NATURE-BASED INFRASTRUCTURE
GLOBAL RESOURCE CENTRE

Sustainable Asset Valuation of Waterway Rehabilitation in Cape Town, South Africa

NBI REPORT

Supported by

Led by

International Institute for Sustainable Development

July 2025

Published by the International Institute for Sustainable Development

The **Nature-Based Infrastructure (NBI) Global Resource Centre** aims to improve the track record of NBI to deliver infrastructure services and adapt to climate change while delivering other environmental, social, and economic benefits. We provide data, training, and customized valuations of NBI projects, based on the latest innovations in systems thinking and financial modelling.

The Centre is an initiative led by IISD, with the financial support of the Global Environment Facility (GEF) and the MAVA Foundation, in partnership with the United Nations Industrial Development Organization.

Sustainable Asset Valuation of Waterway Rehabilitation in Cape Town, South Africa

July 2025

Written by Henri Contor and Ronja Bechauf

Photo: City of Cape Town

Author contributions: Henri Contor developed the system map, the quantitative model, and the integrated cost-benefit analysis, and led writing of the report. Ronja Bechauf contributed to defining the scope of analysis and writing the report.

IISD
nbi.iisd.org
@iisd_sustinfra

UNIDO
unido.org
@unido

GEF
thegef.org
@theGEF

MAVA
mava-foundation.org
@MavaFdn

NATURE-BASED INFRASTRUCTURE
GLOBAL RESOURCE CENTRE

Supported by

Led by

Acknowledgements

We would like to thank Andrew McDonald, Joanne Jackson, Alistair Lee, Luqmaan Abdullah, and Simon Webster from the City of Cape Town for their engagement throughout this process and review of the technical report. The work undertaken by Anchor Environmental Consultants' team, led by Dr. Jane Turpie, for the C40 CFF sponsored technical study was a key source of data for this assignment and underpinned the analysis. Finally, we would like to thank Robin Short and Rahel Hermann of the Deutsche Gesellschaft für Internationale Zusammenarbeit.

CITY OF CAPE TOWN
ISIXEKO SASEKAPA
STAD KAAPSTAD

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Andrea M. Bassi, Liesbeth Casier, Benjamin Simmons, and David Uzsoki reviewed this report and provided valuable feedback.

This report is part of a wider collaboration between C40 Cities Finance Facility and IISD to support the project preparation phase of NBI projects of cities in Colombia and South Africa. C40 Cities Finance Facility and IISD are working together on integrated economic assessments of urban NBI projects to support implementation and showcase the value of nature for cities.

C40 CITIES FINANCE FACILITY

Executive Summary

This assessment evaluates the economic viability of nature-based infrastructure (NBI) interventions within the Diep/Sand and Zeekoe catchments in Cape Town, South Africa, with a focus on enhancing climate adaptation and resilience. Cape Town's rivers and wetlands are crucial for providing fresh water, regulating water flow, purifying water, and sustaining biodiversity. They also offer recreational, tourism, and fishing opportunities. However, urban development, land-use changes, and pollution have significantly degraded these waterways, reducing their capacity to deliver essential services. At the same time, climate change is anticipated to decrease annual rainfall and alter seasonal precipitation patterns, exacerbating risks of drought, water shortages, and flooding in Cape Town.

In response to these challenges, the City developed a Water Strategy to ensure reliable water access for all residents and has initiated the Green Infrastructure Programme and the Liveable Urban Waterways Programme, contributing to broader climate and resilience strategies. In this report, we analyze the planned interventions of the Liveable Urban Waterways Programme in two urban catchments in Cape Town, the Diep/Sand River catchment and the Zeekoe catchment. These nature-based and hybrid infrastructure plans include a range of ecological restoration and community engagement initiatives, including wetland rehabilitation, invasive species removal, canal naturalization, and the installation of litter traps and sediment treatment areas. In addition, the City proposes community-driven programs, such as food gardens and educational spaces, alongside infrastructure upgrades aimed at enhancing accessibility and safety.

The following interventions are planned in the Diep/Sand River and Zeekoe catchments:

- wetland rehabilitation and extension,
- removal of invasive alien plant species,
- canal rehabilitation, removal, and renaturalization,
- stormwater attenuation ponds to retain water,
- installation of litter traps and sediment treatment areas,
- tree planting and landscaping, development of public parks,
- creation of pedestrian pathways,
- development of educational spaces and programs, and
- provision of recreational opportunities.

We applied the Sustainable Asset Valuation (SAVi) methodology to assess the social, economic, and environmental outcomes of investing in these interventions. The scope of this analysis extends from 2025 to 2050[1], considering various climate scenarios to understand the long-term benefits and costs of these NBI interventions. The primary objective is to determine how these interventions can address the growing challenges posed by climate change and urbanization, particularly concerning flood risks, water quality, and ecosystem health.

1 Please note that the analysis and modelling were completed in August 2024 and remained unchanged for publishing the report in June 2025.

Key Results of the Integrated Cost-Benefit Analysis

The results of the cost-benefit analysis (CBA), illustrated in Table ES1, reveal a strong economic case for the NBI interventions across both catchments. The analysis indicates that the NBI strategies provide substantial benefits, including significant reductions in flood damage costs, improved public health outcomes, enhanced biodiversity, and avoided costs of sediment and invasive plant management. Note that Table ES1 showcases the optimistic climate scenario (Shared Socioeconomic Pathway [SSP] 2-4.5) in which flood events happen less frequently than in other scenarios. In other words, the results for this climate scenario are the most conservative. Indeed, other scenarios lead to higher avoided costs related to floods (e.g., avoided cost of mental health impact).

For the Diep/Sand catchment, the analysis estimates that over the 2025–2050 time horizon, the total project costs at ZAR 124 million when discounted at 8% (USD 7.1 million[2]), with benefits projected to range from ZAR 245 to 258 million when looking at both extremes of climate scenarios (USD 14.0 and USD 14.8 million). This results in a net benefit between ZAR 121 and 133 million (USD 6.9 and 7.6 million). The positive return on investment is further shown by a benefit-to-cost ratio (BCR) ranging from 1.97 to 2.07, meaning that every ZAR invested in the NBI yields about ZAR 2 in return for society. The NBI in the Diep/Sand catchment also has a promising internal rate of return (IRR) of between 17.2% and 18.0%.

Similarly, for the Zeekoe catchment, the total costs are estimated at ZAR 122 million (USD 7 million), with benefits ranging from ZAR 190 to 247 million (USD 10.9 to 14.1 million), yielding a net benefit of between ZAR 68 and 125 million (USD 3.9 and 7.2 million). These results correspond to a BCR of 1.56 to 2.02 and an IRR ranging from 13.8% to 18.0%. These metrics underscore the significant economic and financial advantages of the NBI interventions, reinforcing their value as a robust investment in healthy ecosystems and sustainable urban development.

[2] The USD value is a simple conversion from ZAR, using the following exchange rate: USD 1 = ZAR 17.4775.

The following results stand out in the CBA:

1. **Investing in the NBI effectively mitigates flood damages in the face of climate change.** The NBI interventions reduce flood damage costs across climate scenarios. Under the optimistic scenario (SSP2-4.5), they avoid damages of ZAR 39.2 million (USD 2.2 million) in the Zeekoe catchment and ZAR 13.4 million (USD 0.8 million) in the Diep/Sand catchment—costs of flood damages under a "no-action" scenario are ZAR 169.1 million and ZAR 23.6 million respectively (9.7 and 1.4 million USD). In the pessimistic scenario (SSP3-7.0), the NBI shows even higher value by avoiding flood damages of ZAR 89.6 million in the Zeekoe catchment (5.1 million USD) and ZAR 24.3 million (USD 1.4 million) in the Diep/Sand catchment—the cost of flood damages under a "no-action" scenario is ZAR 431.7 million and ZAR 47.6 million (USD 24.7 and 2.7 million).
2. **The NBI preserves the tourism value of Zandvlei and Zeekoevlei.** The two studied vleis (a local phrase for shallow lakes) are important tourism destinations, creating economic opportunities and tax revenues. By creating healthier ecosystems, the NBI avoids losing ZAR 113.6 million in tourism revenue in the Diep/Sand catchment and ZAR 46.4 million in the Zeekoe catchment (USD 6.5 and 2.7 million, respectively), representing the largest single benefits in the CBA. In addition, stopping the degradation of the lakes protects the property values of nearby homes and spares the City of Cape Town from losing substantive property tax revenue.
3. **Implementing the NBI avoids costly grey infrastructure interventions.** On the one hand, naturalizing the waterways avoids spending ZAR 9.8 million and ZAR 7.3 million (USD 0.6 and 0.4 million) that would otherwise be required to repair the crumbling concrete canals. On the other hand, the NBI reduces sedimentation, avoiding dredging costs of ZAR 20.5 million in the Diep/Sand catchment and ZAR 27.8 million in the Zeekoe catchment (USD 1.2 and 1.6 million).
4. **Building and maintaining the NBI creates jobs for local communities.** The employment creation of ZAR 17.4 million in the Zeekoe catchment (USD 1 million) represents 60 jobs created each year during the 7-year implementation period and 67 jobs annually during the remaining maintenance phase. The NBI in the Diep/Sand catchment would create a similar number of jobs worth a total of ZAR 18.6 million (USD 1.1 million).

Table ES1. Integrated CBA—optimistic climate scenario discounted at 8%

	Units	Diep/Sand catchment	Zeekoe catchment
Direct costs			
Implementation costs (capital expenditures) [CapEx])	ZAR million	112.3	107.7
Maintenance costs (operating expenditures [OpEx])	ZAR million	4.8	3.9
Feasibility and concept design costs (prep OpEx)	ZAR million	7.4	10.4
Avoided costs			
Avoided cost of flood damages	ZAR million	13.4	39.2
Avoided cost of disaster relief	ZAR million	0.1	0.5
Avoided cost of mental health impact	ZAR million	0.3	1.2
Avoided cost of human death	ZAR million	No data	No data
Avoided cost of dredging	ZAR million	20.5	27.8
Avoided cost of refurbishment	ZAR million	9.8	7.3
Avoided cost of physical inactivity	ZAR million	3.9	5.9
Added benefits			
Value of employment creation	ZAR million	18.6	17.4
Value of carbon sequestration	ZAR million	0.02	0.03
Value of food provisioning	ZAR million	0.4	6.5
Value of urban cooling	ZAR million	No data	No data
Avoided loss			
Avoided loss in productivity due to floods	ZAR million	0.8	2.8
Avoided loss of tourism revenue	ZAR million	113.6	46.4
Avoided loss of tourism tax revenue	ZAR million	20.1	8.2
Avoided loss of property tax revenue	ZAR million	31.9	11.6
Avoided loss in fish nursery value	ZAR million	6.0	-
Avoided loss in biodiversity conservation	ZAR million	0.9	0.60
Avoided loss of recreational areas	ZAR million	5.0	14.4

	Units	Diep/Sand catchment	Zeekoe catchment
Key performance indicators			
Total costs	ZAR million	124.5	122.1
Total benefits	ZAR million	245.3	189.9
Net benefits	ZAR million	120.8	67.8
Benefit-to-cost ratio (BCR)	ratio	1.97	1.56
Internal rate of return (IRR)	%	17.2	13.8

Note: The values are cumulative over 25 years (2025–2050-time horizon), discounted at 8%.
Source: Authors.

Key Policy Messages

- **Foster systems thinking and holistic solutions.** Cape Town can benefit from more systemic thinking that fosters cross-sectoral solutions and addresses the root causes of environmental challenges. For example, rather than continually dredging sediments, addressing root causes like upstream erosion and water retention through NBI will reduce sedimentation and flood risks more effectively. A collaborative approach that integrates social, economic, and environmental factors can tackle the city's complex challenges more sustainably.
- **Implement tailored measures for climate resilience.** Cape Town's catchments face climate risks, such as reduced precipitation, rising temperatures, and intense rainfall, exacerbating water scarcity, erosion, and heat stress. Addressing these risks requires both immediate and long-term climate strategies. Tailored, localized climate adaptation strategies are essential to manage these specific risks effectively, ensuring Cape Town is resilient to future climate impacts.
- **Ensure the long-term benefits of NBI through careful maintenance.** While the NBI projects involve considerable initial costs, benefits accumulate over time, with break-even points expected by 2039–2040 and even earlier under pessimistic climate scenarios with worse flood damages. However, the long-term success hinges on securing a dedicated budget for ongoing maintenance. Sustainable funding and adaptive management of the NBI will ensure that these benefits—ranging from flood control to biodiversity protection—are maintained in the long term.
- **Accelerate NBI implementation for societal gains.** From an economic perspective, the planned NBI is a clear win when considering its full range of societal benefits, even under high discount rates and conservative assumptions about climate change. However, municipal financial indicators alone may not fully justify the investment. Broader societal goals, such as job opportunities, ecosystem health, and wider value creation, must drive NBI funding decisions. The City stands to gain from swiftly implementing the NBI interventions under the Liveable Urban Waterways Programme.

- **Prioritize investments in NBI to leverage its benefits for diverse policy areas.** Investing in NBI in Cape Town's catchments offers a range of benefits, from flood risk mitigation and job creation to improved recreation and biodiversity. These interventions tackle multiple challenges simultaneously, enhancing physical infrastructure, economic opportunities, and social well-being.

The findings provide valuable insights for managing Cape Town's catchments. Municipalities can use the economic and environmental benefits, such as reduced flood damages and improved water quality, to enhance planning and prioritize NBI interventions. This supports integrating NBI into urban planning and aligning policies with sustainability goals. For financing institutions, metrics like net benefits, BCR, and IRR make a strong case for funding NBI projects due to their economic and environmental returns. Local communities benefit from improved ecosystem health, reduced flood risks, job creation, and recreational spaces, empowering them to support NBI initiatives. Environmental agencies can leverage these benefits to refine conservation strategies and influence policy decisions, helping stakeholders address climate challenges while maximizing the benefits of NBI.

Table of Contents

List of Figures

List of Tables

List of Acronyms

BCR	benefit-to-cost ratio
CapEx	capital expenditures
CBA	cost-benefit analysis
CLD	causal loop diagram
IRR	internal rate of return
LUW	Liveable Urban Waterways
NBI	nature-based infrastructure
NPV	net present value
OpEx	operating expenditures
SSP	Shared Socioeconomic Pathway

Glossary

Benefit-to-cost ratio (BCR): A ratio that measures the efficiency of an investment by comparing the economic benefits (including externalities) to the economic costs associated with a project or initiative over a specified period. It provides a holistic view of the investment's economic viability, considering broader impacts beyond direct financial returns.

Discounting: A financial technique used to adjust the value of future costs or benefits to their present value, reflecting the time value of money. It involves applying a discount rate to future cash flows to determine their current worth, facilitating comparisons and decision making across different time periods. Discounting allows analysts to account for the opportunity cost of capital and the preference for receiving benefits sooner rather than later.

Indicator: Parameters of interest to one or several stakeholders that provide information about the development of key variables in the system over time and trends that unfold under specific conditions (UNEP, 2014).

Internal rate of return (IRR): The discount rate that makes the net present value (NPV) of the economic benefits (including externalities) of a project or initiative equal to zero. It indicates the rate of return at which the project's economic benefits balance its costs, encompassing all economic impacts.

Methodology: The theoretical approach(es) used for the development of different types of analysis tools and simulation models. This body of knowledge describes both the underlying assumptions used as well as qualitative and quantitative instruments for data collection and parameter estimation (UNEP, 2014).

Net benefits: The cumulative amount of monetary benefits accrued across all sectors and actors over the lifetime of investments compared to the baseline reported by the intervention scenario.

Net present value (NPV): The difference between the present value of the economic benefits (including externalities) and the present value of the economic costs associated with a project or initiative over its lifetime. It quantifies the net monetary impact of the economic aspects of the project, considering all relevant costs and benefits.

Scenarios: Expectations about possible future events used to analyze potential responses to these new and upcoming developments. Consequently, scenario analysis is a speculative exercise in which several future development alternatives are identified, explained, and analyzed for discussion on what may cause them and the consequences these future paths may have on our system (e.g., a country or a business).

1.0 Introduction

1.1 Ecological Challenges and Planned Nature-Based Infrastructure in Cape Town

The rivers and wetlands in Cape Town, South Africa, support the city's residents and economy by providing fresh water, regulating water flow, purifying water, and sustaining biodiversity. These natural waterways also offer recreational, tourism, and fishing opportunities. However, urban development, land-use changes, and pollution have significantly degraded these waterways, reducing their capacity to deliver these essential services (City of Cape Town, 2020; City of Cape Town & Liz Day Consulting, 2023).

At the same time, climate change is anticipated to decrease annual rainfall and alter seasonal patterns, exacerbating risks of drought, water shortages, and flooding in Cape Town (City of Cape Town, 2021a, 2021b; Lennard, 2024; OneWorld, 2018, 2019). In 2018, after enduring several years of drought, Cape Town narrowly avoided "Day Zero," a scenario in which the city's water supply would have been cut off for domestic users (Stafford et al., 2019). Research indicates that this drought was three times more likely to occur due to anthropogenic climate change, suggesting that similar events may become more frequent in the future (Otto et al., 2018).

Cape Town is home to nearly 2,000 km of rivers, 480 km of canals, over 800 ponds, and thousands of hectares of wetlands and vleis (a local phrase for shallow lakes), which are essential for sustaining the region's unique biodiversity. In acknowledgement of the importance of wetlands in Cape Town, the City was recently awarded Ramsar City status, an international accreditation recognizing cities that demonstrate exceptional commitment to conserving their wetlands and ecosystem services. However, pollution from sewage and solid waste is degrading these ecosystems, leading to fish kills, algal blooms, and harmful impacts on local biodiversity. In addition, erosion and runoff in the urban catchments lead to sedimentation in the vleis, which the City is currently addressing using costly dredging.

The Zandvlei Nature Reserve exemplifies these challenges. It is home to over 430 plant species, 172 bird species, and various fish, reptiles, and mammals (see Figure 1). However, Zandvlei had to be closed for all forms of recreation for 248 days in one year because of high pollution (City of Cape Town, 2022a). The deteriorating water quality not only threatens Cape Town's biodiversity but also affects recreational activities, tourism activities, property values, and the broader environmental health of the region. Zeekoevlei, the other site we study in this report, is a recognized Ramsar site as part of the False Bay Nature Reserve.

Figure 1. Zandvlei Estuary

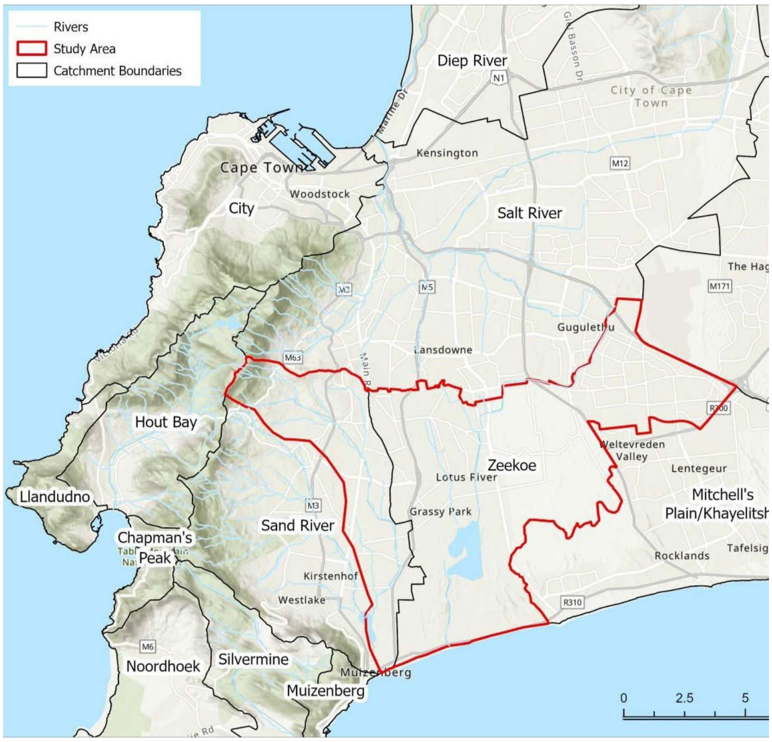
Source: City of Cape Town, 2016.

In response to these challenges, the City developed a Water Strategy aimed at ensuring safe and reliable water access for all residents (City of Cape Town, 2020). Commitment 5 of the strategy is for Cape Town to become a water-sensitive city by 2040. This strategy paved the way for initiatives like the Liveable Urban Waterways Programme (City of Cape Town, 2022a). Additionally, the City's Green Infrastructure Programme (City of Cape Town, 2024) and the Liveable Urban Waterway Programme both contribute to the City's broader Climate Change Strategy (City of Cape Town, 2021b), Resilience Strategy (City of Cape Town, 2019), Environment Strategy (City of Cape Town, 2017), and Integrated Development Plan (City of Cape Town, 2022b).

The Liveable Urban Waterways (LUW) Programme aims to showcase how water-sensitive design, waterway rehabilitation, and investments in nature-based solutions can provide multiple social, environmental, and economic benefits. It defines six key elements of a livable waterway: acceptable water quality, space for water flow, functioning ecology, connection of the waterway to the water table and floodplain, access for communities, and the provision of ecosystem services and economic and social benefits (City of Cape Town, 2022a). As part of the LUW Programme, Cape Town is developing a master plan for nature-based infrastructure (NBI) in urban catchments, establishing a pipeline of bankable projects, supported by an evidence-based benefit case, and a framework for effective implementation.

In this context, the Sustainable Asset Valuation (SAVi) methodology aims to provide a holistic assessment of the first two components of this pipeline. The first component is situated in the Diep/Sand River catchment (area of 33 km²), and the second is in the Zeekoe catchment (area of 93 km²), see Figure 2.

Figure 2. Map of the Diep/Sand and Zeekoe catchment



Source: Anchor Environmental/City of Cape Town, 2024.

The Diep/Sand and Zeekoe catchment masterplans (representing a total of 27 hectares of wetland rehabilitation/creation and 10.7 kilometres of river/canal rehabilitation) both focus on ecological rehabilitation, community engagement, and infrastructure improvement. Key interventions include the rehabilitation of wetlands, removal of invasive alien plant species, canal naturalization, and the installation of litter traps and sediment treatment areas (see Figure 3 for images of current situation). Both plans include the creation of pedestrian pathways, educational spaces, and recreational opportunities, along with beautification efforts like tree planting and landscaping. Additionally, community-focused initiatives include food gardens, public parks, and educational programs, with infrastructure upgrades to enhance overall accessibility and safety for the 19,200 households that live within 200 metres of the proposed project—likely to be more than just for these households. While the specific interventions may vary slightly between the two catchments, the overarching aim is to restore natural environments and, in doing so, build climate-resilient catchments and livable waterways with stronger community connections. More details of the interventions are presented in Section 2.4.2.

The following interventions are planned in the Diep/Sand River and Zeekoe catchments:

- wetland rehabilitation and extension,
- removal of invasive alien plant species,
- canal rehabilitation, removal, and renaturalization,
- stormwater attenuation ponds to retain water,
- installation of litter traps and sediment treatment areas,
- tree planting and landscaping, development of public parks,
- creation of pedestrian pathways,
- development of educational spaces and programs, and
- provision of recreational opportunities.

Figure 3. Sand Langvlei canal & Roscommon road wetlands

Source: City of Cape Town, 2016-2018.

The masterplans for the Diep/Sand and Zeekoe catchments (Turpie et al., 2024a, 2024b) were developed by Anchor Environmental Consultants based on a set of highly detailed and location-specific studies:

- climate change projections review (Lennard, 2024),
- biophysical assessment (Day, 2024),
- socio-economic assessments (Letley & Turpie, 2024a, 2024b),
- hydrological and geo-hydrological assessments (Thewlis & Riemann, 2024a, 2024b), and
- potential impacts of interventions on ecosystem services and climate change vulnerability (Turpie & Letley, 2024a, 2024b).

Stakeholder engagement was integral to this process, ensuring that local communities were involved in conceptualizing and validating the proposed interventions. More specifically, Anchor Environmental Consultants and the City of Cape Town organized co-design workshops with residents of the catchments to collect ideas for interventions and their potential sites and held a workshop to validate the draft masterplans. In total, across both catchments, six workshops were undertaken, and over 200 community and catchment stakeholders participated.

1.2 Purpose and Structure of This Report

In this report, we present a SAVi assessment of waterway rehabilitation in the two catchments. This methodology highlights the extensive list of ecosystem services provided by riverine ecosystems, incorporating not only environmental metrics but also financial, social, and economic dimensions. This report aims to provide a holistic assessment of the NBI interventions, with a focus on their sustainability and long-term viability. The purpose of this study is to go beyond traditional technical studies and financial analysis to offer an integrated evaluation of what can be achieved through the rehabilitation of urban catchments. By employing the SAVi framework, this report seeks to highlight the multifaceted impacts of the proposed interventions. Such a comprehensive assessment is crucial for policy-makers, investors, and stakeholders to make informed decisions that support the various policies of the City of Cape Town, such as the Water Strategy and the implementation of the LUW Programme.

The report is structured into several key sections:

1. The first section introduces systems thinking and its relevance to evaluating complex urban systems, identifying leverage points for sustainability and managing trade-offs.
2. The second section presents a system map to illustrate the dynamic relationships and feedback loops of the dynamics within the catchments.
3. Given the project's climate-sensitive nature, the third section examines climate projections and their implications for flood risks.
4. The fourth section offers an integrated cost-benefit analysis (CBA) of the interventions, comparing a no-action scenario to a rehabilitation scenario for both catchments. This section includes a detailed analysis of key performance indicators across different climate scenarios, economic trends, and perspectives. Additionally, the potential for future flood damage is reviewed, providing insights into area vulnerabilities and guiding mitigation strategies.
5. Finally, the conclusion summarizes the key findings and offers recommendations, emphasizing the need for holistic approaches that integrate environmental, social, and economic considerations.
6. Detailed assumptions and equations used in the quantitative model are provided in Appendix B, ensuring transparency and replicability of the findings.

Box 1. More information about NBI in Cape Town

Cape Town has committed to scaling up NBI in various strategies and plans, and the City has a long track record of implementing NBI. You can find more information here:

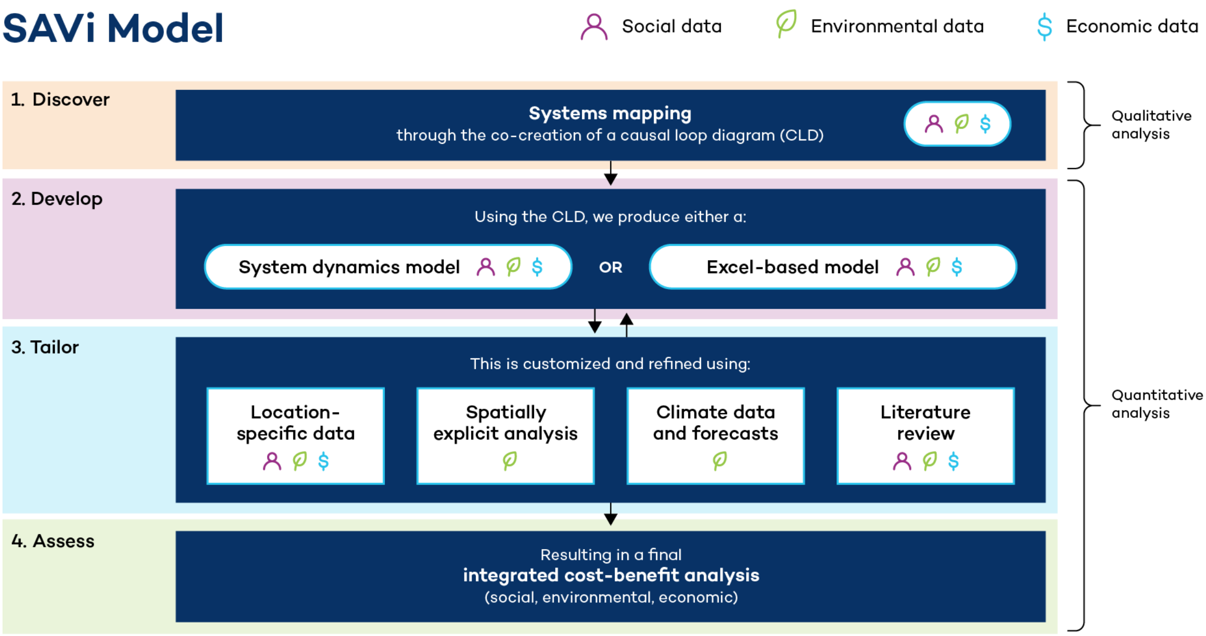
- *Cape Town's Water Strategy: Our Shared Water Future.* https://www.capetown.gov.za/general/cape-town-water-strategy
- *Cape Town's Green Infrastructure Best Practice Guideline: Urban Watercourses* https://capetown.gov.za/departments-city-initiatives/environmental-resource-management/green-infrastructure-programme
- *Cape Town's Liveable Urban Waterways (2022): A Compendium of Case Studies: Guiding the Transition to a Water-Sensitive Future.* https://www.capetown.gov.za/Family%20and%20home/residential-utility-services/residential-water-and-sanitation-services/liveable-urban-waterways

2.0 Sustainable Asset Valuation

This chapter presents the methodology and results of the Sustainable Asset Valuation (SAVi). First, we examine the broader picture in which the interventions are taking place by using system thinking and system mapping. Building on this qualitative storytelling, we then incorporate quantitative tools, including climate scenario projections and a detailed CBA, to assess the long-term implications of the proposed interventions (see Figure 4). This combined approach enables a nuanced evaluation of both the immediate and future impacts of the NBI in Cape Town's Diep/Sand and Zeekoe catchments.

SAVi is an assessment methodology that provides policy-makers and investors with a comprehensive life-cycle analysis of infrastructure projects. It considers social, environmental, and economic impacts that are often overlooked in conventional project assessments. Combining systems thinking and various quantitative modelling tools, SAVi captures the full costs, including environmental, social, economic, and governance risks. It calculates the monetary value of externalities, offering a nuanced evaluation. This holistic approach enables investment decisions to align with regional development priorities, climate change adaptation, and the United Nations Sustainable Development Goals, ensuring a financially sound and sustainable outcome.

Figure 4. SAVi methodological process



Source: IISD.

2.1 Systems Thinking

Systems thinking is crucial for understanding and managing urban ecological systems, such as river catchments, due to the complex interdependencies among social, economic, and environmental factors (McPhearson et al., 2016). As highlighted by Sanneh (2018) and Meadows and Wright (2011), this approach enables us to perceive urban environments as interconnected systems rather than isolated components. In river catchments, for instance, the interactions between water management, land use, and community needs create a dynamic ecosystem that requires holistic strategies for sustainable governance (Wan Rosely & Voulvoulis, 2023). By applying systems thinking, urban planners and policy-makers can better anticipate the nonlinear effects of their decisions, fostering resilience against climate change and environmental degradation. This perspective encourages collaborative, interdisciplinary approaches that integrate diverse stakeholder insights, ultimately leading to more effective and adaptive management of urban ecosystems. Emphasizing the need for a systemic view, these frameworks advocate for solutions that not only address immediate challenges but also enhance the overall health and sustainability of urban environments, ensuring that policies are robust and capable of evolving with changing conditions (Bai et al., 2016). For example, Cape Town spends large sums on dredging canals and vleis to alleviate sediment buildup, a reactive measure that treats the symptom rather than addressing the root causes like upstream erosion and poor land management. A systems analysis would encourage long-term solutions that mitigate these underlying issues, reducing the need for costly interventions.

In South Africa, catchment management has become increasingly complex due to a combination of factors, especially in Cape Town (Obree, 2004). The region's diverse geography and Mediterranean climate create fluctuating water availability, while rapid urbanization drives up demand and contributes to pollution. Environmental challenges, such as invasive species and the need to protect the unique biodiversity of the Cape Floristic Region, add further difficulty. Fragmented governance across various levels of authority complicates policy implementation, ensuring that equitable water and sanitation access remains a significant social and economic challenge. Technological and data management issues, along with aging infrastructure, make efficient water resource management even more difficult. Additionally, climate change, with its resultant increased drought frequency and potential for sea level rise, adds an urgent need for a comprehensive, integrated approach to managing Cape Town's water resources.

The need to incorporate systems thinking is becoming increasingly important as Cape Town faces growing challenges. By encouraging collaboration across different sectors and levels of governance, we can better address issues like unsustainable water use and ensure that feedback mechanisms are in place to support adaptive management. Emphasizing continuous learning and open dialogue among stakeholders will help create a more resilient approach, allowing institutions to respond more effectively to the City's evolving water needs. This integrated, dynamic way of working could be key to sustaining Cape Town's water resources in the long term (Pollard et al., 2011).

2.2 Systems Mapping

One of the many ways to apply systems thinking is by summarizing the different elements and interactions on paper in a process called systems mapping. Systems mapping can be defined as a collaborative and analytical process used to visualize and understand the components and interrelationships within a complex system. This approach serves multiple purposes, including analyzing how a system operates and generating ideas for interventions to improve it (Barbrook-Johnson & Penn, 2022).

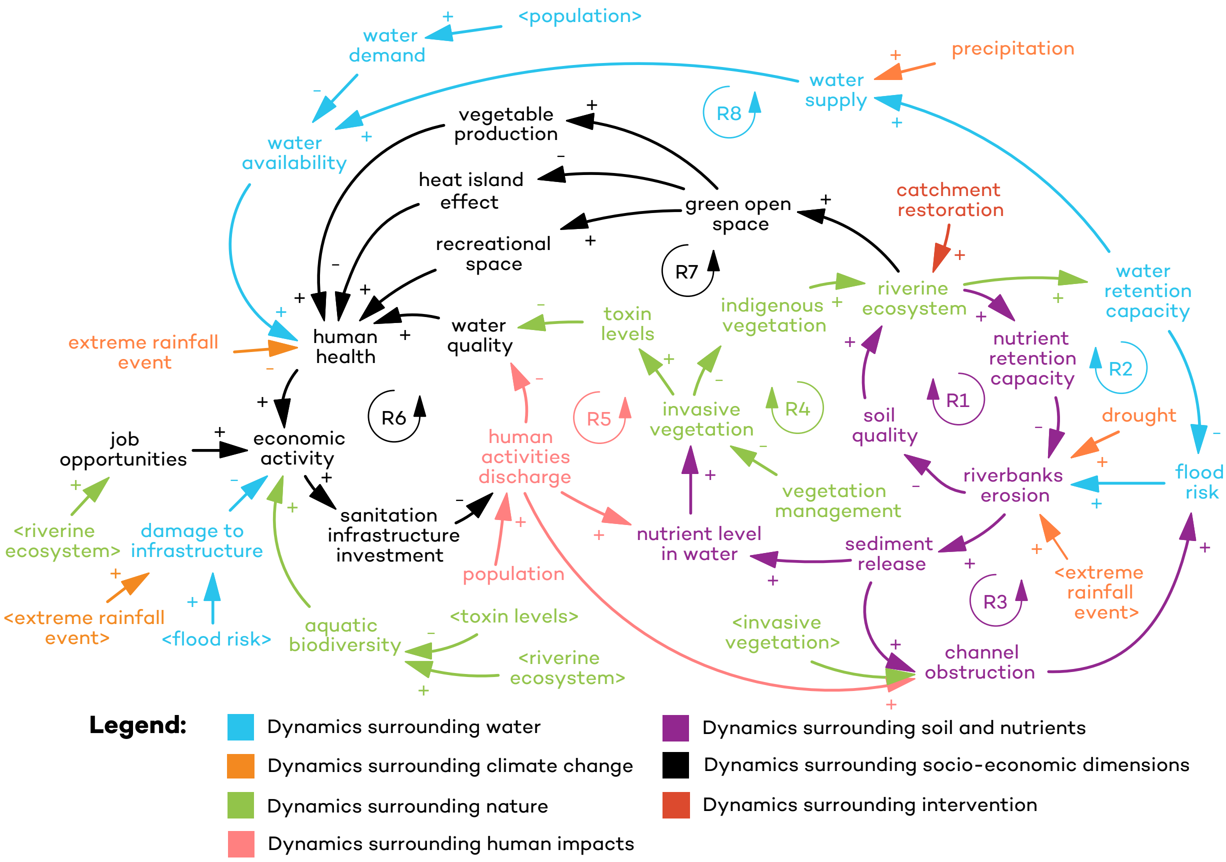
In the context of this SAVi assessment, we established a systems map by looking at the variables in the system, their cause-and-effect relationship, and the feedback loops that generate the observed behaviour. This type of systems mapping results in what is referred to as a causal loop diagram (CLD). This CLD was established using an iterative co-creation process in which Cape Town stakeholders were consulted to provide the location-specific narrative.

As previously stated, to inform decision-makers about the implications of their actions, the SAVi methodology seeks to deliver both qualitative and quantitative evidence. The knowledge described hereafter is the qualitative evidence. It serves as the ground from which the quantitative analysis emerges. More specifically, the components highlighted and discussed through the CLD are directly related to the list of indicators that are quantified in the integrated CBA. To better understand the CLD, we suggest you link the text description to the colour coding of the diagram.

Box 2. Reading a CLD

A CLD is a tool that supports systems thinking. It shows relationships between the components of a system. Arrows indicate causality, and plus and minus signs are used to show the direction of causality. A plus sign means that two variables change in the same direction (a positive correlation), while a negative sign means that they change in opposite directions (a negative correlation). Feedback loops are labelled as either reinforcing (R) or balancing (B). A reinforcing loop indicates that a change in one variable will lead to further change in the same direction, whereas a balancing loop dampens change.

Figure 5. CLD of urban catchment systems



Source: Authors.

Overarching Dynamics. The diagram outlines a complex interplay of dynamics within the Diep (South)/Sand catchment and the Zeekoe catchment. It shows that poor water quality stems from various sources, including runoff carrying pollutants like fecal matter and industrial waste (represented by chemical contaminants and discharge). Socio-economic factors, including informal settlements and inadequate or vandalized sanitation infrastructure, further exacerbate pollution, impacting human health and biodiversity. Additionally, invasive alien vegetation thrives due to nutrient-rich conditions, exacerbating flooding risks and sedimentation, thus creating feedback loops of deteriorating water quality and increased flood risk. Seven overarching dynamics emerge from the analysis: soil and nutrient dynamics, nature dynamics, water dynamics, socio-economic dynamics, human impact dynamics, climate change dynamics, and interventions dynamics. These dynamics interact within the catchments, influencing outcomes such as poor water quality and flooding, exacerbated by changing climate and socio-economic conditions. These challenges necessitate holistic management approaches, including sanitation infrastructure improvements and implementing nature-based solutions to mitigate the complex dynamics threatening the catchments' sustainability.

Dynamics Surrounding Climate Change. Cape Town's climate is classified as "warm-summer Mediterranean climate," and will see its average temperature increase and precipitation decrease, while the extreme events for both these elements may increase in frequency and intensity. These elements have a direct influence on the river catchments of the municipality. Indeed, more floods and droughts lead to higher soil erosion and human health impacts.

Dynamics Surrounding Human Impact. Catchment runoff carries fecal matter (from informal livestock farming, dogs, and horse paddocks), nutrients and pesticides (from gardens, parks, golf courses, and urban agriculture), industrial waste, hydrocarbons (from roads) and sediment. Point-source pollution comes from industrial waste, informal settlements (including backyarders), and poor-performing sanitation infrastructure (mainly pump stations and sewer overflows). The socio-economic impacts of COVID-19, the generally depressed global and local economy, as well as net migration of people into Cape Town result in more informal settlements and, in some places, illegal land invasion (often in flood-prone areas or directly within stormwater infrastructure such as wetlands and ponds). Some of these settlements do not have formal sewage or solid waste services, which leads to sewage and greywater discharge and solid waste entering the waterways.

Dynamics Surrounding Nature. Sewage and urban runoff contain elevated nutrient levels that result in eutrophication. At times, this can cause algal blooms (potentially releasing toxic compounds) and fish kills, particularly in the downstream vleis. High nutrient levels promote the rapid growth of invasive alien plants (for example water hyacinth, parrots feather, water lettuce, giant reed) that outcompete indigenous species. Some indigenous species, such as bulrush and common reed, can also become invasive under high nutrient conditions and require control. These species have a negative impact on indigenous vegetation, and the overall riverine ecosystem is impacted, leading to a higher risk of riverbank erosion and further increases in nutrient levels in the water, therefore creating a reinforcing feedback loop (R4). The alien invasive vegetation can also restrict the channel capacity and alter habitat structure, both of which may cause an increase in flood risk and erosion. The resulting sedimentation further restricts the channel capacity (for example, blocking culverts, reducing the capacity of downstream vleis), creating a second reinforcing feedback loop (R3).

Dynamics Surrounding Water. Floods of certain magnitudes are expected to damage infrastructure, ecosystems, and property. People's lives could also be at risk if the flood is particularly large or if they are in flood-prone areas. Flooding has direct impacts on communities, human health, and service delivery (for example, damaged water and sewage infrastructure) and can reduce tourism and property values and affect reputation. Direct impacts are expected to be more severe in the most vulnerable areas, such as informal settlements. With declining surface water quality, there is also less suitable quality water available to recharge the aquifers, which is then available for abstraction. This is of particular relevance for the Zeekoe catchment that lies above the Cape Flats Aquifer, a primary aquifer that is being used for managed aquifer recharge as part of the City's New Water Programme. Sustaining the aquifer in the long term requires suitable recharge of good-quality surface water. Poor aquifer water quality (partially as a result of the infiltration of poor-quality surface water) may increase the treatment cost of the aquifer water. At the same time, some species of invasive alien vegetation consume large amounts of water, which reduces stream flow and the availability of water to sustain ecosystems and biodiversity or to be available for infiltration into the aquifer.

Dynamics Surrounding Soil and Nutrients. With the loss of native vegetation, soil organic matter also decreases because degraded soils with low organic matter content exhibit compromised fertility, structure, and resilience to environmental stressors. This limits moisture retention and all the biological activity that depends on it. Consequently, overall soil quality also declines with the decrease in organic matter. This leads to reduced riverbank vegetation since the soil lacks the necessary organic material to enable vegetation development. Moreover, given the role that vegetation plays in nutrient retention, a decrease in vegetation further exacerbates the decline in soil quality. This results in a vicious cycle in which soil quality and nutrient retention capacity deteriorate progressively (R1). This cycle is reinforced by extreme events, such as floods and droughts, which amplify soil erosion and worsen the decrease in soil quality (R2).

Dynamics Surrounding Socio-Economic Dimensions. Sewage contains pathogens (such as E.coli) that can cause illness if ingested or if people have prolonged contact with the contaminated water. This has a direct impact on human health and economic activity (for example, the closure of recreational waterbodies and beaches). The loss of recreation and tourism use, specifically for the larger recreational vleis, can have profound impacts that extend beyond the catchment and cut across sectors. All of this contributes to reputational damage, further impacting economic activity. This dynamic defines a vicious cycle in which the lack of expenditure leads to decreased water quality. In turn, the decrease in water quality impacts human health and, therefore, economic activity. With lower economic activity, the city generates lower revenue, therefore limiting its capacity to pursue further expenditures (R6). On the other hand, this vicious cycle could become a virtuous cycle in which further expenditures enhance human health and economic activity, which, in turn, allows for greater revenue.

Dynamics Surrounding Interventions. Various benefits to the economy and communities could emerge if a range of well-maintained nature-based solutions and green infrastructure are used throughout the catchment. Removing invasive alien species and promoting appropriate indigenous vegetation through wetland and river rehabilitation could reduce erosion, increase channel capacity, and allow biodiversity to recover. The uptake of nutrients and trapping of sediments as the water flows through wetlands could improve water quality. As the channel capacity increases and wetlands slow down and store floodwaters, flooding may become less severe. Sustainable drainage systems at various scales (from a local development site up to a regional intervention) can reduce runoff peak flows, further improving water quality and lowering flood risk. Wetlands and sustainable drainage systems can also increase the opportunity for groundwater recharge, which leads to more water availability in the aquifer. In some cases, the aquifer can contribute flow to the surface water system, thereby maintaining stream flow and sustaining biodiversity. NBI can also create jobs through implementation and maintenance activities. Moreover, an increase in the number of green open spaces would allow communities to benefit from recreational areas protected from the heat island effects and its associated health impacts. Finally, green open spaces also make possible vegetable-production activities for local communities to benefit from.

2.3 Climate Data Analysis

With the systemic understanding of the catchment's context illustrated through the CLD, it becomes clear that climate can induce shocks (e.g., extreme rainfall events) and impact the ecosystem's biophysical conditions in the long term (e.g., average precipitation). To effectively manage and adapt to these challenges, it is crucial to analyze how key climate indicators are expected to evolve over time.

In this section, we focus on three critical indicators: average precipitation, average largest 1-day precipitation, and average mean surface air temperature. By examining trends across these indicators from 1950 to 2100 under various scenarios, we aim to provide a comprehensive understanding of how climate change may alter the dynamics within the catchments. This analysis not only highlights potential risks but also informs the design of resilient and adaptive interventions that can mitigate the adverse effects of climate variability. Note that the data used for this assessment is from the World Bank (2024) for the Western Cape Region.

The trends are analyzed within the framework of the Shared Socioeconomic Pathways (SSPs), which provide different narratives about global development and its implications for climate change (Calvin et al., 2023; Hunter & O'Neill, 2014):

- **SSP1: Sustainability**—This pathway envisions a world that prioritizes sustainable development, with a strong focus on environmental protection, social equity, and global cooperation, leading to lower emissions and more stable climate outcomes.
- **SSP2: Middle of the road**—Representing a continuation of current trends, this pathway features moderate economic growth, uneven development, and gradual progress toward sustainability, resulting in a mixed climate outcome.
- **SSP3: Regional rivalry**—This pathway depicts a fragmented world where nations prioritize domestic issues and regional interests, leading to high population growth, slow economic development, and limited international cooperation, causing significant climate challenges.
- **SSP5: Fossil-fuelled development**—Driven by rapid economic growth fuelled by intensive fossil fuel use, this pathway leads to high greenhouse gas emissions and significant global warming, with minimal attention to environmental sustainability.

It is important to note that while the SSPs provide valuable global-level scenarios, the local impacts and narratives may differ significantly. Local realities, including specific geographic, socio-economic, and environmental conditions, can influence how these global trends manifest in particular regions. Therefore, while the SSPs offer a broad understanding of potential futures, localized analyses are essential for capturing the specific climate dynamics and impacts relevant to the catchments in Cape Town. Building on this framework, we now delve into the analysis of three critical climate indicators, illustrated in Figure 6, to understand their historical trends and future projections, examining how these changes could impact the catchment dynamics.

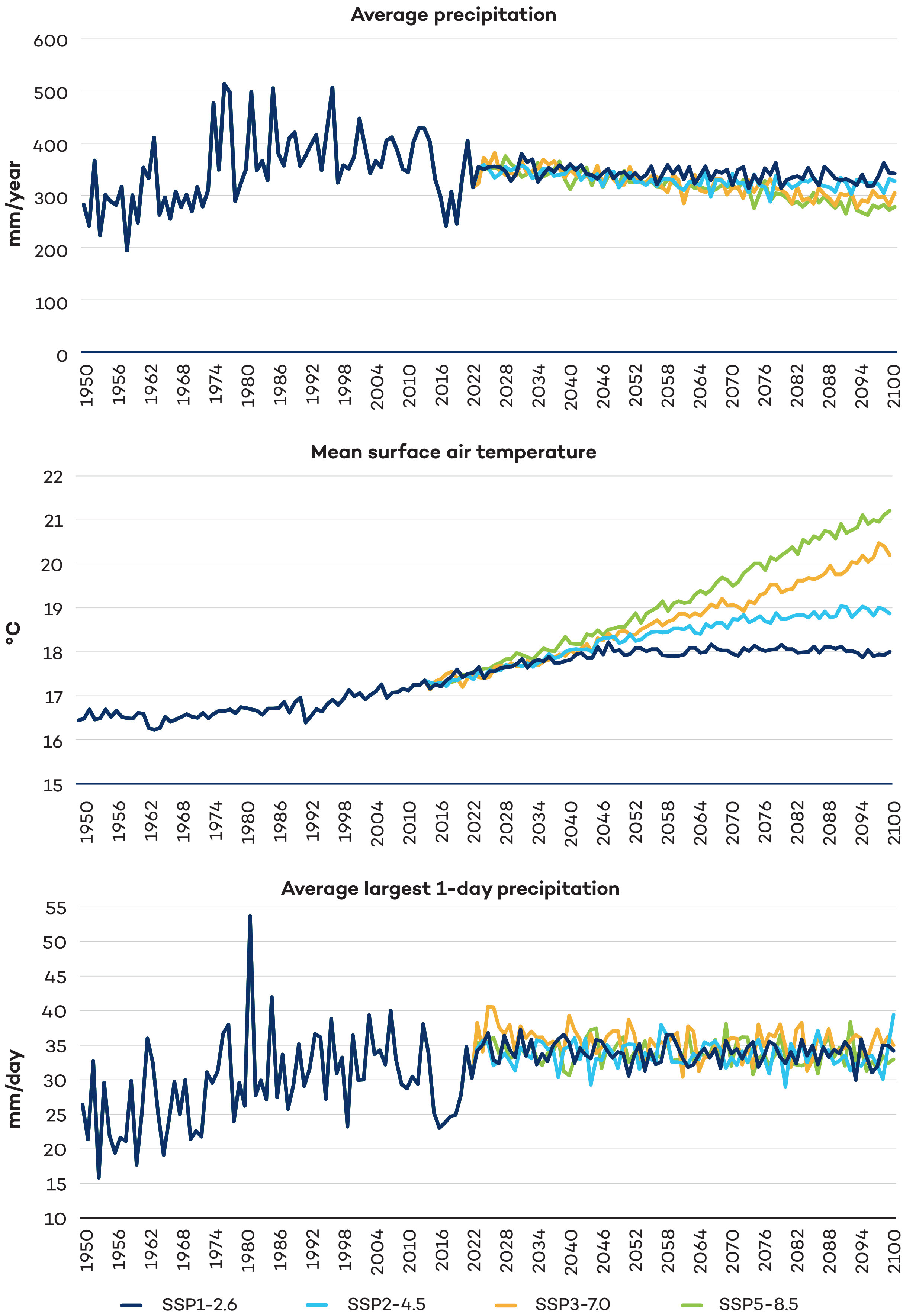
Average Precipitation. Historical data shows that average annual precipitation increased until the end of the 20th century, followed by a significant decline in recent years. Projections indicate this downward trend will continue throughout the 21st century. Specifically, SSP5, which represents a high-emission scenario, forecasts a notable decrease in precipitation from approximately 350 mm/year in 2024 to around 270 mm/year by 2100. In contrast, SSP1, which reflects a more sustainable pathway, predicts a smaller decline, with precipitation expected to decrease from about 350 mm/year in 2022 to 340 mm/year by 2100. This decline exacerbates challenges such as diminished water availability and increased soil erosion, which are critical for maintaining ecological and socio-economic stability in the catchments. Reduced precipitation further reduces water quality and amplifies the impacts of extreme weather events, reinforcing the feedback loops of declining water quality and heightened flood risk identified in the previous section. These variations in precipitation under different SSPs highlight the need for adaptive management strategies that are responsive to both the broader climate scenarios and local catchment conditions.

Mean Surface Air Temperature. Historically, the average mean surface air temperature has increased gradually, from 16.5°C in 1950 to 17°C by 2000. This trend has accelerated recently, with temperatures rising from 17°C in 2000 to 17.5°C in 2024. Future projections reveal a stark contrast across SSPs: SSP5 anticipates a substantial rise, with temperatures climbing from 17.5°C in 2024 to approximately 21.2°C by 2100, while SSP1 predicts a more moderate increase, stabilizing around 18°C by mid-century. This accelerated warming has significant implications for catchment management, exacerbating issues such as increased evaporation rates, soil moisture deficits, and heat stress. The rising temperatures align with the dynamics of soil and nutrient cycles, where higher temperatures could further degrade soil quality, amplify erosion, and foster the development of invasive vegetation. Additionally, increased temperatures contribute to enhanced flood risks and reduced water quality.

Average Largest 1-Day Precipitation. Historical trends indicate a gradual increase in the average largest 1-day precipitation events up to the early 21st century, followed by a stabilization in the 2000s. This stabilization is projected to continue into the future, with variation across different SSPs. Despite this relative stability, high-intensity rainfall events remain a critical factor for water management. Such events can exacerbate flooding, soil erosion, and sedimentation issues, reinforcing the negative feedback loops identified in the CLD. The consistent pattern of large 1-day precipitation events suggests a balance between increasing precipitation intensity and the catchment's capacity to manage these extremes. Effective flood management and infrastructure improvements are essential to address the challenges posed by high-intensity rainfall, emphasizing the need to consider both the frequency and intensity of extreme weather events to enhance the resilience and sustainability of the catchments and their surrounding communities.

These projected trends align with findings from other reports, which similarly highlight the growing concerns about water scarcity and ecosystem stress in response to declining precipitation, increasing temperatures, and climate extremes in the region (City of Cape Town, 2021a, 2021b; Lennard, 2024).

Figure 6. Climate data time series



Source: World Bank, 2024.

2.4 Integrated CBA

The following section presents an integrated CBA aimed at evaluating the economic viability of different interventions within the catchments under various climate scenarios. This analysis is divided into four key subsections.

1. First, the Methodology subsection outlines the approach and key assumptions used to assess the costs and benefits, providing a clear understanding of how the results were derived.
2. Second, the Scenarios subsection describes the two primary scenarios under consideration: the baseline, which reflects the current trajectory without interventions, and the NBI scenario, which incorporates a set of green infrastructure strategies designed to enhance catchment resilience. The narrative is further supported by maps illustrating these interventions.
3. Thirdly, the Indicator subsection goes through the definition of all indicators present in the CBA. This allows the reader to better grasp the meaning of the elements quantified.
4. Finally, the CBA Results subsection presents the monetized outcomes, comparing the costs and benefits of each scenario across the different climate projections. Through this analysis, we aim to provide insights into the long-term economic implications of adopting NBI strategies versus maintaining the status quo.

2.4.1 Methodology

The integrated CBA was developed using an Excel-based model structured as an input-output framework. This model is driven by static input parameters that define the time development of each indicator over the analysis period. For each scenario (baseline and NBI), the model computes absolute values for individual indicators. For example, it calculates the cost of flood damages under both scenarios. Following this, the model measures the difference between the two scenarios, quantifying the net change caused by interventions. This approach allows for capturing the direct benefits of interventions, such as the avoided costs of flood damages. The outputs of this process include aggregated indicators like total costs, total benefits, net benefits, benefit-to-cost ratio (BCR), and internal rate of return (IRR). All results are discounted to their present value, enabling a clear comparison of future costs and benefits. All figures in the **Results** section look at the net change value; however, the absolute value of the baseline and NBI are illustrated in Table A1 and Table A2.

The time horizon for the analysis extends from 2025 to 2050.[3] A discount rate of 8% was selected in consultation with Cape Town's economic appraisal team to ensure consistency with their economic assessment framework. To account for uncertainties in future economic conditions, a sensitivity analysis was conducted by testing the discount rate across a range from 6% to 10%. This sensitivity analysis helps gauge how robust the CBA results are to changes in economic assumptions and informs decision making on the viability of the proposed interventions. While all figures presented in the **Results** section are discounted: the undiscounted values are in Table A3.

[3] Please note that the analysis and modelling were completed in August 2024 and remained unchanged for publishing the report in June 2025.

The analysis relies heavily on data from a series of location-specific studies conducted by Anchor Environmental Consultants, including studies on climate change projections review (Lennard, 2024), biophysical assessment (Day, 2024), socio-economic assessments (Letley & Turpie, 2024a, 2024b), hydrological and geo-hydrological assessments (Thewlis & Riemann, 2024a, 2024b), and potential impacts of interventions on ecosystem services and climate change vulnerability (Turpie & Letley, 2024a, 2024b). Importantly, the hydrological assessment included the development of a PCSWMM rainfall runoff model that was used to determine the extent of flooding and water quality impacts. Where gaps in the data existed, they were filled either through literature review or assumptions through an iterative stakeholder engagement process, all of which is fully documented in the Appendix.

While climate data from the SSPs has already been discussed in the Climate Data Analysis section, it is important to note that this data was integrated into the CBA model to evaluate the range of potential flood-related impacts, such as infrastructure damage, disaster relief costs, and productivity loss. Given the inherent uncertainty in predicting extreme weather events, the analysis also includes an additional test scenario that introduces a large flood event occurring mid-way through the time horizon. This helps capture the possible outcomes of extreme events, ensuring that the results are reflective of both gradual climate change and the potential for unexpected shocks.

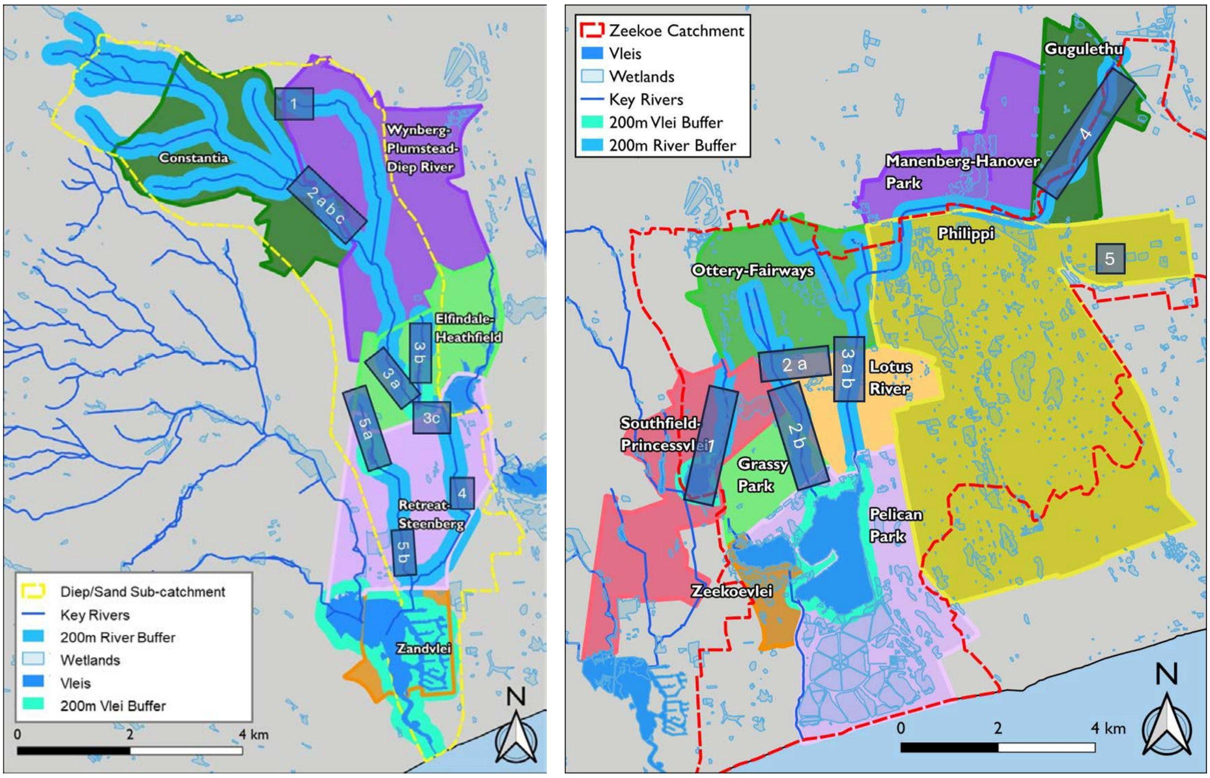
2.4.2 Scenarios

This assessment compares two scenarios: the baseline scenario and the NBI scenario. The baseline scenario represents a "business-as-usual" approach, where the catchment ecosystems continue to deteriorate due to water quality issues, and the built infrastructure remains degraded and unsuitable for the increasing frequency of extreme weather events. Invasive plant species and sedimentation also contribute to significant municipal expenditures, while urban development continues to harden parts of the catchment and take up vital green spaces, exacerbating flood risks. Although we assume that there are some efforts in the baseline scenario, such as the repair of certain canal sections, these activities are primarily maintenance-focused and do not address the underlying flood-related challenges. The key assumption is that the health of the catchments will decline over the next 10 to 15 years, following an S-shaped deterioration curve.

In contrast, the NBI scenario introduces a suite of comprehensive ecological rehabilitation. These interventions, as outlined in the Diep/Sand and Zeekoe catchment masterplans (Turpie et al., 2024a, 2024b), focus on wetland rehabilitation, removal of invasive species, canal naturalization, and the installation of litter traps and sediment treatment areas. Additionally, community-driven programs, such as food gardens and educational spaces, are incorporated alongside infrastructure upgrades that aim to improve overall accessibility and safety. The NBI scenario emphasizes the restoration of natural environments while fostering community connections through beautification efforts like tree planting, landscaping, and the creation of pedestrian pathways. While the specific interventions vary slightly between the two catchments, the broader objective is to enhance ecosystem services and improve flood resilience.

The spatial extent and specific locations of these interventions are detailed in the maps provided for both the Diep/Sand and Zeekoe catchments (Figure 7). These maps illustrate where the ecological and infrastructural changes will be implemented, providing a visual representation of how each scenario impacts the catchments. While the focus is not solely on flood mitigation, the NBI interventions are designed to generate a range of ecosystem services. These services include reduced maintenance costs, improved carbon sequestration, enhanced biodiversity, avoided flood damages, and increased community well-being.

Figure 7. Map of intervention locations



Source: Anchor Environmental/City of Cape Town.

2.4.3 Indicators

To evaluate the costs and benefits of the baseline and NBI scenarios, a range of indicators were identified through the system mapping process to capture the direct and indirect impacts of the interventions. These indicators provide a comprehensive picture of the economic, social, and environmental implications of the scenarios. Each indicator measures a specific aspect of the catchment's ecosystem and infrastructure performance, allowing for a nuanced understanding of the interventions' effects. Table 1 provides a brief definition of each indicator used in the CBA.

Table 1. List and definitions of CBA indicators

Direct costs	
Implementation costs (capital expenditures) [CapEx])	The initial costs associated with carrying out the NBI interventions, including construction, labour, materials, and other one-time expenditures.
Maintenance costs (operating expenditures [OpEx])	Ongoing costs required to keep the NBI interventions functional over time, such as upkeep of rehabilitated wetlands, litter traps, and other infrastructure. For the baseline, this indicator includes the current maintenance costs.
Feasibility and concept design costs (prep OpEx)	Costs incurred during the early stages of the project for technical assessments, design plans, and feasibility studies necessary to implement the interventions. For the baseline, this indicator is set to zero.
Avoided costs	
Avoided cost of flood damages	The estimated reduction in material damages as a result of the NBI interventions that mitigate flood risks. This includes residential properties, industrial areas, utilities, educational buildings, roads, and culverts.
Avoided cost of disaster relief	Savings generated by reducing the need for emergency services and post-disaster recovery efforts.
Avoided cost of mental health impact	The reduction in health care costs associated with mental health and stress-related conditions that may arise from disasters such as floods.
Avoided cost of human death	The value assigned to avoiding fatalities caused by flooding or other extreme events. This indicator was ultimately excluded from the monetary valuation.
Avoided cost of dredging	Savings from reduced sediment and invasive plant buildup in waterways, as the NBI interventions limit sedimentation and remove nutrients through ecological rehabilitation efforts.
Avoided cost of refurbishment	The avoided cost of refurbishment refers to savings from not needing to repair canals in the baseline scenario, as NBI interventions eliminate the need for such repairs at these locations.
Avoided cost of physical inactivity	Benefits related to improved public health from increased physical activity, which are enabled by the creation of recreational areas and pedestrian pathways through NBI interventions.
Added benefits	
Value of employment creation	The economic value of new jobs generated through the implementation, maintenance, and long-term management of NBI projects. The latter is computed based on discretionary spending from labour benefits.

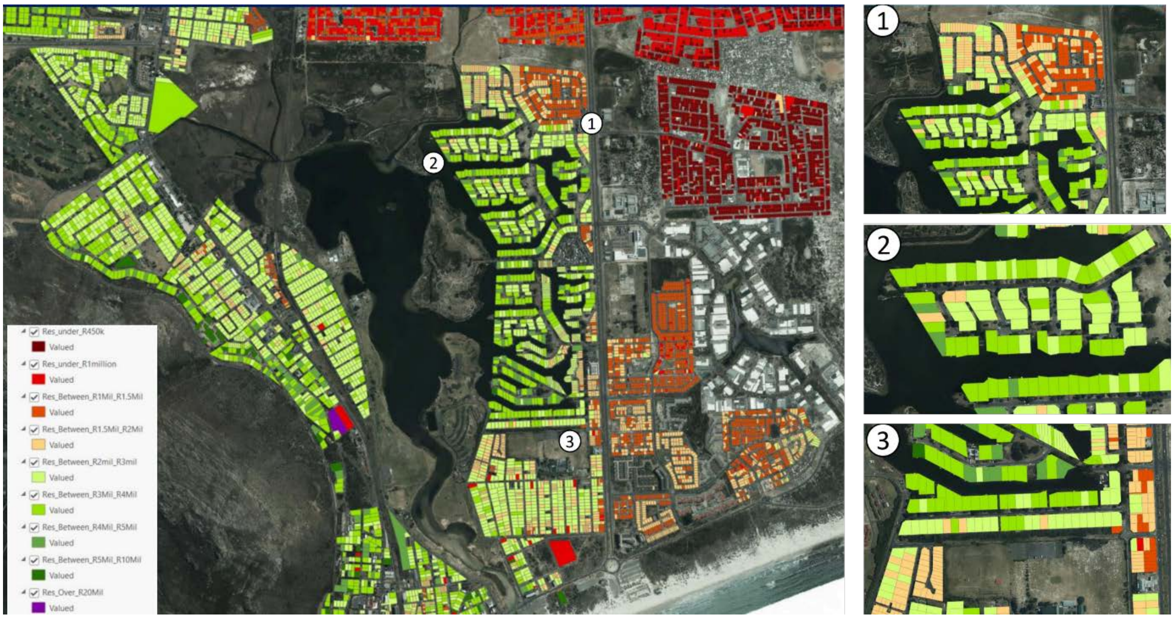
Value of carbon sequestration	The social cost value assigned to carbon dioxide captured and stored by restored ecosystems, contributing to climate change mitigation.
Value of food provisioning	Benefits generated from food gardens established in communities, which enhance food security and provide local agricultural value.
Value of urban cooling	The reduction in energy costs and improvement in public health resulting from lower urban temperatures achieved through increased green spaces and tree planting. This indicator was excluded from the monetary valuation due to a lack of data.
Avoided loss	
Avoided loss in productivity due to floods	The economic benefits of maintaining productivity levels by reducing flood-related disruptions to businesses and communities.
Avoided loss of tourism revenue	The benefits of preserving tourism activity that could otherwise be negatively impacted by environmental degradation in the catchments.
Avoided loss of tourism tax revenue	The retained government revenue from tourism-related taxes, which might decline if environmental deterioration reduces tourism numbers.
Avoided loss of property tax revenue	The municipal revenue from property taxes, specifically property premium associated with waterways' proximity, which would be lost due to deteriorating aesthetic value.
Avoided loss in fish nursery value	Benefits from preserving fish nurseries and biodiversity within the catchments, as healthy ecosystems contribute to the sustainability of downstream fisheries.
Avoided loss in biodiversity conservation	The value of maintaining ecosystem diversity, which is integral to sustaining long-term ecological resilience and ecosystem services.
Avoided loss of recreational areas	The value of maintaining public access to parks, pathways, and other recreational spaces, which contributes to community well-being.

Source: Authors.

Box 3. Property values and associated premium

The values associated with properties, and in particular the proportion attributed to waterway proximity, are computed using land-value capture through spatial mapping, as illustrated in Figure 8. As can be seen, maps reveal a clear gradient in property values, where homes closer to waterways (light green) have significantly higher values compared to those located just a few streets away (dark red). This premium reflects the increased desirability of properties near well-maintained natural assets, underscoring the importance of preserving and enhancing these ecosystems for both economic and environmental benefits.

Figure 8. Map of Zandvlei property values



Source: City of Cape Town.

2.4.4 Results

The results of this analysis underscore the substantial economic and environmental benefits of the NBI interventions, demonstrating their strong value proposition across varying climate scenarios. The positive return on investment, combined with the long-term sustainability of benefits, aligns with the objectives outlined in the Water Strategy and other relevant policies aimed at enhancing climate resilience and environmental sustainability.

The integrated CBA highlights how policy-makers can address critical issues related to flood management, ecosystem preservation, and community well-being by scaling up NBI in Cape Town. These findings provide a robust foundation for advocating for continued support and integration of NBI approaches within broader environmental and urban planning strategies, ultimately contributing to a more resilient and sustainable future.

COMPARISON OF KEY RESULTS FOR THE OPTIMISTIC AND PESSIMISTIC CLIMATE SCENARIOS

The results from the CBA reveal a positive economic impact of the NBI interventions across both the Diep/Sand and Zeekoe catchments, with varying degrees of benefits depending on the climate scenario (see Table A9 and Table A10 for broader flood scenarios). For the Diep/Sand catchment, as highlighted in Table 2 using an 8% discount rate, the optimistic climate scenario (SSP2-4.5) yields total benefits of ZAR 245 million against total costs of ZAR 124 million, resulting in a net benefit of ZAR 121 million and a BCR of 1.97. This ratio indicates that for every ZAR 1 invested, there is a return of ZAR 1.97 in societal benefits. The IRR of 17.2% further underscores the viability of the interventions. Under the pessimistic climate scenario (SSP3-7.0), the total benefits increase to ZAR 258 million, leading to a net benefit of ZAR 133 million and a slightly higher BCR of 2.07, reflecting greater avoided damages due to more frequent floods. The IRR also rises to 18.0%, indicating a robust return on investment.

Similarly, for the Zeekoe catchment, also shown in Table 2, the optimistic climate scenario results in total benefits of ZAR 190 million compared to total costs of ZAR 122 million, achieving a net benefit of ZAR 68 million and a BCR of 1.56. This suggests a return of ZAR 1.56 per ZAR invested. The IRR of 13.8% reinforces the economic justification for investing in the interventions. In the pessimistic scenario, the benefits rise to ZAR 247 million, resulting in a net benefit of ZAR 125 million and a higher BCR of 2.02, demonstrating a more substantial return on investment due to the higher frequency of flood events. The IRR of 18.0% reflects an even more favourable outcome, highlighting the significant economic value of the interventions in mitigating flood-related impacts.

These results illustrate that the returns are favourable across both climate scenarios and both catchments. Moreover, the benefits are notably enhanced in the pessimistic climate scenario due to higher avoided costs from flood damage. This highlights the importance of considering varying climate conditions in evaluating the effectiveness and value of environmental interventions.

Table 2. Key CBA results—optimistic vs pessimistic climate scenario discounted at 8%

	Units	Optimistic climate scenario (SSP2-4.5)	Pessimistic climate scenario (SSP3-7.0)
Diep/Sand			
Total costs	ZAR million	124	124
Total benefits	ZAR million	245	258
Net benefits	ZAR million	121	133
BCR	ratio	1.97	2.07
IRR	%	17.2%	18.0%
Zeekoe			
Total costs	ZAR million	122	122
Total benefits	ZAR million	190	247
Net benefits	ZAR million	68	125
BCR	ratio	1.56	2.02
IRR	%	13.8%	18.0%

Note: The values are cumulative over 25 years (2025–2050 time horizon), discounted at 8%.
Source: Authors.

FULL CBA RESULTS FOR THE OPTIMISTIC CLIMATE SCENARIO

As detailed in Table 3, where all results are discounted at 8%, in the Diep/Sand catchment, the investment in NBI reflects a substantial upfront commitment, with implementation costs amounting to ZAR 112.3 million. This expenditure covers the initial construction and setup required to address the complex environmental challenges within the catchment. Complementing this, maintenance costs of ZAR 4.8 million ensure that the interventions remain effective over time, while feasibility and concept design costs of ZAR 7.4 million represent the necessary preparatory work for successful implementation.

The benefits derived from these investments are notable, including the avoided cost of flood damages at ZAR 13.4 million, which highlights the effectiveness of the NBI in reducing material damage from floods, a critical factor given the increasing flood risks due to climate change. Moreover, we estimate that the avoided cost of refurbishing grey infrastructure is ZAR 9.8 million, highlighting significant savings as NBI interventions negate the need for costly canal repairs.

Table 3. Integrated CBA—optimistic climate scenario discounted at 8%

	Units	Diep/Sand catchment	Zeekoe catchment
Direct costs			
Implementation costs (CapEx)	ZAR million	112.3	107.7
Maintenance costs (OpEx)	ZAR million	4.8	3.9
Feasibility and concept design costs (prep OpEx)	ZAR million	7.4	10.4
Avoided costs			
Avoided cost of flood damages	ZAR million	13.4	39.2
Avoided cost of disaster relief	ZAR million	0.1	0.5
Avoided cost of mental health impact	ZAR million	0.3	1.2
Avoided cost of human death	ZAR million	No data	No data
Avoided cost of dredging	ZAR million	20.5	27.8
Avoided cost of refurbishment	ZAR million	9.8	7.3
Avoided cost of physical inactivity	ZAR million	3.9	5.9
Added benefits			
Value of employment creation	ZAR million	18.6	17.4
Value of carbon sequestration	ZAR million	0.02	0.03
Value of food provisioning	ZAR million	0.4	6.5
Value of urban cooling	ZAR million	No data	No data

	Units	Diep/Sand catchment	Zeekoe catchment
Avoided loss			
Avoided loss in productivity due to floods	ZAR million	0.8	2.8
Avoided loss of tourism revenue	ZAR million	113.6	46.4
Avoided loss of tourism tax revenue	ZAR million	20.1	8.2
Avoided loss of property tax revenue	ZAR million	31.9	11.6
Avoided loss in fish nursery value	ZAR million	6.0	-
Avoided loss in biodiversity conservation	ZAR million	0.9	0.60
Avoided loss of recreational areas	ZAR million	5.0	14.4
Key performance indicators			
Total costs	ZAR million	124.5	122.1
Total benefits	ZAR million	245.3	189.9
Net benefits	ZAR million	120.8	67.8
BCR	ratio	1.97	1.56
IRR	%	17.2	13.8

Note: The values are cumulative over 25 years (2025–2050 time horizon), discounted at 8%.
Source: Authors.

The interventions also provide significant savings in avoided cost of dredging, totalling ZAR 20.5 million, by reducing upstream soil erosion and minimizing sediment buildup in waterways, thus preserving waterway capacity. Note that this dredging cost is induced by having to operate heavy-duty machines as depicted in Figure 9.

Figure 9. Sediment and invasive plant management machinery

Source: City of Cape Town.

Additionally, the avoided cost of physical inactivity, valued at ZAR 3.9 million, underscores the public health benefits associated with the recreational areas created through these projects. The value of employment creation[4] (ZAR 18.6 million) further emphasizes the economic boost provided by job creation related to the NBI, supporting local economies.

Moreover, the avoided loss of tourism revenue of ZAR 113.6 million highlights the crucial role of preserving ecosystem health and the tourism activity that depends on it. Indeed, this latter contributes significantly to the local economy and community well-being, but also to public budgets with an avoided loss of tourism tax revenue of ZAR 20.1 million. Additionally, by investing and maintain the sought NBI, the municipality would avoid a loss of ZAR 31.9 million from property taxes.

In contrast, the Zeekoe catchment presents a slightly lower initial investment, with implementation costs of ZAR 107.7 million. This is complemented by maintenance costs of ZAR 3.9 million and feasibility and concept design costs of ZAR 10.4 million, reflecting the specific needs and complexities of this catchment.

The avoided cost of flood damages in the Zeekoe catchment is notably higher (ZAR 39.2 million), reinforcing the effectiveness of the NBI in mitigating flood impacts. The savings from avoided cost of dredging amount to ZAR 27.8 million, further emphasizing the benefit of reduced sedimentation. Moreover, it is estimated that an additional ZAR 7.3 million would be saved by avoiding the renovation of canal repairs. The avoided cost of physical inactivity at ZAR 5.9 million and the value of food provisioning at ZAR 6.5 million (achieved through a total of 15,000 m^2 of food gardens) illustrate additional health and community benefits provided by the NBI interventions. The value of employment creation[5] at ZAR 17.4 million further emphasizes the support the NBI project can provide to local economies.

In terms of economic impacts, the avoided loss in productivity due to floods is valued at ZAR 2.8 million, reflecting the economic benefit of maintaining business operations and minimizing disruptions caused by flooding. This is complemented by the avoided loss of tourism revenue, which amounts to ZAR 46.4 million, underscoring the importance of protecting tourism activities that could otherwise be adversely affected by environmental degradation, thereby preserving a vital source of income for the region. Additionally, the avoided loss of tourism tax revenue stands at ZAR 8.2 million, highlighting the retained government revenue from tourism-related taxes that would otherwise decline due to reduced tourist activity.

4 In the Diep/Sand catchment, during the implementation phase, an estimated average of 62 full time jobs are created each year, representing a cumulative 432 jobs during this 7-year period. During the maintenance phase, an estimated average of 67 full-time jobs are created each year (compared to 54 jobs under the baseline scenario), representing a cumulative 1,277 jobs.

5 In the Zeekoe catchment, during the implementation phase, an estimated average of 60 full-time jobs are created each year, representing a cumulative 419 jobs during this 7-year period. During the maintenance phase, an estimated average of 67 full-time jobs are created each year (compared to 57 jobs under the baseline scenario), representing a cumulative 1,282 jobs.

The avoided loss of property tax revenue is ZAR 11.6 million, demonstrating the financial benefit of preventing property devaluation and maintaining municipal revenue from property taxes. Finally, the avoided loss in recreational areas, valued at ZAR 14.4 million, illustrates the value of preserving public access to parks and recreational spaces, which contribute significantly to community well-being and quality of life. These results collectively emphasize the broad economic and social benefits of NBI interventions, not only in mitigating flood impacts but also in supporting local economies and community amenities.

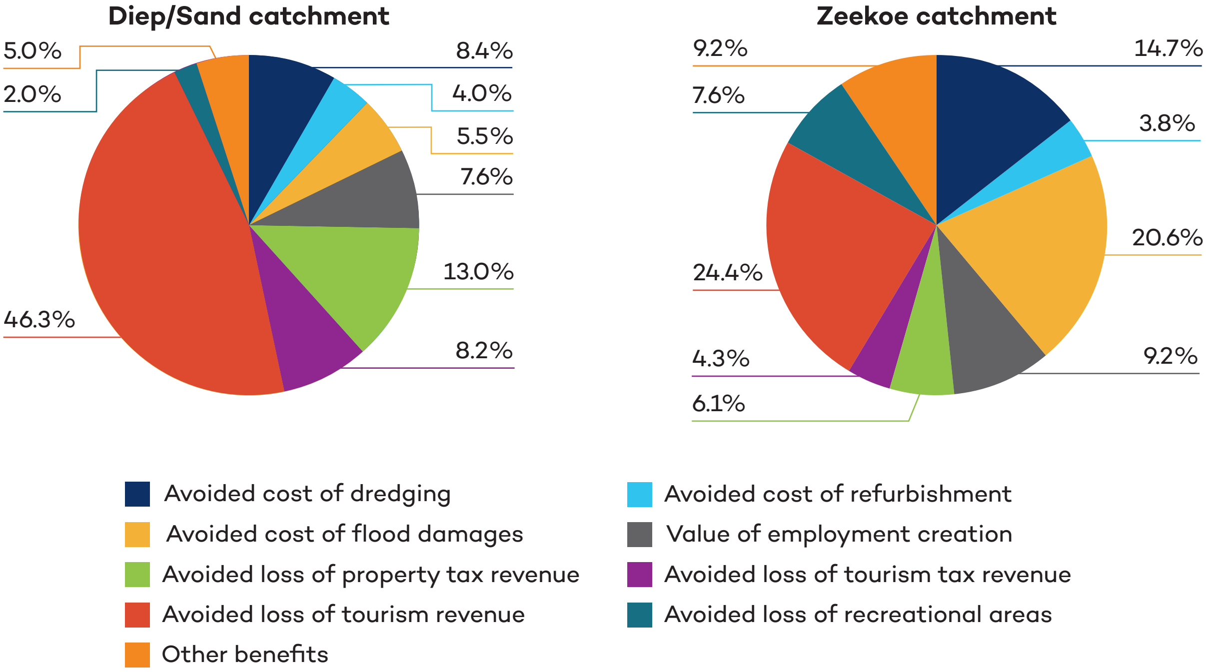
Overall, both catchments demonstrate substantial economic and environmental benefits from the NBI projects. The positive results indicated by the BCRs—1.97 for the Diep/Sand catchment and 1.56 for the Zeekoe catchment—show that for every ZAR 1 invested, there is a return of ZAR 1.97 and ZAR 1.56 respectively, reflecting strong value for money. Additionally, the net benefits of ZAR 121 million for Diep/Sand and ZAR 68 million for Zeekoe underscore the significant benefits of these interventions. These NBI projects effectively address the root causes of poor water quality and flooding, driven by socio-economic factors and climate change, and offer a range of benefits that support both environmental sustainability and community resilience. This evidence underscores the value of investing in NBI to tackle the multifaceted challenges facing urban and natural environments alike.

DISTRIBUTION OF BENEFITS

The distribution of benefits in both catchments reveals distinct patterns in how the NBI interventions create value, as illustrated in Figure 10. In the Diep/Sand catchment, the largest portion of benefits, 46%, comes from the avoided loss of tourism revenue, emphasizing the significant economic role tourism plays in this area. Other major contributions include the avoided loss of property tax revenue at 13% and the avoided cost of dredging at 8.4%, highlighting the infrastructure and ecosystem gains from reducing sediment buildup. Avoided tourism tax losses contribute to 8.2%, while smaller yet meaningful benefits stemming from employment creation contribute 7.6%, flood damages 5.5%, avoided cost of refurbishment 4%, avoided loss of recreational areas 2%, and other benefits comprising 5%.

In contrast, the Zeekoe catchment shows a more diversified distribution, with the avoided loss of tourism revenue still making up the largest share at 24.4%, followed by avoided cost of flood damages at 20.6% and avoided cost of dredging valued at 14.7%. Employment creation (9.2%), avoided loss of recreational areas (7.6%), property tax revenue (6.1%), and avoided loss of tourism tax revenue (4.3%) also provide significant benefits, while other benefits account for 9.2%. This reflects a broader distribution of gains in Zeekoe, where flood management and sediment control play particularly prominent roles.

Figure 10. Distribution of benefits—optimistic climate scenario discounted at 8%



Source: Authors.

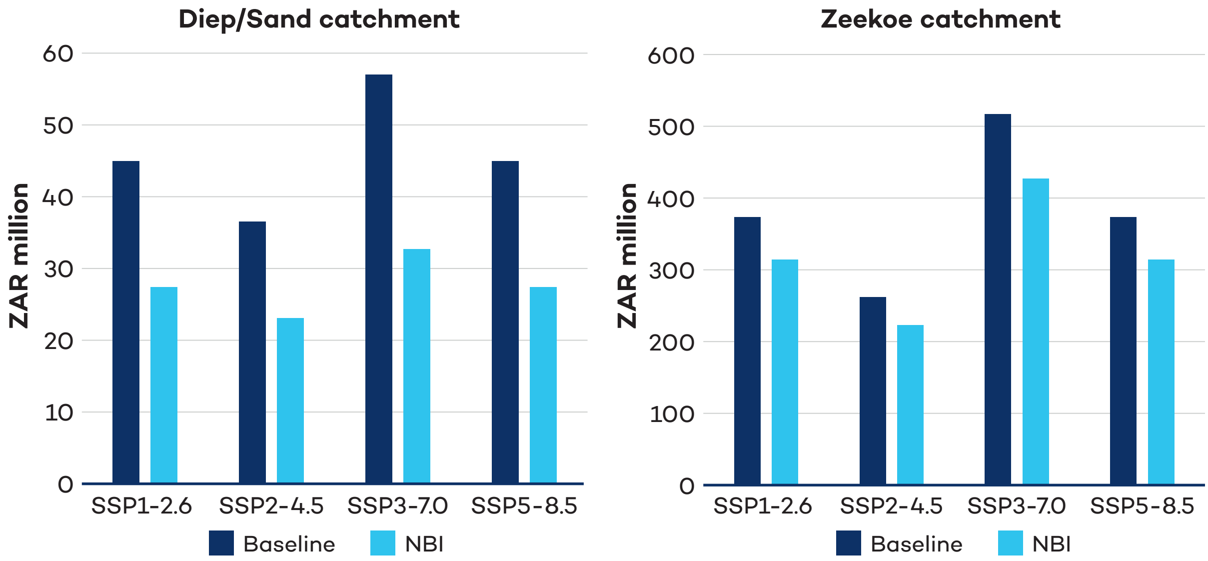
FLOOD DAMAGES UNDER VARIOUS CLIMATE AND FLOOD SCENARIOS

The comparison of flood damage costs across different SSPs for both the baseline and NBI scenarios illustrated in Figure 11 highlights the significant impact of NBI interventions in mitigating flood damages in both catchments. The broader flood scenarios are illustrated in Table A9 and Table A10.

In the Diep/Sand catchment, the baseline flood damage costs vary between ZAR 37 million and ZAR 57 million across the SSPs, with SSP3-7.0 showing the highest damages at ZAR 57 million. The NBI interventions reduce these costs substantially, showing a ZAR 24.3 million reduction, bringing the damages down to ZAR 33 million. Similarly, in SSP1-2.6 and SSP5-8.5, the NBI scenario leads to avoided flood damage costs of ZAR 17.5 million each, reducing damages to ZAR 27 million.

In the Zeekoe catchment, the baseline flood damages are more severe, ranging from ZAR 262 million (SSP2-4.5) to ZAR 517 million (SSP3-7.0). The NBI interventions again show a significant reduction, with SSP3-7.0 witnessing the largest reduction of ZAR 89.6 million, bringing damages down to ZAR 427 million. SSP1-2.6 and SSP5-8.5 also see notable reductions of ZAR 59.2 million each. These results demonstrate that across all climate scenarios, NBI significantly lowers flood damage costs, with the highest benefits realized in the most severe pathways, such as SSP3-7.0, underscoring the value of NBI in reducing flood risks.

Figure 11. Flood damages across climate scenarios—discounted at 8%

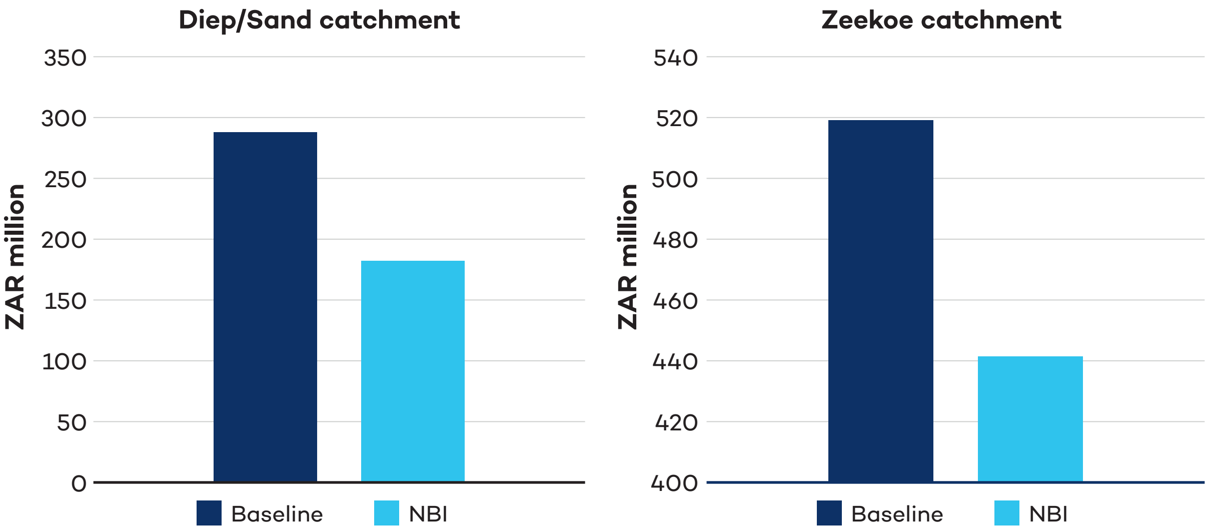


Source: Authors.

Similarly, when considering a more extreme scenario, such as a 1-in-200-year flood event happening twice over the 2025–2050 period, the value of NBI remains clear, as illustrated in Figure 12. In this scenario, the Diep/Sand catchment sees baseline flood damages of ZAR 288 million, which is reduced to ZAR 182 million with NBI interventions, resulting in an avoided cost of ZAR 106 million. In the Zeekoe catchment, baseline damages amount to ZAR 519 million, and the NBI measures lower these costs to ZAR 441 million, leading to an avoided cost of ZAR 78 million.

These results emphasize that NBI interventions are highly effective in mitigating flood damages even under more extreme and less frequent flood events, reinforcing the importance of such infrastructure in an uncertain climate future.

Figure 12. Flood damages with two 1-in-200-years events discounted at 8%



Source: Authors.

KEY METRICS ACROSS DISCOUNT RATES

The analysis of BCR and net benefits across different discount rates and perspectives[6] for the Diep/Sand and Zeekoe catchments, as illustrated in Figure 13, provides valuable insight into the viability of NBI interventions under varying economic assumptions. Further results are illustrated in Tables A5 to A8.

From the economic perspective, which considers all benefits, both catchments display strong performance, with BCRs consistently above 1 even as the discount rate increases. For the Diep/Sand catchment, the BCR starts at 2.48 when discounted at 6%, gradually decreasing to 1.75 at a 10% discount rate. Similarly, the Zeekoe catchment shows a BCR of 2.40 at 6%, tapering to 1.72 at 10%. These figures highlight the robust economic value of NBI projects, even under more pessimistic discounting scenarios.

The net benefits follow a similar pattern from the economic perspective, with the Diep/Sand catchment yielding ZAR 209 million at a 6% discount rate and ZAR 83 million at 10%, while the Zeekoe catchment shows net benefits ranging from ZAR 194 million to ZAR 78 million across the same range. Notably, the societal perspective remains favourable, as BCRs stay above 1, and net benefits remain positive up to a discount rate of 18.0% for Diep/Sand and Zeekoe, underlining the long-term societal gains of NBI investments.

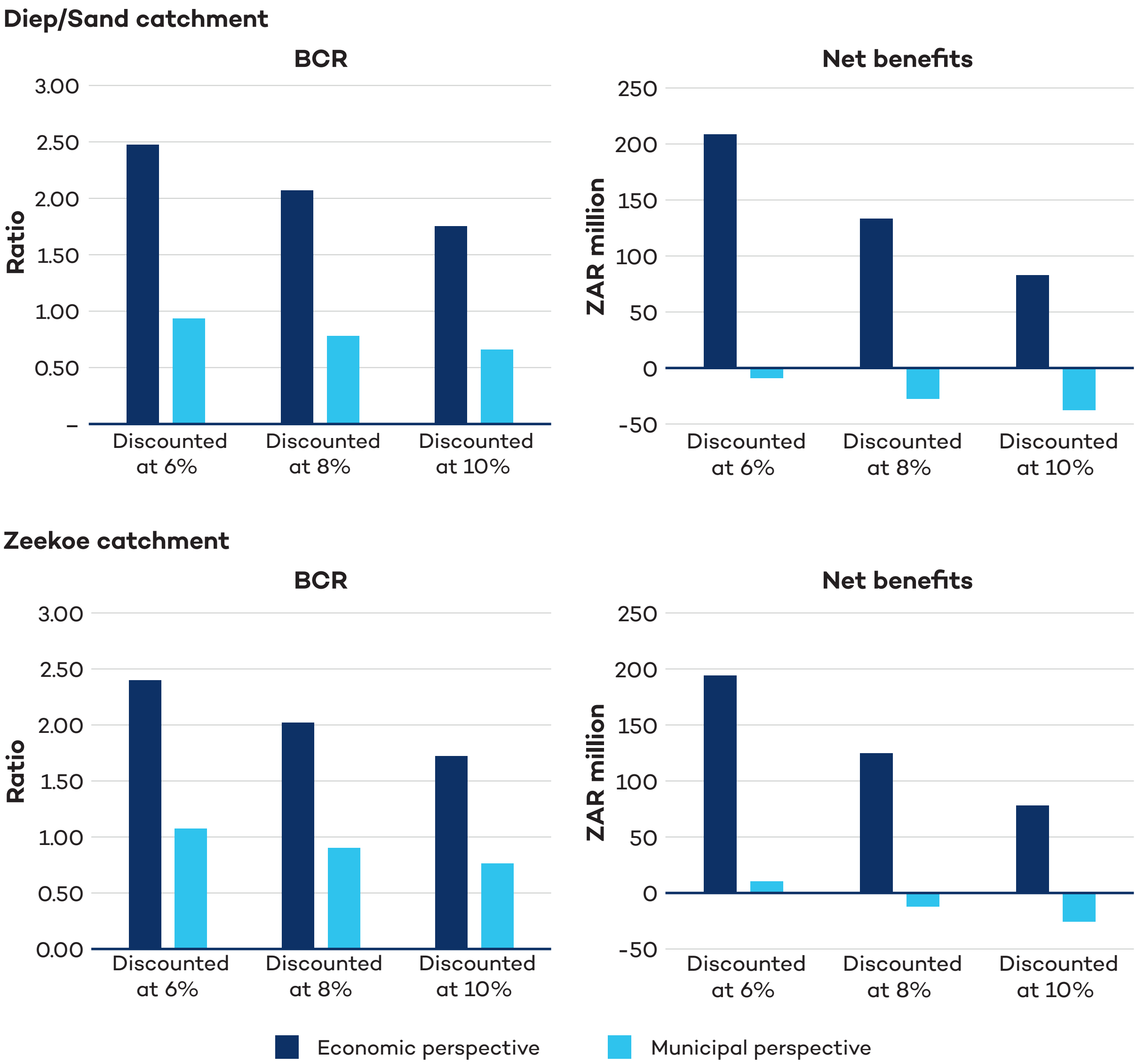
Conversely, the municipal perspective, which excludes all benefits that aren't directly linked to public authorities, presents a more constrained financial outlook. In the Diep/Sand catchment, the BCR under municipal evaluation doesn't make it above the threshold of 1, even at the 6% discount rate, as it stands at a value of 0.94. Moreover, it falls lower at higher rates, reaching 0.66 at 10%. This decline is echoed in the net benefits, which start at ZAR -9 million at 6% and continue going negative as the discount rate increases, dropping to ZAR -38 million at 10%.

The Zeekoe catchment shows a stronger performance from the municipal perspective, with a BCR of 1.07 at a 6% discount rate. It then drops to 0.9 at 8% and continues to decrease to 0.76 at 10%. Net benefits for Zeekoe follow a similar trajectory, starting at ZAR 10 million at 6% and becoming negative at ZAR -12 million at 8% and ZAR -26 million by 10%. These results indicate that while the societal benefits of NBI projects are clear, municipalities can still achieve financial benefits even though they face tighter financial constraints. This is due to flood damage cost avoidance being a large proportion of the overall expected benefits, which is a direct saving to the City and is, therefore, reflected in the municipal perspective calculation.

[6] The two perspectives analyzed in this section are the economic/societal perspective, and the municipal perspective. The economic/societal perspective includes all indicators listed in Section 3.4.3. For the municipal perspective, we exclude all benefits that aren't directly concerning public authorities. In other words, we exclude the following: avoided cost of mental health impact, avoided cost of physical inactivity, avoided loss of productivity due to floods, value of employment creation, value of carbon sequestration, avoided loss of nursery value, avoided loss in biodiversity conservation, avoided loss of tourism revenue, avoided loss of recreational areas, and 40% of avoided cost of flood damages.

Overall, the results reveal that while the economic perspective strongly supports NBI interventions in both catchments, offering significant returns for society, the municipal perspective shows that benefits are more sensitive to higher discount rates. For municipalities, the threshold for maintaining positive returns is lower, with BCRs falling below 1 at discount rates above 5.3% for Diep/Sand and 6.8% for Zeekoe. Figure 13 shows that municipal investments in NBI can still generate positive returns under certain economic conditions, especially at lower discount rates. Municipalities might also explore alternative financing strategies or collaborative partnerships to ensure the long-term viability of these projects as they adapt to different economic circumstances.

Figure 13. Key metrics across discount rate and perspective—pessimistic climate scenario



Source: Authors.

CUMULATE COSTS AND BENEFITS OVER TIME

Looking at the cumulative and discounted results over time while using the most optimistic climate scenario, as illustrated in Figure 14, the benefits are projected to outweigh the costs around 2039–2040 for both catchments. This breakpoint shifts to 2037–2038 when considering the most pessimistic climate scenario. The difference in break-even points between the climate scenarios is largely due to the varying levels of avoided flood damages, which increase significantly under the pessimistic scenario, leading to earlier and higher benefits. If an extreme 1:200-year event were to occur during the projected timeframes (which the current modelling does not account for), then the benefits would outweigh the costs even sooner. This shows that the benefits of NBI will increase under extreme climate conditions, as they act as effective buffers to these extremes. Note that a broader range of trajectories is depicted in Figure A1.

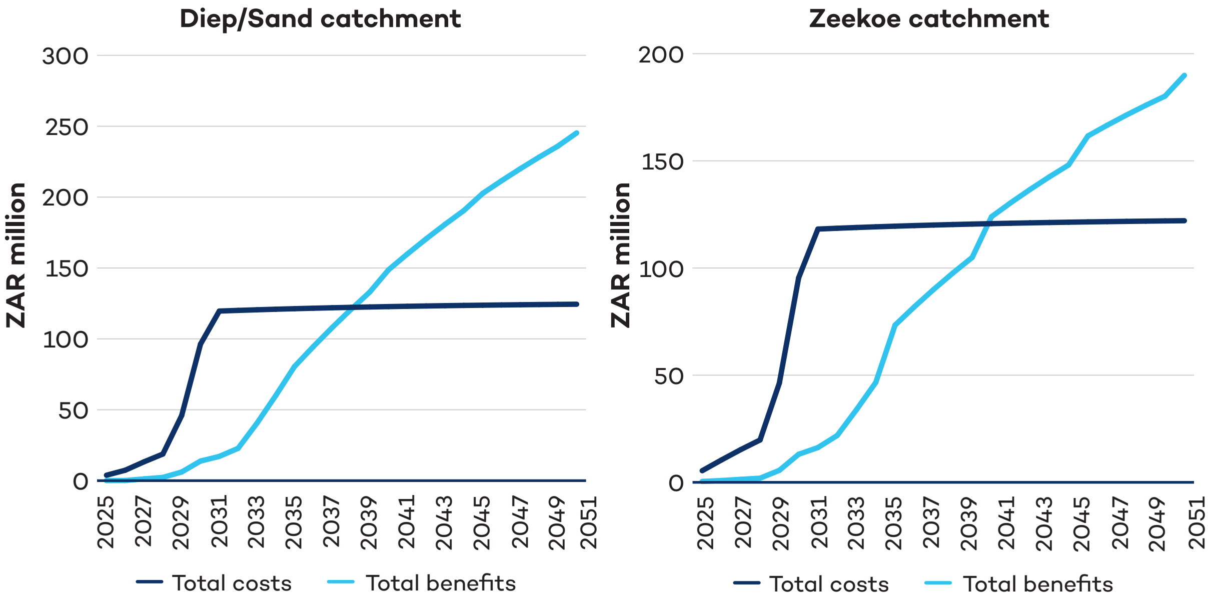
The total cost trajectory follows an S-shaped curve. During the first 2 years, the costs remain relatively low, consisting primarily of feasibility and design expenditures. However, once these studies are completed, the construction phase over the following 3 years causes a sharp rise in total costs. After this phase, only ongoing maintenance costs remain, which grow slowly and almost stabilize, as maintenance expenses are significantly lower compared to the construction phase.

On the other hand, the total benefits show a delayed linear growth. In the early years, benefits are minimal and mainly stem from employment creation related to feasibility, design, and implementation activities. However, once the NBI interventions are fully operational, a consistent and steady increase in benefits occurs, driven by the infrastructure services provided by the NBI. This upward trajectory is not entirely smooth, reflecting the variability in avoided flood damages. A notable shift occurs around 2033–2034, when a steeper increase in benefits is observed, driven by the avoided canal repair costs that would have been necessary in the baseline scenario.

While the analysis demonstrates that costs stabilize relatively early in the project timeline, it is crucial to emphasize that the benefits of NBI interventions continue to accrue and accelerate over time. The long-term value of these interventions is highlighted by the steady increase in benefits (if the interventions are maintained correctly), which reflect both future improvements in flood mitigation and the enhancement of ecosystem services. This trajectory of benefits suggests that the NBI interventions will continue to provide significant economic and environmental returns well beyond the 2050 time horizon. As climate risks and ecosystem demands evolve, the enduring benefits of these interventions will become increasingly important, reinforcing the need for continued investment and support.

Given the extended timeline over which benefits from NBI interventions materialize, it is vital to emphasize the importance of securing adequate funding and institutional arrangements for maintenance activities. As the benefits of the interventions emerge over time, the performance of the infrastructure must be maintained at optimal levels to ensure that these benefits are fully realized. Without proper maintenance, the effectiveness of the NBI projects could be compromised, reducing their overall value (an overgrown and silted-up wetland will stop providing flood attenuation and water treatment services). Therefore, proactive budget planning and allocation for maintenance are essential to sustain the economic and environmental returns projected in the analysis.

Figure 14. Cumulative costs and benefits—optimistic climate scenario discounted at 8%



Source: Authors.

3.0 Conclusions

The assessment presented in this report involved a detailed and iterative process to evaluate the impacts of NBI interventions on the urban ecological systems of Cape Town, particularly the Diep/Sand and Zeekoe catchments. Our methodology began with a systems thinking approach, recognizing the intricate and interdependent nature of the region's social, economic, and environmental factors. This approach allowed us to consider Cape Town's water management challenges as part of a larger, interconnected system, thus warranting holistic strategies for sustainable governance. We employed systems mapping to visually represent the dynamics at play, creating a CLD that elucidates the feedback loops and interactions influencing water quality, flood risks, and socio-economic conditions.

Our quantitative analysis utilized an Excel-based model to integrate and compare scenarios, employing a range of input parameters and discount rates to ensure robustness, transparency, and adaptability in our findings. The model assessed the costs and benefits of the NBI interventions, including avoided flood damages, improved water quality, and enhanced socio-economic outcomes. This process incorporated data from extensive location-specific studies, sensitivity analyses, and climate projections to account for uncertainties and potential extreme events. While the ecosystems continue to degrade in the baseline scenario, the NBI interventions demonstrate a significant net benefit over time.

Implementing NBI interventions promises substantial long-term value when looking at results over the 2025–2050 time horizon and discounting them with an 8% discount rate. For the Diep/Sand catchment, the analysis estimates total project costs at ZAR 124 million (USD 7.1 million), while the benefits are projected to range from ZAR 245 to ZAR 258 million (USD 14.0 and USD 14.8 million). This results in a net benefit between ZAR 121 and ZAR 133 million (USD 6.9 and USD 7.6 million). The positive return on investment is further evidenced by a BCR ranging from 1.97 to 2.07 and an IRR estimated at between 17.2% and 18.0%.

Similarly, for the Zeekoe catchment, the total costs are estimated at ZAR 122 million (USD 7 million), with benefits ranging from ZAR 190 to ZAR 247 million (USD 10.9 to USD 14.1 million), yielding a net benefit between ZAR 68 and ZAR 125 million (USD 3.9 and USD 7.2 million). These results correspond to a BCR of 1.56 to 2.02 and an IRR ranging from 13.8% to 18.0%. These metrics underscore the significant economic and financial advantages of the NBI interventions, reinforcing their value as a robust investment in sustainable urban development.

Our analysis of costs and benefits over time revealed an initial spike in costs due to construction, which stabilized over time, while benefits showed a steady increase with significant acceleration in later years. This indicates that the interventions yield growing economic and environmental returns, particularly through avoided flood damages and improved ecosystem health. The examination of BCR and net benefits across different discount rates and perspectives revealed that, from an economic perspective, the NBI projects offer strong and sustained value, demonstrating robust potential for delivering positive returns.

However, the municipal perspective shows more sensitivity to higher discount rates, reflecting tighter financial constraints. Despite these challenges, the societal perspective remains positive, emphasizing the long-term gains of the interventions.

The findings from this assessment offer valuable insights for a range of stakeholders involved in the management and development of Cape Town's catchments.

3.1 How different stakeholders can use the results

Municipalities

The results provide a clear understanding of the economic, social, and environmental benefits associated with NBI, such as reduced flood damages and improved water quality. This information supports strategic planning and prioritization of interventions, ensuring that resources are allocated effectively to enhance urban resilience and sustainability. Municipal authorities can use these insights to integrate NBI into urban planning processes and to advocate for policy adjustments that align with long-term environmental goals, sustainability goals, and climate change risks.

Financing Institutions

For financiers, the assessment demonstrates the financial viability of the proposed interventions through metrics like net benefits, BCR, and IRR. By highlighting the robust economic returns and long-term benefits, the analysis provides a compelling case for investment in NBI projects. It can assist in securing funding by showcasing the potential for significant and sustainable societal returns and aligning with investment criteria focused on environmental impact and risk mitigation.

Communities

Local communities stand to benefit from improved ecosystem health, higher water quality, reduced flood risk, and enhanced recreational spaces. The findings underscore the potential for job creation and increased access to green spaces, which can directly improve quality of life. Community groups can leverage this information to advocate for NBI projects, participate in planning processes, and engage in local initiatives aimed at maintaining and enhancing urban ecosystems.

Environmental Agencies

For environmental agencies, the assessment provides evidence of the ecological benefits of NBI, such as improved biodiversity and enhanced ecosystem services. It offers a basis for developing and implementing strategies that support ecosystem restoration and sustainability. Agencies can use these findings to refine conservation goals, influence policy decisions, and coordinate efforts to address environmental challenges effectively.

3.2 Suggested Next Steps for Scaling NBI in Cape Town

By addressing these diverse interests, the assessment fosters a collaborative approach to managing Cape Town's catchments, aligning economic, social, and environmental objectives for a more resilient urban landscape. To successfully implement NBI and leverage their potential for sustainable development in Cape Town, we suggest the following next steps:

- Prioritize the NBI interventions of the Livable Urban Waterways Programme to fund their swift implementation.
- Secure a dedicated budget for ongoing maintenance activities to ensure long-term effectiveness. A one-off investment is not going to yield the results shown, rather a continued commitment to the upkeep of these green waterways is needed for the entire period assessed. Without continued operational support, these corridors may go into disrepair and may no longer fulfill the function that they are being invested in for.
- Engage stakeholders in continuous dialogue and feedback mechanisms to make sure the NBI meets local needs, to create synergies with other efforts and to support adaptive management.
- Continuously integrate NBI findings into broader policy frameworks, such as Cape Town's Water Strategy and Integrated Development Plan, in line with regional and national priorities.
- Diversify funding sources to support and expand NBI initiatives across the city and explore alternative financing strategies to ensure long-term project viability.
- Foster collaborative partnerships with private sector entities, non-governmental organizations, and international organizations to enhance financial stability and resource mobilization.

References

Bai, X., Surveyer, A., Elmqvist, T., Gatzweiler, F. W., Güneralp, B., Parnell, S., Prieur-Richard, A.-H., Shrivastava, P., Siri, J. G., Stafford-Smith, M., Toussaint, J.-P., & Webb, R. (2016). Defining and advancing a systems approach for sustainable cities. *Current Opinion in Environmental Sustainability, 23*, 69–78. https://doi.org/10.1016/j.cosust.2016.11.010

Barbrook-Johnson, P., & Penn, A. S. (2022). *Systems mapping: How to build and use causal models of systems*. Springer International Publishing. https://doi.org/10.1007/978-3-031-01919-7

Breytenbach, I. J., & Fourie, H. G. (2021). The variability in commercial laboratory aggregate testing for road construction in South Africa. *Journal of the South African Institution of Civil Engineering, 63*(1), 37–44. https://doi.org/10.17159/2309-8775/2021/v63n1a4

Calvin, K., Dasgupta, D., Krinner, G., Mukherji, A., Thorne, P. W., Trisos, C., Romero, J., Aldunce, P., Barrett, K., Blanco, G., Cheung, W. W. L., Connors, S., Denton, F., Diongue-Niang, A., Dodman, D., Garschagen, M., Geden, O., Hayward, B., Jones, C., … Péan, C. (2023). *Climate change 2023: Synthesis report. Contribution of Working Groups I, II and III to the sixth assessment report of the Intergovernmental Panel on Climate Change* [Core Writing Team, H. Lee and J. Romero (eds.)]. Intergovernmental Panel on Climate Change. https://doi.org/10.59327/IPCC/AR6-9789291691647

Charman, A., Govender, T., Kruger, H., Mfaku, A., Puentes-Santos, J. F., & Skeyi, S. (2024). *City of Cape Town township economic development project—Public open space & social facilities research report*. Sustainable Livelihoods Foundation.

Cheng, C., Li, M., Xue, Z., Zhang, Z., Lyu, X., Jiang, M., & Zhang, H. (2020). Impacts of climate and nutrients on carbon sequestration rate by wetlands: A meta-analysis. *Chinese Geographical Science, 30*(3), 483–492. https://doi.org/10.1007/s11769-020-1122-3

City of Cape Town. (2017). *Environmental strategy for the City Of Cape Town*. https://resource.capetown.gov.za/documentcentre/Documents/Bylaws%20and%20policies/Environmental%20Strategy.pdf

City of Cape Town. (2019). *Cape Town resilience strategy*. https://resource.capetown.gov.za/documentcentre/Documents/City%20strategies%2C%20plans%20and%20frameworks/Resilience_Strategy.pdf

City of Cape Town. (2020). *Our shared water future—Cape Town's water strategy*. https://resource.capetown.gov.za/documentcentre/Documents/City%20strategies%2c%20plans%20and%20frameworks/Cape%20Town%20Water%20Strategy.pdf

City of Cape Town. (2021a). *City of Cape Town climate change action plan*. https://resource.capetown.gov.za/documentcentre/Documents/City%20strategies%2c%20plans%20and%20frameworks/CCT_Climate_Change_Action_Plan.pdf

City of Cape Town. (2021b). *City of Cape Town climate change strategy*. https://resource.capetown.gov.za/documentcentre/Documents/City%20strategies,%20plans%20and%20frameworks/Climate_Change_Strategy.pdf

City of Cape Town. (2022a). *Cape Town's liveable urban waterways—A compendium of case studies: Guiding the transition to a water-sensitive future*. https://resource.capetown.gov.za/documentcentre/Documents/City%20research%20reports%20and%20review/CCT_Liveable_urban_waterways_Case_Studies.pdf

City of Cape Town. (2022b). *Five year integrated development plan July 2022–June 2027*. https://resource.capetown.gov.za/documentcentre/Documents/City%20strategies%2c%20plans%20and%20frameworks/IDP_2022-2027.pdf

City of Cape Town. (2024). *Green infrastructure programme*. https://www.capetown.gov.za/departments-city-initiatives/environmental-resource-management/green-infrastructure-programme

City of Cape Town, & Liz Day Consulting. (2023). *City of Cape Town inland water quality report for the period April 2020 to March 2022 (2020 and 2021 reporting periods)*. https://resource.capetown.gov.za/documentcentre/Documents/City%20research%20reports%20and%20review/Inland_water_quality_report_2020-2021.pdf

Day, L. (2024). *Green infrastructure options for improved waterway and catchment management for the City of Cape Town—Biophysical assessment*. Liz Day Consulting.

Hunter, L. M., & O'Neill, B. C. (2014). Enhancing engagement between the population, environment, and climate research communities: The shared socio-economic pathway process. *Population and Environment, 35*(3), 231–242. https://doi.org/10.1007/s11111-014-0202-7

International Federation of Red Cross, & Red Crescent Societies. (2022). *South Africa: Floods in KwaZulu Natal—Emergency Plan of Action (EPoA), DREF Operation MDRZA012*. https://reliefweb.int/report/south-africa/south-africa-floods-kwazulu-natal-emergency-plan-action-epoa-dref-operation?gad_source=1&gclid=Cj0KCQjw-5y1BhC-ARIsAAM_oKnWhyWwW35NZf2yjjgo8u9z5xNnHRlyur1JCqvY2RkvutMRFtFff4QaAgCAEALw_wcB

Lennard, C. (2024). *Green infrastructure options for improved waterway and catchment management for the City of Cape Town—Climate change projections review*. Climate System Analysis Group.

Letley, G., & Turpie, J. (2024a). *Green infrastructure options for improved waterway and catchment management for the City of Cape Town—Socio-economic assessment: Diep/Sand Sub-catchment*. Anchor Environmental Consultants.

Letley, G., & Turpie, J. (2024b). *Green infrastructure options for improved waterway and catchment management for the City of Cape Town—Socio-economic assessment: Zeekoe catchment*. Anchor Environmental Consultants.

McPhearson, T., Haase, D., Kabisch, N., & Gren, Å. (2016). Advancing understanding of the complex nature of urban systems. *Ecological Indicators, 70*, 566–573. https://doi.org/10.1016/j.ecolind.2016.03.054

Meadows, D. H., & Wright, D. (2011). *Thinking in systems: A primer*. Chelsea Green.

Murray, M., Barr, G. D. I., & Department of Statistical Sciences, Faculty of Science, University of Cape Town, South Africa. (2022). The cost of harmful alcohol use in South Africa: A commentary. *South African Medical Journal, 112*(3), 187–188. https://pubmed.ncbi.nlm.nih.gov/35380517/

Obree, M. (2004). Catchment, stormwater and river management in Cape Town, South Africa. *Journal of Water Management Modeling*. https://doi.org/10.14796/JWMM.R220-28

OneWorld. (2018). *Elaboration of a "climate change hazard, vulnerability and risk assessment" study to the benefit of the City of Cape Town—Inception report*. Agence Française de Développement. https://resource.capetown.gov.za/documentcentre/Documents/City%20research%20reports%20and%20review/ClimateChangeHazardVulnerabilityRiskAssessment-InceptionReport.pdf

OneWorld. (2019). *Elaboration of a "climate change hazard, vulnerability and risk assessment" study to the benefit of the City of Cape Town—Vulnerability and hazard assessment report*. Agence Française de Développement.

Otto, F. E. L., Wolski, P., Lehner, F., Tebaldi, C., Van Oldenborgh, G. J., Hogesteeger, S., Singh, R., Holden, P., Fučkar, N. S., Odoulami, R. C., & New, M. (2018). Anthropogenic influence on the drivers of the Western Cape drought 2015–2017. *Environmental Research Letters, 13*(12), Article 124010. https://doi.org/10.1088/1748-9326/aae9f9

Payscale. (2024). *Average salary in Cape Town, South Africa*. https://www.payscale.com/research/ZA/Location=Cape-Town/Salary

Pollard, S., du Toit, D., & Biggs, H. (2011). *A guide to complexity theory and systems thinking for integrated water resources research and management*. Water Research Commission. https://www.wrc.org.za/wp-content/uploads/mdocs/KV%20277.pdf

Ricke, K., Drouet, L., Caldeira, K., & Tavoni, M. (2018). Country-level social cost of carbon. *Nature Climate Change, 8*(10), 895–900. https://doi.org/10.1038/s41558-018-0282-y

Sanneh, E. S. (2018). *Systems thinking for sustainable development: Climate change and the environment*. Springer.

Stafford, L., Shemie, D., Kroeger, T., Baker, T., Apse, C., Turpie, J., & Forsythe, K. (2019). *Greater Cape Town Water Fund business case. Assessing the return on investment for ecological infrastructure restoration*. The Nature Conservancy. https://www.nature.org/content/dam/tnc/nature/en/documents/GCTWF-Business-Case-August-2019.pdf

Thewlis, G., & Riemann, K. (2024a). *Green infrastructure options for improved waterway and catchment management for the City of Cape Town—Hydrological and geo-hydrological assessment: The Diep/Sand Sub-catchment*. Anchor Environmental Consultants.

Thewlis, G., & Riemann, K. (2024b). *Green infrastructure options for improved waterway and catchment management for the City of Cape Town—Hydrological and geo-hydrological assessment: The Zeekoe catchment*. Anchor Environmental Consultants.

Turpie, J., & Letley, G. (2024a). *Green infrastructure options for improved waterway and catchment management for the City of Cape Town—Potential impacts of green infrastructure interventions on ecosystem services and climate change vulnerability in Cape Town's Diep/Sand sub-catchment*. Anchor Environmental Consultants.

Turpie, J., & Letley, G. (2024b). *Green infrastructure options for improved waterway and catchment management for the City of Cape Town—Potential impacts of green infrastructure interventions on ecosystem services and climate change vulnerability in Cape Town's Zeekoe catchment*. Anchor Environmental Consultants.

Turpie, J., Letley, G., Engberts, R., & Day, L. (2024a). *A masterplan for green infrastructure investments for improved waterway and catchment management in the Diep/Sand sub-catchment, City Of Cape Town*. Anchor Environmental Consultants.

Turpie, J., Letley, G., Engberts, R., & Day, L. (2024b). A *masterplan for green infrastructure investments for improved waterway and catchment management in the Zeekoe catchment, City Of Cape Town*. Anchor Environmental Consultants.

United Nations Environment Programme. (2014). *Using models for green economy policymaking*. https://archive.un-page.org/files/public/content-page/unep_models_ge_for_web.pdf

Viavattene, C., & Priest, S. (2021). *A method for monetising the mental health costs of flooding*. Department for Environment, Food and Rural Affairs & Environment Agency, UK Government. https://www.gov.uk/flood-and-coastal-erosion-risk-management-research-reports/a-method-for-monetising-the-mental-health-costs-of-flooding

Wan Rosely, W. I. H., & Voulvoulis, N. (2023). Systems thinking for the sustainability transformation of urban water systems. *Critical Reviews in Environmental Science and Technology, 53*(11), 1127–1147. https://doi.org/10.1080/10643389.2022.2131338

World Bank. (2024). *Climate change knowledge portal*. https://climateknowledgeportal.worldbank.org/

Appendix A. Further Results

Integrated CBA—Absolute values

Table A1. Absolute values of Diep/Sand catchment—optimistic climate scenario discounted at 8%

Diep/Sand	Units	Baseline	NBI
Implementation costs (capital expenditures) [CapEx])	ZAR million	-	124.7
Maintenance costs (operating expenditures [OpEx])	ZAR million	38.0	42.9
Feasibility and concept design cost (prep OpEx)	ZAR million	-	7.4
Cost of flood damage	ZAR million	23.6	10.2
Cost of mental health impact	ZAR million	0.4	0.2
Cost of dredging	ZAR million	51.0	30.6
Cost of refurbishment	ZAR million	9.8	-
Cost of disaster relief	ZAR million	0.2	0.1
Cost of physical inactivity	ZAR million	30.0	26.1
Cost of human death	ZAR million	No data	No data
Value of employment creation	ZAR million	11.4	30.0
Value of carbon sequestration	ZAR million	-	0.0
Value of food provisioning	ZAR million	-	0.4
Value of nursery	ZAR million	22.9	28.9
Value of biodiversity conservation	ZAR million	3.0	3.9
Value of recreational area	ZAR million	17.9	22.9
Productivity loss due to floods	ZAR million	1.4	0.6
Productivity loss due to heat	ZAR million	No data	No data
Tax revenue from property premium	ZAR million	18.8	50.7
Tax revenue from tourism	ZAR million	75.4	95.5
Tourism revenue excluding tax	ZAR million	427.4	541.0

Note: The values are cumulative over 25 years (2025–2050 time horizon), discounted at 8%.
Source: Authors.

Table A2. Absolute values of Zeekoe catchment—optimistic climate scenario discounted at 8%

Zeekoe	Units	Baseline	NBI
Implementation costs (CapEx)	ZAR million	-	119.7
Maintenance costs (OpEx)	ZAR million	40.0	43.9
Feasibility and concept design cost (prep OpEx)	ZAR million	-	10.4
Cost of flood damage	ZAR million	169.1	130.0
Cost of mental health impact	ZAR million	5.2	4.0
Cost of dredging	ZAR million	101.1	73.3
Cost of refurbishment	ZAR million	7.3	-
Cost of disaster relief	ZAR million	2.3	1.8
Cost of physical inactivity	ZAR million	45.2	39.3
Cost of human death	ZAR million	No data	No data
Value of employment creation	ZAR million	12.0	29.4
Value of carbon sequestration	ZAR million	-	0.03
Value of food provisioning	ZAR million	-	6.5
Value of nursery	ZAR million	-	-
Value of biodiversity conservation	ZAR million	0.7	1.3
Value of recreational area	ZAR million	18.4	32.9
Productivity loss due to floods	ZAR million	12.0	9.2
Productivity loss due to heat	ZAR million	No data	No data
Tax revenue from property premium	ZAR million	6.9	18.5
Tax revenue from tourism	ZAR million	10.0	18.2
Tourism revenue excluding tax	ZAR million	56.9	103.4

Note: The values are cumulative over 25 years (2025–2050 time horizon), discounted at 8%.
Source: Authors.

Integrated CBA—Undiscounted values

Table A3. Integrated CBA—optimistic climate scenario undiscounted

	Units	Diep/Sand catchment	Zeekoe catchment
Direct costs			
Implementation costs (CapEx)	ZAR million	188.7	181.6
Maintenance costs (OpEx)	ZAR million	17.7	14.3
Feasibility and concept design cost (prep OpEx)	ZAR million	8.9	12.7
Avoided costs			
Avoided cost of flood damages	ZAR million	55.1	160.4
Avoided cost of disaster relief	ZAR million	0.5	2.2
Avoided cost of mental health impact	ZAR million	1.0	4.9
Avoided cost of human death	ZAR million	No data	No data
Avoided cost of dredging	ZAR million	75.1	101.9
Avoided cost of refurbishment	ZAR million	22.0	16.3
Avoided cost of physical inactivity	ZAR million	14.2	21.4
Added benefits			
Value of employment creation	ZAR million	33.9	31.3
Value of carbon sequestration	ZAR million	0.1	0.12
Value of food provisioning	ZAR million	1.5	23.9
Value of urban cooling	ZAR million	No data	No data
Avoided loss			
Avoided loss in productivity due to floods	ZAR million	3.3	11.4
Avoided loss of tourism revenue	ZAR million	467.5	191.0
Avoided loss of tourism tax revenue	ZAR million	82.5	33.7
Avoided loss of property tax revenue	ZAR million	137.1	50.2
Avoided loss in nursery value	ZAR million	23.1	-
Avoided loss in biodiversity conservation	ZAR million	3.5	2.3
Avoided loss of recreational areas	ZAR million	20.5	58.1

	Units	Diep/Sand catchment	Zeekoe catchment
Key performance indicators			
Total costs	ZAR million	215.3	208.5
Total benefits	ZAR million	940.8	709.2
Net benefits	ZAR million	725.5	500.8
Benefit-to-cost ratio (BCR)	ratio	4.37	3.40
Internal rate of return (IRR)	%	17.2%	13.8%

Note: The values are cumulative over 25 years (2025-2050 time horizon), undiscounted.
Source: Authors.

Integrated CBA—USD values

Table A4. Integrated CBA in USD[7]—optimistic climate scenario

	Units	Diep/Sand catchment	Zeekoe catchment
Direct costs			
Implementation costs (CapEx)	USD million	6.43	6.16
Maintenance costs (OpEx)	USD million	0.27	0.22
Feasibility and concept design cost (prep OpEx)	USD million	0.42	0.60
Avoided costs			
Avoided cost of flood damages	USD million	0.77	2.24
Avoided cost of disaster relief	USD million	0.01	0.03
Avoided cost of mental health impact	USD million	0.02	0.07
Avoided cost of human death	USD million	No data	No data
Avoided cost of dredging	USD million	1.17	1.59
Avoided cost of refurbishment	USD million	0.56	0.42
Avoided cost of physical inactivity	USD million	0.22	0.34

[7] The USD value is a simple conversion from ZAR, using the following exchange rate: USD 1 = ZAR 17.4775.

	Units	Diep/Sand catchment	Zeekoe catchment
Added benefits			
Value of employment creation	USD million	1.06	1.00
Value of carbon sequestration	USD million	0.00	0.00
Value of food provisioning	USD million	0.02	0.37
Value of urban cooling	USD million	No data	No data
Avoided loss			
Avoided loss in productivity due to floods	USD million	0.05	0.16
Avoided loss of tourism revenue	USD million	6.50	2.65
Avoided loss of tourism tax revenue	USD million	1.15	0.47
Avoided loss of property tax revenue	USD million	1.83	0.66
Avoided loss in nursery value	USD million	0.34	-
Avoided loss in biodiversity conservation	USD million	0.05	0.03
Avoided loss of recreational areas	USD million	0.29	0.82
Key performance indicators			
Total costs	USD million	7.12	6.99
Total benefits	USD million	14.04	10.87
Net benefits	USD million	6.91	3.88
BCR	ratio	1.97	1.56
IRR	%	17.2%	13.8%

Note: The values are cumulative over 25 years (2025-2050 time horizon), undiscounted.
Source: Authors.

Sensitivity Analysis—Discount rate

Table A5. Sensitivity analysis of discount rate from an economic perspective—Diep/Sand

Diep/Sand catchment			
Economic perspective			
	Discounted at 6%	**Discounted at 8%**	**Discounted at 10%**
Optimistic climate scenario			
Total benefits	333.9	245.3	183.2
Total costs	141.5	124.5	109.9
Net benefits	192.4	120.8	73.3
BCR	2.36	1.97	1.67
Pessimistic climate scenario			
Total benefits	350.3	257.7	192.7
Total costs	141.5	124.5	109.9
Net benefits	208.8	133.2	82.8
BCR	2.48	2.07	1.75

Note: The values are cumulative over 25 years (2025-2050 time horizon), undiscounted.
Source: Authors.

Table A6. Sensitivity analysis of discount rate from municipal perspective—Diep/Sand

Diep/Sand catchment			
Municipality perspective			
	Discounted at 6%	**Discounted at 8%**	**Discounted at 10%**
Optimistic climate scenario			
Total benefits	123.6	90.5	67.2
Total costs	141.5	124.5	109.9
Net benefits	-17.9	-34.0	-42.7
BCR	0.87	0.73	0.61

Diep/Sand catchment			
Municipality perspective			
	Discounted at 6%	**Discounted at 8%**	**Discounted at 10%**
Pessimistic climate scenario			
Total benefits	132.4	97.1	72.3
Total costs	141.5	124.5	109.9
Net benefits	-9.1	-27.3	-37.6
BCR	0.94	0.78	0.66

* The values are cumulative over 25 years (2025-2050 time horizon), undiscounted.
Source: Authors.

Table A7. Sensitivity analysis of discount rate from an economic perspective—Zeekoe

Zeekoe catchment			
Economic perspective			
	Discounted at 6%	**Discounted at 8%**	**Discounted at 10%**
Optimistic climate scenario			
Total benefits	256.6	189.9	142.9
Total costs	138.4	122.1	108.1
Net benefits	118.2	67.8	34.8
BCR	1.85	1.56	1.32
Pessimistic climate scenario			
Total benefits	332.3	246.8	186.2
Total costs	138.4	122.1	108.1
Net benefits	193.9	124.7	78.0
BCR	2.40	2.02	1.72

Note: The values are cumulative over 25 years (2025-2050 time horizon), undiscounted.
Source: Authors.

Table A8. Sensitivity analysis of discount rate from municipal perspective—Zeekoe

Zeekoe catchment			
Municipality perspective			
	Discounted at 6%	**Discounted at 8%**	**Discounted at 10%**
Optimistic climate scenario			
Total benefits	107.5	79.0	59.0
Total costs	138.4	122.1	108.1
Net benefits	-30.9	-43.1	-49.1
BCR	0.78	0.65	0.55
Pessimistic climate scenario			
Total benefits	148.8	110.0	82.6
Total costs	138.4	122.1	108.1
Net benefits	10.4	-12.0	-25.5
BCR	1.07	0.90	0.76

Note: The values are cumulative over 25 years (2025-2050 time horizon), undiscounted.
Source: Authors.

Broader Range of Flood Scenarios

Box A1. Reading and interpreting heat maps

The heat maps visualize how flood intensity (horizontal axis) and flood frequency (vertical axis) affect the BCR. Each cell shows the value for a specific combination of intensity and frequency, with colour indicating the result. Red represents the lowest values, light yellow indicates values around 1 (where costs equal benefits), and green highlights values around or above 2, where benefits significantly outweigh costs. By interpreting the colour transitions, readers can easily identify the most favourable or critical scenarios for each indicator.

Table A9. BCR across flood scenarios discounted at 8% from an economicperspective

Diep/Sand catchment

Flood frequency (flood of intensity X every Y year)	Flood intensity/size (1 in X event type)									
	1	2	3	4	5	6	7	8	9	10
1	2.26	2.32	2.37	2.42	2.48	2.53	2.58	2.64	2.69	2.74
2	2.05	2.07	2.10	2.12	2.15	2.17	2.20	2.22	2.25	2.27
3	1.98	1.99	2.01	2.02	2.04	2.06	2.07	2.09	2.10	2.12
4	1.96	1.98	1.99	2.00	2.02	2.03	2.05	2.06	2.07	2.09
5	1.93	1.94	1.95	1.96	1.97	1.98	1.99	2.00	2.01	2.02
6	1.91	1.92	1.92	1.93	1.94	1.94	1.95	1.96	1.96	1.97
7	1.93	1.94	1.95	1.96	1.97	1.98	1.99	2.00	2.01	2.02
8	1.92	1.93	1.94	1.95	1.96	1.96	1.97	1.98	1.99	2.00
9	1.90	1.91	1.92	1.92	1.93	1.94	1.94	1.95	1.96	1.96
10	1.90	1.91	1.91	1.92	1.92	1.93	1.94	1.94	1.95	1.95

Diep/Sand catchment

Flood frequency (flood of intensity X every Y year)	Flood intensity/size (1 in X event type)									
	1	2	3	4	5	6	7	8	9	10
1	2.89	2.95	3.00	3.05	3.10	3.14	3.19	3.23	3.27	3.31
2	1.99	2.02	2.05	2.07	2.09	2.11	2.13	2.15	2.17	2.19
3	1.71	1.73	1.74	1.76	1.77	1.78	1.80	1.81	1.82	1.83
4	1.65	1.66	1.68	1.69	1.70	1.71	1.72	1.74	1.75	1.76
5	1.52	1.53	1.54	1.55	1.56	1.56	1.57	1.58	1.59	1.60
6	1.42	1.43	1.44	1.44	1.45	1.46	1.46	1.47	1.47	1.48
7	1.51	1.52	1.53	1.54	1.55	1.56	1.57	1.57	1.58	1.59
8	1.48	1.48	1.49	1.50	1.51	1.52	1.52	1.53	1.54	1.54
9	1.41	1.42	1.42	1.43	1.43	1.44	1.44	1.45	1.45	1.46
10	1.39	1.39	1.40	1.41	1.41	1.42	1.42	1.43	1.43	1.43

Source: Authors.

Table A10. BCR across flood scenarios discounted at 8% from a municipal perspective

Diep/Sand catchment

Flood frequency (flood of intensity X every Y year)	Flood intensity/size (1 in X event type)									
	1	2	3	4	5	6	7	8	9	10
1	1.17	1.47	1.77	2.05	2.33	2.59	2.85	3.09	3.33	3.55
2	0.90	1.04	1.18	1.31	1.44	1.57	1.69	1.80	1.91	2.02
3	0.81	0.91	0.99	1.08	1.16	1.24	1.32	1.39	1.46	1.53
4	0.80	0.88	0.95	1.03	1.10	1.17	1.24	1.30	1.37	1.43
5	0.76	0.81	0.87	0.92	0.98	1.02	1.07	1.12	1.16	1.21
6	0.73	0.77	0.81	0.85	0.88	0.92	0.95	0.98	1.02	1.05
7	0.75	0.81	0.87	0.92	0.97	1.02	1.07	1.11	1.15	1.20
8	0.74	0.79	0.84	0.89	0.93	0.98	1.02	1.06	1.10	1.13
9	0.72	0.76	0.80	0.83	0.87	0.90	0.93	0.96	0.99	1.02
10	0.72	0.75	0.79	0.82	0.85	0.88	0.91	0.93	0.96	0.98

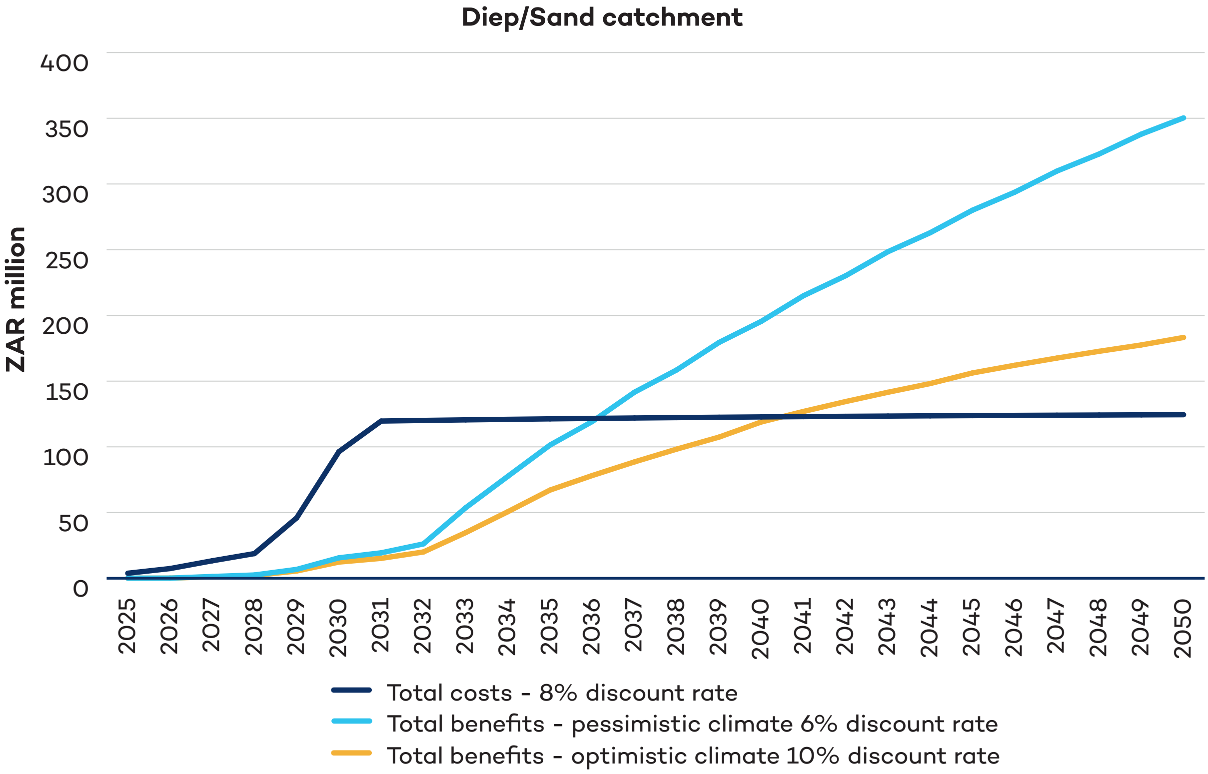
Zeekoe Catchment

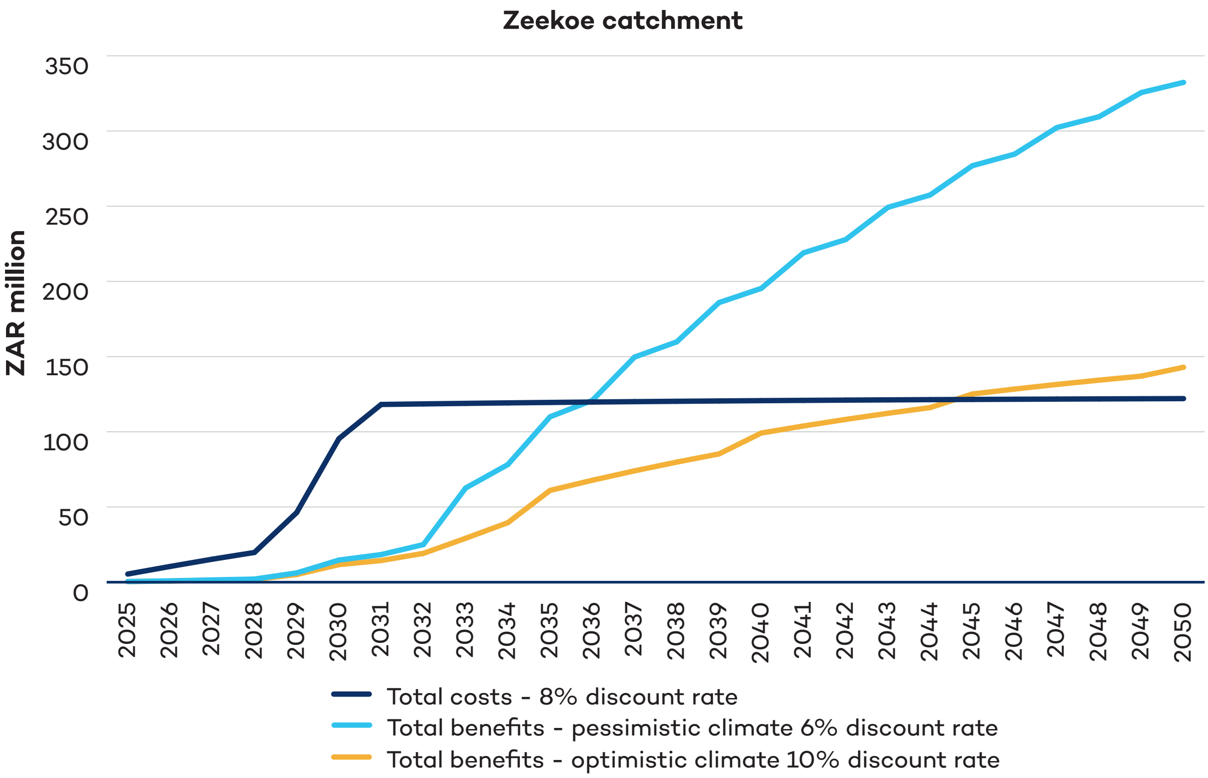
Flood frequency (flood of intensity X every Y year)	Flood intensity/size (1 in X event type)									
	1	2	3	4	5	6	7	8	9	10
1	1.62	1.84	2.04	2.23	2.41	2.57	2.73	2.87	3.01	3.14
2	1.00	1.10	1.20	1.29	1.37	1.45	1.52	1.59	1.65	1.71
3	0.80	0.87	0.93	0.99	1.04	1.09	1.14	1.18	1.22	1.26
4	0.76	0.82	0.87	0.92	0.97	1.01	1.05	1.09	1.13	1.16
5	0.67	0.71	0.75	0.79	0.82	0.85	0.88	0.91	0.93	0.96
6	0.61	0.64	0.66	0.69	0.71	0.73	0.75	0.77	0.79	0.81
7	0.67	0.71	0.74	0.78	0.81	0.84	0.87	0.90	0.92	0.95
8	0.64	0.68	0.71	0.74	0.77	0.80	0.82	0.85	0.87	0.89
9	0.60	0.62	0.65	0.67	0.69	0.71	0.73	0.75	0.77	0.78
10	0.58	0.61	0.63	0.65	0.67	0.69	0.71	0.72	0.74	0.75

Source: Authors.

Cumulative Costs and Benefits Over Time Across Scenarios

Figure A1. Cumulative costs and benefits—upper and lower bound





Source: Authors.

Appendix B. Modelling Assumptions

Direct Costs

Implementation Costs (Capital Expenditures, [CapEx])

Implementation costs (CapEx) are the initial costs associated with carrying out the NBI interventions, including construction, labour, materials, detailed design, and other one-time expenditures. For the baseline, these costs are defined as zero. On the other hand, for the NBI scenario, these costs occur from year 3 till year 7 in both catchments.

- For the Diep/Sand catchment, the costs are estimated by the City of Cape Town at ZAR 8.9 million in year 3, ZAR 8.9 million in year 4, ZAR 47.9 million in year 5, ZAR 95.9 million in year 6, and ZAR 47.9 million in year 7.
- For the Zeekoe catchment, the costs are estimated by the City of Cape Town at ZAR 7.3 million in year 3, ZAR 7.3 million in year 4, ZAR 46.8 million in year 5, ZAR 93.6 million in year 6, and ZAR 46.8 million in year 7.

Maintenance Costs (Operating Expenditures [OpEx])

The maintenance costs (OPEX) include all activities necessary to upkeep the various waterways of the two catchments, excluding the dredging activities (e.g., clearing branches and waste).

- For the Diep/Sand catchment, the City of Cape Town estimates that in the baseline maintenance costs represent an annual expenditure of ZAR 3.8 million. On the other hand, under the NBI interventions, these estimates go up to ZAR 4.7 million annually.
- For the Zeekoe catchment, the City of Cape Town estimates that in the baseline maintenance costs represent an annual expenditure of ZAR 4 million. On the other hand, under the NBI interventions, these estimates go up to ZAR 4.75 million annually.

In both catchments, we assumed that during the implementation phase (first 7 years), the maintenance costs would follow the baseline expenditures and then jump up once the NBI interventions are in place.

Feasibility and Concept Design Costs (Prep OpEx)

Feasibility and concept design costs (prep OpEx) are the costs incurred during the early stages of the project for technical assessments, concept design plans, and feasibility studies necessary to implement the interventions. For the baseline, these costs are defined as zero. On the other hand, for the NBI scenario, these costs occur in the first 2 years of the projects in both catchments.

- For the Diep/Sand catchment, the costs are estimated by the City of Cape Town at ZAR 4.5 million in years 1 and 2.
- For the Zeekoe catchment, the costs are estimated by the City of Cape Town at ZAR 6.3 million in years 1 and 2.

Avoided Costs

Avoided Costs of Flood Damages

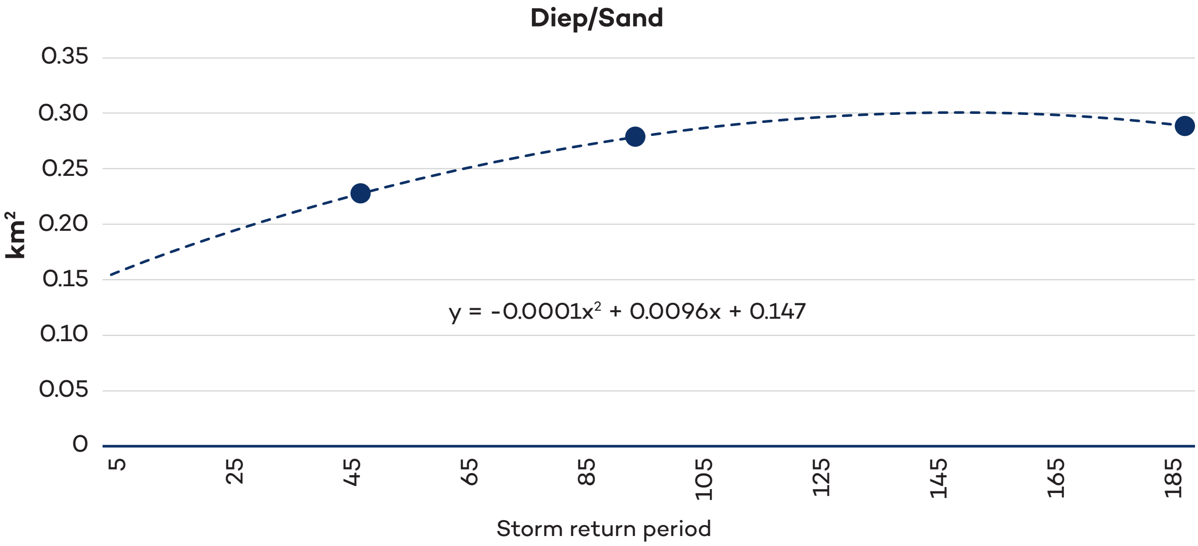
Avoided costs of flood damages represent the estimated reduction in material damages as a result of the NBI interventions that mitigate flood risks. This includes residential properties, industrial areas, utilities, educational buildings, roads, and culverts.

In both catchments, to compute the avoided costs, the method used consists of estimating the costs in the baseline separately from the costs in the NBI scenario and then measuring the difference between the two.

For the baseline, the total damage costs are the sum of damages to residential properties, industrial areas, utilities, educational buildings, roads, and culverts. Each of these depends on the intensity/scale of the flood event. (e.g., 1 in X event type). This latter is extracted from the climate data (World Bank, 2024) or is defined based on manual inputs. If using climate data projections, we assume that flood events occur when precipitations are above 35 mm/day, after which we measure the occurrence of events in which precipitation goes above this threshold. This gives us the average frequency of events (e.g., one event every X years). We then assume that this frequency is homogenous over the 2025–2050 time horizon. This allows us to estimate the flood occurrence over time. We then combined this time series with a monetary estimation of the damages when a flood occurs.

This monetization process is based on curves defining the relationship between the intensity of flood events and the identified number of buildings, industrial area, utility area, and inundation area affected. The hydrological studies (Thewlis & Riemann, 2024a, 2024b) estimate each of these affected infrastructure based on three storm return periods (1:50, 1:100, and 1:200) and their associated flood lines. From these three data points, we extrapolated each damage function for each variable, as depicted in Figure B1 for inundation areas.

Figure B1. Damage functions of inundation area for both catchments



Source: Authors, based on Anchor Environmental Consultants' work.

For damages to buildings, these curves give us an estimation of the number of buildings affected associated with a specific type of flood. Based on this latter, we assume an average size of 120 square metres per building, valued at ZAR 8,100 per square metre, and for which 15% of this value would be damaged. For damages to industrial areas, we assume a value of ZAR 6,075 per square metre and, for which 10% of this value would be damaged. For damage to utility, we assume a value of ZAR 4,000 per square metre and, for which 10% of this value would be damaged. For damage to education, we assume a value of ZAR 8,200 per square metre and, for which 10% of this value would be damaged. For damages to roads, we use the area of inundation, assume a road density of 2.5 kilometres of road for each square metre, and value the cost of strengthening roads as ZAR 3 million per kilometre (Breytenbach & Fourie, 2021). For damages to culverts, we assume a cost of ZAR 21.3 million to replace road culverts.

Finally, hydrological studies (Thewlis & Riemann, 2024a, 2024b) and ecosystem services studies (Turpie & Letley, 2024a, 2024b) estimate that NBI interventions yield a 91% and 37% decrease in damages for the Diep/Sand catchment and Zeekoe catchment, respectively. We assume that these benefits materialize right after implementation of interventions.

Avoided Costs of Disaster Relief

Avoided costs of disaster relief are the savings generated by reducing the need for emergency services and post-disaster recovery efforts through proactive flood risk management.

In both catchments, to compute the avoided costs, the method used consists of estimating the costs in the baseline separately from the costs in the NBI scenario and then measuring the difference between the two.

The baseline costs follow the same logic as those detailed in the "avoided cost of flood damages" in terms of estimating flood intensity and linking it to its impacts. In the particular case of costs of disaster relief, we use the number of residential buildings affected when a flood occurs and multiply it by the number of people per household, estimated at 3.34 and 3.5 in the Diep/Sand and Zeekoe catchment, respectively (Letley & Turpie, 2024a, 2024b). Finally, we use an estimation of the disaster relief cost per person assisted from the Red Cross in South Africa (2022), equal to ZAR 960 per person.

Finally, hydrological studies (Thewlis & Riemann, 2024a, 2024b) and ecosystem services studies (Turpie & Letley, 2024a, 2024b) estimate that NBI interventions yield a 91% and 37% decrease in damages for the Diep/Sand catchment and Zeekoe catchment, respectively. We assume that these benefits materialize right after implementation of interventions.

Avoided Costs of Mental Health Impact

Avoided costs of mental health impact captures the reduction in health care costs associated with mental health conditions that may arise from disasters such as floods, given the stabilizing effect of NBI on reducing extreme events.

In both catchments, to compute the avoided costs, the method used consists of estimating the costs in the baseline separately from the costs in the NBI scenario to then measure the difference between the two.

The baseline costs follow the same logic as the one detailed in the "avoided cost of flood damages" when it comes to estimating flood intensity and linking it to its impacts. In the particular case of cost of mental health impact, we use the number of residential buildings affected when a flood occurs, multiply it by the number of people per household, estimated at 3.34 and 3.5 in the Diep/Sand and Zeekoe catchment, respectively (Letley & Turpie, 2024a, 2024b). We then assume that 10% of people affected need mental health assistance. Finally, we use an estimation of the average mental health cost per person assisted from the British Government (Viavattene & Priest, 2021) and level it to the South African economy, equal to ZAR 50,000 per person.

Finally, hydrological studies (Thewlis & Riemann, 2024a, 2024b) and ecosystem services studies (Turpie & Letley, 2024a, 2024b) estimate that NBI interventions yield a 91% and 37% decrease in damages for the Diep/Sand catchment and Zeekoe catchment respectively. We assume that these benefits materialize right after the implementation of interventions.

Avoided Cost of Human Death

Avoided cost of human death is the value assigned to avoiding fatalities caused by flooding or other extreme events. This indicator was excluded from the monetary valuation given its sensitive nature, but it could be quantified by using the value of a statistical life or the government's willingness to pay. In the case of South Africa, this latter value is valued at ZAR 460,000 (Murray et al., 2022).

Avoided Cost of Dredging

Avoided cost of dredging represents the savings from reduced sediment buildup in waterways, as the NBI interventions limit sedimentation through ecological restoration efforts.

- For the Diep/Sand catchment, the average costs are estimated by the City of Cape Town at ZAR 5.1 million each year under the baseline. On the other hand, the NBI interventions make these costs drop to ZAR 1.15 million.
- For the Zeekoe catchment, the average costs are estimated by the City of Cape Town at ZAR 10.1 million each year under the baseline. On the other hand, the NBI interventions make these costs drop to ZAR 4.7 million.

In both catchments, we assumed that during the implementation phase (first 7 years), the dredging costs would follow the baseline expenditures and then go down once the NBI interventions are in place.

Avoided Cost of Refurbishment

Avoided cost of refurbishment refers to savings from not needing to renovate canals in the baseline scenario, as NBI interventions eliminate the need for such repairs.

- For the Diep/Sand catchment, the canals' length needing repair is estimated by the City of Cape Town at 2,700 metres. Applying a unit cost of ZAR 8,153 per metre leads to a cost estimate of ZAR 22 million.
- For the Zeekoe catchment, the canals' length needing repair is estimated by the City of Cape Town at 2,000 metres. Applying a unit cost of ZAR 8,153 per metre leads to a cost estimate of ZAR 16.3 million.

In both catchments, we assumed that the expense would be covered in 2033 and 2034.

Avoided Costs of Physical Inactivity

Avoided cost of physical inactivity undermines the benefits related to improved public health from increased physical activity, which are enabled by the creation of recreational areas and pedestrian pathways through NBI interventions.

In both catchments, the socio-economic studies (Letley & Turpie, 2024a, 2024b) estimated the number of households within 200 metres of waterways (11,980 and 17,200 for the Diep/Sand and Zeekoe catchment, respectively). Combined with the number of people per household (3.34 and 3.5 for the Diep/Sand and Zeekoe catchment, respectively), we have an estimation of the number of people that could benefit from the newly created spaces. Finally, we use an estimation of the annual cost to treat non-communicable disease and mental health per person, equal to ZAR 75 per person per year (Charman et al., 2024).

Added Benefits

Value of Employment Creation

Value of employment creation defines the economic value of new jobs generated through the implementation, maintenance, and long-term management of NBI projects. This latter is computed based on discretionary spending from labour benefits.

In other words, for both catchments, the implementation and maintenance expenditures are partially considered as societal benefits. From total expenditures, we extract the labour costs by assuming that for maintenance expenditure, 100% of the costs go to labour, while for feasibility and design, the proportion of labour costs falls to 90%; for implementation, these represent only 50%. Finally, out of the labour costs, representing the salary benefits for workers hired, only 30% are considered discretionary spending. It's this latter that defines the value of employment creation.

Concerning the job creation benefits and the estimated number of people hired, we aligned our assumption with the City of Cape Town's estimate by using an average salary for maintenance activities of ZAR 70,400 per person per year; for all other activities, we used an average salary of ZAR 282,200 per person per year (Payscale, 2024).

Value of Carbon Sequestration

Value of carbon sequestration is computed based on the social cost value assigned to carbon dioxide captured and stored by restored ecosystems, contributing to climate change mitigation.

Based on the masterplans (Turpie et al., 2024a, 2024b), 41.8 and 77.8 thousand square metres of wetlands are going to be created in the Diep/Sand and Zeekoe catchments, respectively. We then use an estimated sequestration rate of 0.77 tons of carbon per hectare per year (Cheng et al., 2020), which, converted into carbon dioxide, gives 2.8 tons of CO_2 per hectare per year. Finally, we use an estimation of the social cost of carbon for South Africa of USD 15.6/tCO_2 (Ricke et al., 2018), which translates to ZAR 288.4/tCO_2 when using an exchange rate of ZAR 18.5 per USD.

Note that the benefits of carbon sequestration only materialize after implementation of the NBI interventions.

Value of Food Provisioning

Value of food provisioning captures the benefits generated from food gardens established in communities, which enhance food security and provide local agricultural value.

Based on the masterplans (Turpie et al., 2024a, 2024b), 1,000 and 15,000 square metres of food gardens are going to be created in the Diep/Sand and Zeekoe catchments, respectively. We then use an average yield of 5.4 kilograms per year, and an estimated value of production of ZAR 15 per kilogram (Turpie & Letley, 2024a, 2024b).

Note that the benefits of food provisioning only materialize after implementation of the NBI interventions.

Value of Urban Cooling

Value of urban cooling is defined as the reduction in energy costs and improvement in public health resulting from lower urban temperatures, achieved through increased green spaces and tree planting. This indicator was excluded from the monetary valuation, given the lack of data.

Avoided Losses

Avoided Loss in Productivity Due to Floods

Avoided loss in productivity due to floods refers to the economic benefits of maintaining productivity levels by reducing flood-related disruptions to businesses and communities.

In both catchments, to compute the avoided loss, the method used consists of estimating the loss in the baseline separately from the loss in the NBI scenario and then measuring the difference between the two.

The baseline loss follows the same logic as the one detailed in the "avoided cost of flood damages" when it comes to estimating flood intensity and linking it to its impacts. In the particular case of the loss in productivity due to floods, we use the inundation area affected when flood occurs and multiply it by the population density, estimated at 4,996 and 12,229 in the Diep/Sand and Zeekoe catchment respectively (Letley & Turpie, 2024a, 2024b). We then assume that 30% of people affected are working. Additionally, we use the average salary of ZAR 282,000 per person per year, which we bring down to a salary of ZAR 1,282 per person per day by assuming workers work 220 days per year. Finally, we assume that people lose 3 days of work after being affected by a flood event.

Finally, hydrological studies (Thewlis & Riemann, 2024a, 2024b) and ecosystem services studies (Turpie & Letley, 2024a, 2024b) estimate that NBI interventions yield a 91% and 37% decrease in damages for the Diep/Sand catchment and Zeekoe catchment respectively. We assume that these benefits materialize right after implementation of interventions.

Avoided Loss of Tourism Revenue

Avoided loss of tourism revenue are the benefits of preserving tourism activity, which could otherwise be negatively impacted by environmental degradation in the catchments.

In both catchments, to compute the avoided loss, the method used consists in estimating the loss in the baseline separately to the loss in the NBI scenario to then measure the difference between the two.

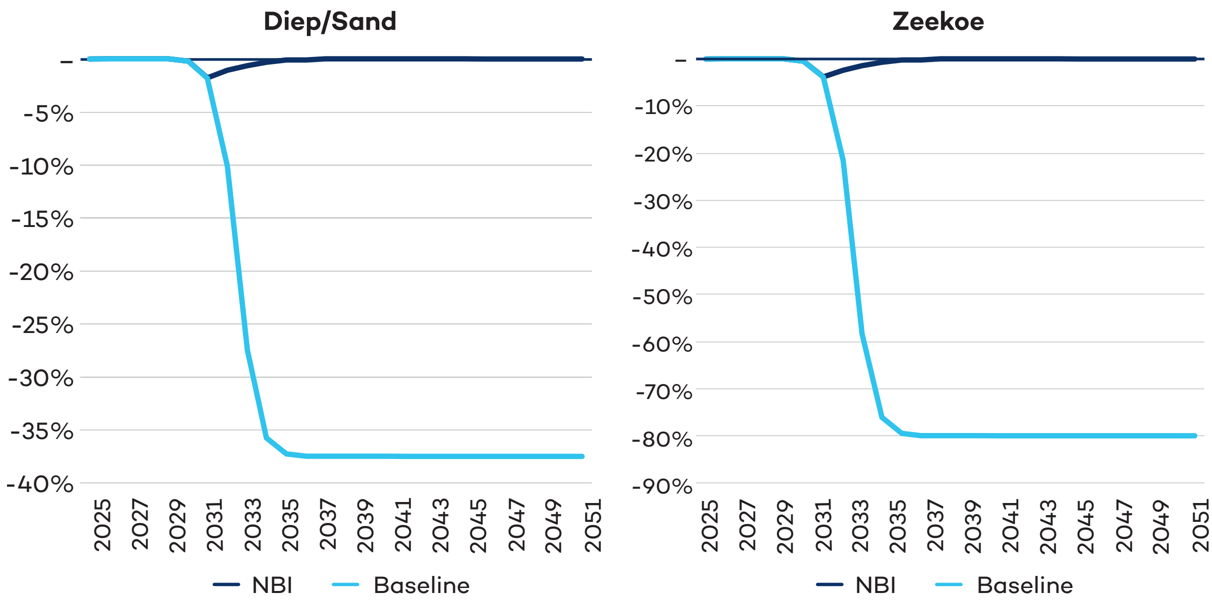
Based on the ecosystem services studies (Turpie & Letley, 2024a, 2024b), the economic value of tourism activities of each catchment were analyzed. The total spending from tourism activities is estimated at ZAR 44 million and ZAR 8 million annually (with a yearly growth of 3.31%) for the Diep/Sand and Zeekoe catchment, respectively. In this indicator, we exclude 15%, which we assume goes to tax revenue.

As mentioned in the ecosystem services studies, tourism plays a critical role in Cape Town's economy. The waterways support a range of nature-based activities, including picnicking, camping, walking trails, water sports, and fishing, which draw both domestic and international visitors. Fishing, in particular, is a major draw, attracting tourists seeking unique experiences. These tourism activities contribute directly to local spending and generate economic benefits specific to the area. As these activities are closely tied to the health of the ecosystem, any degradation could significantly reduce the influx of tourists, impacting local businesses and overall revenue. The assumptions behind the tourism-related benefits in this study are based on detailed spatial mapping of visitor densities and attraction-related expenditures, emphasizing the importance of the two catchments' waterways as unique destination for tourists, separate from other areas in the city.

As touristic activities are closely linked to the ecosystem's health, the biophysical assessments made in each catchment informed us about how the ecosystem's health is projected to be deteriorating. For the Diep/Sand catchment, the deterioration is projected to go from an ecosystem of class D to class E. For the Zeekoe catchment, the deterioration is projected to go from an ecosystem of class E to class F. These changes in classes were translated into a 37.5% and 80% loss in tourist spending (Turpie & Letley, 2024a, 2024b). We then assume that this loss will occur in the next decade following the S-shape curves defined in Figure B2.

Moreover, the NBI interventions are projected to maintain the ecosystem at its current health status, therefore maintaining tourism spending on its current trajectory. Note that the benefits of ecosystem health materialize only after implementation of the NBI interventions, which explains why the NBI curve of Figure B2 follows the baseline for the first 7 years.

Figure B2. Net change in tourism spending based on ecosystem's health



Source: Authors, based on Anchor Environmental Consultants.

Avoided Loss of Tourism Tax Revenue

Avoided loss of tourism tax revenue is the retained government revenue from tourism-related taxes, which might decline if environmental deterioration reduces tourism numbers.

The computation logic is equivalent as the one described in the "avoided loss of tourism revenue," with the exception that we assume that 15% of tourist spending would be taxed (i.e., VAT on transactions). It's this latter share of tourism spending that is considered through this indicator.

Avoided Loss of Property Tax Revenue

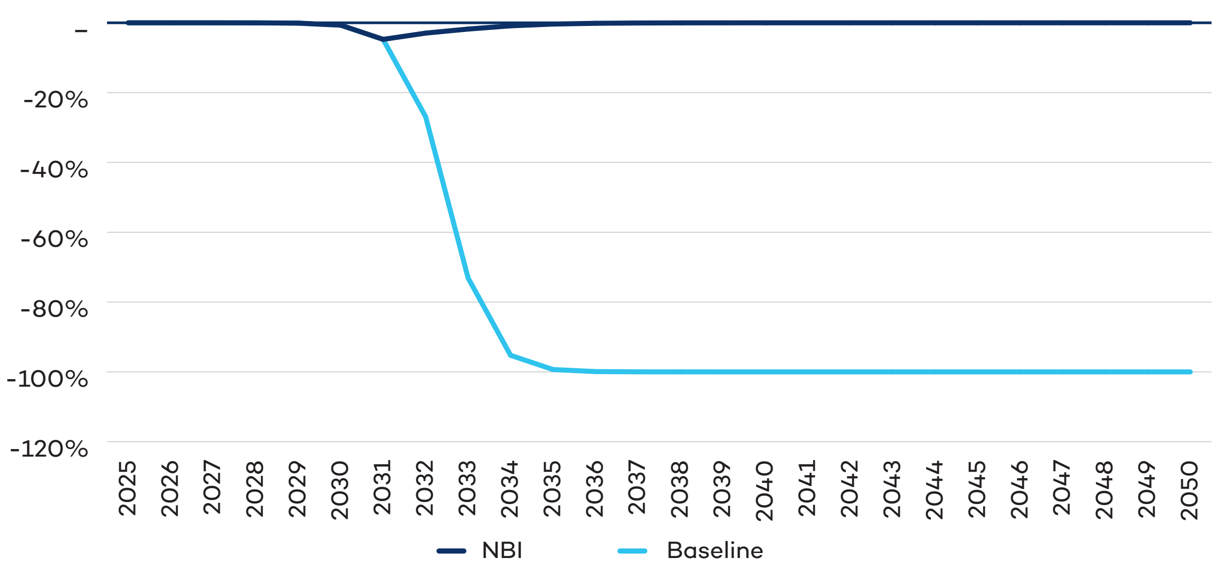
Avoided loss of property tax revenue refers to the retained municipal revenue from property taxes, which could decrease due to property devaluation caused by ecosystem health.

In both catchments, to compute the avoided loss, the method used consists in estimating the loss in the baseline separately to the loss in the NBI scenario and then measuring the difference between the two.

The baseline loss follows the same logic as the one detailed in the "avoided loss of tourism revenue" when it comes to estimating the ecosystem's deterioration and linking it to its impacts. In the particular case of the loss in property tax revenue, we use the City of Cape Town's result from property valuation maps (see Figure 8 for an example) to estimate the total property value that is taxable, estimated at ZAR 5.3 and ZAR 1.9 billion for the Diep/Sand and Zeekoe catchments (with a 5.65% annual growth). We then assume that 8% of property value is attributed to waterways proximity. Additionally, we use the city's official rate of 0.663% to estimate the municipal revenue generated yearly.

Finally, to account for the ecosystem health deterioration, we assume that property premiums will be lost if the ecosystem continues its current health trajectory. The materialization of this latter loss is illustrated in Figure B3. Note that the benefits of ecosystem health materialize only after implementation of the NBI interventions, which explains why the NBI curve of Figure B3 follows the baseline for the first 7 years.

Figure B3. Net change in property premium



Source: Authors.

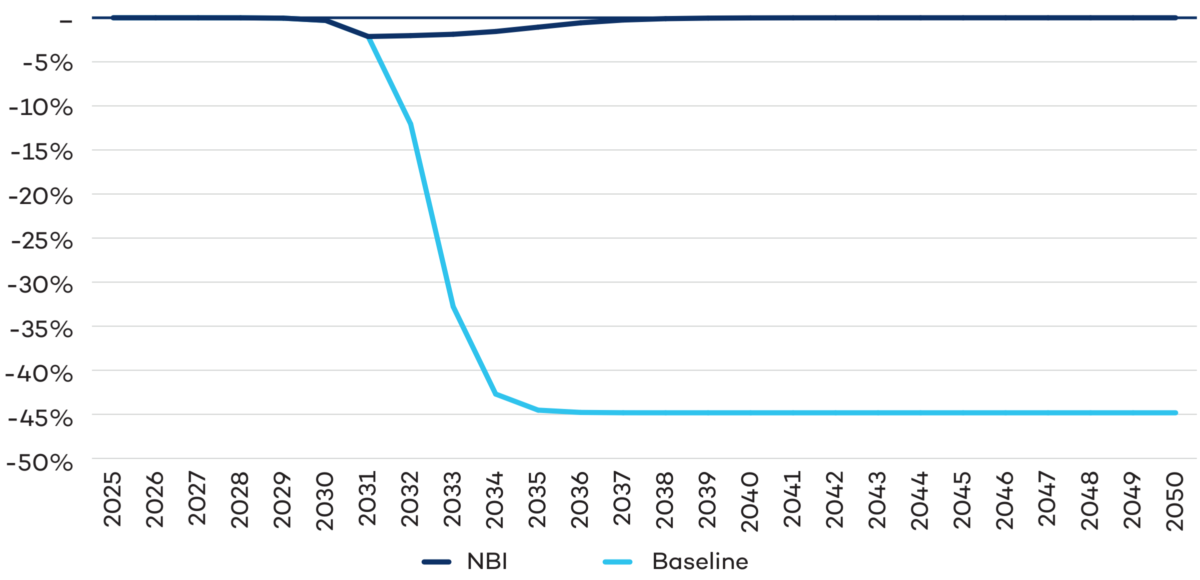
Avoided Loss in Fish Nursery Value

Avoided loss in fish nursery value represents the benefits of preserving fish nurseries and biodiversity within the catchments, as healthy ecosystems contribute to the sustainability of downstream fisheries.

In both catchments, to compute the avoided loss, the method used consists in estimating the loss in the baseline separately from the loss in the NBI scenario and then measuring the difference between the two.

The baseline loss follows the same logic as the one detailed in the "avoided loss of tourism revenue" in terms of estimating the ecosystem's deterioration and linking it to its impacts. In the particular case of the loss in fish nursery value, we use the ecosystem services studies (Turpie & Letley, 2024a, 2024b) to estimate the nursery value, estimated at ZAR 2.9 million for the Diep/Sand catchment. No estimation was provided for the Zeekoe catchment. Finally, we followed the studies' results by assuming that 45% of this value will be lost when going from a class D ecosystem to a class E. The materialization of this latter loss is illustrated in Figure B4. Note that the benefits of ecosystem health materialize only after implementation of the NBI interventions, which explains why the NBI curve of Figure B4 follows the baseline for the first 7 years.

Figure B4. Net change in nursery value



Source: Authors, based on Anchor Environmental Consultants.

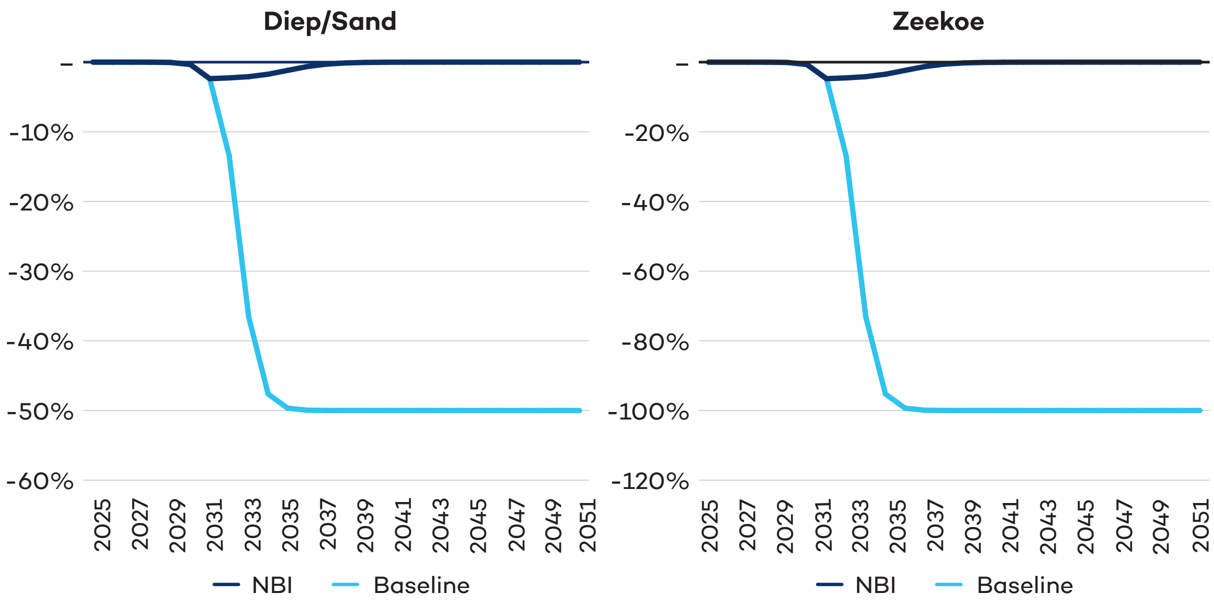
Avoided Loss in Biodiversity Conservation

Avoided loss in biodiversity conservation is the value of maintaining ecosystem diversity, which is integral to sustaining long-term ecological resilience and ecosystem services.

In both catchments, to compute the avoided loss, the method used consists in estimating the loss in the baseline separately from the loss in the NBI scenario and then measuring the difference between the two.

The baseline loss follows the same logic as the one detailed in the "avoided loss of fishery nursery value." In the particular case of the loss in fish nursery value, we use the ecosystem services studies (Turpie & Letley, 2024a, 2024b) to estimate the biodiversity existence value, estimated at ZAR 390,000 and ZAR 130,000 for the Diep/Sand and Zeekoe catchment, respectively. Finally, we followed the studies' results by assuming that 50% and 100% of the biodiversity value will be lost because of ecosystem deterioration. The materialization of this latter loss follows the trend defined by the curves of Figure B5.

Figure B5. Net change in biodiversity value



Source: Authors, based on Anchor Environmental Consultants.

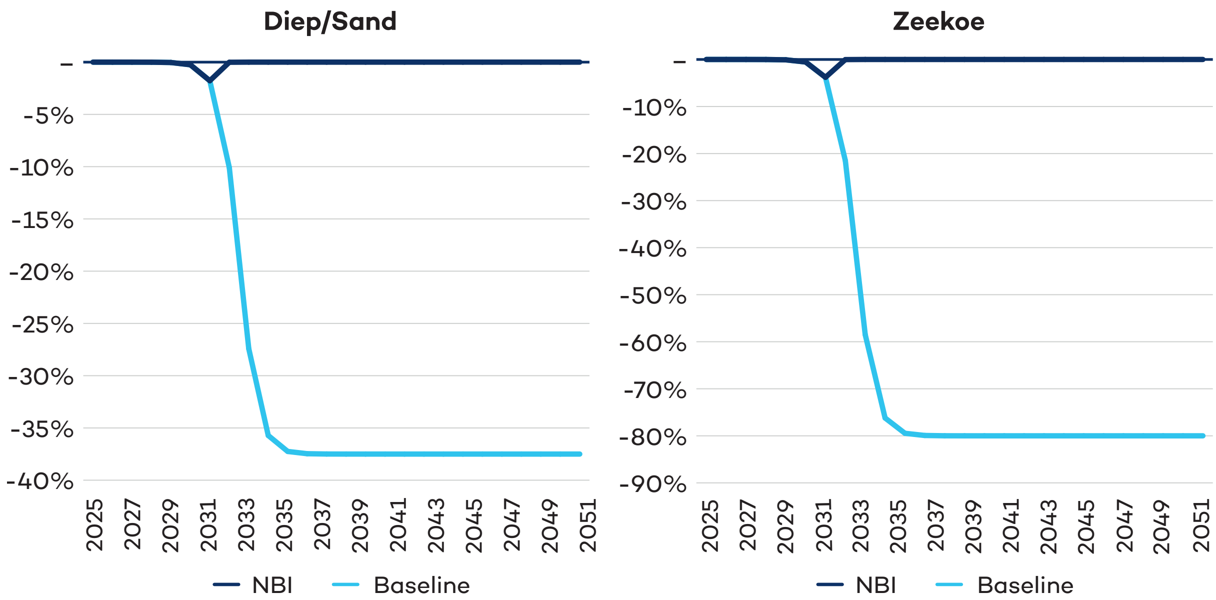
Avoided Loss of Recreational Areas

Avoided loss of recreational areas is the value of maintaining public access to parks, pathways, and other recreational spaces, which contribute to community well-being and physical health.

In both catchments, to compute the avoided loss, the method used consists in estimating the loss in the baseline separately from the loss in the NBI scenario and then measuring the difference between the two.

The baseline loss follows the same logic as the one detailed in the "avoided loss of fishery nursery value." In the particular case of the loss of recreational areas, we use the ecosystem services studies (Turpie & Letley, 2024a, 2024b) to estimate the value of recreational areas, that is to be understood as the willingness to pay for having access to these areas, estimated at ZAR 1.4 million and ZAR 2.4 million for the Diep/Sand and Zeekoe catchment, respectively. Finally, we followed the studies' results by assuming that 37.5% and 80% of the recreational value will be lost because of ecosystem deterioration as people won't be willing to go to these areas anymore. The materialization of this latter loss follows the trend defined by the curves of Figure B6.

Figure B6. Net change in recreational value



Source: Authors, based on Anchor Environmental Consultants.

NATURE-BASED INFRASTRUCTURE
GLOBAL RESOURCE CENTRE