildlife, improved water quality, and created a new local environmental amenity for the community.

Potential transferable actions for Australian and New Zealand utilities: e.g.

- Look for opportunities where a project that isn't viable as a single-stakeholder project, would benefit from a collaborative/partnership approach with multiple stakeholders combining their skills, powers, and funding allocations to justify a project proceeding, and deliver worthwhile outcomes for customers. (I)
- Consider WSUD solutions to flood risk mitigation that also provide additional benefits for the local community and ecology. (C&I)



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WATER SERVICES ASSOCIATION OF AUSTRALIA

Institute for Sustainable Futures

Case Study 10: United Utilities: Improving Operational Response and Recovery

Country: England

City: Numerous – (northwest of England)

CLIMATE SHOCK:

Extreme rainfall (flooding)
Storm surge / coastal inundation
Extreme weather (wind, hail etc)
Extreme temperature (heat / cold)
Fire

SECTOR:

Transport
Water
Electricity
Stormwater
Wastewater
Housing / Buildings

ENTITY:

Private
Utility
Council
State

TYPE OF INITIATIVE:

Strategy/Policy
Planning
Implementation / Construction
Operational

ENABLERS:

Strong Leadership
Regulations
Economics
Engagement & Expectations
Collaboration & Co-benefits
Knowledge & Experience

RESILIENCE OUTCOME:

Robustness
Flexibility
Preparedness

Heslop E & Mukheibir P, 2022 Building utility resilience to climate shocks: Lessons from global case studies. Water Services Association of Australia

SUMMARY

United Utilities in England have been focused on the cheapest whole life cost solutions to improve water and wastewater operational response and recovery measures to prepare for climate shocks.

BACKGROUND / DESCRIPTION:

United Utilities (UU) is responsible for delivering water and wastewater services to more than 3 million homes and businesses in the Northwest of England.

United Utilities have five regulators that enforce standards of service, water quality and pricing. The economic regulator Ofwat (The Water Services Regulation Authority, responsible for ensuring England and Wales' water and wastewater utilities provide good-quality, efficient services at a fair price) has been a key driver for UU's focus on operational response and recovery measures, which is discussed in the enabling factors section below.

CASE STUDY 10:
United Utilities:
Improving Operational Response and Recovery

CLIMATE RISK PROFILE

Although UU did not use any climate risk profiles for the operational response which is the focus of this case study; UU has recently undertaken climate risk projection modelling for 2050 and 2100 to inform adaptive planning. UU used the latest climate research from the Met Office UK Climate Projections 2018 (UKCP18) and used Representative Concentration Pathways (RCP) 6.0, which is consistent with peak emissions occurring in 2080 and an expected 2.0-3.7oC increase in global average temperatures from pre-industrial levels.

CASE STUDY 10:
United Utilities:
Improving Operational Response and Recovery

NATURE OF THE RESPONSE:

UU have focused on improving their operational response and recovery measures for both water and wastewater services. This work is referred to within UU as "situational awareness" and has been in progress since 2015.

One of UU's largest investments has been in the establishment of The Integrated Control Centre (ICC) for both water and wastewater systems. The ICC brings all alarm signals and online monitoring into one place so each system can be viewed holistically. Duty managers and an incident manager are always on duty for leadership, and there are teams of people monitoring the systems. For example, the ICC monitors for water: instantaneous production volume; instantaneous storage conditions, customer insights. There is also a clear procedure for launching a response plan when information or alarms indicate an incident response is necessary.

The ICC also monitors short range weather forecasts, a form of demand forecasting so UU can be prepared for high demands (e.g. water from good weather, and waste water from storms) this includes instigating recovery plans pro-actively so as to reduce the total impact on services.

UU has also rolled out a wastewater Dynamic Network Modelling (DNM) project that has increased network sensors to ensure system operational capacity is maintained and UU can pre-emptively prepare for storm events (for example by emptying storage tanks, drain the sewer network more to provide maximum capacity to absorb the storm effects).

A key initiative in the water space is a large investment in UU water tanking capabilities. UU have one of the biggest tanker fleets in the UK and have recently directly employed water tanker drivers (rather than rely on engaging Contractors) who are stationed at strategic locations across the water distribution system. This ensures UU can organise and control resource allocation as needed. There are also pre-determined water tanker injection points across the network. This approach means that when there is a problem in the network, which may be caused by climate shocks, UU can quickly respond and ensure supply by dispatching a water tanker to inject drinking water where required in the network to sustain water supply in the impacted area. Dispatching a water tanker is typically one of the first actions UU will do, even as a precautionary measure. Increasingly UU have begun deploying temporary generators to sites where power loss (as a result of a forecast storm) is likely.

Another key aspect of UU's response and recovery approach is the development of network re-zone plans. These plans clarify how the water network can be isolated and secured before water tanker water can be injected. These plans have helped UU to understand their network infrastructure and have clear documentation for operational staff to use during a network incident. These network re-zone plans, for example, allow operators to know the following when a water pipe fails:

- The nearest network isolation point(s).
- How many people have been isolated.
- How many water tankers are needed to sustain supply.

Development of network re-zone plans have been prioritised at high criticality assets, meaning those that are single supply systems, have the greatest customer service impact, no current contingency plans, and/or strategic assets.

CASE STUDY 10:
United Utilities: Improving Operational Response and Recovery

THE ENABLING FACTORS THAT MADE THIS INTERVENTION HAPPEN:

Regulation: The key enabler for United Utilities' response and recover approach has been Ofwat's Outcome Delivery Incentive (ODI), which requires UU to report on the interruption to supply (or customer minutes lost). This requirement has been in place since 2015 across England and Wales, with a clearer definition, metric, and reporting process established in 2019. It has incentivised UU to be an upper quartile company because failure to deliver on the target results in cash penalties.

Interruption of supply is measured as the average interruption that each customer has had in minutes from water supply over the year. The measure is calculated by multiplying the time supply was lost for more than 3 hours (including the 3 hours) by the number of people affected and dividing by total connected property base.

UU have another ODI from Ofwat that rewards the de-risking of their water service via the delivery network re-zone plans at high criticality assets. The ODI for this is for 2020 – 2025.

Economics: Failure to perform against the interruption of supply targets means financial penalties / losses which can't be passed onto the customer. This has been shown to be good incentive for resilience planning.

WATER SERVICES
ASSOCIATION OF AUSTRALIA

CASE STUDY 10:
United Utilities:
Improving Operational Response and Recovery

APPROACH:

The main driver for improving UU's operational response and recovery approach was to address failures quicker to meet Ofwat's Outcome Delivery Incentive. Though importantly, the improvements have still enabled UU to respond quicker and better to failures that are cause by climate shocks.

UU built their business cases for response and recovery projects through a "value framework" approach, which used customer engagement to place a dollar value on the service. Depending on the type of service this value was either informed by customers estimated compensation for a loss of service, or an amount that customers were willing to pay to either improve or prevent deterioration. Customer value was triangulated between multiple datasets to arrive at a representative value.

Values were then assigned to lowest level consequences (LLCs) in our decision support tool, effectively assigning a cash value to a minute of supply interruption, or a property flooded with sewerage as examples.

The decision support tool aggregates the value of the benefits being delivered by a proposed solution which can be across multiple LLCs. Net present value calculations are then calculated for the solution cost (operational and capital costs (Totex)) accounting for the anticipated design lives of the assets forming the solution.

Customer engagement to determine value was required by Ofwat for all utilities under their jurisdiction, and was specific to each company, allowing local priorities and circumstances to be more highly valued.

We are currently developing our approach further for the next price review to incorporate a multi-capital approach, moving to a best value assessment over a cheapest whole life cost model.

CASE STUDY 10:
United Utilities:
Improving Operational Response and Recovery

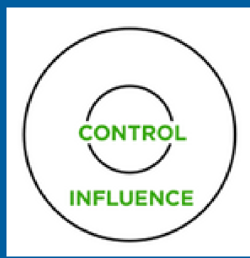
OUTCOME: BENEFITS

Improvements in UU's operational response and recovery approach has significantly reduced supply interruptions to customers, and improved customer service (CMEX) scores.

UU receives financial rewards through Ofwat's ODI for performing well as well as early determination of their price review. There is also an incentive to do well as performing poorly can result in a maximum penalty of $16 million each year. Performing well has meant UU has received less scrutiny from Ofwat as they focus on the poor performers.

Potential transferable actions for Australian and New Zealand utilities: e.g.

- In climate risk assessments, consider appropriateness of response and recovery as a form of climate adaptation (considering potential cost of failure and impact to customers). (C)
- Explore United Utilities and Ofwat's "value framework" approach to business case economic assessments. Engage with the relevant state/territory pricing regulator on any associated regulatory reform. (I&C)



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