Benefit Cost Analysis Technical Report

Business Case for Durban's Transformative Riverine Management Programme

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C40 CITIES FINANCE FACILITY

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ABOUT THE C40 CITIES FINANCE FACILITY

The C40 Cities Finance Facility (CFF) is a collaboration of the C40 Cities Climate Leadership Group and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The CFF supports cities in developing and emerging economies to develop finance-ready projects to reduce emissions to limit global temperature rise to 1.5°C and strengthen resilience against the impacts of a warming climate. The CFF is funded by the German Federal Ministry for Economic Cooperation and Development (BMZ), the Children's Investment Fund Foundation (CIFF), the Government of the United Kingdom and the United States Agency for International Development (USAID).

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1. INTRODUCTION

To support the preparation of a Business Case for Transformative Riverine Management in the eThekwini Municipal Area, a Benefit Cost Analysis (BCA) has been undertaken for a range of future scenarios. These scenarios included the costs to society and the municipality of not managing rivers as climate change continues to drive flooding and water quality risks, and a comparison of the financial costs of a range of riverine management models against associated financial and societal benefits of these interventions. Climate change has been included in all scenarios as a driver of increased ecological, social, economic and financial risk.

A Benefit Cost Analysis approach was adopted (as opposed to a Cost Benefit Analysis), because the eThekwini Municipality's mandate is to deliver public goods through service delivery, rather than to generate a positive return on investment through its investments. This approach has allowed the Benefit to Cost ratios to be framed as an answer to the question: "If the municipality spends R1, how much benefit or value does it generate or buy?".

2. METHDOLOGY & KEY ASSUMPTIONS

2.1 Scenarios

Benefit Cost Analyses (BCA) were undertaken for three landownership categories (i.e. municipal, private and Traditional Authority land in riverine areas), under three separate riverine management scenarios (i.e. do nothing, basic and transformative riverine management) (see Figure 1). In total, nine BCA scenarios were modelled to understand the implications of different riverine management models in relation to landownership types. As a foundation or baseline for all scenarios, a BCA of the eThekwini Municipality's Sihlanzimvelo Stream Cleaning Programme was initially undertaken. A spreadsheet of costs and benefits was developed for this and is available as a supporting file to this report.

As the management of the rivers involves natural capital or ecological infrastructure (as well as built infrastructure), it was also necessary to develop an understanding of the management implications for ecological functions and associated supply of and demand for ecosystem services from rivers in the eThekwini Municipal Area. For this purpose, a social-ecological systems model was developed for the Ohlanga River Catchment[1] (which has all three types of landownership) as representative for all other catchments in the municipal area. This process was used to model the changes in riverine ecosystem services that would occur with climate change, as well as how basic and transformative management interventions would affect ecosystem services delivery. The results were used to inform the likely changes to human well-being associated with each of the BCA scenarios.

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[1] Mander, M., Mander, N., de Winnaar, G., and Graham, M. 2020. *Ohlanga Proto-Masterplan for Transformative Riverine Management: Business Case for Durban's Transformative Riverine Management Programme*. C40 Cities Finance Facility report.

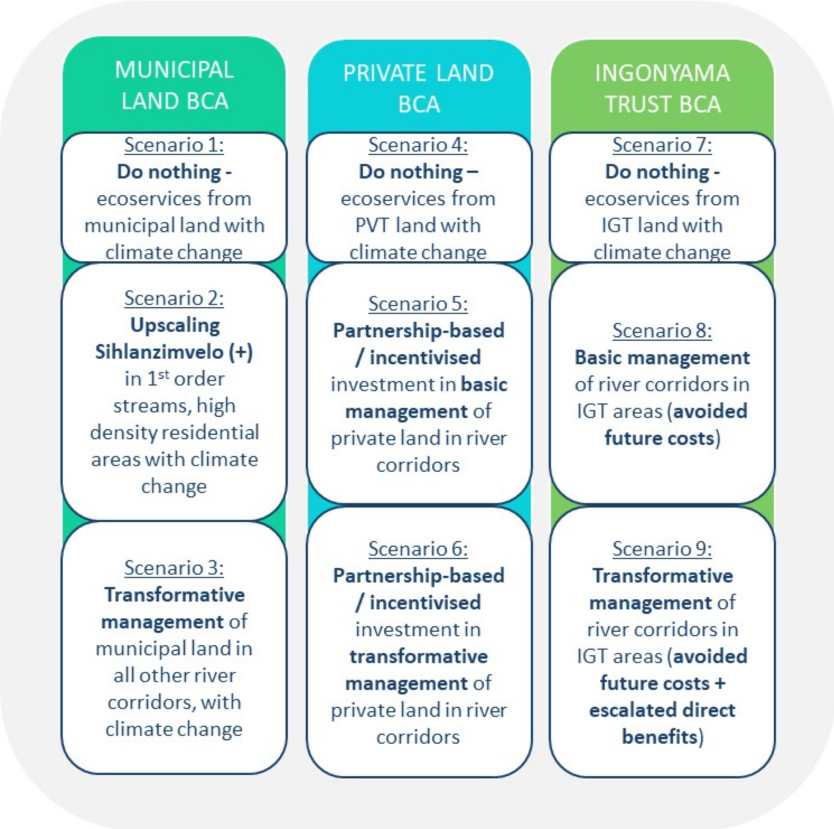

Figure 1: Summary of BCA scenarios

2.2 Method Summary

A summary of the three-step analytical process and method used in the BCA is outlined below. The process is summarised in Figure 2.

1) Current Sihlanzimvelo Programme BCA

a. **Financial baseline**: A baseline for all the analyses was established by firstly developing the costs and benefits of the eThekwini Municipality's Sihlanzimvelo Stream Cleaning Programme using current implementation data – i.e. this represented the known context.

   Current municipal budgets were assessed to identify total implementation costs for the 450km of river currently managed under the Programme. From this, the implementation costs per kilometre of river managed were determined.

   The financial benefits of Sihlanzimvelo were estimated by modelling the avoided damage costs to a range of culvert types and sizes. The analysis was based on the known damage frequency, repair and reconstruction costs in the uMhlangane and other catchments where Sihlanzimvelo is being implemented[2]. To account for predicted climate change, the frequency of damage events for the different culverts were escalated using assumptions provided by detailed eco-hydrological modelling (ACRU modelling undertaken by Davis and Schultze, 2020[3]).

The benefits had to be modelled as explained above, because the damages to culverts before and after implementation of Sihlanzimvelo had not been explicitly recorded by eThekwini Municipality. An average benefit value per kilometre of river managed was estimated and adopted as an average value for all municipal catchments.

These financial costs and benefits were used and/or adapted for the other BCA scenarios to provide a 'strictly' financial BCA of each management scenario.

b. **Ecosystem services & user number assumptions:** The Ohlanga River Catchment was modelled using the Eco-Futures[4] tool to develop an understanding of the supply of riverine ecosystem services under current land uses and ecological conditions, and under various future scenarios, and to determine who would be affected by changes in the delivery of these services. The Ohlanga Catchment was selected as a representative catchment in the eThekwini Municipal Area for this modelling because, i) the whole catchment is contained within the municipal boundary, ii) it contains municipal, private and Traditional Authority land, and iii) the catchment morphology and land uses are broadly representative of catchments within the eThekwini Municipal Area.

   Using assumptions provided by Davis and Schultze (2020), the impacts of climate change on river condition and ecosystem services supply were modelled. Following this, two management responses were modelled, i.e. i) basic riverine / riverine management; and ii) transformative riverine management. For the climate change scenario and the two riverine management scenarios, the likely changes to ecosystems were workshopped and the consequent changes in ecosystem services modelled.

   The number of ecosystem service users alongside rivers was estimated by counting households in close proximity to streams and rivers (see Annexure 4 for detailed method statement). Coastal user numbers estimated using published literature and Umhlanga Tourism estimates. The numbers of

[2] Note that as data was not available for damages to other types of municipal infrastructure, such as roads, electrical cables, water and sewer pipelines and pump stations, the damage costs for these are not included. See more in Section 2.5: Data Limitations.
[3] Davis, N and Schultze, R. 2020. Vulnerability Assessment Report. Report produced for C40 Cities Finance Facility and GIZ.
[4] Eco-Futures is an ecosystem services supply and demand assessment process that enables stakeholders to quantify changes to ecosystem services in alternative land use and management scenarios.

users of ecosystem services were moderated using a weighting index that recognised levels of dependence on the ecosystem services. The weightings allow for a comparison between 'full-time' users and 'part-time' users. For example, 2.2 million part-time users of the Durban beachfront per annum, when weighted, become equivalent to 131 000 full-time users, which can then be used in calculating benefit values.

Based on the Eco-Futures modelling, changes in each ecosystem service under each of the future scenarios were estimated based on projected changes in ecosystem condition and associated productivity. An average change in all ecosystem services was then estimated for each scenario, which could then be used to understand changes in societal well-being.

c. **Proxy for societal costs / benefits:** A proxy value for riverine management impacts on individual productivity and well-being was developed, using a Human Capital Approach[5]. This approach puts an economic value on the productivity or well-being of affected catchment users and provides an indicator of the economic benefits of the riverine management actions to the catchment community. The modelled percentage change in ecosystem service levels with management of rivers is combined with a proxy annual value of human well-being or productivity, and a one month period of time (or duration of impact), to estimate an annual value to ecosystem users living near rivers, and downstream users (including coastal users).

d. **Sihlanzimvelo BCA:** A BCA was prepared for the current Sihlanzimvelo Programme.

2) Basic Riverine Management BCA

a. **Upscaling Sihlanzimvelo**: Once the benefits and costs of the existing Sihlanzimvelo Programme had been established (i.e. the financial and economic baseline), the benefits and costs were then upscaled to develop a basic riverine management scenario for all catchments within the eThekwini Municipal Area by combining the total municipal river length (all first and second order streams on municipal land[6]) with the average benefit and cost values per kilometre. A benefit cost ratio was calculated.

b. **Basic Riverine Management on private and Traditional Authority land:** The Sihlanzimvelo benefits and costs were then adapted for the private landownership and Traditional Authority ownership contexts, such as lower

[5] An approach often used with respect to the economic valuation of investments in ecosystem and public benefit services (Blignaut and Lumby 2004, Beli *et al.* 2001, Tietenberg 1996, and Mooney 1977).

[6] Note that only first and second order streams were included owing to the current Sihlanzimvelo implementation model only being applicable in these contexts. Larger floodplains associated with third order streams and greater were considered to need an expanded management model. This expanded management model (including municipal land on all rivers in the municipal area, regardless of stream order classification) is covered in the Transformative Riverine Management scenario for municipal land.

populations densities per kilometre, lower management costs (in the case of Traditional Authority rivers) and the respective estimated river lengths. This analysis generated the respective costs, benefits and benefit cost ratios.

c. Note that all the preceding basic management estimates were based on annual costs and benefits as only annual maintenance costs are incurred.

3) Transformative Riverine Management BCA

a. **Defining transformative management assumptions:** The transformative riverine management approach was developed by estimating the capital and management costs of a suite of management and social interventions[7] for the Ohlanga Catchment. The capital costs were assumed to be incurred over a 10-year period, and the all the costs and benefits were modelled over a 20-year period. The net present value (NPV) of the costs and benefits were estimated for the catchment, and a benefit cost ratio calculated. Furthermore, the average NPV for costs and benefits per kilometre were calculated, and then upscaled for the all the municipal owned river length.

Note that in the transformative management models, the avoided costs to municipal culvert damage is kept the same as for the basic management as no additional infrastructure protection gains are anticipated over and above basic management or Sihlanzimvelo management interventions embedded in the transformative management scenario. However, the societal benefits associated with avoided service losses doubles in response to the transformative ecological and social investments.

b. **BCA:** The transformative management analysis model for the municipal land was then duplicated and adapted for the private owned land and the Traditional Authority owned land contexts, assuming fewer riverine management actions, lower riverine population densities, different river lengths (for small and large rivers), and importantly different municipal facilitation costs. Note that the downstream coastal users were kept at a constant level as the 2.2 million users per year for the Durban beachfront was assumed a given, irrespective of the number of upstream rivers.

A series of tables were produced to show both individual and comparative key values and benefit cost ratios.

[7] Identified by the eThekwini Municipality project management team, workshopped with riverine stakeholders, and costed by the FutureWorks team.

1. Current Sihlanzimvelo Programme BCA

Quantify the benefits and costs of the existing Sihlanzimvelo Programme	Adapt the current benefits and costs in response to anticipated climate change	Model ecosystem services changes for climate change, basic and transformative management scenarios	Value changes to ecosystem services in terms of human well-being and productivity for each scenario	Conduct a BCA of the Sihlanzimvelo Programme, highlighting both financial benefits to the municipality and economic benefits for the catchment community

2. Basic Riverine Management Scenarios BCA

Upscale the current programme for the management of all rivers on municipally owned land and conduct a BCA	Identify municipal actions necessary to facilitate river management on private and iNgonyama Trust land	Adapt the municipal basic river management programme for the management of rivers on private owned land and conduct a BCA	Adapt the municipal basic river management programme for the management of rivers on iNgonyama Trust owned land and conduct a BCA

3. Transformative Riverine Management Scenarios BCA

Identify and cost transformative river management actions for a model Ohlanga social and ecological river management plan	Calculate the average management costs, capital costs and social investment costs per kilometre of river	Calculate the additional benefits of transformative management to riverine and downstream ecosystem services users	Adapt the model river management actions, costs and benefits for implementation on i) municipal, ii) private and iii) Ngonyama Trust land	Calculate the Net Present Value of municipal and other land owner costs, municipal avoided losses (as benefits), societal avoided losses or gains and the respective BCA ratios for the three ownership regimes

Figure 2: Summary of the three-step Benefit Cost Analysis process

2.3 Costs

The known operational costs of implementing the existing Sihlanzimvelo Programme[8] on 450km of first and second order streams is outlined in Table 1.

Table 1: Summary of Sihlanzimvelo costs and jobs generated

Annual operational costs		
Annual co-op management costs per 1km of river	R	6 178
Total annual cost per co-op (each managing 5km of river)	R	392 280
Total annual cost to manage 1km of river	R	78 456
Total annual operational costs (over 450km of river) including annualised start up	R	35 305 160
Jobs		
Average number of jobs per co-op (5km unit)		6.7
Jobs per 1km of river		1.3
Annual cost per job	R	58 842
Income to household per job	R	54 000

The assumed cost of transformative riverine governance at the municipal scale (i.e. the municipal role in coordinating a transformative riverine management programme) is outlined in Table 2.

Table 2: Assumed transformative riverine governance costs

City costs to implement transformative management - all ownership for 7004 km						
	Unit costs	**Number**	**Annual costs**	**Operating cost f**	**Operating cost**	**Total annual costs**
Strategic coodinator - policy level	R 1,382,400	1	R 1,382,400	0.3	R 414,720	R 1,797,120
Programme manager - implementation	R 1,382,400	1	R 1,382,400	0.3	R 414,720	R 1,797,120
Programme ecohydrologist / engineer	R 1,382,400	1	R 1,382,400	0.3	R 414,720	R 1,797,120
Catchment project managers	R 1,152,000	10	R 11,520,000	0.3	R 3,456,000	R 14,976,000
Programme M&E specialist	R 1,152,000	1	R 1,152,000	0.3	R 345,600	R 1,497,600
Total costs for 7004 km - all land ownership						**R 21,864,960**
Total costs per km						**R 3,122**
Assume 1/3 split between land ownership types per km						**R 1,030.19**
Total annual costs per year per ownership type						**R 7,215,437**

The representative cost of implementing a range of transformative riverine management actions (biophysical and social) in the Ohlanga River Catchment (as a model for other catchments in the municipal area) is outlined in Table 3.

[8] From Geoff Tooley and Mark Tomlinson, eThekwini Municipality Coastal, Stormwater and Catchment Management Department.

Table 3: Representative costs of transformative riverine management interventions in the Ohlanga River Catchment

Summary of biophysical Interventions		Capital costs
Invasive Alien Plant control programme	R	18 200 000
Revegetation – indigenous vegetation restoration	R	7 000 000
Riverbank stabilisation - Gabions	R	10 000 000
River channel and bank stabilisation - riprap	R	6 300 000
Debris walls	R	3 240 000
Wetland rehabilitation	R	83 900 000
Wetland creation - stormwater ponds	R	4 125 000
Litter Booms	R	280 000
Litter Socks - Drains and Culverts	R	1 265 000
Groynes	R	1 170 000
Pocket Parks	R	13 000 000
Biophysical Interventions		**Annual costs**
River maintenance (294km)	R	23 066 038
Summary of social Interventions		**Annual costs**
School Programmes adopting up to 30 km of river	R	480 000
EnviroChamps for 25 informal settlements	R	1 800 000
Training and awareness	R	300 000
Treepreneurs	R	500 000
Municipal TRMP coordination and management unit (1/3 of total unit cost)	R	7 215 437

The costings for transformative riverine management interventions at catchment-scale, per land ownership type, in the Ohlanga River Catchment as a prototype for other catchments in the municipal area, are included in Annexures 1, 2 and 3.

2.4 Benefits

2.4.1 Sihlanzimvelo implementation benefits

Avoided monetary damages to municipal culverts

To estimate the benefits of riverine management, it was necessary to identify the ongoing monetary damages to municipal culverts in the Sihlanzimvelo project areas (which included the uMhlangane and Isipingo River Catchments). The ongoing damage costs constitute the baseline for estimating the value of river management interventions, which reduce damage costs. The monetary benefits of riverine management for the municipality are the value of the avoided damage resulting from interventions.

To establish the current baseline of damage costs, the following process was followed:

- Four culvert classes were identified, including two culvert types (single or multiple cell culverts) with two risk profiles (higher risk narrow culverts and lower risk wider culverts). The construction and maintenance costs of each of the 4 classes were identified.
- Three damage/frequency categories for each culvert class were identified, with each type expected to have:
  - minimal damage every year (e.g. 1 time a year),
  - moderate damage every few years (e.g. 1/3 times a year) and
  - major damage every 20 to 30 years (e.g. 1/25 times a year).
  - In total, twelve damage categories were identified, and each of their respective costs of repair and reconstruction were estimated.
- Note that damage costs were annualised, that is, converted to annual costs to account for the randomness of flood events within catchments and as the Sihlanzimvelo project operates on an annual maintenance basis (with no capital costs).
- The four culvert classes were then assigned three types of annual damage costs, which were summed to provide an annual total damage cost per culvert type.
- The 91 culverts within the 450 km of rivers in the uMhlangane and Isipingo catchments, were then categorised into the four culvert classes numbers (using a municipal database), and the annual damage costs were modelled.
- To account for future climate change with an elevated storm intensity (20%), the annual frequency of culvert damage was increased by 10% for low damage class, and 5% for both moderate and high damage classes.
- The estimated damage costs for a ‘do nothing’ scenario and a Sihlanzimvelo management scenario are outlined in Table 4.

Table 4: Annual culvert damage costs in two scenarios

Do nothing scenario (with climate change)		
Annual damage costs per culvert	**High risk**	**Low risk**
Single cell – individual damage costs	R382 080	R 166 773
Multi cell - individual damage costs	R853 891	R 395 745
Annual damage costs per culvert type	**High risk**	**Low risk**
Single cell damage costs[9]	R 8 023 680	R 9 339 307
Multi cell damage costs[10]	R 9 392 796	R 1 187 236
Total damage costs – all 4 categories for 91 culverts		**R 27 943 018**
Sihlanzimvelo management scenario (with climate change)		
Annual damage costs per culvert	**High risk**	**Low risk**
Single cell individual damage costs	R 58 817	R 32 268
Multi cell individual damage costs	R 177 125	R 92 856
Annual damage costs per culvert type	**High risk**	**Low risk**
Single cell damage costs	R 1 235 153	R 1 807 030
Multi cell damage costs	R 1 948 373	R 278 569
Total damage costs		**R 5 269 125**
Annual damage avoidance with Sihlanzimvelo		**R 22 673 893**

Note that the total damage without management was estimated to be R27.9 million, whilst with management the damage declined to R5.3 million per year. This implies that current management generates avoided damage cost or savings of R22.7 million a year.

Avoided monetary damages to other infrastructure

The benefits of avoided damage to culverts is only a partial estimate of municipal financial benefits as there are also benefits in terms of avoided damage to other municipal infrastructure associated with either the streams or the culverts. The protection of culverts through management of rivers prevents damage to other assets, such as:

- Municipal water pipes,
- Municipal roads,
- Municipal sewer pipelines, and
- Municipal electricity cables.

[9] In terms of single cell culverts, 21 high risk and 56 low risk culverts were present within the Sihlanzimvelo project area.
[10] In terms of multi cell culverts, 11 high risk and 3 low risk culverts were present in the project area.

In addition, riverine management prevents or limits damage to additional assets, such as:

- Beaches (from solid waste deposition),
- Port (from solid waste accumulation),
- Private or government communication cables, and
- Private properties, including buildings, driveways and walls/ fences.

In addition, the continuous monitoring of rivers ensures that any infrastructure failures are identified timeously and reported, avoiding delays in repairs and escalating costs to the municipality.

These additional benefits were not estimated as no data was available for analysis. The estimated avoided damage is therefore only a partial estimate.

2.4.2 Avoided loss of ecosystem services

Why use ecosystem services?

Whilst riverine management reduces flood damage to municipal culverts and other infrastructure, it also elevates flood reduction services, and several other services, to riverine communities living immediately adjacent to the rivers and to downstream communities or users, such as coastal residents, businesses and visitors.

Table 5 outlines the demand for a suite of river-related ecosystem services. The potential number of service users in the upper catchment (70 290 people) and middle catchment (51 480) were estimated by undertaking a count (using the Eskom Households Database 2009) of structures within a buffer area adjacent to the river and combined with average household size. Upper catchment river buffers were narrower (50 metres) than middle and lower catchment river buffers (100 metres) (see Annexure 4), accounting for the wider floodplains in lower catchment areas.

Coastal users of ecosystem services were estimated at 2.2 million in 2017[11]. Based on local knowledge (Patrick Martel and Gary De Winnaar) of the communities in the catchment and local built services' supply, the project team estimated the percentage of the users using each of the ecosystem services, to produce an estimated total number of beneficiaries[12]. However, the users may include people highly dependent on ecosystem services, such as poor households living immediately adjacent to the river and experiencing flooding, through to people which may only make use of the service for a few days a year for recreation purposes. Clearly, the benefits or value of these services to the individuals are very different. In order to generate a comparable number and to use a value to describe the benefits, the dependence of users was weighted to produce a set of 'full-time' beneficiaries that could be compared and assigned a common Human Capital Value. For example, one full-time user could be

[11] E. Vetrimurugan, V.C.Shruti, M.P.Jonathan, Priyadarsi D. Roy, N.W.Kunene, Lorena Elizabeth Campos Villegas. (2017). Metal concentration in the tourist beaches of South Durban: An industrial hub of South Africa. Marine Pollution Bulletin. 117. 10.1016/j.marpolbul.2017.02.036.

[12] Due to Covid-19, no direct stakeholder participation in workshops was possible and the expertise of team members and municipal officials were used to gauge user needs and dependencies.

comparable to 10 part-time users, using a service for 1/10th of the year. A weighted benefit score is generated to produce a common index or indicator of users.

The BCA adopts the flood reduction service users as representative indicator of the number of human beneficiaries, as 100% of the river neighbours use these services and no coastal users use this service. This is the biggest group of exclusively riverine community users and is therefore a fair representative of total riverine ecosystem service user numbers.

In terms of coastal users, the water quality maintenance service users were adopted, as this represents an estimated 1.1 million service users, which when weighted suggests the number of full-time equivalent users could be 131 393. However, there are some riverine community users of this water quality maintenance service, which when excluded, provides an estimated indicator of some 125 832 coastal users.

The BCA uses 50 230 as an indicative number of riverine users and 125 832 as an indicative number for downstream coastal users.

Table 5: The demand for riverine ecosystem services in the uMhlangane River Catchment and on the associated coastline

	Total number of beneficiaries				Dependence				Weighted benefit score
	Upper catchment	Middle catchment	Coastal		% Very high dependence	% High dependence	% Moderate dependence	% Low dependence	
SERVICES	70 290	51 480	2 247 000	**Sub-total**	1	0.5	0.1	0.05	
Surface water supply	45%	35%		49 649	3%	10%	87%		8 291
Dry season flows	45%	35%		49 649	5%	20%	75%		11 171
Water quality maintenance	45%	35%	50%	1 173 149	2%	4%	50%	44%	131 393
Erosion & sediment reduction	10%	15%	20%	464 151	2%	4%	50%	44%	51 985
Flood reduction	100%	100%		121 770	25%	25%	25%	25%	50 230
Transport access	100%	100%		121 770	5%	10%	30%	55%	19 179
Food production	2%	3%		2 950	80%	20%			2 655
Bioenergy	1%	1%		1 218	100%				1 218
Solid waste capture	100%	100%	50%	1 245 270	2%	4%	8%	86%	113 320
Carbon capture and storage	100%	100%		121 770				100%	6 089
Refugia and nursery	0.5%	0.5%		609			100%		61
Recreation	30%	30%		36 531	2%	4%	8%	86%	3 324
Visual amenity / Elevated property values	100%	100%	30%	795 870	2%	4%	8%	86%	72 424
Biodiversity conservation	100%	100%		121 770	1%	2%	4%	93%	8 585

2.4.3 A indicator of the societal implications of changes to ecosystem services

Human Capital Approach

With respect to the determination of the economic benefits of investments in riverine management for public benefit, we applied the theoretical construct of the human capital approach – an approach often used with respect to the economic valuation of investments in ecosystem and public benefit services (Blignaut and Lumby 2004[13], Beli et al. 2001[14], Tietenberg 1996[15], and Mooney 1977[16]). This approach can be used within various contexts, such as in estimating the benefits of investing in a service that will avoid pre-mature death. In such avoided mortality cases the value of a human life is estimated as the discounted present value of that individual's earnings over the remainder of his or her expected life – or then the period between the expected and avoided death. A person's income becomes the proxy of his/her return on human capital, hence the name of the technique. The use of income as a monetary proxy to value human life is ethically controversial. Since the value of life obtained with this method is based on the statistical estimation of a change in the probability of death due to an environmental change, the monetary value derived by using this technique is the value of a "statistical life".

A second application is within the context of the monetary opportunity cost (forgone income) due to illness or morbidity. This requires a dose-response function that would be linked to the number of chronic illnesses due to the change in environmental quality and not only short-term illnesses. A third application is within the context of higher learning whereby people enhance their capabilities as producers and as consumers by investing in themselves. In this context there is an opportunity cost of waiting. Consequently, before being induced to wait, most of us would look for some compensation either in terms of a positive inducement now or in terms of a higher benefit in the future through the investment of time and money into study. In the final instance, and the application used herein, is the impact of an investment on the quality of life and/or well-being due to an investment, or, alternatively, the avoided inconvenience of not having the service due to the absence of the investment. In this case there are three important variables to consider in the calculation of the benefit of the investment, namely:

- The level of income: In this case we applied the Gross Geographic Product, or income per capita of the municipality as a reasonable proxy for the income of the residents, although personal disposable income could also have been used. This we kept constant for all the scenarios.

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[13] Beli, P., Anderson, J.R., Barnum, H.N., Dixon, J.A. and Tan, J-P. 2001. Economic Analysis of Investment Operations. Washington D.C.: World Bank

[14] Blignaut, J.N. and Lumby, A. 2004. Economic valuation. In Blignaut, J.N. and De Wit., M.P. Sustainable options. UCT Press.

[15] Mooney G.H. 1977. The Accounting or Human Capital Approach to Life Valuation. In: The Valuation of Human Life. Palgrave, London. https://doi.org/10.1007/978-1-349-03193-1_5.

[16] Tietenberg, T. 1996. Environmental and Natural Resource Economics. New York: Harper Collins.

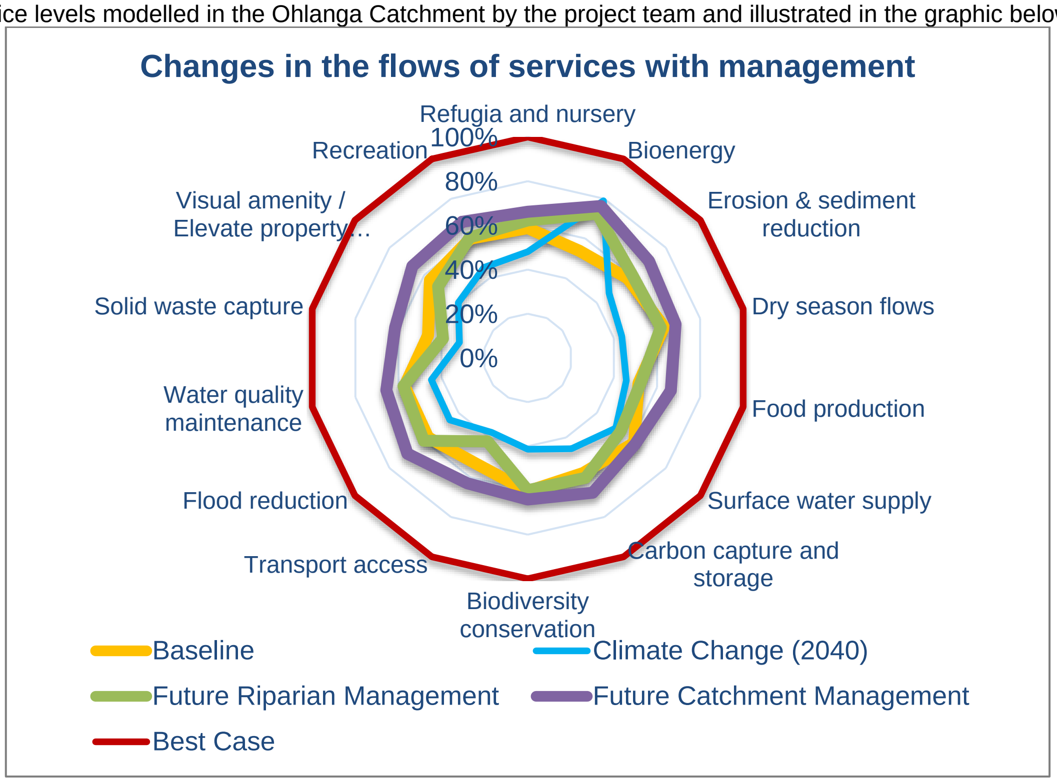
- Term or duration: We applied the period of inconvenience avoided (1 month) expected from the municipal investment in riverine management - as the duration of the benefit.

- Number of beneficiaries: We applied the number of beneficiaries of the intervention as the quantum of the number of people positively impacted because of the investment. This changes as per the scenario requirement.

In calculating an indicative monetary value for the changes in ecosystem services it was assumed that the Gross Geographic Product per capita for eThekwini (R75 547 for 2019[17]) reflected the value of individual productivity for a year (2019), and any changes to ecosystem service levels, such as transport access, reduced flooding, water quality maintenance, etc for a period of time, was assumed to reflect a corresponding loss in value to an individual.

Using an average 11% decline in ecosystem services (estimated through Eco-Futures modelling[18]), an 11% avoided decline in one month's GGP per capita was calculated for basic management. A proxy value for changes to ecosystem services for a month was calculated to be R693 per affected individual. One month was adopted as it reflects a conservative period to time for disruptions before repaired by individuals or the municipality. Similarly, using an average 21% avoided decline or gain in services, because of transformative riverine management, the individual and societal values were calculated for a month. See Table 6. The same method was used for estimating an indicative value for the coastal users. The loss of riverine ecosystem services within the catchment was estimated for riverine community users and coastal service users

[17] Personal communication, Denny Thaver, eThekwini Municipality Economic Development Unit.
[18] The 11% and 21% changes adopted for the changes in service levels was calculated from the average change in service levels modelled in the Ohlanga Catchment by the project team and illustrated in the graphic below.



by multiplying the respective weighted user numbers by the potential individual proxy losses.

Note the implications of ecosystem services supply interruptions or reductions for a greater period of time, such as six months, are significantly greater than for 1 month. The range of values highlights the benefits of preventive river management action, thereby avoiding possible greater costs if repairs are not timeously undertaken.

The basic management scenario could be considered a preventative action that maintains ecosystem service levels which would otherwise decline due to future climate change. This, however, includes little or no buffer against the effect of population growth and potential increased demand for ecosystem services.

The transformative or catchment scenario would not just avoid such losses but would grow the ecosystem service levels beyond the present level, to offer gains relative to the status quo and promote greater resilience. This scenario represents climate risk responsive, resilience-building opportunity.

Table 6: The proxy value of ecosystem service avoided losses or gains associated with basic and transformative river management

Gross geographic product (GGP) per capita[19] - eThekwini			R75 547
Avoided services loss due to basic river management			11%
Number people affected: Riverine community population (uMhlangane catchment)			50 230
Time period of impacts	1 week	1 month	6 months
Individual proxy value of avoided productivity loss relative to GGP per capita (per year)	R160	R693	R4 155
Societal proxy value of avoided productivity loss relative to GGP per capita	R8 027 305	R34 784 987	R208 709 920
Avoided services loss or gain due to transformative management			21%
Number people affected: Riverine community population (uMhlangane catchment)			50 230
Time period of impacts	1 week	1 month	6 months
Individual proxy value of avoided productivity loss or gain relative to GGP per capita (per year)	R305	R1 322	R7 932
Societal proxy value of avoided productivity loss or gain relative to GGP per capita	R15 324 854	R66 407 702	R398 446 210

Note that the change in the value to individuals doubles with transformative management. The benefits to riverine and coastal individual users is assumed to be similar.

2.5 Data & Scope Limitations

The study was undertaken between April and November 2020, during the peak of the COVID 19 pandemic and lockdown in South Africa. As a result, the professional team's ability to access data and workshop assumptions for the BCA was severely constrained. All engagements took place virtually, and data gathering with heavily delayed by office closures and municipal staff not being available to collate and share data.

[19] D. Thaver, Ethekwini Economic Development (from Global Insight 2019)

While some data had been collected by eThekwini Municipality on damage costs to municipal culverts, this dataset was not complete and required extensive modelling to be completed in order for it to be used in the BCA.

Furthermore, because the eThekwini Municipality has not collected data on damage costs to other kinds of municipal infrastructure as a result in changes in flooding / sedimentation and erosion patterns in eThekwini Municipality's rivers, the limited time and budget available for the study meant that it was not possible include those in the study. As such, only the damage costs associated with municipal culverts were included.

The above indicates that the BCA is highly conservative in its estimates of:

a) The anticipated cost of damage to municipal infrastructure in / near rivers with climate change; and

b) The value of avoided municipal infrastructure damages that could be achieved with implementation of riverine management.

The BCA model has been provided to eThekwini Municipality and it is recommended that it be further refined as more data becomes available on other kinds of municipal damage costs that could be incurred / avoided in relation to rivers and climate change.

3. RESULTS

3.1 Do Nothing Scenarios

A do-nothing scenario was modelled for each of the three landownership regimes, to provide a baseline for measuring management impacts. These scenarios include the impacts of climate change. The potential losses to the municipality and society are substantial and have been summed across all the different landownership regimes to provide an indication of total damage. See Table 7.

Note the following with regard to costs and benefit values in the BCA:

- The costs (for all landownership regimes) always relate to financial values (or market-based prices).
- The benefits relating to the municipality are always the financial value of avoided damage to culverts.
- The benefits to individuals and society are always indicative economic values.

Table 7: The do-nothing scenarios for rivers on municipal, private and Traditional Authority land

DO NOTHING SCENARIO	Municipal owned land	Private owned land	Traditional Authority land	Total for eThekwini
River management distance in kilometres[20]	1 168	1 350	2 611	5 129
Riverine management costs to residents[21]		R10 591 548		
Damage costs to municipal infrastructure[22]	**R72 527 656**	**R62 871 791**	**R16 213 160**	**R151 612 607**
Likely decline in ecosystem services (average of ecosystem services)	11%	11%	11%	
Number of people impacted (Full time equivalents) riverine[23]	130 375	37 673	29 145	197 192
Proxy wellbeing and productivity loss (for 1 month) to riverine community communities[24]	R90 286 365	R26 088 740	R20 183 072	R136 558 178
Total riverine societal value of loss - municipality & community	R162 814 021	R88 960 531	R36 396 233	R288 170 785
Number of people impacted (Full time equivalents) on the coast[25]	125 832	125 832	125 832	125 832
Proxy wellbeing and productivity loss to coastal users (for 1 month)[26]	R87 140 226	R87 140 226	R 87 140 443	R87 140 226
Total societal value of loss - municipality & community	R249 954 247	R176 100 757	R123 536 675	R375 311 011

The implication of these scenarios is that both the municipality and citizens could be exposed to significant costs in the future. Furthermore, several hundred thousand people will experience either productivity losses or well-being declines due to a reduction in riverine ecosystem services levels.

3.2 Basic Riverine Management Scenarios

The current Sihlanzimvelo costs and benefits were adapted and upscaled for the three different ownership regimes (see Table 8). Note that the municipal owned land scenario is based on Sihlanzimvelo estimates and is therefore robust, and the two other scenarios were derived from the municipal model, adopting significant assumptions and are therefore more speculative.

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20 1st and 2nd order streams only.
21 It is assumed that 10% of private landowners currently comply with legal requirements (especially alien plant management)
22 The average culvert damage costs per kilometre were calculated for the uMhlangane catchment and assumed as representative for all municipal rivers. Private land and Traditional Authority areas were assumed to have 75% and 10% respectively, of municipal owned land culvert damage costs per kilometre of river.
23 Municipal rivers were assumed to have 112 users per km (based on uMhlangane catchment estimates), private rivers some 28 users per km and Traditional Authority rivers some 11 users per km.
24 The number of users multiplied by the R693 productivity loss per person residing adjacent to the river.
25 The coastal users are kept constant at 125 832 (the weighted 2.2 million beach front users).
26 The number of users multiplied by the R693 productivity loss per river user.

Table 8: Basic Riverine Management scenarios for rivers on municipal, private and Traditional Authority land

BASIC RIVERINE MANAGEMENT SCENARIO – Annual[27] costs and benefits	Municipal owned land	Private owned land	Traditional Authority land	Totals for eThekwini
River management distance – 1st and 2nd order streams (in km)	1 168	1 350	2 611	5 129
Riverine management costs to municipality[28]	R91 636 504	R8 340 480	R4 839 332	104 816 316
Riverine management costs to third parties[29]	R0	R105 915 480	R102 424 192	208 339 672
Damage costs avoided to municipal infrastructure (culverts and roads)[30]	R58 851 349	R27 208 672	R16 213 160	102 273 181
Benefit cost ratio – to municipality (partial value – only for culverts)	**0.6**	**3.3**	**3.4**	**1**
Avoided decline in ecosystem services	11%	11%	11%	11%
Number of people impacted (Full time equivalents) riverine[31]	130 375	37 673	29 145	197 192
Proxy wellbeing and productivity avoided loss (for 1 month) to riverine community communities[32]	R90 286 365	R26 088 740	R20 183 072	R136 558 178
Total riverine societal value of avoided loss – municipality & community	R149 137 714	R53 297 412	R36 396 233	R238 831 358
Benefit cost ratio – riverine community, municipality & third party	**1.6**	**0.5**	**0.3**	**0.8**
Number of people impacted (Full time equivalents) on coast[33]	125 832	125 832	125 832	125 832
Proxy wellbeing and productivity avoided loss to society (for 1 month) to coastal users[34]	R87 140 226	R87 140 226	R87 140 443	R87 140 226
Total societal value of avoided losses – riverine community, municipality & coastal users	R236 277 940	R140 437 637	R123 536 675	R325 971 584
Benefit cost ratio – to broader society including municipality & third parties	**2.6**	**1.2**	**1.2**	**1**
Number of jobs created[35]	1 557	1 800	1 741	5 098
Number of potential cooperatives created [36]	234	270	261	765

[27] Note these are annual costs as no capital costs are involved and the table therefore represents an annual cycle.
[28] The costs for municipal owned river management are based on the Sihlanzimvelo programme operational, start-up and organisational management costs per kilometre. The municipal costs associated with leveraging private land river management are associated with law enforcement (directly or indirectly by other government agencies), facilitation, incentives and support to special rating areas. The municipal costs associated with Traditional Authority land river management are assumed to be 30% of Sihlanzimvelo management costs and are associated with fund raising and facilitation.
[29] The river management costs to the private sector are assumed to be the same as for Sihlanzimvelo per km, but with only 50% of residents compliant in 5 years after project start. The Traditional Authority costs are assumed to be 50% of Sihlanzimvelo costs per km due to less pressure on the river system and assumes that fund raising for management is successful.
[30] The average avoided culvert damage costs per kilometre were calculated for the uMhlangane catchment and assumed as representative for all municipal rivers. Private land and Traditional Authority areas were assumed to have 75% and 10% respectively, of municipal owned land avoided culvert damage costs per kilometre of river. Note that not all damages are averted, with an average residual damage of R11 709 per km per year for the uMhlangane catchment.
[31] Estimated number of people directly associated with the river ecosystem services.
[32] The number of users multiplied by the R693 productivity loss per river user.
[33] The coastal users are kept constant at 125 832 (the weighted 2.2 million beachfront users).
[34] The number of users multiplied by the R693 productivity loss per river user.
[35] The job numbers on based on the Sihlanzimvelo job intensity per kilometre (1.3 per km) and the river length for the respective landownership regimes.
[36] Based on the average number of persons employed by cooperatives (6.7 person per co-op) in the Sihlanzimvelo programme.

Implications for municipal land

- A R1.00 investment into basic river management generates a R0.60 benefit in terms of avoided culvert damage costs. Note this represents a conservative value as municipal water, sewer and road damage have not been included.
- The existing Sihlanzimvelo Programme benefits both municipal cost savings and vulnerable riverine communities' well-being to a similar value. When combining the two benefit values, a R1.00 municipal spend generates R1.60 benefits to society (including the municipality). The basic management scenario generates greater societal benefits (as human well-being) than municipal costs when the riverine users are included.
- While basic riverine management benefits riverine low-income households, it also significantly benefits the downstream users – with the same actions (i.e. with no extra costs), generating a R2.60 in societal benefit for a R1.00 spend.

Implications for private land

- The municipality and broader society could make significant gains if the municipality is able to leverage riverine management by private landowners.
- In this scenario, the avoided losses to private landowners does not offset their management costs. For example, a private landowner spend of R1.00 could produce as little as R0.25 benefit to themselves. Current costs to private landowners may be too high to generate the investment necessary to unlock public good.
- The challenge is to identify and develop the necessary incentives for effective private land management to unlock private and public benefits. For example, the avoided losses could escalate significantly from R693 to R4 155 per person, should a reduction in service level supply extend from 1 month to 6 months. Greater private landowner investment in riverine management, that specifically targets riverine threats, could be prudent action to avoid escalating future costs, thereby insuring against greater future losses. Special Rating Areas have emerged to deal with similar issues[37].
- The benefits to society when including the coastal users, does offset the management costs. This could present an opportunity for cost sharing or a Payment for Ecosystem Services system, between the municipality, private landowners, and coastal users (such as property and tourism sectors). For example, a coastal hotel bed levy could co-finance upstream management by a cost-effective non-profit management agency or cooperative.

Implications for Traditional Authority land

- Attaining the benefits in this scenario assumes that the municipality facilitates large-scale third-party investment into riverine management.

[37] Brian Wright personal communication.

- Riverine benefits are relatively lower compared with other ownership regimes due to small dispersed resident populations.
- Downstream and coastal benefits are comparable to other scenarios, which implies effective upstream management for broader societal benefits may be a necessary investment.
- Modelling suggests that neglect of upstream rural rivers could result in significant declines in downstream ecosystem services[38], with associated productivity and wellbeing losses to downstream users.

Implications for eThekwini Municipality and associated society

- The number of people affected (to a greater or lesser degree) by river management, both riverine and on the coast, is likely to be between 2million to 3million people per year or at least 50% of the population within the eThekwini Municipal Area. This user population, when condensed into 'fulltime equivalent users', using a weighted index, implies that some 320 000 people (or 8% of the eThekwini Municipality population) could be highly dependent on the river services.
- From a municipal perspective, if the municipality can effect management through its own direct investment in management and through investment in leveraging third party river management, then the financial costs equal the financial benefits.
- The Benefit Cost ratio for societal spend on basic river management indicates that benefits broadly equal costs, but the private and Traditional Authority landowners may not gain sufficient benefits to offset costs. This implies there is a need to facilitate cost sharing, especially between coastal users, upstream river landowners and the municipality. The financial potential gains for the municipality warrant investment into both direct river management on its own land and facilitating management on private and Traditional Authority land.

3.3 Transformative Riverine Management Scenarios

Transformative river management interventions were identified, applied spatially, ecologically and socially in the Ohlanga River Catchment (a model catchment for the municipal application) and then costed. This provided a model set of costs which could then be adapted and applied to the three ownership regimes (see Annexures 1,2 and 3). Table 9 outlines the estimates and Table 10 compares the Benefit Cost ratios.

The costs include basic management costs, ecological restoration costs, social development costs and a Transformative River Management Programme

[38] An additional 'upper catchment neglected' scenario was modelled for the Ohlanga Catchment using the Eco-Futures process, and showed that the 11% avoided loss associated with river management, could be curtailed to only a 3% avoided loss, implying that the upper catchment plays a critical role in downstream river functionality and services supply.

Management Unit[39] cost. The benefits included both avoided damage costs to municipal culverts and societal benefits through access to ecosystem services. Note that in the transformative management scenarios, the avoided damages to culverts remains the same as for basic river management scenarios, but the human benefits double in comparison.

Unlike the basic management model, which only operates on annual costs and benefits, the transformative model includes capital investments over 10 years, and is therefore modelled over a 20-year period. The net present value (NPV) of management costs and municipal benefits are discounted by 6%. However, the NPV of societal benefits accruing from river management are modelled using a two discount rates, 6% and a negative discount rate of -1%, to provide two perspectives on societal benefits. Conventional discounting would employ the 6% in South Africa. However, investing in natural capital, which does not depreciate with use as with built infrastructure, escalates in value as population grows and demand greater levels of services. For example, the value to beach users does not decline with use as the consumption is not competitive (as it would be with fishing for food). In this case, a -1% discount rate is employed to reflect a 1% to 2% increase population, to show an alternative perspective to societal value. The real value is likely to lie between the alternative values.

[39] The TRMP unit is assumed for BCA purposes to consist of 14 staff, including a strategic policy coordinator, a programme implementation manager, a programme ecohydrologist / engineer, 10 catchment project managers, and a programme monitoring and evaluation specialist.

Table 9: Transformative River Management scenarios for rivers on municipal, private and Traditional Authority land

TRANSFORMATIVE MANAGEMENT SCENARIO - discounted costs and benefits over 20 years	Municipal owned land	Private owned land	Traditional Authority owned land
River management distance - in kilometres[40]	1 592	1 852	3 560
Net Present Value (NPV) Costs - social discount rate 6%			
Municipal costs for leverage, facilitation and enforcement (regarding private and NT land)[41]		R153 121 282	R117 746 950
Capital costs - Municipality[42]	R673 424 758		
Capital costs - Private landowners & third parties[43]		R524 951 199	R251 235 320
Management and social costs – municipality, private landowners & third parties[44]	R2 072 055 612	R1 889 121 857	R1 803 178 801
Total costs	R2 745 480 370	R2 567 194 338	R2 172 161 071
Net Present Value (NPV) Benefits - social discount rate 6%			
Benefits to municipality (discount rate 6%)[45]	R920 061 967	R802 742 507	R205 742 500
Proxy benefits to riverine community users (discount rate 6%)[46]	R2 284 808 795	R664 488 990	R510 924 580
Proxy benefits to coastal users (discount rate 6%)[47]	R6 962 268 796	R8 099 322 745	R7 784 446 267
Net Present Value (NPV) Benefits - social discount rate of -1% for users			
Proxy benefits to riverine community users (discount rate -1%)	R4 707 992 317	R1 369 221 384	R1 052 792 252
Proxy benefits to coastal users (discount rate -1%)	R14 346 193 025	R16 689 164 248	R16 040 341 447
Jobs - construction for 10 years	723	720	773
Jobs - maintenance yearly	2 123	2 469	2 373
Number of potential cooperatives	318	370	356

[40] This includes large and small rivers.
[41] Costs are based on the basic management municipal costs per kilometre associated with leveraging private land river management and Traditional Authority land river management.
[42] A comprehensive suite of municipal investments into ecological infrastructure (such as wetland establishment) were identified and costed, and implemented in the first 10 years of the scenario's project term.
[43] The private landowner capital costs were reduced in comparison to the municipal spend. Traditional Authority land investments were much smaller given the relatively intact natural assets.
[44] Management costs included a TRMP management unit (R22m per year split equally between the three ownership regimes) and the basic riverine management costs. Social costs include a significant investment into capacity building, river monitoring and entrepreneur development.
[45] Exclusively avoided damage to culverts, representing a conservative value.
[46] Values based on the numbers of users per km of river and a 21% change in avoided and/or gain in productivity or wellbeing (R1 322 per person per year). Note this change is double that of basic management. TRMP (as opposed to basic management) doubles the gains to society.
[47] The coastal user values are kept constant at 125 832 (the weighted 2.2 million beach front users) multiplied by the R1 322 per person per year.

Table 10: A comparison of Benefit Cost ratios for the different transformative river management scenarios on municipal, private and Traditional Authority land

TRANSFORMATIVE RIVERINE MANAGEMENT Benefit Cost Ratios	Municipal Land	Private Land	Traditional Authority Land	Implications
BCR for municipal benefits and costs (discount rate 6%)	**0.3**	**5.2**	**1.7**	Private land performs best as municipal actions leverage large scale management. Justifies facilitation and developing incentives.
BCR for societal benefits and costs to riverine community users (discount rate 6%)	**0.8**	**0.3**	**0.2**	Municipal land performs best for riverine users as relatively greater numbers of vulnerable people benefit from management. Justifies preventative expenditure as coastal users would improve this ratio without additional costs. The weak performance of private and Traditional Authority land may justify some form of cost sharing facility.
BCR for societal benefits and costs to coastal users (discount rate 6%)	**2.5**	**3.2**	**3.6**	Traditional Authority land performs best as large numbers of coastal (and downstream users) benefit from the relatively lower management costs per km (as the rivers are already in good condition). The good returns and lower costs justify maintenance management.
BCR for municipal and societal benefits and costs (discount rate 6%)	**1.8**			
BCR for municipality and riverine community benefits and costs (municipal benefits and all costs at 6% SDR[48], societal benefits at -1% SDR)	**1.71**	**0.53**	**0.48**	Even with escalated service values, the weak performance of private and Traditional Authority land indicates unfavourable returns to landowners or third-party management costs due to low riverine user numbers. The actions' objectives need to focus on broader societal benefits and may necessitate a cost sharing facility such as payment for ecosystem services.
BCR for coastal users benefits and costs (municipal benefits and all costs at 6% SDR, coastal benefits at -1% SDR)	**5.23**	**6.50**	**7.38**	When all catchment and coastal beneficiaries are included, with escalated service values, all landownership types perform similarly well. A growing population with a growing demand for ecosystem services, justifies preventative investment into management.
BCR for municipal and societal benefits and costs (discount rate 6% for costs and municipal benefits, and minus 1% for benefits to riverine community and coastal users)	**3.4**			

[48] Social Discount Rate.

Implications for municipal land

- The NPV of management and social development costs are 3 times greater than capital costs.
- Municipal financial costs are 3 times greater than the direct financial municipal savings generated, with a Benefit Cost ratio of 0.3, implying R1.00 buys a R0.30 benefit.
- Societal gains are significant for both riverine and coastal users and are delivered simultaneously through single actions.

Implications for private land

- As with the basic management scenario, if the municipality can facilitate effective private land management, then both the municipality and broader society can benefit significantly.
- However, the value of benefits to the riverine private landowner community is lower than in the municipal owned land scenario, due to lower numbers of users per km of river.
- As with the basic management scenario, broader society is better off with transformative management, but for private landowners, management costs exceed the benefits. Consequently, a mutually beneficial partnership may need to be developed between private landowners, the municipality and the coastal users to foster higher levels of river management, that also benefits broader society.

Implications for Traditional Authority land

- As in the private landowner scenario, the downstream beneficiaries have an incentive to support upstream management, given the risk of future ecosystem service declines. A basis for a Payment for Ecosystem Services facility is present. However, this facility will only function in so far as the desired ecosystem service levels are delivered to the paying users.

Summation of all land ownership scenarios

The costs and benefits (NPVs) of the different scenarios were summed to provide indicative values of transformative riverine management across the entire eThekwini Municipal Area. See Table 11.

Table 11: Summation of all land ownership regimes' NPV costs, NPV benefits and benefit cost ratios

TRANSFORMATIVE MANAGEMENT SCENARIO - discounted costs and benefits over 20 years	Entire eThekwini Municipal Area		Benefit Cost ratio
River management distance - in kilometres	7 004		
Net Present Value (NPV) Costs - social discount rate 6%			
Municipal costs for leverage, facilitation and enforcement	R	270 868 232	
Capital costs - Municipality	R	673 424 758	
Capital costs - Private landowners & third parties	R	776 186 519	
Shared management and social costs – all landowners & third parties	R	5 764 356 270	
Total costs to society	R	7 484 835 779	
Net Present Value (NPV) Benefits - social discount rate 6%			
Benefits to municipality (discount rate 6%)	R	1 928 546 974	0.6
Proxy benefits to riverine community users (discount rate 6%)	R	3 460 222 365	0.5
Proxy benefits to coastal users (discount rate 6%)	R	8 099 322 745	1.1
Net Present Value (NPV) Benefits - social discount -1% for users			
Proxy benefits to riverine community users (discount rate -1%)	R	7 130 005 952	1.0
Proxy benefits to coastal users (discount rate -1%)	R	16 689 164 248	2.2
Jobs - construction for 10 years	2 215		
Jobs - maintenance yearly	6 965		
Number of potential cooperatives	1 045		

- The municipality and private landowners could gain R0.60 and R0.50 respectively for their R1.00 invested in management.
- Coastal users benefit significantly with little or no costs, and it may be prudent for them to offer cost sharing to secure long term access to desired ecosystem services.
- Private landowners may wish to invest in management to avert future escalations in ecosystem service loss and associated risk.
- The municipality may wish to invest in management to avert future escalation in ecosystem services loss to vulnerable communities, and escalating damage costs to municipal infrastructure.
- An escalating value in ecosystem services is likely with population growth.
- Preventative actions generate systemic benefits to both poor and better off communities and would also benefit both the informal and formal economies.
- A significant number of jobs and cooperatives could be generated, with the additional jobs contributing to a greater Gross Geographic Product in eThekwini. The increasing number of cooperatives could contribute to entrepreneurship in the municipality.

ANNEXURE 1: MUNICIPAL COSTS OF TRMP IN THE OHLANGA CATCHMENT[49]

Municipal costs for the Ohlanga Proto-plan								
	Unit	Cost per unit	No. of units	Total costs	Ave unit	Annual costs	Once off costs	Replacement term in years
Biophysical Interventions								
IAP control programme								
Upper	Ha	R65 000	60	R3 900 000			R3 900 000	
Middle	Ha	R65 000	120	R7 800 000			R7 800 000	
Lower	Ha	R65 000	100	R6 500 000			R6 500 000	
Revegetation				R0			R0	
Upper	Ha	R25 000	60	R1 500 000			R1 500 000	
Middle	Ha	R25 000	120	R3 000 000			R3 000 000	
Lower	Ha	R25 000	100	R2 500 000			R2 500 000	
River bank stabilisation - Gabions				R0			R0	
Upper	m3	R8 000	250	R2 000 000			R2 000 000	10
Middle	m3	R8 000	1000	R8 000 000			R8 000 000	10
River channel and bank stabilisation - riprap				R0			R0	
Upper	Ha	R7 000 000	0.5	R3 500 000			R3 500 000	10
Middle	Ha	R7 000 000	0.3	R2 100 000			R2 100 000	10
Lower	Ha	R7 000 000	0.1	R700 000			R700 000	10
Debris walls				R0			R0	
Upper	Ha	R360 000	2	R720 000			R720 000	
Middle	Ha	R360 000	3	R1 080 000			R1 080 000	
Lower	Ha	R360 000	4	R1 440 000			R1 440 000	
Wetland rehabilitation	Ha			R0			R0	
Upper (34 wetlands)	Ha	R350 000	74	R25 900 000	2.2		R25 900 000	
Middle (14 wetlands)	Ha	R225 000	53	R11 925 000	3.8		R11 925 000	
Lower (61 wetlands)	Ha	R475 000	97	R46 075 000	1.6		R46 075 000	
Wetland creation (stormwater ponds)	Ha			R0			R0	
Upper	Ha	R165 000	15	R2 475 000			R2 475 000	
Middle	Ha	R165 000	10	R1 650 000			R1 650 000	
Litter Booms				R0			R0	
Upper	Number	R35 000	1	R35 000			R35 000	3
Middle	Number	R35 000	3	R105 000			R105 000	
Lower	Number	R70 000	2	R140 000			R140 000	
Litter Socks for Drains and Culverts				R0			R0	3
Upper	Number	R115 000	8	R920 000			R920 000	
Middle	Number	R115 000	3	R345 000			R345 000	
Groynes				R0			R0	
Middle	Number	R585 000	1	R585 000			R585 000	
Lower	Number	R585 000	1	R585 000			R585 000	
Pocket Parks				R0			R0	
Upper	Number	R6 500 000	1	R6 500 000			R6 500 000	
Middle	Number	R6 500 000	1	R6 500 000			R6 500 000	
Social Interventions				R0				
School Programmes adopting up to 30 km of river				R0				
Primary	Schools	R10 000	23	R230 000		R230 000		
Secondary	Schools	R25 000	10	R250 000		R250 000		
EnviroChamps selected from up to 25 informal settlements				R0		R0		
Training	People	R10 000	30	R300 000		R300 000		
Monitoring of leaks, solid waste, IAPs, river health, etc.	People	R50 000	30	R1 500 000		R1 500 000		
Training and awareness				R0		R0		
Private business	People	R15 000	10	R150 000		R150 000		
Ward Councilor training, CBOs	People	R15 000	10	R150 000		R150 000		
Other				R0		R0		
Tree preneurs	People	R50 000	10	R500 000		R500 000		
Municipal TRMP coordination and management unit	Unit	R21 864 960	0.33	R7 215 437		R7 215 437		
				Total costs		**Annual costs**	**Once off costs**	
Totals				**R158 775 437**		**R10 295 437**	**R148 480 000**	

[49] Excludes Sihlanzimvelo implementation costs.

ANNEXURE 2: PRIVATE COSTS OF TRMP IN THE OHLANGA CATCHMENT[50]

Private Landowner costs for the Ohlanga Proto-plan							
	Unit	Cost per unit	No. of units	Total costs	Annual costs	Once off costs	Replacement term in years
Biophysical Interventions							
IAP control programme							
Upper	Ha	R65 000	60	R3 900 000		R3 900 000	
Middle	Ha	R65 000	120	R7 800 000		R7 800 000	
Lower	Ha	R65 000	100	R6 500 000		R6 500 000	
Revegetation				R0		R0	
Upper	Ha	R25 000	60	R1 500 000		R1 500 000	
Middle	Ha	R25 000	120	R3 000 000		R3 000 000	
Lower	Ha	R25 000	100	R2 500 000		R2 500 000	
River bank stabilisation - Gabions				R0		R0	
Upper	m3	R8 000	0	R0		R0	10
Middle	m3	R8 000	0	R0		R0	10
River channel and bank stabilisation - riprap				R0		R0	
Upper	Ha	R7 000 000	0	R0		R0	10
Middle	Ha	R7 000 000	0	R0		R0	10
Lower	Ha	R7 000 000	0	R0		R0	10
Debris walls				R0		R0	
Upper	Ha	R360 000	0	R0		R0	
Middle	Ha	R360 000	0	R0		R0	
Lower	Ha	R360 000	0	R0		R0	
Wetland rehabilitation	Ha			R0		R0	
Upper (34 wetlands)	Ha	R350 000	74	R25 900 000		R25 900 000	
Middle (14 wetlands)	Ha	R225 000	53	R11 925 000		R11 925 000	
Lower (61 wetlands)	Ha	R475 000	97	R46 075 000		R46 075 000	
Wetland creation (stormwater ponds)	Ha			R0		R0	
Upper	Ha	R165 000	15	R2 475 000		R2 475 000	
Middle	Ha	R165 000	10	R1 650 000		R1 650 000	
Litter Booms				R0		R0	
Upper	Number	R35 000	0	R0		R0	3
Middle	Number	R35 000	0	R0		R0	
Lower	Number	R70 000	0	R0		R0	
Litter Socks for Drains and Culverts				R0		R0	3
Upper	Number	R115 000	0	R0		R0	
Middle	Number	R115 000	0	R0		R0	
Groynes				R0		R0	
Middle	Number	R585 000	0	R0		R0	
Lower	Number	R585 000	0	R0		R0	
Pocket Parks				R0		R0	
Upper	Number	R6 500 000	0	R0		R0	
Middle	Number	R6 500 000	0	R0		R0	
Social Interventions				R0			
School Programmes adopting up to 30 km of river				R0			
Primary	Schools	R10 000	23	R230 000	R230 000		
Secondary	Schools	R25 000	10	R250 000	R250 000		
EnviroChamps selected from up to 25 informal settlements				R0	R0		
Training	People	R10 000	30	R300 000	R300 000		
Monitoring of leaks, solid waste, IAPs, river healt	People	R50 000	30	R1 500 000	R1 500 000		
Training and awareness				R0	R0		
Private business	People	R15 000	10	R150 000	R150 000		
Ward Councilor training, CBOs	People	R15 000	10	R150 000	R150 000		
Other				R0	R0		
Tree preneurs	People	R50 000	10	R500 000	R500 000		
				Total costs	**Annual costs**	**Once off costs**	
Totals				**R116 305 000**	**R3 080 000**	**R113 225 000**	
Municipal TRMP coordination and managemen	Unit	R21 864 960	0.33	R7 215 437	R7 215 437	This value is not included in the costs to private sector but kept separate	

[50] Excludes Sihlanzimvelo implementation costs.

ANNEXURE 3: TRADITIONAL AUTHORITY COSTS OF TRMP IN THE OHLANGA CATCHMENT[51]

Tribal Authority costs for the Ohlanga Proto-plan							
	Unit	Cost per unit	No. of units	Total costs	Annual costs	Once off costs	Replacement term in years
Biophysical Interventions							
IAP control programme							
Upper	Ha	R65 000	220	R14 300 000		R14 300 000	
Middle	Ha	R65 000	0	R0		R0	
Lower	Ha	R65 000	0	R0		R0	
Revegetation				R0		R0	
Upper	Ha	R25 000	220	R5 500 000		R5 500 000	
Middle	Ha	R25 000	0	R0		R0	
Lower	Ha	R25 000	0	R0		R0	
River bank stabilisation - Gabions				R0		R0	
Upper	m3	R8 000	0	R0		R0	10
Middle	m3	R8 000	0	R0		R0	10
River channel and bank stabilisation - riprap				R0		R0	
Upper	Ha	R7 000 000	0	R0		R0	10
Middle	Ha	R7 000 000	0	R0		R0	10
Lower	Ha	R7 000 000	0	R0		R0	10
Debris walls				R0		R0	
Upper	Ha	R360 000	0	R0		R0	
Middle	Ha	R360 000	0	R0		R0	
Lower	Ha	R360 000	0	R0		R0	
Wetland rehabilitation	Ha			R0		R0	
Upper (34 wetlands)	Ha	R350 000	7.4	R2 590 000		R2 590 000	
Middle (14 wetlands)	Ha	R225 000	5.3	R1 192 500		R1 192 500	
Lower (61 wetlands)	Ha	R475 000	9.7	R4 607 500		R4 607 500	
Wetland creation (stormwater ponds)	Ha			R0		R0	
Upper	Ha	R165 000	0	R0		R0	
Middle	Ha	R165 000	0	R0		R0	
Litter Booms				R0		R0	
Upper	Number	R35 000	0	R0		R0	3
Middle	Number	R35 000	0	R0		R0	
Lower	Number	R70 000	0	R0		R0	
Litter Socks for Drains and Culverts				R0		R0	3
Upper	Number	R115 000	0	R0		R0	
Middle	Number	R115 000	0	R0		R0	
Groynes				R0		R0	
Middle	Number	R585 000	0	R0		R0	
Lower	Number	R585 000	0	R0		R0	
Pocket Parks				R0		R0	
Upper	Number	R6 500 000	0	R0		R0	
Middle	Number	R6 500 000	0	R0		R0	
Social Interventions				R0			
School Programmes adopting up to 30 km of river				R0			
Primary	Schools	R10 000	10	R100 000	R100 000		
Secondary	Schools	R25 000	5	R125 000	R125 000		
EnviroChamps selected from up to 25 informal settlements				R0	R0		
Training	People	R10 000	15	R150 000	R150 000		
Monitoring of leaks, solid waste, IAPs, river healtl	People	R50 000	15	R750 000	R750 000		
Training and awareness				R0	R0		
Private business	People	R15 000	0	R0	R0		
Ward Councilor training, CBOs	People	R15 000	5	R75 000	R75 000		
Other				R0	R0		
Tree preneurs	People	R50 000	5	R250 000	R250 000		
				Total costs	**Annual costs**	**Once off costs**	
Totals				**R29 640 000**	**R1 450 000**	**R28 190 000**	
Municipal TRMP coordination and managemen	Unit	R21 864 960	0.33	R7 215 437	R7 215 437	This value is not included in the costs to Ngonyama Trust but kept separate	

[51] Excludes Sihlanzimvelo implementation costs.

ANNEXURE 4: METHOD FOR DEFINING NUMBERS OF USERS OF RIVERINE ECOSYSTEM SERVICES

A river management zone was mapped for the Ohlanga Catchment using the 1 in 100 year floodplain (polygon) and river (line) GIS layers provided by the city (see Figure 3).

The rivers layer was classified into river orders according to the Strahler Stream Ordering method[52] whereby first-order rivers represent small, headwaters river systems located at the top of catchments. Where two first-order rivers join they become second-order rivers. River orders increase as more rivers of the same order number flow into each other (i.e. two second-order rivers produce a third-order river). Where two rivers with different stream orders join, the river downstream is given the higher of the two order numbers.

Once the river orders had been defined, the width of the 1 in 100 year floodplains of each were defined as follows:

- 5 m for second order,
- 10 m for third order,
- 20 m for fourth order; and
- 30 m for fifth order.

In addition, a riverine corridor was mapped for each river. The riverine corridors were mapped by buffering each of the rivers according to river order as follows:

- 5 m for first order,
- 10 m for second order,
- 25 m for third order,
- 50 m for forth order; and
- 100 m for fifth order.

These buffers were verified against aerial imagery. The assumed 1 in 100 year floodplain and riverine corridors were merged into a single GIS layer to represent the 'river management zone', which was used in the ecosystem services modelling. The final river management zone occupied 1,130 ha (or 14%) of the Ohlanga Catchment.

An additional buffer was applied to represent the users of riverine ecosystem services that are located adjacent to the river management zone. This **'riverine user zone'** was defined using a 50 m buffer of the river management zone for first- and second-order rivers, while a 100 m buffer was added to the river management zone for all higher order rivers. Other users of riverine ecosystem services not living in this zone were accounted for by using Umhlanga Tourism data on the annual average number of visitors to Umhlanga, which is 1,200,000.

In order to determine the demand for ecosystem services provided by the various types of land cover, 2011 point data representing dwellings was used to calculate the number of users residing in 'riverine user zone' in the upper, middle and lower parts

52 Strahler, A.N. (1957). *Quantitative analysis of watershed geomorphology. Transactions of the American Geophysical Union 38(6), 913-920*

of the catchment. The number of dwellings were verified using aerial imagery and scaled up to provide a more accurate number for the current (2020) scenario.

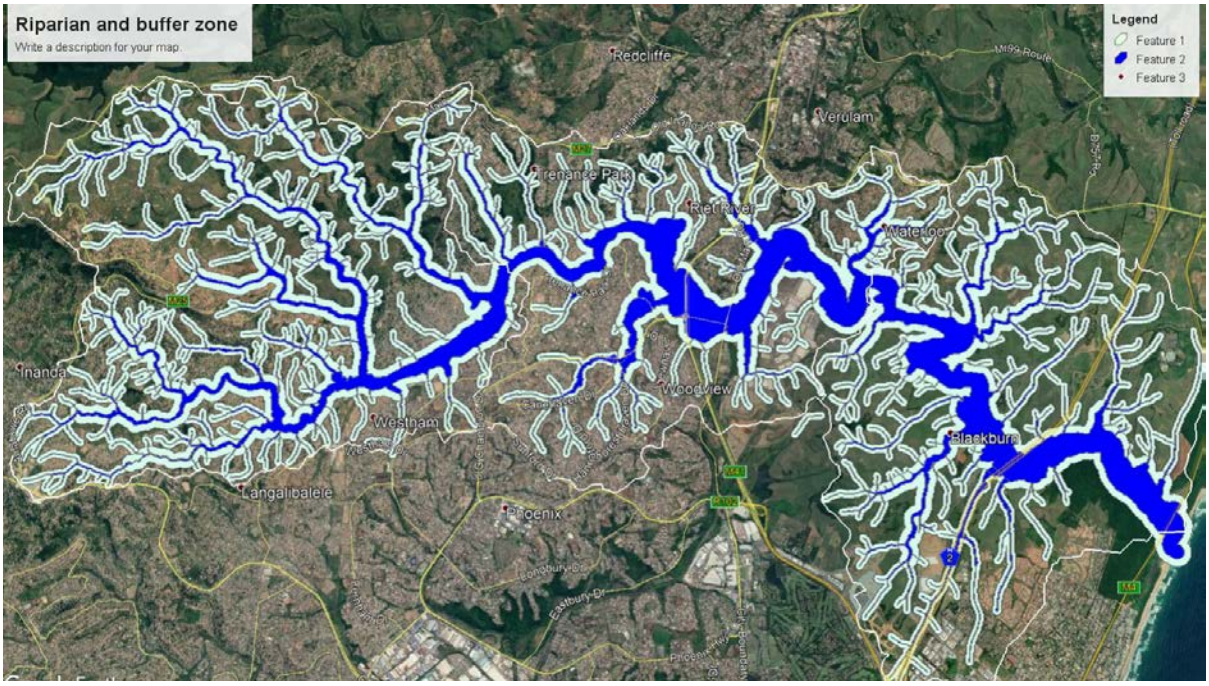

Figure 3: Map showing the riverine areas with associated buffers used in calculating numbers of users of riverine ecosystem services

A similar count was also undertaken for the areas within the uMhlangane River Catchment where the Sihlanzimvelo Programme is being implemented. Using these numbers of the ones from the Ohlanga Catchment, an average number of users of ecosystem services per kilometre of river could be established.

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