CLIMATE CHANGE AND IMPACT ON STORMWATER SYSTEMS – CAN WE CHANGE OUR FUTURE ?

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ABSTRACT

We face an uncertain future as a changing climate starts to expose our historical land use decisions. The Intergovernmental Panel on Climate Change identified key climate risks to New Zealand being continuing sea level rise and the increased frequency and intensity of flood damage on our low-lying and coastal infrastructure (IPCC, 2014).

White et al, (2017) identify that "*Stormwater and wastewater systems are particularly vulnerable to climate change as the discharge points of these systems are often at the lowest elevation of populated areas. Even small changes in rainfall extremes, including intensity and duration, can overwhelm the design capacity of these systems. In low-lying areas where groundwater is linked to the sea, sea level rise will affect the performance of stormwater systems and wastewater systems where infiltration occurs.*

Droughts will also affect the performance and maintenance of wastewater systems. Increased urbanization associated with new greenfield housing, and densification in existing areas will also challenge existing design parameters. Furthermore, some of the stormwater and wastewater systems most exposed to climate change hazards are aging. Funding any replacement is already challenging in some areas, where there are declining rate bases due to population shifts towards urban centres, combined with caps on local government lending. However, as systems are replaced there is an opportunity to redesign for resilience."

This paper will focus on communicating the outputs from a recently completed ***Deep South Challenge Dialogue on Climate Change impacts on stormwater and wastewater systems across New Zealand*** (White et al., 2017). With over $50 billion of our built assets and approx. 6.6% of our population located within a 'particularly exposed' area (Bell et al., 2016), New Zealand is at a cross roads, with 'tough decisions' being required to help us adapt our communities, our critical infrastructure and our overall way of life to the forthcoming challenge.

Selwyn District Council (2017) identifies that climate change effects on three waters infrastructure systems are harder to distinguish compared with inter-decadal climatic patterns. The paper will share the lessons learnt from this research, which would include changing our messaging such that we are not to be solely focused on communicating 'future' risk, but equally and more relevant to land use planning, the risks we have overcome to date and the ones we face cyclically.

The paper showcases some examples of the transformational changes from our historic land use approaches through to those that will be required for us to better adapt our rural and urban environments now and into the future. This way we can seek to deliver increased resilience, better outcomes and places that people want to live and work in.

The paper will identify how communities around New Zealand are starting to 'plan' for adaptation as a means for resolving current and future issues, drawing examples from across the spectrum of Local Government entities, such as Christchurch and Gisborne.

KEYWORDS

Stormwater assets, vulnerability, climate change, preparedness, resilience, adaptation, deep south challenge

1. INTRODUCTION

For communities across New Zealand and those responsible for providing water services, the future is now. Climate change is being seen to have a profound impact on our three waters systems as evidenced by changes in increasing extreme events, river flows and sea levels. Bold steps are required now to help deliver a more climate friendly future, across both the actions to reduce our carbon emissions, as well as in our fundamental responses to the systemic changes in our climatic patterns and the consequences that are occurring now and into the future.

The Intergovernmental Panel on Climate Change identified several key climate risks to New Zealand being continuing sea level rise and the increased frequency and intensity of flood damage on our low-lying and coastal infrastructure (IPCC, 2014). Sea level rise will have a profound impact on our communities' health and wellbeing, given our natural affinity to living adjacent or within these coastal margins, both from physical increases in the sea level, but the resulting increase in impacts of storm surges and king tides. Groundwater in these coastal margins will also be impacted and rise in line with sea level.

Recent events such as two major ex-tropical cyclones impacting New Zealand are driven by fundamentally a warmer South Pacific Ocean. This points to a future where extreme rainfall events will be more commonplace and widespread. With all this in mind, what is there that we can do to shape a more climate friendly as well as urban and rural communities that are more Future Ready. This paper examines some of these questions and seeks to identify a few options available.

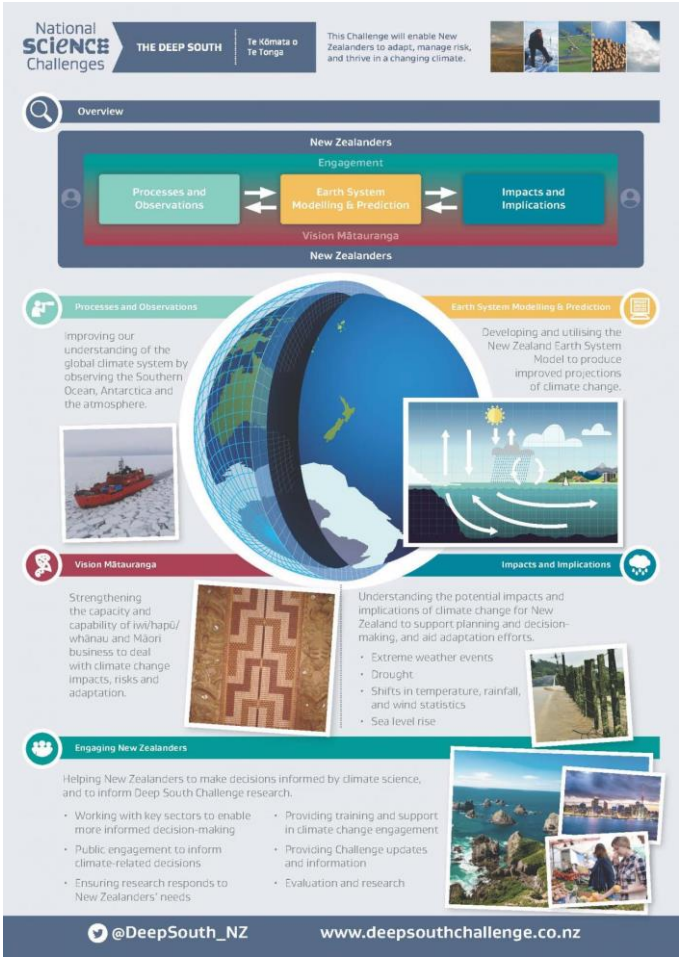
The author recognises that these challenges are not easy and fundamental shifts are required in governance, appetite and move to a more dynamic adaptive approach, whereby the many competing uncertainties and inter-dependencies are recognised and a move towards delivering future processes, policies and solutions that are fundamentally the 'least regretful' and adaptive in nature.

2. DEEP SOUTH CHALLENGE RESEARCH

The mission of the Deep South (Te Kōmata o Te Tonga) National Science Challenge is to transform the way New Zealanders adapt, manage risk, and thrive in a changing climate (http://www.deepsouthchallenge.co.nz/about-us).

In addition to the core requirement to 'understand the role of the Antarctic and Southern Ocean in determining our climate and our future environment', the challenge is seeking to develop new research approaches to support the understanding of the risks and challenges facing New Zealand, influence planning and policy and to aid decision making.

To ensure this Challenge benefits all New Zealanders, it is intending to incorporate and develop innovative engagement practices to connect the science with Māori, industry, regulators, planners and communities. This will give New Zealanders a greater level of certainty in their planning and decision making in the face of a changing climate. This collaborative approach will ensure that the science remains focused on and directed by societal needs, help build capability within Māori, stakeholder organisations and communities, and is used by all.



One such approach was the use of a Dialogue session, where the Deep South Challenge team engaged with practitioners and researchers from eighteen New Zealand organizations involved in long-term decision making on stormwater and wastewater systems during mid-2017. The output took the form of the delivery of a paper that captured the facilitated discussion, released during October 2017, which this paper draws upon heavily in subsequent sections.

3. IMPACT OF CLIMATE CHANGE ON STORMWATER SYSTEMS

Stormwater management services provided by Local Government bodies across New Zealand are increasingly showing the signs of climatic stress currently and are recognised to be potentially at risk from climate change and may need adaptation. Stormwater systems are particularly vulnerable to climate change as the discharge points of these systems are often at the lowest elevation of populated areas. The likely issues are mostly related to:

- Precipitation Patterns - Small changes in rainfall extremes, including intensity and duration, can overwhelm the design capacity of these systems and impact on the timing of contaminant load to the receiving environments.
- Sea Level Rise - Low-lying areas where groundwater is linked to the sea, sea level rise will impact the performance of stormwater systems where infiltration occurs.
- Droughts - Droughts will also affect the performance and maintenance of wastewater systems.
- Temperature – impacts on soil moisture, speed of runoff and potential for warmer water impacting on quality, capacity and of the receiving environment

In regions where the frequency and intensity of extreme rainfalls are projected to increase, there are several potential impacts that climate change could result in including:

- Increased frequency and intensity of rainfall events (flooding at site, local and regional scales) and droughts.
- Sea level rise – coastal inundation and rising groundwater
- Temporal shifts in seasons and extremes – greater potential for volume and temperature to stress the receiving water environments.
- Increasing impacts on the receiving water environment (sediment, water quality, erosion and deposition etc.) as treatment devices or wastewater system interactions are impacted through changes in baseline conditions.

Stormwater management is an activity sensitive to climate change. Climate change and variability will aggravate these challenges and impacts, which in turn could create new 'unforeseen' implications or magnify existing issues to untenable levels. For example, sea levels around New Zealand have risen by up to 22cm in 100 years. This is expected to rise at a faster rate in future (Royal Society of New Zealand, 2016) and recent guidance suggest that sea-level rise scenarios are available on a decadal increment up to between 0.69 - 1.88 m by 2150 (MfE, 2017) depending on the emissions scenario modelled.

Current research into the actual impacts on our three waters infrastructure, shows that on a local scale, there are no discernable 'statistically significant' impacts of climate change within the historic record. This continues to pose a perception issue when investment into 'future-proofing' our communities is put in context of many other local governmental services facing up to a fundamental affordability pressure.

As a result, this evidence continues to represent a challenge to how we can seek to persuade communities and their elected authorities to invest in future adaptation activities to face into an uncertain climatic future.

Selwyn District Council, (Rutter et al., 2017) undertook a study to assess the impact of climate cycles and trends on Selwyn District Council's potable water, wastewater, stormwater, land drainage, and water race assets. The project was delivered to support infrastructure investment decisions contained within their 2018 to 2048 Infrastructure Strategy. '*The project considered projected changes in climate in the light of historically observed climate cycles and trends and assessed what the impact of future changes could be on water assets.*

A robust analysis of long term historical climate (100 years+) was carried out, which allowed climate projections to be placed in context. The results suggested that, for certain climate variables, natural variability is often much greater than climate change effects, particularly over a 30-year horizon. The study was a high-level risk assessment, to identify the assets that were most likely to be affected by climate change. Priority areas were guided by a risk matrix, identifying that the greatest likely impact for infrastructure were:

- *groundwater levels (high shallow well levels and reduced deep well levels),*
- *extreme rainfall,*
- *high river flows, and*
- *sea level rise.*

A review of the records, suggest that there is currently no evidence of an increasing trend in extreme rainfall events. If a trend exists, it is masked by the high variability.'

The study goes onto identify that '*rainfall is projected to increase in the mountain regions of the district so the alpine rivers (i.e. the Waimakariri and the Rakaia) could show an*

increase in flow, with implications for associated water supply, stormwater and wastewater infrastructure in the alpine settlements.

Over the next 30 years, sea level rise will increase the likelihood of issues with wastewater, stormwater and land drainage in the areas close to Te Waihora/Lake Ellesmere and the mouth of the Rakaia.'

Two elements that are important to note on this study, one being *the recognition that the climate affecting New Zealand*, has fundamentally, been in a constant flux. This has led to our piecemeal and cyclical focus on infrastructure delivery which, with good intent, has sought to enable economic growth primarily in the past.

Secondly, it is evident, though that our historical approaches are not designed with extremes in mind and as such disconnecting our communities from water is increasingly delivering a more fragile society.

This is particularly the case as we discover that the patterns experienced in the past are not likely to be perfect forecasting tools of the future conditions. One key example, is how our backward-looking rainfall and flow frequencies (probability estimates) are constantly being modified as climate record length increases. Depending on the macro climatic trend we could be severely over or understating future frequencies and risks.

4. CURRENT DESIGN APPROACHES AND LIMITATIONS MOVING FORWARD

Stormwater systems are designed and constructed to take account of topography, climate, regulatory context, and intensity of development. They therefore vary widely across Aotearoa New Zealand (SPM Consultants Ltd, 2009). The traditional approaches of seeing stormwater as a nuisance rather than an opportunity, has led to a focus on the rapid and efficient draining of urban areas

Our 'Minor' urban drainage systems (predominantly a network of pipes, culverts and urban watercourses) are typically designed to provide a level of service aimed at removing the 'nuisance' of stormwater from affecting our daily lives arising from the frequent, low intensity rainfall events.

With its predominantly maritime location, New Zealand is exposed to periods of heavy, intense rainfall events for which the Minor systems do not cater for. As such, the 'Major' drainage network is then required to cater for these larger events, allowing the water to move across the topography safely through defined overland flow paths. This approach has enabled the delicate balance of sustainable investment to be delivered into the stormwater systems, where the road network and wider open spaces are utilised to prevent water from entering private habitable property.

The design of stormwater infrastructure is based on an underlying assumption that the probability distribution of precipitation extremes is statistically stationary. This assumption is called into question by climate change, resulting in uncertainty about the future performance of systems constructed under this paradigm.

This assumption will be tested most in the marginal coastal 'delta-like' urban environments where the issues are further exacerbated as the topography. In such locations, water cannot drain away without the regular and routine use of pumps. This includes several major settlements across New Zealand, such as Christchurch, Dunedin and Napier amongst others.

Degraded urban and rural stormwater runoff is leading to increasingly inadequate and unacceptable water quality across many catchments, which is further damaging the 'provision of value' from the overall ecosystems in which we live.

From the above, it is evident that stormwater management is an increasingly difficult challenge across our communities. These challenges include:

- Aging and overloaded infrastructure,
- increasing imperviousness (paving over gardens)[1], increasing alteration of landscapes, increasing community awareness and aspirations for good environments and the consequential increase in standards for freshwater management exemplify the characteristics of human and social systems that contribute to challenges of stormwater management

Climate change impacts are further exacerbated through human and demographic activity – Further urbanisation (both through development of greenfield or increasing densification) also challenge existing design parameters reducing the effectiveness of the 'traditional approaches'.

Furthermore, our stormwater systems that are most exposed to climate change hazards are aging. Funding any replacement is already challenging in some areas, where there are declining rate bases due to population shifts towards urban centres, combined with caps on local government lending. However, as systems are replaced there is an opportunity to redesign for resilience, which in turn helps us better align our responses to deliver multi-beneficial outcomes through responding to increasing community awareness and aspirations for good quality water environments.

Finally, the legislative framework is evolving to provide for this consequential increase in the standards for our freshwater management, effectively providing us with a fundamental driver that will help shift towards the inevitable change in our industry.

5. A SHIFTING FOCUS – COMMUNITY, RESILIENCE & ADAPTATION

In recent years, the shift in focus has been positioned into re-engineering existing buildings and urban infrastructure to achieve something more than the sum of the parts. The concept of 'placemaking' has taken on the challenge to create spaces where people want to live and work and start the re-healing process of our previous urban development approaches. Cities are largely seen as being the driver of this change looking at opportunities to be creative and innovative. This is in stark contrast to current and historical opinions that they represent the source of the most pressing environmental challenge facing us.

Now more than ever, cities are seeing the need to envision and then deliver a more sustainable future, one that moves the city away from its conventional approach to urban water management, which has led to a:

- Fragmentation of service delivery resulting in non-optimal and localised solutions, where the three waters are needing to be managed separately;

[1] Between 2001 and 2011, the properties with a 'paved' front garden rose from 28% to 48% of all housing stock in towns and cities. (ASC, 2012)

- Delivery of short term solutions, continuing to think of the system as being a linear entity rather than a dynamic system.
- Lack of flexibility of approach, with hard solutions still being preferred to softer 'greener' solutions
- Centralized systems, with a tendency for being energy intensive, mechanized and less resilient to shock events and a perception that we can continue to meet the challenges in front of us through delivery of new supplies or engineering solutions – the concept being we have unlimited resources.

Stepping away from the urban water management sphere, sees an equally pressing need for our communities to be more cogniscent and make better decisions about the choices they make in prevailing the 'take – make - dispose' economy that has led to such rapid increases in 'prosperity'. Our industrial based economy has hardly evolved since the early days of industrialization in one fundamental way, being the way in which organisations seek to deliver wealth to communities. Thinking purely about the impact that this consumptive society has on waste management, we are reaching the limits of this linear consumption (take – make – dispose).

Whilst the communities in general are becoming more aware of the physical impacts on the environment of this approach, including the recent exposure to the public about plastic waste in our oceans, it is indeed the leading corporations that realise the short termism of our historical urbanisation approach. For instance, the increased risk exposure that is placed upon them through the macro-economic trends (such as supply and demand as rising raw material or energy prices) the bottom line making some organisations vulnerable to shifts in demand or supply.

Within the spheres of both urban water management and urban economies it is clear to see that there is a growing shift towards the circular economy. The fundamental principles of which is to design out waste and to build resilience through diversity.

One such mechanism is the growing focus on the delivery of strategic planning, which is providing a useful focus to city development and driving through an increased level of collaboration and participation across the community and professionals who can all influence the shape of the urban space to drive through the place-making agenda.

Multi-disciplinary approaches are critical to driving this success, such that future visions for urban communities include for developments and communities being energy / carbon neutral, involve and can adapt to future disruptors (such as those around transportation), contain decentralized water management activities that allow for circular water usage and reuse. The subsequent case studies, seek to explore this further. The challenges are still ahead of us as scaling up these urban visions and resultant retrofit activities implies a coordinated and strategic approach. The future is one where we can:

- reconcile the multiple stakeholders and social interests (e.g. policymakers, owners, occupiers, developers, financiers, contractors and utilities);
- deliver new forms of governance that move beyond the short termism of both political cycles and capital funding markets to one that can engender a systemic change focusing on the continued delivery of positive outcomes across the four well beings;
- integrate new and future environmental technologies that allow us to have a 'lighter' touch to our development, and;
- grow resilience across our communities through enabling the formation of strong interdependences of a truly circular local economy and move us away from the

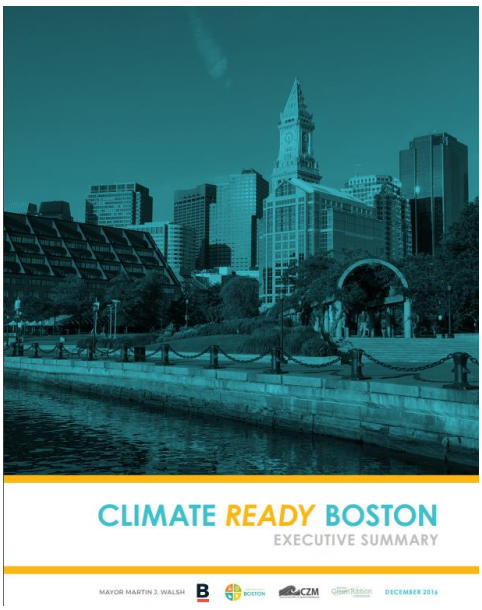
'take – make – dispose' approaches that have dictated our general growth since the mid-19th Century.

- Provide our communities and infrastructure with greater levels of 'fail-safe' mechanisms, through embracing the concept of landforms that can manage events greater than designed for (the concepts of designing for exceedance).

6. CAN WE CHANGE OUR FUTURE?

6.1 CASE STUDIES – INTERNATIONAL

6.1.1 CLIMATE READY BOSTON, BOSTON, USA



Between 1991 and 2016, Boston experienced 21 federal/state disaster declaration events. With this recent history of consequences from natural hazard events fresh on the mind and growing awareness of future challenges such as climate change and sea level rise, the city started on delivering the 'Climate Ready Boston' project composing of four components:

- Updating regional and local climate projections;
- Undertaking a comprehensive evaluation of current and future risks;
- Showcasing the impacts to examine the likely consequences of action and inaction, and;
- Developing SMART action plans around five key resilience initiatives to help increase Boston's resilience.

The project identified many key initiatives that can help increase Boston's ability to thrive in the face of intensifying climate hazards, with the aim of creating stronger neighborhoods and improved quality of life for all residents. The relevant ones for us to take cogniscance of are listed below:

- **Generate multiple benefits**. Effective climate resilience initiatives both reduce risks from climate hazards and create other benefits. Resilience initiatives that produce multiple benefits generate more resources to support their implementation and sustainability. Multiple-benefit approaches enable Boston to address some of the other pressing challenges that it faces beyond climate risks.
- **Incorporate local involvement in design and decision-making**. Effective resilience initiatives require on-the-ground knowledge and sustained community support for implementation and long-term operations and maintenance. Local stakeholders can help illuminate critical resilience opportunities in their communities and generate creative ideas for solving multiple challenges at once.
- **Leverage building cycles**. Buildings and infrastructure experience regular cycles of rehabilitation and replacement over time. Acting within the context of the building cycle can reduce disruption and cost, as in the case of green infrastructure installed as part of a road reconstruction project. While the building cycle progresses, operational changes, as opposed to physical adaptations, can be made to reduce risks.
- **Design in flexibility and adaptability**. Climate conditions will continue to change over time, and climate resilience initiatives must be designed to adapt to

them. To be effective, the stormwater system must be flexible enough to adapt to this increase in extreme precipitation. In practice, this often means decentralized, distributed stormwater storage across cities that can be expanded without disrupting the gray stormwater system. Similarly, the elevation of 1 percent annual chance floods is also projected to increase throughout the century.

6.1.2 SLACK'S CREEK, BRISBANE, AUSTRALIA (LOGAN CC, 2013)

Slacks Creek encompasses some of the oldest settled areas in Logan and has been highly modified by past urbanisation. Its location in the heart of the City presents an opportunity to convert this asset from a forgotten and undervalued drain into a highly valued and vibrant waterway corridor. Slacks Creek Catchment Recovery Project is about reclaiming lost spaces.

Logan City Council's 2013 project - The Slacks Creek Catchment Futures Study involved a participatory and holistic planning approach which engaged all Council departments and the local community. Drawing on high level aspirations set by the community and Council's own strategic visions and plans, a range of initiatives were identified to help deliver the vision for Slacks Creek "a vibrant, green corridor bringing people and nature together, inspiring healthy living and creativity".

The action plan included initiatives to boost waterway health, restore environmental corridors and to connect people with their creek by activating, beautifying and cleansing. The initiatives were based on a fundamental understanding of the Slacks Creek Catchment's history, current condition, future pressures and community aspirations.

The figures below show some of the typologies that have been utilised to show what the future urban environment would look like resulting from this renewed focus to connect people back with the waterway and the catchment functions.

Local parklands provide residents with safe access to the waterway, providing education and encouraging community stewardship of the local waterways. These open space areas can also form part of important ecological corridors, which can extend into backyards to connect habitats across the catchment.

Figure 1 – Future Catchment opportunities mapping – Visualisations to show typical applications for open spaces and residential areas.

The success of the Slacks Creek Catchment Futures Study is evidenced by the substantial funding secured to date allowing projects to be delivered on the ground and being awarded the 2014 Healthy Waterways Partnership Government Award and is providing a catalyst for urban transformation.

6.1.3 HAMMARBY SJÖSTAD, STOCKHOLM, SWEDEN

In the early 1990s, Hammarby Sjöstad had a reputation for being a run-down, polluted and unsafe industrial and residential area. Now, Hammarby Sjöstad is recognised as being a world leading example of urban renewal on a district level. The area is home to 25,000 people and provides employment to another 10,000 people. The district represents a truly mixed use urban development project containing a mix of apartments, shops, offices and small traders with a focus on culture and entertainment. Despite its suburban location it gives Hammarby Sjöstad an inner-city atmosphere.

Hammarby Sjöstad was designed as a comprehensive infrastructure project from the beginning. The heating, transport, and waste collection systems were intended to work in conjunction to reduce their long-term usage of energy and resources. In addition, through the water governance arrangements, the project meets high environmental standards in comparison with similar developments internationally. The success of this regeneration project was set in place from the start through the delivery of integrated planning with significantly challenging targets for sustainability, such as trying to achieve:

- A 50% reduction in overall residential water consumption (setting a goal of 100liters/person/day)
- Agricultural reuse of wastewater treatment streams – such as using 95% of the phosphorous for agricultural purposes
- A 50% reduction in the amount of heavy metals and contaminants in the wastewater stream compared to other local systems
- 100% of stormwater, rain water and snowmelt should be retained, infiltrated or treated to allow for the removal of sediments and contaminants

- Bio-active treatment of all highly trafficked roads (those greater than 8,000 cars/day) before releasing to the natural water environment

Hammarby Sjöstad demonstrates how high environmental targets can be met using a well-developed master plan, high levels of initial investment in infrastructure, and a focus on environmentally-friendly housing and a high-quality living environment placing water at the centre of the redevelopment and allowing communities to learn to live with water. Large scale catchment water management approaches were utilised to achieve not only good water quality outcomes but to achieve an aesthetically pleasing landscape that allows the community to connect with waterways and drive economic, social and cultural wellbeing benefits as well. utilised include:

- Strategic and spatial planning to capture any runoff from streets, buildings, walkways and even the adjacent ski resort within first flush treatment basins, including the delivery of oversized multi-use basins that can store all locally generated storm runoff for a short period to allow for the settling of sediments and pollutants
- A focus on creating natural waterway features (drains, ditches, swales, canals and creeks) to deliver a connected blue green network, delivering amenity, habitat and recreation opportunities as well as capturing and providing treatment opportunities for all produced stormwater before being discharged into the lake.

The outcomes are striking as the district is livable and attractive: A mix of housing units, parks and services are provided, it is easy to access the area from different parts of Stockholm (as the fundamental travel mode of choice is Mass Rapid Transport in the form of tram lines. Located adjacent to the inner City of Stockholm, the area has become highly popular and is inhabited by a wide range of people.

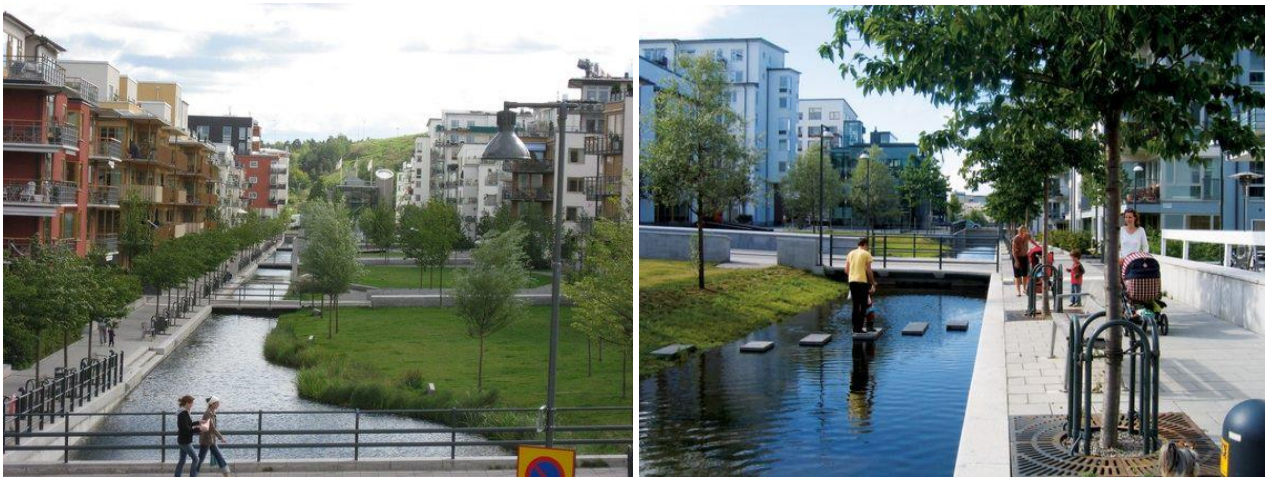


Figure 2 – Stormwater management features within the development (photos courtesy of C. Gaudreau, Slow Ottawa and M. Clark)

The district is economically successful: Property values have increased over and above comparable areas across the City of Stockholm. Even though construction costs were only five percent higher than normal, the property value alone has risen over 25 percent.

6.2 CASE STUDIES – NEW ZEALAND

6.2.1 THE DRAINWISE PROJECT – GISBORNE DISTRICT COUNCIL

Although this project is not looking to fundamentally deliver urban renewal, this case study identifies the benefits of thinking at a catchment wide urban water cycle level and delivering an approach that shifts focus away from continued large-scale capital investment to restoring natural hydrological functions, helping to drive some significant changes in outcomes.

The aspirations, contained within the Drainwise project are such that the wider social, cultural, environmental and economic value of the region will be radically improved and are worthy of note when trying to identify how we may in the future seek to manage our stormwater (and wastewater) systems to provide improved states for the well-beings in uncertain times.

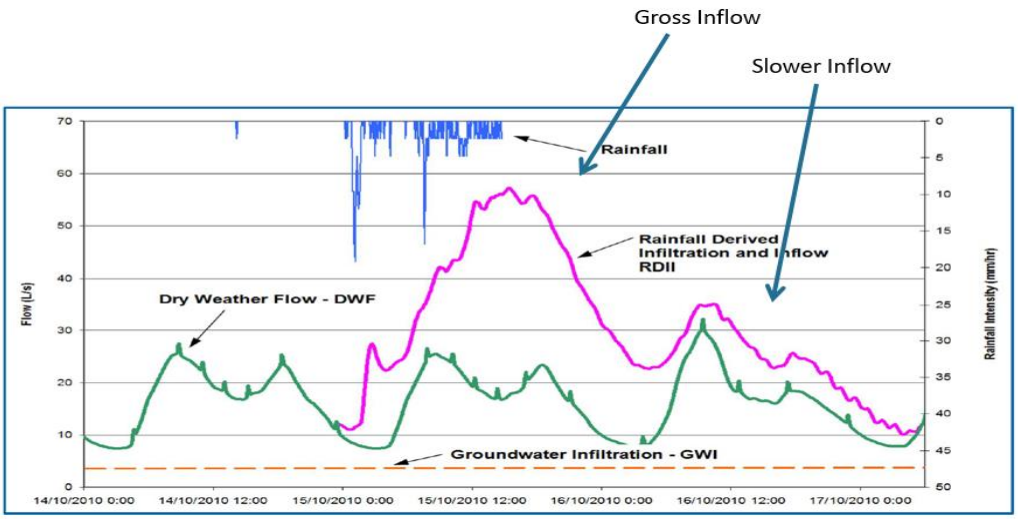


Figure 3 – Flow hydrograph showing the various'flow contribution' components wihtin the wastewater system from the Kaiti catchment, Gisborne (courtesy of GDC, 2015).

Gisborne, like most of other New Zealand Local Government organisations faces a series of challenges in the operation of their urban drainage infrastructure. Gisborne has areas that are highly susceptible to inflow and infiltration within the wastewater systems.

The consequences of which have been deemed unacceptable by the local community and include discharges to riverine and marine environments of untreated/unscreened wastewater, flooding of private property and associated health/wellbeing impacts. This has been an on-going concern since the 1970's and an earlier tranche of significant capital investment into the main wastewater network has had no discernable improvement.

The focus switched during 2015, away from delivering a further multi-million dollar investment in the wastewater infrastructure, in the form of storage. The newer catchment wide understanding delivered through catchment modelling, proved what operational theory/experience had identified previously, namely the potential for some significant improvements to the performance of the wastewater system through reducing the 'Gross' Inflows.

The Drainwise concept was thus born out of a realization that from an environmental, health and cultural view, discharging of untreated wastewater to the regions waterways was damaging at best.

The wastewater modelling identified that the significance of targeted reductions in the gross inflow was enough to dramatically reduce the frequency of wet-weather discharges, leading to the focus changing. One of the key outcomes was the understanding of the overland flow path and impacts on people's parcels and properties. Individual parcels of land across Gisborne are shown to have been developed at lower levels than the surrounding road network, with these depressions catching runoff and holding it on the parcels.

Figure 4 – Outputs from catchment modelling of the Kaiti catchment, Gisborne (showing that overland flow is trapped on parcels as roads are higher than surrounding area) and event photo from Sept 2015.

The real impact of this occurring is that there are many key issues affecting the community:

- An unacceptably high frequency of wastewater discharges to the waterways during wet weather;
- A high frequency of uncontrolled wastewater overflows on to private property during wet weather;
- During these events, many properties are unable to use their toilets/showers;

- Potentially significant health issues within our community due to property flooding which is also contributing to our discharges and overflows.

As time has passed, residents have taken matters into their own hands and identified ways and means to reduce their flooding impact. These include private drainage solutions such as connecting new pipe connections to available below ground infrastructure as well as using the wastewater gully traps adjacent to buildings to maintain a lower water level on the parcel.

These 'ad-hoc' approaches can help to explain why the multi-million dollar investment in the wastewater assets over the latter part of the 20th Century have not yielded any demonstrable benefits, as the private assets have kept pace or even exceeded the gains from these public capital works. The lowering of the gully traps on each property has the potential to allow vast quantities of stormwater (not unusual for there to be between 10 and 30 litres per second) discharging into the network.

The Drainwise project, following on from these technical studies, identified that the on-property stormwater was a major focus and that to avoid further contribution to health (rising damp/moisture) issues, that there are three high impact areas where effort was to be focused:

- Reducing on-property flooding (removing stormwater from entering gully traps);
- Fix cracked and leaky pipes in both private and public network
- Remove roof water from discharging into the wastewater network

In parallel, with this work, Council is focusing on the delivery and improvement of a suitable mechanism to collect, use and transfer the water away from properties. This will involve an investment in a mix of additional grey (pipes, tanks, etc.) and green (swales, basins, etc.) stormwater facilities, presenting an opportunity to reconnect the urban landscape with the more natural and historic waterway patterns.

It is realised that the programme will have a significant impact on the community both in terms of costs but equally in terms of achieving the Council's key Community Outcomes, as below:

- Environmentally Sustainable, Tairāwhiti/Tairāwhiti Ukauka Taiao by reducing the frequency of wastewater discharge to our waterways and private property during wet weather
- Healthy Tairāwhiti/Tairāwhiti Hauora Pai by reducing the frequency of wastewater discharge to our waterways and private property during wet weather, where we swim and live and gather food.

The challenge effectively revolves around achieving the communities' aspiration for reducing the frequency of wastewater discharges into the waterways and onto private properties during wet weather, whilst ensuring its affordability and delivers to an acceptable timeline.

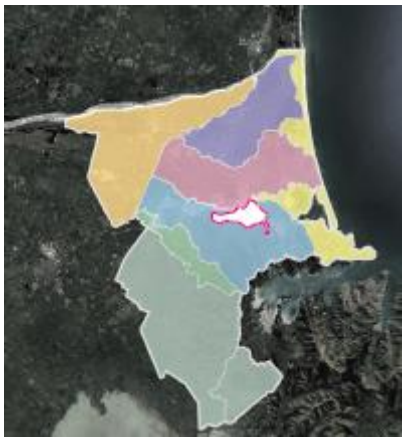
Table 1 – GDC's identification of key benefits for pursuing the Drainwise project (Wet Weather Discharge Reduction Project (WWDR)).

Issue	Benefit of undertaking the WWDR Project
Discharges to Rivers	- Minimising risk of contamination, (Health) - Minimising environmental impacts, - Improving social and community expectations, - Tourism not negatively affected,
On-Property Overflows (gully trap discharges)	- Can use toilets/showers during a wet weather event, - Health risk reduced as no discharge of wastewater, - Can safely use property grounds during and after wet weather, - No longer inconvenienced by having to go elsewhere to use toilet, - No shame or stigma, - Property values are not negatively affected, - No clean-up work required to disinfect the area.
On-Property Flooding	- Health benefits by reducing ponding under houses (mould, damp), - House insulation more effective resulting in warmer houses (Health Benefits), - Reduction in asset deterioration/rot of building from moisture, - Can use property grounds during and after wet weather,
Wastewater Treatment	- Improved treatment during wet weather, - Reduced operating costs, - Reducing amount bypassed to outfall during wet weather, - Cost savings for potential wetlands.

This whole water cycle catchment approach, being pursued by Council, represents a stepping stone in the right direction to consider and deliver catchment wide and integrated water management thinking. Through this pragmatic approach, Council can start to deliver 'real' benefits across the four well beings by unpicking and resolving our historical views of dealing with urban drainage (stormwater and wastewater).

It is clear, that ultimately a managed overland flow path process will need to be formalised to avoid further deterioration in the levels of service as economic and climate pressures mount up. This represents an opportunity to deliver 'above-ground' regeneration to open these permanent and ephemeral watercourses and deliver a connected network of hydrologically and ecologically sensitive corridors across the existing urban fabric of Gisborne.

6.2.2 FUTURE CATCHMENT VISIONING – JACKSONS CREEK, CHRISTCHURCH



Christchurch has been well served over the past through the traditional means of dealing with rainfall, enabling economic development to take place and deliver a city that is able to thrive in a coastal delta swamp area. The opportunities to deliver a significant change in the way the city can adapt to an uncertain future, despite the recent traumatic impacts of the earthquake on the cityscape, are limited.

Urban regeneration is piecemeal in nature and usually allows for interventions to take place in a disjointed manner around the urban environment. As such, a recent study completed identified the potential opportunities for setting a vision of a possible future for an existing waterway catchment in an urbanised environment.

This integrated growth and regeneration focus allows the Council to deliver a visualisation of what a future urban environment can deliver through looking at a typical urban

catchment within Christchurch. The Jacksons Creek Catchment (white polygon with red outline on image on page previously) covers 810ha covering some of the oldest settled areas in the District and contributes flow to the Ōpāwaho / Heathcote River catchment (light blue).

The Creek is located directly to the south of the Central City, comprising of range of distinct land use zones, light industrial, commercial and residential. This urban catchment has over time 'forgotten' the watercourse flowing through the area, with development turning its back on the waterway resulting in disconnected 'islands' of open waterway covering less than 45 % of the lineal length of the watercourse.

Figure 5 – The current state of the six values across the catchment showing that the Drainage value has predominated our urban landscape resulting in significant piping of the waterway.

Other key issues are now being recognised because of the delivery of the existing urban approach, which include:

- Isolated islands of residential and industrial land uses that turn their backs on each other and in doing so often turn their backs on the creek network;
- Lack of passive surveillance of the available open creek network;
- Limited open space destinations such as parks, playgrounds, community gardens or kick-play areas within the creek / park area that encourage patronage;
- Flooding across the catchment during extreme events;
- Contribution of rapid runoff from the heavily urbanised catchment into the lower Heathcote catchment – an area of existing flooding concern within the city;
- Heavily urbanised and trafficked catchment providing enduring contaminant contributions continuing to further deteriorate the Heathcote River (sediment, heavy metals, nutrients, organic compounds and pathogens);
- Waterways largely buried away with minimal opportunities for engagement with it;

- Travel issues across the catchment;
- Disjointed communities, and;
- Beheading of the upper catchment from the lower Jacksons Creek at Austin Street, has resulted in an orphan watercourse in its lower segment with the baseflow removed from the upper springs and catchment flows, presenting challenges around water quality, stagnant water and siltation.

The current plans within the District Plan include for significant infill development across this catchment, representing further challenges to the issues identified above that can further degrade the natural ecosystems.

This change allows us an opportunity to think more holistically on a catchment basis to deliver urban development that moves us away from the traditional linear unsustainable development mechanisms. Away from ones that continue to promote a 'take – make – dispose' society to one where we can deliver a net positive urban community, centered around delivering spaces and places that the four well-beings can thrive within.

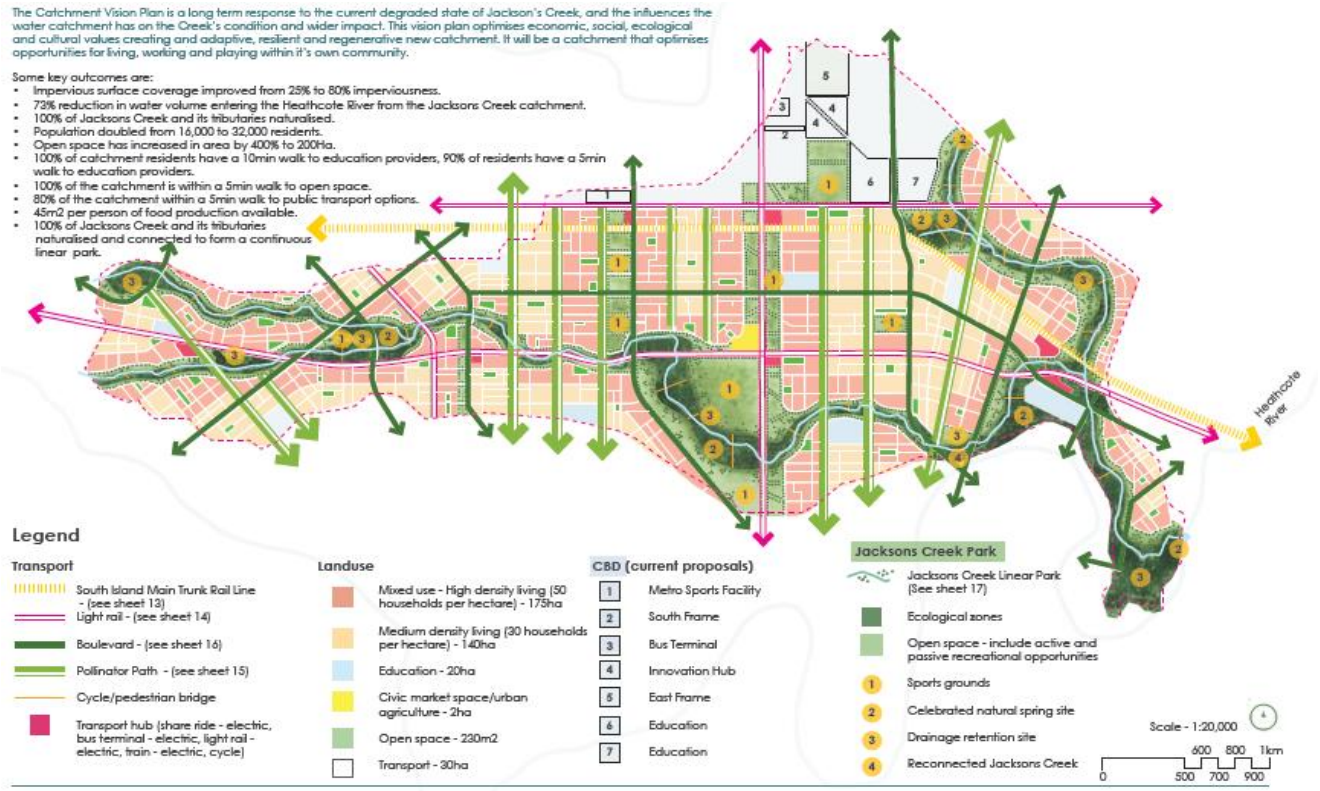


Figure 6 – A draft possible future land use vision to recreate natural waterway corridors and develop a thriving 'net-positive' community within the wider context of Christchurch

This possible futures works has identified:

- A vision for placing people at the centre of the redevelopment in a sustainable manner delivering low-carbon communities;
- An interpretation of a vibrant and future proofed community precinct with connections across the city and wider region;
- A connected network of green / blue corridors for more effective stormwater management into the future, delivering better receiving water environments;
- Activation of the river corridor for improving multiple co-benefits, and;

- Vibrant, high quality and well-designed precincts that encourage inward investment, delivering a circular economy and a lower consumptive community.

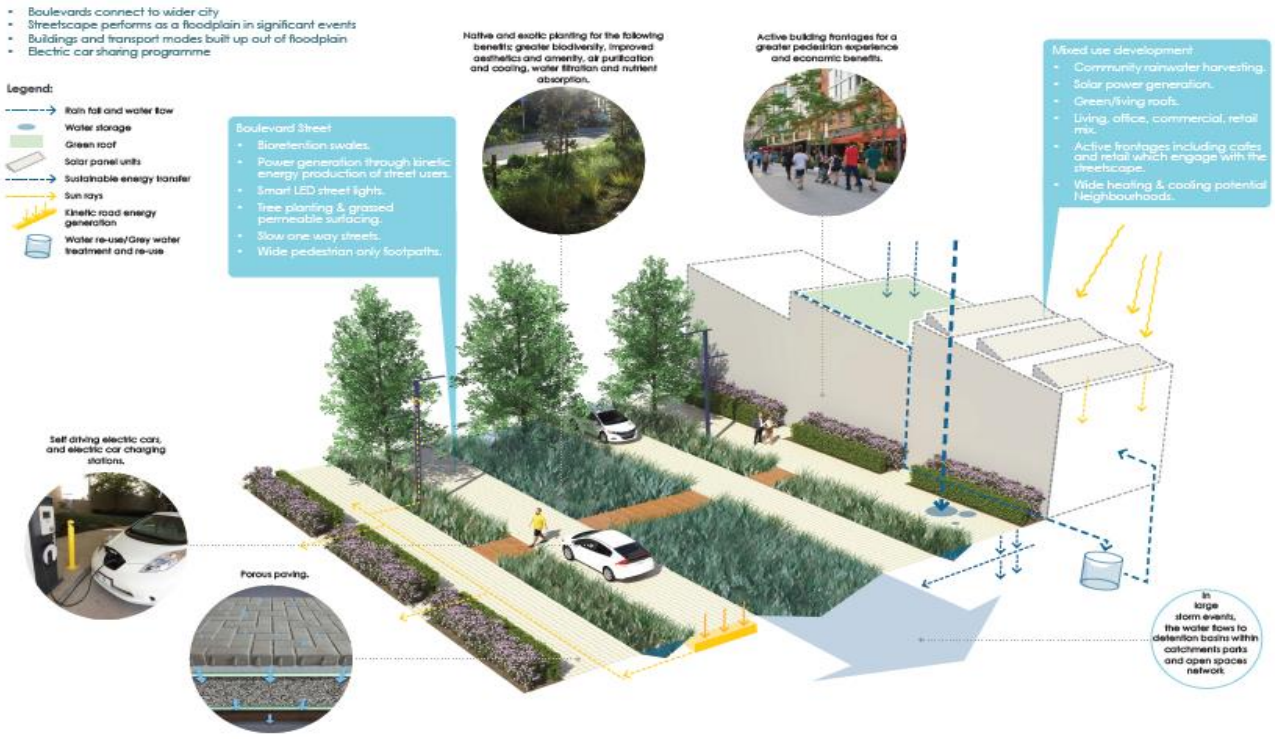


Figure 7 – An interpretation of a potential application of how the future urban spaces around Jacksons Creek, allowing for significant water quantity and quality benefits as well as improving overall catchment identity.

7. CONCLUSIONS

The most common natural hazards affecting New Zealand are floods (including both rain events and coastal flooding with storm surge), severe storms (which include both rain and high wind conditions), and extreme temperatures (both hot and cold). A common secondary impact from extreme weather events are the loss of critical infrastructure services, including energy, water, wastewater, transportation, and communications.

Much of New Zealand's stormwater and wastewater infrastructure is vulnerable to the risks associated with a changing climate. Most of our major cities have large areas that are vulnerable to sea-level rise (Bell et al., 2015) and increasing intense rainfall events are causing increased surface flooding. The nature of stormwater and wastewater systems are that they discharge to low lying areas, and it is these coastal and riverine locations that are most at risk to the effects of a changing climate.

The case studies presented above show across their range that we can indeed make positive steps to improve the current and future performance and deliver multiple net-positive outcomes that help to position ourselves better to adapt and face the future uncertainties. In doing so, it is essential that there is direct consideration of a multi-hazard approach with proactive development and implementation of upgrades to help improve the resilience of existing urban and rural landscape stormwater systems.

With the expected climate change impacts increasing the frequency and magnitude of extreme events across each year, this paper is a clarion call for us consider the multitude of climate related hazards affecting our communities and there is a clear benefit to doing so. Further evidence of the benefits, produced for CIRIA (2013), has discovered that for

the City of Philadelphia, there are significant benefits in undertaking 'surface' green/grey solutions for surface water management as opposed to the traditional piping solution. The assessment identified that the 'surface' strategies would yield in the order of US $3 billion net benefits compared to US $100m for the piped solution. The surface strategies allow for the inclusion of many diverse benefits, such as changes to property values; green jobs created; reduction in greenhouse gas emissions; and reduced crime.

The author realises that the publication of this paper is in advance of the on-going research seeking to deliver a clearer understanding of the *'Impacts and Implications on our Economy, Environment, Culture and Society of Climate Change across the Stormwater and Wastewater systems'.* This project is being undertaken as part of the Deep South Challenge and will start to provide a specific New Zealand focus on which to develop future National, Regional and Local approaches to how we can adapt to (or in some cases, mitigate) the potential impacts and implications of climate change on both our rural and urban communities.

Finally, the author requests that we (as an industry) collaborate wider (across industries, communities, individuals and private businesses) and make the best of all available opportunities to derive significant positive outcomes. The steps identified below, are one such framework, that can be applied to determine and shape how 'Future Ready' your community is. It can unlock the steps required to allow our hydrologically sensitive urban environments to achieve multiple co-benefits and gradually lift our game towards delivering resilient communities / urban fabrics.

8. POTENTIAL NEXT STEPS

It is possible, even now, that each community can start to demand for our authorities to develop 'Future Ready' strategies. As such, the author recommends, that using the latest available climate change projections across New Zealand available from MfE, Local Government and private entities pursue this potential 'Future Ready' framework:

1. Undertake a comprehensive integrated water management (or at the very least stormwater) vulnerability assessment. This will include deriving a consistent understanding of the current levels of vulnerability across the four well beings;
2. Consult with the local community and relevant stakeholders to share pertinent information but determine and agree on a suitable way forward to address the challenges that is acceptable;
3. Consult with relevant stakeholders (including across Council Departments) and others with regional and local capital delivery programmes. Identify key collaborative opportunities for making significant local changes to the resilience and adaptation to ongoing and likely future climate impacts, and;
4. Encourage the delivery of infrastructure that is designed with this uncertainty in mind around the scale of future exceedance events. Designing with a 'precautionary' approach will help to best prepare us for climate change impacts and implications.

To support a greater level of consistency of application across Local Government, it is anticipated that Central Government and its bodies will deliver specific guidance and data to facilitate each community develop appropriate 'Future Ready' decisions:

- An overarching National Receptor Dataset – critical to understanding the vulnerability across NZ Inc. is the presence of a robust and uniform dataset that relevant authorities/communities can utilise in the assessment phases.

- Specific and focused National level guidance on undertaking the assessments, including appropriate and consistent approaches to rainfall-runoff modelling and coastal hazard assessments.

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