Embracing sponge cities: A nature-based approach to urban climate change adaptation in Aotearoa New Zealand

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Abstract

Explore the transformative potential of 'Sponge Cities' in New Zealand's battle against climate change-induced disasters. This presentation shares innovative and mātauranga Māori informed nature-based flood management strategies to build resilient, sustainable, and biodiverse urban environments.

Aotearoa New Zealand faces heightened risks from natural disasters like floods and cyclones due to climate change. A report by the Helen Clark Foundation and WSP suggests transforming urban areas into 'Sponge Cities' as a proactive strategy.

The current reliance on aging infrastructure falls short against increasing rainfall threats and continued urban expansion. Sponge Cities, inspired by ancient Chinese techniques, promote water harmony through innovative measures.

The paper explores the key outputs from our work and emphasises the potential of sponge cities, a nature-based approach, to address the complex challenges that face our urban environments nationally. The paper specifically looks to share the important role that infrastructure asset managers have in enabling further uptake of sponge city approaches, identify what the key actions that the many varied urban infrastructure asset owners can do to enhance their own asset resilience and the wider urban environment to better face the complex nature of the challenges ahead to support future generations.

Sponge Cities represent a promising approach for Aotearoa New Zealand to adapt to climate change and build more resilient, sustainable, and liveable communities. This paper proposes a roadmap for infrastructure asset managers and policymakers to guide successful implementation, emphasizing collaboration, data-driven decision making, and the integration of Mātauranga Māori. Embracing this innovative approach and providing a structured approach through Āpōpō will give our asset management community an opportunity to positively influence and secure a more sustainable future for generations to come.

Key Words

Sponge cities, flooding, waterways, Low Impact Design, Water Sensitive Urban Design, city wide strategy, resilience, communities, multi-benefits, adaptation, climate change, droughts, green infrastructure

Key Definition - A ***sponge city*** is an urban area designed to mimic a sponge, absorbing and storing rainwater rather than letting it overwhelm drainage systems. It uses blue / green infrastructure like parks, wetlands, and permeable pavements to slow down and capture water, reducing flood risks, improving water quality, and enhancing biodiversity. Essentially, it's about working with nature instead of against it to adapt cities to heavier rainfall and climate change impacts.

Introduction

Aotearoa New Zealand is rated as the second riskiest in the world for expected annual losses from natural disasters, as a proportion of GDP (Lloyds and CEBR (2018)), with flooding identified to be the most common natural hazard in Aotearoa New Zealand. On average, the country experiences a major flood event every eight months (MfE, 2008), with over 150 flooding events recorded since the turn of the century (NIWA, 2024).

Flooding costs more than $160 million dollars in direct economic damages each year, and causes ongoing economic, social, cultural, and environmental impacts (Te Uru Kahika (2022)). The study also identifies that floods are also one of the most avoidable hazards – they can be planned for and mitigated.

Urban areas often exhibit the greatest risk from climate change due to the concentration of human settlement, increasing the vulnerability of infrastructure and communities to climate change hazards (Hobbie & Grimm 2020). Hobbie and Grimm caution that climate change will worsen various hazards, including sea-level rise, coastal storms, extreme heat, water security and flooding. The risks also extend to other natural hazards like fires, tornados, hurricanes, landslides. All these events are becoming more severe due to climate change, challenging our current infrastructure, designed to operate under historical climate conditions. Traditional grey infrastructure, relying on concrete and drainage systems, often struggle to cope with extreme weather events, leading to flooding, water quality issues, and infrastructure damage.

This paper builds on the Helen Clark Foundation Sponge Cities report released (Mercier, 2023), providing the key reasons as to why sponge cities can support a nature-based approach to urban climate change adaptation and specific advice for infrastructure asset managers across the spectrum of private and public entities.

The paper lays down the wero / challenge to embrace sponge city thinking as part of current and future iterations of asset and activity management plans. The roadmap provided for asset managers is a core output to use as a tool to help you mitigate and adapt, your business or community and the assets that you provide, against an uncertain climate future.

Key Themes:

As Aotearoa New Zealand determines its response to an uncertain climate future, it is imperative that we evolve both traditional and innovative approaches to enhancing the resilience of our assets, our businesses and our communities. As such, four key themes are evident if we are to embrace sponge cities approaches:

- Move away from "fighting" water through conventional drainage systems and working collaboratively across urban environments and asset owners. Recognising water is a valuable resource, mitigating floods and replenishing groundwater helps us to adapt to future climates.
- Prioritise nature, including the restoration and creation of urban green spaces. parks, wetlands, and green roofs to support the four Community Well-beings and enhance our urban areas to make them more liveable.
- Involve communities to understand the value of nature-based solutions, will lead to designs that are embraced and nurtured, fostering a sense of ownership and collective responsibility.

- Celebrate what is unique about NZ and embed Mātauranga Māori, the accumulated knowledge of generations, and tikanga Māori, customary practices, into our approaches. They provide guidance on living in harmony with the natural world, informing sustainable water management strategies.

Urgency for change

Climate change is no longer a distant threat; its impacts are being felt acutely in Aotearoa New Zealand. From intensifying rainfall and extreme weather events to rising sea levels, the urgency for action has never been greater. All this growing evidence highlights the pressing need for adaptation measures, outlining the current and projected consequences of inaction.

Notably, the following demonstrate the broad nature and complexity of what is facing us as we seek to enhance the overall resilience across the motu (taken from Mercier, 2023):

- Extreme rainfall events will continue to intensify.
- Our assets are ageing and not fit for future climates.
- Our cities are becoming less green and losing trees.
- We need to house more people.
- Flooding causes impacts, these will grow.
- Maori face unique challenges due to their cultural connection to at-risk landscapes and traditional knowledge systems.

Nature Based Approaches and Sponge Cities

Ecosystems are essential for our well-being, providing a variety of services like clean water, air quality regulation, food production, and recreation. However, climate change is disrupting these ecosystems in a multitude of ways including changing rainfall patterns. Degraded ecosystems are likely to be more vulnerable to climate change.

Nature based approaches can help to make ecosystems more resilient to climate change and ensure that they continue to provide the services that people need (more commonly referred to as Nature Based Solutions (NbS)). These solutions look to seek not only to withstand climate impacts but to thrive in concert with the ecosystems that sustain us.

NbS are defined by the IUCN (International Union for the Conservation of Nature) as being "*Actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.*" NbS can be defined by three key concepts. NbS interventions:

- Address one or more societal challenges (such as flooding, drought, water quality degradation)
- Use ecosystems to address that challenge (through protection, management, or restoration)
- Deliver simultaneous benefits to people (human well-being) and biodiversity (net gain).

Figure 1 – Nature Based Solution examples (taken from the World Bank website)

Because NbS projects often involve protection or restoration of ecosystems, there is often a cross over with conservation projects. A critical distinction between NbS and nature conservation is that, although NbS activities protect or restore ecosystems, that protection or restoration is not the main purpose of the

investment. A societal function is usually the main delivery outcome, such as enhancing the overall resilience of our communities and urban landscapes, such as reducing people's risk from floods.

Mercier (2023), reports that the term 'sponge city' was coined by a landscape architect, Dr Yu Kongjian in 2003, inspired by traditional approaches used by Chinese farmers over the past 2,000 years. The farmers regulated water through the wet and dry seasons by setting aside 20% of their cultivated land for ponds and through taking this approach into the urban landscape, would enable whole cities to turn into giant, absorbent sponges using a network of 'blue' and 'green' nature-based infrastructure.

Sponge cities are not only about absorbing water but looking to prepare the community for a largely accepted future where the cities and towns would need to adapt to a living with water more. They are intended to enhance cities and ecosystems, through restoring and promoting biodiversity, supporting cities to become more resilient to climate change and natural hazard disasters.

This practice will help reverse the trend in urban development over the past 80 years with a reduction in urban green spaces and tree cover as shown in the figures below.

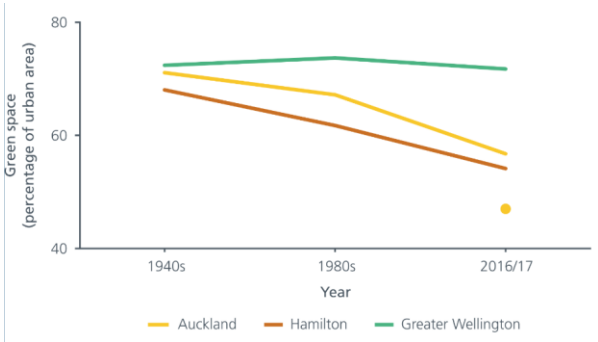

Figure 2 – The declining trend in green space cross three NZ cities since the 1940's (PCE, 2023).

The name 'sponge cities' has caught the public's imagination following recent flooding events, with a range of applications already delivered nationally.

Figure 3 – Comparing the intensity of suburbs 1940's development (Mt Roskill) on the left to 2010's (Flat Bush), taken from PCE (2023).

Across the motu, applications include the small scale (streetscapes and neighbourhoods) through to more catchment wide solutions.

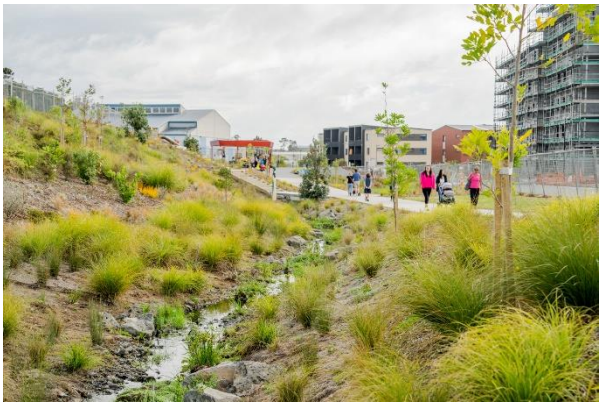

Figure 4 – Te Ara Arawhata Northcote's Greenway (Eke Panuku), 2023

Sponge city applications across several Chinese cities have shown impressive results:

- Jinan – high risk flooding areas reduced by 45 % for the 1 in 50-year rainfall event.

- Wuhan – reduced flooding, sequestered CO_2 and reduced temperatures in the city.
- Shaoxing - installation of 45,000m^2 of permeable pavements and landscaped waterbodies has allowed for 87% of rainfall (by volume) to be captured rather than directed to stormwater networks – double that captured previously – reducing flooding impacts across a wide area.

Applying a sponge cities framework offers a revolutionary approach for infrastructure asset managers working across urban environments to enhance resilience against climate change by fundamentally shifting how we manage urban water for the benefit of their organisation, through maintaining business continuity and protecting assets as well as supporting the wider community.

Several key opportunities emerge from transforming our approach to living with water (under a sponge city framework) as opposed to the more 'traditional' stormwater management approaches, namely:

- Flood mitigation: Absorption and storage reduces peak flows, slowing runoff protects infrastructure assets, people and the receiving water environments.
- Water quality improvement: Natural filtration removes pollutants, reducing treatment needs.
- Infrastructure longevity: Reduced stress extends lifespan, lowers maintenance costs.
- Additional benefits: Increased biodiversity, improved human health, reduced heat island effect.

There are several challenges associated with these potential solutions, including:

- Initial investment: Implementing nature-based solutions can be costly at first, but evidence points to widescale and longer-term benefits accruing.
- Data limitations: Long-term performance data may be scarce.
- Integration: Combining traditional & green infrastructure requires planning.

Overall, sponge cities offer a proactive approach to climate change adaptation for infrastructure asset managers. By integrating nature-based solutions with traditional infrastructure, you can enhance the resilience of urban systems to withstand future challenges, provide environmental benefits, and enhance quality of life for residents.

Figure 5 – Greenslade Reserve, Auckland image series showing the original Auckland Council Concept and on completion its performance during the Auckland Anniversary flooding in 2023 – with the park open for use

the next afternoon. (Photo Credit – Kate Johnson), 2023

The Helen Clark Foundation report (Mercier, 2023) shares several further case studies and is a recommended read that offers valuable insights, empowering asset managers to adopt sponge city thinking and realise the value of nature-based approaches for effective climate adaptation planning.

Embracing the Opportunity - What can Asset Managers do now?

Transitioning to sponge cities presents both challenges and immense opportunities. Initial investments in infrastructure and planning may seem daunting, but the long-term benefits are undeniable as identified above.

The research distills several essential recommendations for managers overseeing infrastructure asset portfolios of both private and public assets (across all forms of political entities), as shown in Table 1 below. Implementing these recommendations will enhance the resilience of your assets, supply chains and customers.

Table 1 – Opportunities to embrace Sponge Cities within infrastructure asset management.

1. Integrate nature into your asset management	○ **Invest in green infrastructure** - Treat green spaces as valuable assets by incorporating them into building design, planning, and maintenance. ○ **Work with Water** - Restore natural drainage systems to mitigate floods and improve water quality.
2. Prioritise long-term resilience	○ **Whole of life analysis** - Evaluate the long-term benefits of NbS for sustained adaptation. ○ **Climate resilient investments** - Focus investments on assets that enhance resilience to climate change impacts.
3. Collaborate across infrastructure groups	○ **Systems level approach** - Establish a body for communication channels for information sharing and joint planning across infrastructure sectors. ○ **Integrate asset plans** - Develop holistic plans considering multiple systems and climate resilience strategies. ○ **Cross-disciplinary teams** - Engage urban planners, ecologists, and climate scientists for comprehensive solutions.
4. Embrace data-driven decision making	○ **Joint risk assessments**: Collaboratively assess climate risks on diverse infrastructure portfolios. ○ **Standardise resilience metrics** - Develop common metrics across sectors for performance comparison and collective resilience improvement. ○ **Share systems level knowledge** – Exchange infrastructure data for cross-sectoral analysis and vulnerability identification.
5. Grow capacity & incentives	○ **Cross-sectoral training** - Foster collaboration through knowledge exchange and best practices sharing. ○ **Incentive programs** - Motivate collaboration with financial rewards, recognition, or shared resources. ○ **Explore alternative funding arrangements** - Leverage expertise and resources of private entities for comprehensive climate resilience initiatives.
6. Community engagement &	○ **Involve communities** - Engage residents to ensure projects align with needs and increase public awareness.

regulatory flexibility	○ **Advocate for flexible regulations** – Call for regulatory frameworks that encourage collaboration, joint projects and adoption of NbS.
7. Investing in the Future	○ **Explore sustainable technologies** – Investigate and adopt smart infrastructure systems, real-time monitoring sensors, and low-impact materials.

Following these recommendations will enable infrastructure asset managers to build collaborative networks that can look holistically to deliver the optimal solutions across an urban landscape, maximising the value of investments. Through the sharing of information and resources asset managers can enhance the evidence to enable more resilient and sustainable investments.

What are the Challenges associated with greater investment?

Infrastructure asset managers adopting the sponge cities approach for climate change adaptation may encounter several key concerns, which are identified in the Table presented in Appendix A. The table shares evidence and potential mitigation opportunities to proactively addressing the concerns.

By addressing these concerns with strategic planning, clear communication, and adaptive management approaches, infrastructure asset managers can navigate the challenges associated with embracing the Sponge Cities approach to support urban climate change adaptation.

A Roadmap for the Infrastructure Asset Management community

By 2050, Aotearoa New Zealand boasts a network of thriving and evolving sponge cities, where infrastructure seamlessly aligns with natural systems, delivering multiple benefits for communities and the environment.

Central to the attainment of this vision, there are several key Guiding Principles that the Infrastructure Asset Management community would need to enable.

Embedding Mātauranga Māori - Integrating indigenous knowledge and values into planning and implementation.

Investing in a holistic approach - Enabling enhanced outcomes across social, economic, and environmental aspects across scales.

Trusting adaptive management - Continuously learn, monitor, and improve applications.

Accept collaboration as the central tenet for your future thinking - Work collaboratively across sectors, disciplines, and communities to maximise the outcomes possible.

Implementation of sponge city approaches is not a destination, throughout the rollout and process, lessons learnt will enhance it.

By working together, under the leadership of Āpōpō, Aotearoa's asset managers can lead the way in building truly resilient and thriving cities for generations to come. Close collaboration between multiple utility and council asset managers will enable success.

It requires Āpōpō to lead on the delivery of the roadmap to support implementation, leverage external expertise and partner with organisations that are delivering innovation.

The roadmap should embed Mātauranga Māori principles into the process, respecting the cultural values and knowledge of local communities in planning, design, and implementation to better enhance outcomes across infrastructure asset owners.

1. Develop a unified & compelling vision.

Emphasise the benefits of infrastructure resilience, environmental sustainability, and community well-being across stakeholders across the urban system as a whole..

3. Engage senior management across utilities & councils.

Emphasise the importance of collaboration and provide dedicated resources to enable the benefits to be accrued for each organisation and collectively..

3. Network. Establish a Sponge City Forum.

Communication between different asset managers, building trust and understanding each other's needs and priorities, through establishment of a Sponge City Task Force.

4. Understand system vulnerability. Undertake collaborative assessments

Considering the wider urban system, identifying shared flood risks and opportunities for integrated Sponge City solutions that benefit multiple infrastructure systems.

5. Work together. Create a unified action & implementation plan.

Outlining implementation phase, responsibilities, funding mechanisms, and performance metrics for monitoring progress and ensuring shared accountability.

6. Lead the industry. Invest in joint training & workshops.

Organize workshops and training sessions for asset managers on Sponge City principles, design solutions, and best practices for collaborative implementation.

7. Transparency is key. Work with broader community and communicate regularly.

Involve communities in planning and design processes, incorporating their needs. Regularly engage with the public, businesses, and community groups, informing them about Sponge City plans, addressing concerns, and building shared ownership and support.

8. Continuously improve. Establish monitoring metrics.

Define clear performance metrics to track the effectiveness in reducing flood risks, improving water quality, and enhancing liveability.

Ensure collaboration throughout all stages.

Success can be enhanced through sharing data, information and lessons learnt to drive continuous improvement as well as setting up mechanisms to support trialling novel solutions.

Successful application requires a long-term commitment and ongoing collaboration. By implementing this strategy, Āpōpō can guide utility and council asset managers to work together to deliver a resilient, sustainable, and biodiverse future for your assets and your customers as well as the wider community.

Conclusion

Aotearoa New Zealand is facing both a climate and biodiversity crisis. Our future rainfall climate is facing the double spectre of more frequent and higher intensity events. These challenge the performance of our historic infrastructure assets and our ongoing land management practices (both rural and urban).

These will require us to shift how we ‘manage’ our environments to work with nature and overtime reverse the current decline in biodiversity and the vegetative cover in urban environments.

The report (Mercier, 2023) makes a clear recommendation that Aotearoa New Zealand cities become sponge cities. Nature-based sponge city approaches provide a promising way to help conceptualise and coordinate the work that urgently needs to be done to prepare for the impacts of climate change.

While sponge cities are a relatively new concept, the ideas behind them are not, and there is good evidence to support the approaches they propose. They are also compelling from a cost-benefit point of view.

Furthermore, adoption of the approach is not straightforward or cheap, however failing to prepare will be considerably more expensive and create a burden that will be disproportionately borne by future generations.

Beyond traditional financial metrics, NbS enables a broad range of whole of life cost savings, not always won by the asset owner, including operational cost savings, enhanced asset values, reduced insurance premiums, positive public relations, and societal well-being.

NbS emerge as essential cornerstones of resilience in the face of climate change impacts. Infrastructure asset managers can no longer afford to overlook the transformative potential of integrating green infrastructure, sustainable design, and natural systems into urban development.

The research emphasises the importance of interconnected urban infrastructure planning. Collaborative efforts across diverse infrastructure portfolios, facilitated by city-wide coordination, integrated master planning, and data-sharing mechanisms, will enhance collective urban resilience and adaptability.

To successfully implement NbS, regulatory policies must support cross-sectoral collaboration, incentivize sustainable practices, and adapt to changing environmental conditions.

Mercier (2023) shares several real-world examples that demonstrate successful integration of NBS principles, offering practical insights, lessons learned, and replicable strategies for overcoming challenges in diverse urban contexts.

Community engagement is identified as a crucial pillar for the success of NBS initiatives. Involving local communities in decision-making processes, fostering awareness, and addressing cultural and social contexts ensure that NBS projects align with community needs and values.

We conclude by presenting a roadmap for infrastructure asset managers embarking on a sustainable and resilient journey. This roadmap encompasses policy considerations, collaborative approaches, capacity-building initiatives, and strategies for navigating challenges, providing a comprehensive guide for future-oriented urban development.

This roadmap provides a starting point for asset managers to contribute to the development of sponge cities in Aotearoa New Zealand. By working collaboratively and embracing innovative approaches, we can create more resilient, sustainable, and livable communities for generations to come.

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Biography

Liam Foster, Kaiarataki Hangarau – Wai (technical principal water) at WSP based in Ōtautahi Christchurch is a seasoned expert in sustainable urban development and climate resilience. With a robust background in flood resilience and a passion for innovative solutions, he has played a pivotal role in addressing the challenges posed by climate change-induced disasters.

Liam spearheads transformative projects that integrate nature-based solutions. His commitment extends to incorporating indigenous knowledge and community-centric approaches for comprehensive flood management. A thought leader and advocate for resilient urban design, Liam navigates the intersection of infrastructure and sustainability, shaping a future where cities thrive in harmony with nature.

Appendix A – Table identifying the perceived challenges associated with the delivery of NbS and Sponge city approaches and some potential mitigations.

Challenge	Evidence	Potential mitigations
Upfront costs & retrofitting urban environments are often most costly.	While initial costs may be higher, long-terms savings and benefits offset this (Zuniga-Teran et al., 2021).	Explore financial models that value return on investments over an asset's life. Seek alternative funding mechanisms like green bonds.
Urban areas have limited space for implementation and may have challenging land-use regulations.	Strategic planning and innovative design can optimise limited urban space (Kabisch et al., 2016).	Advocate for flexible zoning regulations Undertake a catchment-based planning approach to deliver strategic infrastructure collaboratively. Retrofit existing infrastructure
Concern about the long-term efficacy and management requirements.		Share and develop clear maintenance plans. Provide opportunities for local community organisations to deliver ongoing maintenance through social enterprise.
Uncertain performance over time and the influence of variable environmental conditions on performance	Continuing long-term monitoring studies and share lessons learnt.	Conduct thorough risk assessment and invest in long-term monitoring. Commit to sharing lessons learnt and develop adaptive management strategies to adjust approaches based on evidence.
Collaboration and working across organisations is difficult		Create champion groups, cross sector working groups to investigate strategic and quick win opportunities to build trust. Create a network for sharing knowledge and lessons learnt.
Alignment of current regulations are not conducive to delivering sponge city approaches	The role of policy frameworks on delivering sustainable infrastructure development (Zabel & Hausler, 2024).	Work with industry groups to advocate for clear policy that preferentially delivers sponge cities and nature-based solutions. Demonstrate the benefits to influence future policy.
Community acceptance of NbS is varied and often lead by negative perceptions	Concerns about aesthetics, safety, asset performance and impact on property value rate high on community perception studies.	Collaborate and deliver a comprehensive community engagement approach to educate residents. Involve communities in the decision-making processes and deliver regular opportunities.
Uncertainty of how NbS will perform with future climate conditions	IPCC studies identify the impacts of climate change on rainfall and flows	Design with safe exceedance in mind. Plan to regularly update climate projections, Adopt adaptive governance structures.