Socio-Economic Analysis of the Costs of inaction of plastic debris leakage into the uMngeni River catchment in KwaZulu-Natal, Durban, South Africa

Final report

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Final report

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PREFACE

The environmental, economic and social impacts of plastic pollution in fresh and marine waters are a matter of growing concern. This report builds on a costs-of-inaction-study, assessing social and economic costs of not dealing with plastic pollution in rivers and oceans. It is a result of Swedish and South African cooperation on environment and climate change, funded by the Swedish government and implemented by the Swedish Agency for Marine and Water Management (SwAM). Our findings provide a strong incentive for action, in line with the ambition of the recently endorsed UN-resolution to end plastic pollution. We argue that a holistic water management from source to sea is key to address pollution in fresh and marine waters.

SwAM is the responsible Swedish government agency tasked with protecting, restoring and ensuring sustainable use of freshwater and ocean resources, including fisheries management. However, far from all environmental problems can be solved by solely working nationally. Instead many challenges, such as plastic pollution and marine debris, are transboundary and needs to be solved through international cooperation. Therefore, in order for Sweden to achieve several of its environmental goals and international commitments, cooperation between countries becomes necessary. Our cooperation with the Oceans and Coasts (OC) branch of the South African Department of Forestry, Fisheries and the Environment is an illustration of how this can be realised in practice. OC deals with the promotion, management and strategic leadership on oceans and coastal conservation in South Africa and have been a partner to SwAM since 2015.

There are lessons to be learned for both Sweden and South Africa when it comes to challenges of dealing with plastic pollution. Marine litter is a global concern, not only because it wash up on beaches and look unsightly all over the world, but because debris can be transferred from one country to another via ocean currents. We know that litter and debris impacts commercial fisheries, human health, marine ecosystems and other ecosystem services. But to what degree? Which are likely scenarios we might face if not taking any action against plastic pollution? This study is an attempt to answer parts of these questions.

In March 2022, a historic resolution to end plastic pollution and forge an internationally legally binding agreement by 2024 was taken at the United Nation’s Environment Assembly. Time is short and we need to learn more about the consequences of not acting to reach an agreement that is approved globally. I hope this study can be one of the puzzle pieces needed to help the world design an effective and fair agreement to end plastic pollution.

Thomas Klein, Head of the Department of Environmental Analysis

SWEDISH SUMMARY

Översvämningarna i KwaZulu Natal i april 2022 belyste många av de sprickor i det institutionella och fysiska landskapet som utgör en stor del av den kris som konstaterats när det gäller regional plastförorening i denna miljö. Det var många rapporter och fotografier av tonvis med plastskräp som hamnade på stadens stränder som en följd av översvämningarna, och detta inför hela världens ögon! (BBC, 2022)

Över 440 personer rapporteras ha dött, nästan 4 000 bostäder förstördes och mer än 8 000 skadades, främst i Durban och dess omgivningar. Vatten- och elförsörjningen har störts allvarligt, liksom annan kommunal infrastruktur (vägar, broar, kommunikationer etc.).

Provinsens premiärminister (Sihle Zikalala) sägs ha sagt att skadornas omfattning kommer att uppgå till miljarder rand (Pijoos, 2022), och eThekwini-kommunen uppger att skadorna uppgår till minst 757 miljoner rand (Pijoos, Devastating KwaZulu-Natal floods may have cost eThekwini R757 million, 14).

Hur yttrar sig dessa institutionella och fysiska sprickor i fråga om plastfrågan, och hur avslöjades de i samband med denna översvämning?

För det första har många år av bristande funktionalitet och dålig service inom Durbans avfallshantering (och dålig hantering av plast i synnerhet) gjort det möjligt för en stor del av det plastavfall som hittats i floden och på stränderna att tydliggöras. De olika korruptionsanklagelser om avfallshanteringen som för närvarande är föremål för en brottsutredning visar också på den bristfälliga hanteringen avfallsfrågan på institutionell nivå och särskilt i lantliga områden och townships som drabbats hårdast av översvämningarna.

Som framgår av denna rapport finns det en stark koppling mellan dålig hantering av plast vid källan (i avrinningsområdet, på gatorna och i stads- och tätortsnära områden) som sedan hamnar i floderna. På vägen till den lägsta punkten i avrinningsområdet blockeras ofta många av de dåligt underhållna dagvattenavloppen (ofta med överflödig plast och annat skräp) och blir överfyllda. Detta gör att dagvatteninfrastrukturen inte längre är effektiv, vilket leder till större stormskador i de nedre delarna av avrinningsområdet, vilket var uppenbart vid de senaste översvämningarna.

När plasten väl har hamnat i floden och nu färdas nedåt i översvämmade flodsystem fastnar den dessutom i annat bråte, särskilt kring kulvertar, mindre broar och vägbroar. Öppningarna på dessa vägar, kulvertar och broar blockeras ofta av detta bråte, varav en stor del består av plast och annat skräp, och detta material leder till att broarna översvämmas och att den tillhörande infrastrukturen kollapsar. Detta har enorma konsekvenser för reparationskostnaderna för infrastrukturen.

På samma sätt sätter sviktande och överfyllda dagvattensystempress på avloppsinfrastrukturen, som ofta ligger i samma låglänta områden i avrinningsområdena, och som sedan översvämmas av dagvatten. Denna kaskadverkan och koppling leder i sin tur till att avloppsledningar och brunnar överbelastas och orenat avloppsvatten tränger ut i floder, flodmynningar och ut i havet. Detta har en enorm inverkan på uppfattningen om vattenkvaliteten och strändernas lämplighet för rekreation och därmed turism. I denna rapport betonas, och detta är en av de viktigaste slutsatserna, de ekonomiska kopplingarna mellan turismens värde på kommunal nivå (cirka 20 miljarder rand) och den potentiella minskningen av dessa turistintäkter, som främst beror på turismens minskade attraktionskraft på grund av turistområdenas försämrade estetik. Denna mindre uppenbara effekt av plastföroreningar och kopplingen till andra, mer uppenbara aspekter som vattenkvalitet är ofta inte tydlig förrän denna typ av landskapsanalyser görs.

UMngeni-flodens avrinningsområde är det största avrinningsområdet i eThekwini-kommunen och har ett betydande inflytande på andra system inom avrinningsområdet. År 2017 var dock flera av uMngeni-flodens bifloder i dåligt/mycket dåligt skick, medan huvudfloden rapporterades vara i måttligt ekologiskt skick. Det dåliga tillståndet i denna del av avrinningsområdet beror delvis på den stora mängden fast avfall som kommer in i floden - främst plast. Det finns bevis för att plastansamlingen i floderna inte bara är av estetisk karaktär utan också leder till föroreningar som förändrar flodens fysikalisk-kemiska egenskaper, orsakar blockeringar och stillastående vatten. Dessutom kan plastblockeringar orsaka att avloppssystemen svämmar över och leda till fekaliska föroreningar i flodsystemet.

Det försämrade tillståndet i uMngenis avrinningsområde har allvarliga konsekvenser för ekosystemets välbefinnande och flodernas och strändernas förmåga att förse samhället med ekosystem tjänster och produkter. Sydafrika har dessutom åtagit sig att uppfylla de mål för hållbar utveckling som fastställts av Förenta nationerna (FN). Lösningen på problemet med plastföroreningar måste bli en nationell prioritering - för att skydda människornas och miljöns välbefinnande (den främsta drivkraften för att leverera miljötjänster) och för att upprätthålla åtagandet gentemot FN och dess mål för hållbar utveckling.

I den studie som gjordes 2019 av Havs- och vattenmyndigheten (SwAM), Source-to-Sea, presenterades information om det senast kända tillståndet i området. Studien granskade relevanta aspekter för bra vattenförvaltning i KZN-provinsen, till exempel nyckelflöden, intressenter och styrning, tillsammans med information om plastens källor, spridningsvägar och effekter samt möjliga lösningar i avrinningsområdet. Dessa centrala aspekter inkluderades i den aktuella studien (2022).

Det huvudsakliga målet för SwAM-studien 2022 var att undersöka de sociala och ekonomiska konsekvenserna av att plastavfall samlas i uMngeni-flodens avrinningsområde och dess ekosystem (nedströms från Inanda-dammen).

"Sociala konsekvenser" omfattar hur plast påverkar följande:

- Människors hälsa (psykologiskt och fysiskt välbefinnande).
- Rekreation.
- Andliga värden.

"Ekonomiska konsekvenser" fokuserar på hur plast påverkar följande:

- Företags/industriers inkomster.
- Kostnader i samband med sanering av ekosystemen i undersökningsområdet.

I studien beaktas en rad olika scenarier runt plastavfallsproblemet och flera framtida utfall förutsägs, baserat på hur kraftfullt man agerar på problemet. Innovativa lösningar föreslås för att ta itu med de viktigaste frågorna.

Studiens huvudmetoder var följande:

- Intervjuer med intressenter och en analys av uppfattningar om plast i undersökningsområdet.
- Modellering av flödet av ekosystemens varor och tjänster inom systemet och de som påverkas av plast, och sedan
- Modellering av en rad troliga scenarier kring plastfrågan.

Onlineintervjuer genomfördes med nyckelintressenter som tidigare identifierats i SwAM-studien 2019. Alla intressenter hade, vilket är viktigt, interagerat med det berörda flod-/marinsystemet på någon nivå. Ett dokument med bakgrundsinformation (BID), som

tillhandahölls före intervjun, gjorde det möjligt för intressenterna att vara välinformerade före intervjuerna.

Intervjuerna syftade till att utveckla en förståelse för de socioekonomiska frågor som är förknippade med plastföroreningar. Intressenterna fick öppna frågor om sina uppfattningar om två nyckelfrågor - de sociala respektive ekonomiska kostnaderna i samband med plastavfall.

Intressenterna ansåg att plast påverkade negativt, främst när det gäller följande ekosystemtjänster:

- kulturellt (miljöns estetik, samhällets lycka, turismens attraktionskraft och andlighet),
- försörjning (intressenternas möjlighet att interagera med vattenmiljön på ett sätt som ger dem möjlighet att bedriva fiske och jordbruk) och
- stöd (försvagad kommunal infrastruktur som påverkas negativt av översvämningar).

I mötena med intressenterna framkom det att plastföroreningar är en del av en större uppsättning frågor som är förknippade med avfallshanteringssystemet. Intressenternas uppfattningar tyder starkt på att en sanering av plastavfallet skulle leda till en förbättrad livskvalitet för samhällena i det berörda området.

Plastförsörjningskedjan, plastens kostnader och plastens inverkan på ekosystemtjänsterna sammanfattades utifrån litteratur och opublicerade uppgifter från intressenterna. Syftet var att identifiera de rutter som plastprodukterna följde innan de hamnade i miljön som avfall - till exempel (men inte bara) rutter i bostadsområden, industriområden, rekreationsområden och vägar.

De främsta ekonomiska kostnaderna förknippade med plastföroreningar var följande:

- Kostnader för sanering av plast i miljön (främst för stränder och floder),
- Skador på kommunal infrastruktur,
- Minskade turistintäkter (som berodde på turistområdenas försämrade estetik),
- Hälsovårdskostnader och psykologiska kostnader,
- Förlust av rekreationsvärde och
- Minskning av fastighetsvärdet.

Det finns många, ofta inte uppenbara, men allvarliga negativa effekter av plastavfall som förvärras i miljön och påverkar andra aspekter av systemet. Dessa kan i detta sammanhang sammanfattas på följande sätt:

- Försämrade översvämnings och vattenkvalitetsproblem: Plast kan fastna i växtmaterial och skräp, vilket begränsar öppningarna i kulvertar och broar och minskar deras kapacitet vid översvämningar, vilket leder till översvämningar, högre översvämningsnivåer och därmed skador på den omgivande infrastrukturen.
- Plastavfall som tränger in i dagvatten- och avloppssystem orsakar blockeringar och fel i vatten- och sanitetsinfrastrukturen, vilket förvärrar effekterna av översvämningar och leder till att orenat avloppsvatten kan fyllas upp och förorena akvatiska ekosystem (floder, flodmynningar och den kustnära marina miljön).
- Plastavfall och patogener - Plastavfall kan vara en bärare av bakterier och skydda vattenburna patogener från de naturliga steriliserande effekterna av solens ultravioletta ljus och ytterligare förvärra fekal förorening.

Utbud och efterfrågan på ekosystemtjänster simulerades för en tioårsperiod med hjälp av ECOFUTURES-modelleringssystem. Geografiska och socioekologiska uppgifter om undersökningsområdet samlades in och sammanställdes i Microsoft Excel. Dessa uppgifter

användes också för att fastställa de relativa storlekarna av servicenivåerna, marktypen som tillhandahåller flest tjänster och de största nivåerna av tjänster per hektar.

Flera simuleringsscenarier utarbetades och delades med intressenter och lokala experter under en workshop som hölls den 10 mars 2022. Baserat på de insikter som erhölls under workshopen förfinades modellen till tre troliga framtidsscenarier - nämligen:

- Maximum (övre gräns för förbättrad nytta, upp till 60 % ökning av servicenivåerna),
- High Road (mest troliga lösning, mellan 0–30 % ökning av servicenivåerna) och
- Low Road-scenarier (inga förändringar/förbättringar görs, 20–80 % minskning av nuvarande servicenivåer).

Efterfrågan på tjänster fastställdes på grundval av Human Benefit Index (HBI), en parameter som rangordnar ekosystemtjänsterna i förhållande till den nytta som dessa tjänster genererar för människor. Resultaten visade en hög nivå av efterfrågan och beroende av tjänster som rörde Durbans turistindustri - till exempel marknadsföringsikon, strandrekreation och visuell upplevelse. På grund av den stora efterfrågan och det begränsade utbudet, är dessa tjänster också de tjänster som löper störst risk att drabbas av negativ påverkan.

Plastavfall har infiltrerat och stört viktiga ekologiska och urbana system, vilket har minskat deras förmåga att tillhandahålla varor och tjänster och därmed hotar välbefinnandet för intressenterna i undersökningsområdet. Traditionella lösningar, såsom deponier och förbränningsanläggningar, har dock begränsad kapacitet eller tenderar att generera avfall - och erbjuder därför tillfälliga lösningar på ett oundvikligt problem, vilket inte stämmer överens med målen för hållbar utveckling.

Därför krävs det innovativa lösningar, och för Durban föreslås scenariot High Road. I detta scenario föreslås flera kostnadseffektiva, hållbara lösningar. The Transformative Riverine Management Programme, TRMP, syftar till att rensa bort fast avfall och främmande vegetation från undersökningsområdet, med den extra fördelen att det främjar samhällets engagemang. Passiva fällor för fast avfall rekommenderas också som ett enkelt sätt att fånga upp och avlägsna plast från försörjningskedjan.

Olika sociala och institutionella insatser, till exempel utbildning av EnviroChamps, miljöprogram i skolor, medvetenhet om och utbildning om floder, rekommenderades också. Dessa åtgärder är inriktade på bristen på medvetenhet hos allmänheten och syftar till att ändra allmänhetens beteende till mer hållbara och plastmedvetna metoder. Slutligen syftar lösningar som pyrolys- och förgasningsenheter till att skapa en värdekedja för plast. Dessa lösningar genererar intäkter genom att förbruka plast för att producera användbara produkter, till exempel bränsle eller gas (som kan användas för energiproduktion) - vilket i praktiken skapar en avkastning på investeringar som kan finansiera andra åtgärder.

För att lösa problemet med plastavfall kommer det att krävas insatser för att införa nya, hållbara lösningar. Det nuvarande status quo har varit ineffektivt mot den fortsatta ansamlingen av plast i stadsmiljöer och ekologiska miljöer och kommer så småningom leda till en ohållbar situation. Detta kommer oundvikligen att leda till att de urbana och ekologiska tjänsterna misslyckas, vilket kommer att ha en negativ inverkan på människors och miljöns hälsa.

Ekonomiska kostnader för företag och branscher som är beroende av dessa tjänster kan förväntas, med de mest omfattande kostnaderna till följd av tillbakagången av Sydafrikas turistindustri - som bidrog med 125 miljarder rand till den sydafrikanska ekonomin 2016. Att lösa problemet med plastavfall ger dock också nya möjligheter till skapande av arbetstillfällen, kompetensutveckling och genomförande av långsiktiga, hållbara lösningar som genererar intäkter.

SUMMARY

The KZN (KwaZulu Natal) floods of April 2022 highlighted many of the fault lines and fractures over the institutional and physical landscape and which constitutes much of the crisis noted with respect to regional plastic pollution in this environment. There were numerous reports and photographs of tonnes of plastic litter which arrived on the city's beaches as an aftermath of the floods, and this for all the world to see! (BBC, 2022)

Over 440 people are reported to have died, with nearly 4,000 homes destroyed and more than 8,000 damaged, mostly in Durban and its surrounding areas. Water and electricity supplies were severely disrupted, along with other municipal infrastructure (roads, bridges, communications etc.).

The Premier of the province (Sihle Zikalala) is quoted as saying that the magnitude of the damage, will run into billions of rand (Pijoos, 2022), with the eThekwini municipality quoting at least R757million worth of damage (Pijoos, Devastating KwaZulu-Natal floods may have cost eThekwini R757 million, 14).

How do these institutional and physical fractures manifest in terms of the plastics issue, and how were they laid bare in this flooding?

For one, many years of dysfunctionality and poor service delivery within the Durban solid waste environment (and the mismanagement of plastics particularly) allowed much of the plastic waste found in the river and on the beaches to manifest. The various solid waste corruption charges currently under criminal investigation also allude the mismanagement of the solid waste issue at an institutional level and particularly in some of the more rural and township areas that have been most hard hit by the flooding.

As indicated in this report there is a strong link between poor plastic management at source (within the catchment, on the streets and within urban and semi urban areas) and which then finds its way into the rivers. Often on the way to the lowest point in the catchment, many of the poorly serviced stormwater drains are blocked (often with excessive plastic and other litter) and surcharge. This negates the efficacy of the stormwater infrastructure which then has a more significant storm damage effect in lower reaches of the catchment, and which was patently evident in the latest floods.

Additionally, once in the river and now travelling down flooded river systems, this plastic is caught up in other debris blocks and often particularly around culverts, smaller bridges and road causeways. The aperture on these causeways, culverts and bridges are often blocked with this debris, much of it from plastic and other litter and this material causes these bridges to become flooded and the associated infrastructure to fail. This has massive infrastructural repair cost implications.

Similarly, failing and surcharging stormwater systems puts pressure on sewerage infrastructure which is often in the same low-lying areas of catchments, and which is then inundated by stormwater. This cascading effect and linkage in turn causes the sewer lines and manholes to surcharge raw sewerage into rivers, estuaries and into the ocean. This has a massive impact on perceptions on water quality and suitability of the beaches for recreation and hence tourism perspectives. As this report highlights, this is one of the major findings, the monetary cost linkages between the value of tourism at the municipal scale (approximately R20billion) and the potential decline in this tourism revenue, stemming principally from a decrease in tourism appeal due to plastic diminishing aesthetics of tourist locations. These other, less obvious linkages between the effects of plastic pollution and other aspects around

things like water quality, are not often evident, until this sort of linkages and landscape analysis are made.

The uMngeni River Catchment is the largest catchment within the eThekwini Municipality and has a significant influence on other systems within the catchment. However, as of 2017, several of the uMngeni River tributaries were in poor/very poor condition, while the mainstem was reportedly in moderate ecological condition. The poor condition of this part of the catchment is partially attributable to the abundance of solid waste entering the river - primarily plastics. Evidence suggests that plastic accumulation in rivers is not only aesthetic in nature, but results in contamination, altering the Physico-chemical properties of the river, causing blockages and stagnating water. Furthermore, plastic blockages in sewer systems can result in overflow and exacerbate faecal pollution in river systems.

The decline in the health of the uMngeni catchment has dire consequences for ecosystem wellbeing, and the ability for rivers and beaches to provide goods and services. Furthermore, South Africa has committed to the Sustainable Development Goals (SDGs) set out by the United Nations (UN). The resolution of plastic pollution must become a national priority – to safeguard the wellbeing of humans and the environment (the primary engine for the delivery of environmental goods and services) and to uphold the commitment made to the UN and its SDGs.

The 2019 Swedish Agency for Marine and Water Management (SwAM) Source-to-Sea study provided information on the last known state of the study area. The study reviewed aspects relevant to good water management in the KZN province, such as key flows, stakeholders, and governance, along with information on the sources, pathways, and impacts of plastics and possible solutions in the catchment. These key aspects were incorporated into this current study (2022).

The primary objective of the 2022 SwAM study was to investigate the social and economic impacts associated with plastic waste accumulating in the uMngeni River Catchment and the catchment-derived ecosystems therein (downstream of the Inanda Dam).

“Social impacts” encapsulates how plastic affects the following:

- Human health (psychological and physical wellbeing),
- Recreation,
- Spiritual values.

“Economic impacts” focuses on how plastic affects the following:

- Businesses/ industries revenue generation,
- Costs associated with clean-up activities in the study area ecosystems.

Finally, this study considers a range of scenarios and predicts several future outcomes related to the plastic-waste problem, based on the level of response to this issue. Innovative solutions are proposed to tackle the main issues.

The methodology has at its core:

- Stakeholder interviews and an analysis of perceptions around plastics in the study area.,
- Modelling of the flow of ecosystems goods and services within the system, and those influenced by plastics, and then
- Running of a suite of likely scenarios around the plastics issue.

Online interviews were conducted with key stakeholders previously identified in the 2019 SwAM study. All stakeholders had, importantly, interacted with the affected river/marine system at some level. A Background Information Document (BID), provided prior to the interview, allowed stakeholders to participate in the interviews from an informed perspective.

The interviews were aimed at developing an understanding of the socio-economic issues associated with plastic pollution. Stakeholders were presented with open-ended question about their perceptions regarding two key issues - the **social** and **economic costs** associated with plastic waste, respectively.

Stakeholders primarily felt that plastic **negatively influenced** the:

- cultural (aesthetics of the environment, happiness of the community, tourist appeal, and spiritual practises),
- provisioning (ability for stakeholders to interact with the aquatic environment in a way that provides, such as fishing and agricultural activities) and
- supporting (municipal infrastructure negatively impacted by flooding and its attenuation) ecosystem services.

The stakeholder engagement process highlighted that plastic pollution is part of a larger set of issues associated with the waste management system. Stakeholder perceptions strongly indicated that clearing plastic waste would lead to an improvement in quality of life for stakeholders in the affected area.

The plastic supply chain, costs of plastic and impacts of plastic on ecosystem services was summarised from literature and unpublished data from the stakeholder engagement. This was aimed at identifying the routes that plastic products followed before ending up in the environment as waste – such as (but not limited to) routes in residential areas, industrial areas, recreational sites, and roads.

The primary monetary costs associated with plastic pollution were:

- the clean-up costs of plastic in environment (primarily for beaches and rivers),
- damage to municipal infrastructure,
- decline in tourism revenue (which stemmed from a decrease in tourism appeal due to plastic diminishing aesthetics of tourist locations),
- health and psychological costs,
- recreation value loss and
- decline of property value.

There are numerous, often not obvious, but perverse negative impacts from plastic waste which compound in the environment and affect other aspects of the system. These may be summarized in this context as:

- Aggravating flooding and water quality problems – plastic becomes entangled with plant material/debris, restricting the apertures on culverts/bridge infrastructure and reducing their flood design capacity, leading to back-flooding, higher flood levels and consequently damage to surrounding infrastructure.
- Plastic waste ingress into stormwater and sewer systems cause blockages and failures to water and sanitation infrastructure exacerbating the impacts from flooding as well as causing untreated sewage to surcharge and contaminate aquatic ecosystems (rivers, estuaries, and the near shore marine environment).

- Plastic waste and pathogens – plastic waste may be a carrier for bacteria and shield waterborne pathogens from the natural sterilising effects of the sun's ultraviolet light and further exacerbate faecal pollution.

The supply and demand of ecosystem services were simulated for a period of 10 years using the ECOFUTURES modelling system. Geographical and socio-ecological data of the study area was gathered and compiled in Microsoft Excel. This data was also used to determine the relative magnitudes of service levels, land cover supplying the most services, and the greatest levels of services per hectare.

Several simulation scenarios were prepared and shared with stakeholders and local experts during a workshop held on the 10th of March 2022. Based on insights gained from the workshop, the model was refined into three plausible future scenarios – namely:

- Maximum (upper boundary of improved benefits, up to 60% **increase** in service levels),
- High Road (best plausible solution, between 0-30% **increase** in service levels) and
- Low Road scenarios (no changes/improvements are made, 20-80% **decline** to current service levels).

The demand for services was determined based on the Human Benefit Index (HBI), a parameter which ranked ecosystem services according to the level of benefit these services generated for people. Results showed a high level of demand and dependency on services that related to Durban's tourism industry – such as marketing icon, beach recreation and visual amenity. Consequently, due to the large demand and limited supply, these are also the services that are most at risk to negative impacts posing a serious risk to the wellbeing of its users.

Plastic waste has infiltrated and disrupted key ecological and urban systems, reducing their ability to provide goods and services, and consequently threatening the wellbeing of stakeholders in the study area. However, traditional solutions, such as landfill sites and incinerators, have finite space or tend to generate waste - therefore offering temporary solutions to an inevitable problem, and misaligning with the SDGs.

As such, innovative solutions are required, and the High Road scenario is proposed for Durban. This scenario proposes several cost-effective, sustainable solutions. The Transformative Riverine Management Programme (TRMP) aims to clear solid waste and alien vegetation from the study area, with an added benefit of promoting community involvement. Passive solid waste traps are also recommended as a simplistic means to capture and remove plastic from the supply chain.

Various social and institutional interventions, such as EnviroChamps training, school environmental programmes, and river awareness and training, were also recommended. These interventions target the lack of public awareness, with the aim to shift public behaviour to more sustainable, plastic-conscious practises. Finally, solutions such as pyrolysis and gasification units aim to create a plastic value chain. These solutions generate revenue by consuming plastic to produce useful products, such as fuel or gas (which can be used for energy generation) – effectively creating a return on investment that can fund other interventions.

Resolving the plastic waste issue will require efforts to implement new, sustainable solutions. The current status-quo has been ineffective against the continued accumulation of plastics in the urban and ecological environments and will eventually become completely overwhelmed. This will inevitably lead to urban and ecological services failing, negatively affecting the health of humans and the environment.

Unavoidable financial costs to businesses and industries relying on these services can be expected, with the most detrimental costs resulting from the degradation of South Africa's tourism industry - which contributed R125 billion to the South African economy in 2016. However, resolving the plastic waste issue also presents new opportunities for job creation, skills development, and implementation of long-term, sustainable solutions that generate revenue.

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INTRODUCTION

The uMngeni River Catchment is the largest catchment within the eThekwini Municipality located in the province of KwaZulu-Natal on the east coast of South Africa. It drains approximately 32% of the municipality and is twice the size of the next largest catchment (i.e., the Umlaas River). The eThekwini State of Rivers report defines the uMngeni River mainstream, downstream of Inanda Dam, as being in a moderate ecological condition in 2017. Due to implementation of flow regulation in 2018, the water quality of the mainstream saw a slight improvement (de Winnaar *et al.* 2020). However, the above State of Rivers report highlights that many of the tributaries that enter the mainstream are in a poor to very poor condition.

One of the main drivers of riverine vulnerability is the generation of solid waste. Solid waste generation is rapidly increasing as the human population grows. Over 320 million tons of plastic are produced globally every year. South Africa is a significant contributor, and is ranked 11th in the World, producing up to 2 million tons of municipal solid waste every year (Sadan & de Kock, 2020). Significant amounts of waste enter rivers that flow through the eThekwini Municipality. The 2019 flooding event highlighted this when massive volumes of solid waste were carried by flood waters down river systems and eventually deposited along the beaches of Durban (NIRAS and GroundTruth, 2019).

The accumulation of solid waste in river systems results in contamination of the water, which negatively impacts its physico-chemical parameters, such as turbidity and pH, and consequently the health of the river systems. There is also increasing evidence that the presence of plastics in rivers, blockages and damage to sewerage infrastructure from this and other solid waste exacerbates faecal pollution to surface waters. The negative water quality impacts of solid waste also have consequences for the health of both human and animal populations that rely on these river systems. The Millennium Ecosystem Assessment (2005) identified a suite of ecosystem goods and services derived from ecosystems and classifies these as being, **provisioning, regulating/supporting** and **cultural**. The ability of rivers and beaches to provide these ecosystem goods and services is dependent upon their ecological condition, size and connectivity, which, in turn, is influenced by numerous factors, such as pollution by solid waste such as plastic. A change in supply or state (quality and/or quantity) of these ecosystem services has numerous impacts on human health and well-being, and economic activities.

South Africa has committed to upholding the Sustainable Development Goals (SDGs) set out by the United Nations (link to the SDG webpage showing South Africa). At present, plastic pollution is prevalent in all South African environments. The marine environment remains especially vulnerable to the effects of plastic pollution, the target identified in SDG 14.1, “by 2025, prevent and significantly reduce marine pollution of all kinds, particularly from land-based activities, including marine debris and nutrient pollution”. Other SDGs that relate to the reduction of plastic pollution are SDG 3 (Good health and well-being)[1] [2], SDG 6.3 (improve

[1] Human well-being is a complex multi-dimensional concept that is inextricably linked to a combination of factors such as happiness, desire fulfilment, income and resources, needs and rights, and incorporates aspects of physical and mental health. It is also a function of environmental issues and various notions of sustainable development (Clark (2014); McGillivray and Clark (2006)).

[2] SDG 3’s official wording is ”Ensure healthy lives and promote well-being for all at all ages” (WHO, 2022). Reducing the spread of illnesses due to contamination of soil, air and water resources is a target for this SDG, as stated by SDG 3.3: ” By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases.”, and SDG 3.9: ”By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.”

water quality by reducing pollution, eliminating dumping, and minimizing release of hazardous chemicals and materials), SDG 12 (Responsible consumption and production) and SDG 14 (Life below water).

To achieve these goals, South Africa must make every effort to resolve the widespread plastic pollution in its urban and natural environments. This project and case study highlights the linkages between plastics and the costs to society of not better managing this key issue.

Overview of the 2019 Source-to-Sea study

Freshwater and ocean systems are a central part of South Africa's environment, economy and national identity. Sweden and the Swedish Agency for Marine and Water Management (SwAM) have engaged in a collaboration with the Republic of South Africa, in which Source-to-Sea management has been a designated topic of collaboration since 2015. South Africa's Department of Forestry, Fisheries and the Environment (DFFE) has since introduced a national Source-to-Sea programme, with a pilot project focussing on plastic litter pollution in five river systems in the KwaZulu-Natal province. A screening study was conducted by SwAM in 2019 with the objective to use a Source-to-Sea approach (of which there are several) in supporting the DFFE in their work in terms of reviewing and analysing key flows, stakeholders and governance aspects relevant to good water management in the province. In dialogue with SwAM and the DFFE, the project team selected a section of the major uMngeni River for more detailed study to explore its Source-to-Sea management (S2S) using the six-step planning approach designed by SIWI (Stockholm International Water Institute) and found in its their Source to Sea Practitioners guides, of which the first four steps were implemented:

- **Step 1:** characterised the highly urbanised, lower uMngeni River catchment (below the Inanda Dam) in terms of water, sediment, pollutants, biota, materials and ecosystem services. The flow of solid waste pollution, in particular plastic litter, was identified and selected as a key flow process that can be effectively targeted by S2S interventions.
- **Step 2:** presented an overview of stakeholders of plastic pollution and management in the lower uMngeni River catchment, with stakeholders grouped according to five different functional groups (primary, targeted, enabling, supporting and external stakeholders) each with specific 'spheres of influence' to bring about system change through their respective roles. Many key stakeholders (primary and targeted) have the power to influence positive change but lack capacity or knowledge while others have high capacity but lack influence.
- **Step 3:** outlined the governance systems and how key policies and legislation provide a solid foundation for good management, but that lack of resources, capacity and coordination form a bigger challenge. For various stakeholder groups, there is a need for increased communication and harmonisation of practices, strengthened institutional capacity, clear accountability, and the alignment of incentives for both producers and consumers to create a more sustainable market.
- **Step 4:** provided the foundation for a Theory of Change, building on the important interlinkages of Steps 1 to 3 (especially stakeholder engagement and the assessment of governance and gaps of current practices) and how these can improve the enabling conditions to enhance governance (transparency, accountability, and participation), reduce environmental stress, and improve social and economic status.

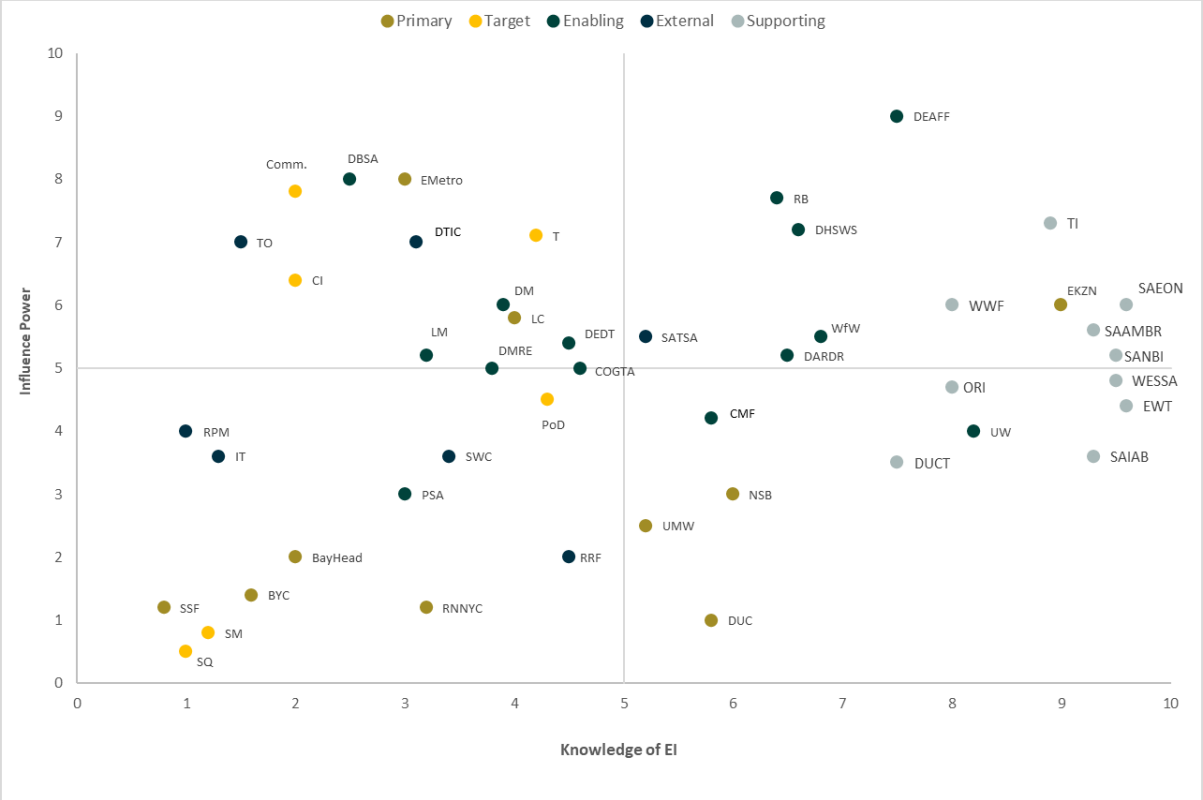

Figure 1 Stakeholder power mapping undertaken during the 2019 S2S project.

Key aspects, insights and learnings were distilled from the 2019 study and integrated into this current study and approach to further the understanding of the sources, pathways, impacts and solutions to the plastics issue within this part of the catchment.

Objective of this study

The purpose of this study is to investigate the social and economic impacts of plastic waste associated with the lower uMngeni River Catchment from downstream of Inanda Dam (Figure 2). Recommendations will also be made to address the elements of the plastic waste issue covered in this study. Recommendations will be directed at all levels of parties that have the ability to make a difference where plastic accumulation in the study area is concerned – from government, NGOs and businesses to the ordinary South African citizen. The study focuses on a range of key stakeholders identified in the 2019 SwAM study, in government, private sector and civil society that are within the eThekwini Municipality.

The study emphasizes three key issues:

1. Social impacts of plastic waste such as human health, which has the potential to affect both psychological and physical wellbeing, as well as recreation and spiritual values.
2. Economic impacts associated with loss of revenue for key industries/businesses benefiting from catchment-derived ecosystem services and, clean-up costs in and around the river and beaches; and
3. Estimation of the relative magnitude and change to ecosystem services under the different future scenarios to guide future plastic waste management scenarios, using best practice, innovative ideas, and community driven initiatives to tackle water and land-based plastic pollution within the Municipality.

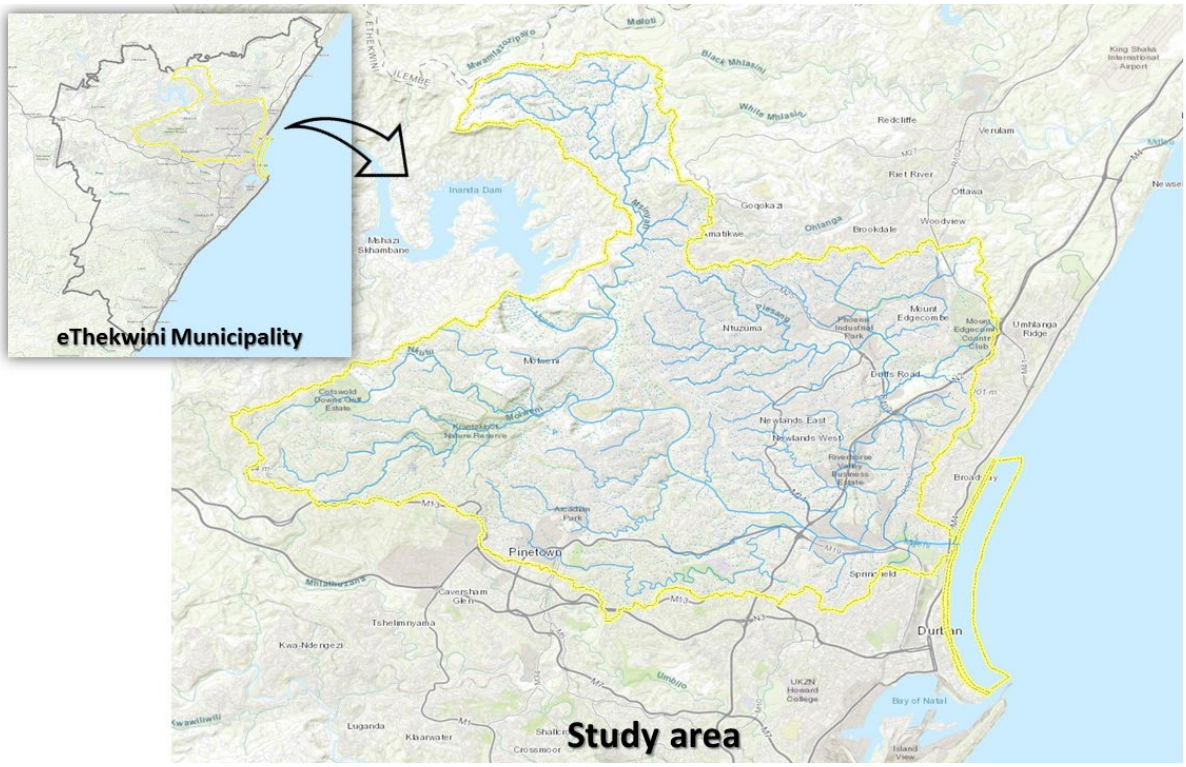

Figure 2 Location of the lower uMngeni River catchment (yellow polygon) in relation to Durban and the eThekwini municipal area

BRIEF METHODOLOGY

Plastic pollution within the lower uMngeni River catchment is a complex and extensive issue, and in this study, a range of key tasks have been undertaken to understand the impacts of plastic pollution on human health, and the social, economic and ecological wellbeing of the study area.

To analyse each of the above-mentioned impacts, several steps have been followed to collect data and inform the overall study objective. The methods used are described in detail in each chapter and are summarised in the following tasks.

Stakeholder perceptions of the Socio-economic impacts of plastic pollution (interviews)

For this task, a range of key stakeholders identified from the 2019 SwAM study as well as those identified from a review of information on types of ecosystem users in the target area, were interviewed to develop an understanding of the extent to which they are affected by plastic debris occurring in the study area as well as their perception of its implications on them. Stakeholders were interviewed regarding two key issues:

- the perceptions of the social costs of plastic waste, and
- the perceptions of the economic cost of plastic waste, respectively.

The interview process was held one-to-one, and a background information document (BID; see Appendix 111) was supplied to promote engagement from an informed perspective. The following steps were carried out for this component:

- Identify eligible stakeholders based on criteria of being a user of river and/or marine ecosystems, such as:

  - × Residents of informal settlements
  - × People affiliated with sport, recreation, property, tourism sector
  - × Non-Government Organizations (NGOs)
  - × Municipal governance sector
  - × Business sector
- Supply stakeholders with the BID
- Interview stakeholders, either telephonically or virtually
  - × Discuss social costs of plastic waste, and record response
  - × Discuss economic costs of plastic waste, and record response
- Compile information in report format and discuss implications and recommendations.

Socio-economic costs of plastic pollution

This component of the study focused on gathering and reviewing information about social and economic issues related to plastic pollution, and specifically building an understanding about the financial implications related to plastic pollution. The following steps were carried out for this component:

- Gather information from online academic literature and other accounts of the following key issues:
  - × Plastic impacts on ecosystem services
    - Services relating to food security
    - Water quality maintenance
    - Ecotherapy
    - Pest control
    - Etc.
  - × Plastics supply chain
    - Identification of sources of plastic
    - Associated complexities (alien plant material, pathogens)
  - × Costs of plastic pollution
    - Direct and indirect monetary costs to services and societal sectors
    - Direct and indirect non-monetary costs (health and psychological)
    - Density and size of plastic pollution within the impact area
    - Parties affected by costs
- Present the findings of human perceptions outlining the perceived costs of ecosystem decline resulting from waste management inaction.

Assessment of ecosystem services supply and demand

The aim of this study is to investigate the impacts of plastic waste in the landscape on human wellbeing. A proprietary spreadsheet modelling system (ECOFUTURES) was used to develop a simulation of the state of the study area, due to the complexity of interconnected ecological and social systems. The following steps were carried out for this component:

- Collate available data on land cover for the area using a Geographic Information System
- Build a social-ecological systems spreadsheet model
- Map the land cover types to determine their geographic location and size (in hectares)
- Demarcate the boundaries of the affected area
- Populate the model with available data and prepare several scenarios to share with stakeholders

- Hold a workshop with local experts and stakeholders to outline likely supply and demand for key ecosystem services
- Identify scope of ecological infrastructure, ecological services and service users by consulting literature and local experts
- Using information obtained, project and then simulate three future scenarios which Durban may experience related to plastics
- Remodel and review outcomes in terms of services supply and demand

CHAPTER 1: ASSESSMENT OF STAKEHOLDER PERCEPTIONS

1.1 Introduction

Plastic litter is being discarded in streets, drains, storm-water channels and culverts in settlements and suburbs, either blocking these channels or discharging directly into the uMngeni River via a hydrologically connected network of smaller streams, particularly during high rainfall events and floods. This is resulting in plastic litter moving along the uMngeni River Catchment from source to sea. Seasonal flooding in the greater Durban area results in excessively high volumes of plastic waste being transported along the length of the uMngeni River and deposited into the marine environment and along Durban's beaches.

The stakeholder engagement process aimed at developing an understanding of, and insights into, the effected ecosystems and impacts of changes to the associated ecosystem services. Stakeholders were engaged to assess perceptions and to collect information on two key issues:

- Assess perceptions of the social costs of plastic waste – interviews were undertaken with key stakeholders to assess perceptions regarding the impact and costs of plastic pollution on various ecosystem goods and services, including human well-being. These included discussions on direct impacts of plastic (e.g., on aesthetics and health and safety) as well as indirect impacts and costs associated with changes in ecosystem services (e.g., provisioning, regulating and cultural services). The interviews were also used to gather information on estimates of the number of users (of ecosystem services) and a ranking of the significance of impacts.
- Estimates of economic and monetary costs of plastic waste in the environment – stakeholders were engaged on perceptions of the monetary costs incurred, or benefits generated, from plastic pollution. These included, for example, costs associated with collection and repairing damage, as well as benefits from job creation from picking up litter and recycling plastic.

This section of the report provides a summary of stakeholder perceptions of the impacts of plastic waste on a range of ecosystem services and the associated social and economic costs and impacts.

1.2 Method

a. Stakeholder engagement approach

The stakeholder engagement process involved a series of one-on-one interviews (telephonic or via virtual meeting platforms, e.g., Zoom). Prior to interviews, a background Information Document (BID – Appendix 1) was prepared and shared with stakeholders. The purpose of the BID was to provide stakeholders with insight into the project so that they could participate in the interviews from an informed position.

A semi-structured interview process was adopted, framed broadly around an ecosystem services approach. This involved a combination of (i) directed, open-ended questions from a pre-prepared interview guide, and (ii) opportunities for the stakeholders to share information that they identify as important and relevant to the assessment.

b. This stakeholder engagement process provided the basis for two essential elements of this project:

- Forming a key component of the social learning process that will support the co-design of interventions to change current waste management practices by stakeholders.
- Providing baseline information as input into building a structured model of ecosystem goods and services.

c. Stakeholder identification

Based on the 2019 SwAM Source to Sea study in the area, and particularly the power mapping of the stakeholders to provide context around those with power/influence on the management of plastics, a range of categories of key stakeholders were identified as representative of the users, and influencers of, the river and marine ecosystem services in the target area. This was built on and updated through a review and internet search of current user groups. The categories and number of stakeholders are shown in Table 1, below:

Table 1 Categorical distribution of stakeholders

Category	Number of stakeholders
Tourism Enterprise	2
Business	1
Real Estate	1
Government	9
Communities	2
Research/ Academic	2
NGO/Private Sector	7
Total	24

Stakeholders across these eight categories were identified through a combination of referrals and internet searches. A total of key 32 stakeholders were identified and engaged:

- 24 interviews have been successfully conducted. (See Appendix 2 - Stakeholders engaged)
- Eight stakeholders responded but declined the opportunity to take part in the study (not relevant / not interested).

d. Key ecosystem services affected by plastic waste

While ecosystems may generate a wide range of ecosystem services, this study only focuses on those services which are impacted by plastic waste. The following ecosystem services are assessed in this report:

- **Food security services -** plastic waste can impact on fishing and wetland / floodplain agriculture. Fish that are caught and found to have ingested plastic are viewed by some people as unsafe to consume. Wetlands and floodplains that are used as illegal dump sites for plastic and other solid waste are no longer accessible to local households to practice agricultural production activities.

- **Recreation amenity –** plastic waste affects recreation in rivers, estuaries, beaches and the ocean. Parks and other terrestrial open space may also be impacted. Plastic waste is deemed to be unsightly and detracts from the enjoyment or rewards to users using these areas for recreational purposes.
- **Water quality maintenance and health security –** plastic waste may elevate bacteria levels in rivers, estuaries, beaches and the ocean by affecting the effective functioning of wastewater treatment works and associated sewerage reticulation infrastructure, with resultant leaks or spills pouring into rivers and downstream onto beaches and the ocean impacts on the health of human users as well as recreational amenity value.
- **Municipal marketing icons –** Durban's attractive beaches are a key asset for attracting tourists and new city residents. Plastic waste degrades tourists' perceptions of these assets' attractiveness and negatively affects tourists' desire to return. This reduces the ability of Durban to attract residents and tourists and compete nationally and internationally.
- **Sense of place –** the quality of an experience - be it cultural, spiritual or religious, is shaped by the quality of the environment. Plastic waste is perceived to degrade the environment which drives a change in the sense of place and the associated experiences.
- **Ecotherapy –** people may engage with ecosystems to engender, maintain and promote physical, psychological and spiritual wellbeing. The presence of plastic waste in such settings is perceived to degrade the environment, which detracts from the quality of the experience and reduces the value of ecotherapy to it users.
- **Pest control –** plastic debris in the ecosystem hosts insects and other pests, such as rodents, which may then negatively impact on neighbouring households and communities.
- **Flood water reduction –** healthy ecosystems and built structures – like culverts - offer flood reduction or avoidance services. However, the addition of large volumes of plastic to streams and drainage lines (along with general litter) accentuates blocking of these systems and may exacerbate the negative impacts flooding (with cost impacts on damaged infrastructure).
- **Nurseries and refugia –** sheltered sites such as estuaries and mangroves are critical for fish, crustaceans and birds as critical spawning and breeding grounds. These biodiversity assets then support users such as artisanal and commercial fishermen and bird watchers. Plastic waste can smother key nurseries and other sites, preventing effective breeding and recruitment.
- **Biodiversity conservation goals –** natural assets in the Durban region support society in meeting its provincial conservation objectives and meeting international commitments such as the SDGs (see for example, SDG 15 "*protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss*"). Plastic pollution within these systems degrades the quality of ecosystems and their functioning, which reduces the assets capability to meet conservation goals.

1.3 Results

Stakeholder perceptions can be summarised into the following 4 categories:

a. Perceptions relating to cultural ecosystem services:

- Stakeholders widely expressed perceptions that plastic pollution is bad and has many negative impacts, but they are unable to provide substantive examples or evidence to support this perception. Their perceptions of the negative costs and impacts are largely founded on an emotive response relating to aesthetics, i.e., the quality of the experience declines when seeing a littered beach or surfing amongst plastic waste resulting in a feeling of dissatisfaction.
- There is a perception among many stakeholders that plastic pollution is dirty and unsafe, but no examples of anecdotal evidence were provided by stakeholders to substantiate this perception.
- Plastic pollution has substantial indirect social impacts, because of its significant psycho-logical impacts, such as:
  - × Plastic pollution affects well-being by negatively impacting on happiness of people, particularly when they see it negatively impacting on marine life, which people find upsetting and makes people angry.
  - × Plastic pollution affects peoples' dignity and perceptions about self-worth. People living in areas littered with solid waste and plastic pollution start to believe that they do not deserve anything better. Conversely, when areas are cleared and re-stored people start taking pride in the area and themselves and this has potential to build social capital and a sense of community, which in turn has potential to enhance investment in environmental restoration and management.
- Negative impacts on sport and recreation arise because plastic is unsightly and detracts from enjoyment. However, many people, particularly those involved in water sports, are far more concerned about water quality due to chemical pollution and *E. coli* contamination. Interestingly, the links between how plastic pollution can and does impact stormwater and sewerage infrastructure, and which in turn causes additional faecal contamination of surface water resources was NOT identified by stakeholders. This is a key theme identified in this project and elucidated later in this report.
- Spiritual and cultural activities (along the river and on beaches) are also impacted on more significantly by water quality (*e.g., E. coli* contamination and chemical pollution) than by plastic and solid waste pollution. Users are more tolerant of plastic pollution and its impacts on aesthetics and suggest that, unless plastic pollution in an area is "terrible" it is still acceptable for use for cultural and spiritual ceremonies and practices.
- Plastic pollution is perceived to have a significantly negative impact on tourism, and associated revenue potential. However, interestingly tourism surveys are not currently collecting data on tourist perceptions of the impacts of plastic pollution. Anecdotal evidence does suggest that foreign and domestic tourists are "put off" by the negative aesthetic impacts of plastic pollution and, particularly after storm or flood events, are likely to plan alternative destinations in future. Given that Durban is described as a "tourism economy", the negative impacts of plastic pollution on the sector translate into significant monetary impacts.
  - × Blue Flag status is very important for attracting tourists. Criteria for certification of Blue Flag beaches include impacts of plastic on water quality and waste

management requirements. So plastic management is essential to maintain the beaches as a tourist attraction.

- × eThekwini is developing an early warning system that includes circulation model to forecast where plastic and waste will end up after storms/floods to inform planning and resourcing of clean-up operations, for example to clean up Blue Flag beaches straight after storms to protect status.

b. Perceptions relating to provisioning ecosystem services:

- Potential negative impacts of plastic pollution on provisioning services, such as fishing and agricultural production on floodplains and in wetlands are not perceived by stakeholders to be significant, mainly due to the low level of use / dependence on these services in the target areas.
- There is very little fishing in the river due to a scarcity of fish. However, when fish are caught (in the river or sea) the presence of plastic in the guts of the fish is not perceived to be negative or a health risk and the fish are still consumed.
- There is limited agriculture being undertaken on the banks of the river below Inanda Dam, so there are limited perceptions expressed about the impacts of plastic pollution on this crop production. However anecdotal evidence indicates that in areas such as wetlands where rehabilitation has taken place, there may be some reintroduction of vegetable gardens. The direct relationship with plastic pollution and perceptions about impacts on crop cultivation is however not yet clear.
- Harvesting of natural resources is not perceived to be significantly affected by plastic pollution, but rather by alien invasive species.

c. Perceptions relating to supporting ecosystem services:

- In particular, the impacts of plastic pollution on supporting services such as flood attenuation, have been expressed by stakeholders in the Municipality, especially the Stormwater and Catchment Management and the Coastal Policy Departments. The direct impact of plastic pollution on amplifying flood risks and the associated damage costs to key infrastructure (roads/culverts/bridges) is widely recognised. The indirect social and economic costs of these impacts are also highlighted, for example, the social inconvenience and economic losses to private individuals from the damage and loss of public infrastructure or access thereof.

d. Perceptions of broad impacts and consequences:

- **Demand for properties** correlates with tourism, and anecdotal evidence indicates that as tourist numbers to an area increase so too does the demand for property (and associated services). Conversely decreasing tourism popularity negatively impacts on demand for property. The property market and real estate values are affected by demand and supply. If the demand for properties decreases and supply of properties starts to exceed demand by buyers, so the prices people are willing to pay decline. This would and does affect the municipal rates base, and income to provide key municipal services.

  Another criterion affecting demand for property is perceptions relating to the Municipality's capacity to maintain service delivery and infrastructure. Anecdotal evidence suggests that solid waste and plastic pollution decrease confidence in the Municipality's capacity, and therefore contribute to a decrease in the demand for properties and the associated prices that buyers are willing to pay. This translates into a decrease in revenue that the Municipality can generate from property rates

(which are related to property values) and further reduces the municipal resources for management and service delivery.

- Plastic pollution is one component of a bigger challenge, and the collective issues of **waste management needs** to be addressed holistically and innovatively.

  The Transformative River Management Programme is an initiative started and run by the eThekwini Municipality to improve the health, cleanliness, and usefulness of 7 400km of riverine corridors in the Kwazulu-Natal Province. This project is a process towards securing support / awareness among communities to take responsibility for cleaning / maintaining "their" stretch of the river, which includes alien invasive plant cleaning and solid waste management (including plastic).

- Several stakeholders, particularly those from the NGO (Non-Government Organizations) and the economic sectors, highlight **a range of benefits** that can be generated from the clearing of plastic waste.

  There are numerous examples of the potential for job creation and income generation from the collection of plastics waste from litter booms, riverbanks and beaches. These initiatives are particularly targeting unemployed people from low-income communities.

  There is also evidence of the potential to generate benefits from channelling the plastic waste that is collected to stimulate new value chains and create greater demand for recycled materials (for example to produce “green aggregates” limiting the impacts on and need for the use of river sand – a key biodiversity asset and also for regeneration of beach sands affecting tourism and recreation).

- **Keeping plastic out of landfills** is a climate change mitigation target for eThekwini and is therefore linked to some solid waste management interventions i.e., focus on reducing emissions by reducing amount of plastic entering landfill by recycling and upcycling plastic waste programmes. Includes community-based programmes for plastic collection and recycling.

  Critically linked to the landfill issue is the loss of volumetric capacity which is being taken up by plastics and shortening of the lifespan of these sites when excessive plastic is disposed of there.

  Several stakeholders highlighted the need to invest in efforts to not only collect plastic pollution, but to also reduce the flow of plastic waste into landfill sites by increasing opportunities for it to be repurposed and to address the plastic waste challenge more holistically.

Overviews of the perceptions expressed by stakeholders of the social and monetary costs and impacts of plastic waste are detailed in Appendix 3: Table A shows the Informal settlement communities, recreational clubs and businesses, NGOs and CSOs (Civil Society Organisations), and Table B shows the perceptions of the property/real estate sector, tourism sector, government/municipality, and business sector.

In conclusion, while there was some variation in the perceptions of stakeholders regarding the extent to which plastic waste impacts on them and the implications of these impacts, there was one consistent view held in common by all stakeholders – that plastic waste has negative impacts for all people and the environment, and there is an urgent need for it to be more effectively managed.

CHAPTER 2: THE KNOWN MONETARY COSTS ASSESSMENT OF PLASTICS IN THE UMNGENI RIVER

2.1 Introduction

This component of the study focused on the known monetary costs of plastic waste in the lower uMngeni River Catchment and outlines how monetary costs are generated in the environment.

This key question was framed as: What is the plastic waste supply chain and where are the costs of plastic waste generated?

The focus of this section is on how plastic changes from useful packaging or a product – to become waste. It is the point at which plastic exits or escapes from a controlled waste management system and becomes 'free range' plastic - outside of a managed system.

Plastic waste moves through the environment, starting at its point of discard to its final site of deposition. Plastic waste impacts on each ecosystem or natural asset that it passes through, and at each stage reduces the ecosystems' ability to supply ecosystem services. It is estimated that of the plastic waste that enters the ocean some 2/3 of plastic litter sinks to the seabed, with the remaining 1/3 either landing on the beach or remaining floating in the water (UNEP 2014).

Plastic waste impacts on human wellbeing, affecting peoples' consumption or enjoyment of ecosystem services in the natural environment – this may be along rivers, estuaries, beaches, parks, and residential areas. The impacts may occur by reducing access to services, reducing the quality of services and/or reducing the quantity of services used.

a. The plastic waste supply-chain

The sites of plastic waste production or discard may include residential areas, industrial areas, commercial centres, recreation sites, open space and roads, and transport routes. Plastic waste may travel along a range of routes. In terrestrial areas wind may blow litter across the landscape, and surface runoff from rainfall events will move plastic into stormwater and drainage lines. In aquatic related ecosystems plastic waste may move from stormwater systems and drainage lines into streams, rivers, estuaries and the ocean. The sites where plastic may be temporarily or permanently deposited may occur in stormwater canals, streams and rivers, wetlands, at culverts and bridges, within estuaries, beaches and within the ocean. Plastic litter may finally be deposited on the ocean floor or may remain floating in the water column itself.

b. Perverse and compounding aspects of plastic waste supply chain

There are numerous, often not obvious, but perverse negative impacts from plastic waste which compound in the environment and affect other aspects of the system.

Plastic appears to aggravate flooding and water quality problems. For example:

- Plastic waste and plant material (including alien plants) are entrained in floods and get caught on built infrastructure such as culverts and low bridges. Waste then gets entangled with plant material/debris thereby restricting the apertures on this

infrastructure and reducing their flood design capacity, leading to back-flooding, increased water mass, higher flood levels and consequently damage to associated infrastructure – such as culverts, roads, pipelines and houses (Geoff Tooley pers comm – eThekwini stormwater engineer).

- Plastic waste ingress into stormwater and sewer systems cause blockages and failures to water and sanitation infrastructure exacerbating the impacts from flooding as well as causing untreated sewage to surcharge and contaminate aquatic ecosystems (rivers, estuaries and the near shore marine environment).
- Plastic waste and pathogens – plastic waste may be a carrier for bacteria such as *E. coli*. For example, discarded disposable nappies may carry faecal pollution into aquatic ecosystems. Plastic may also shield waterborne pathogens from the natural sterilising effects of the sun's ultraviolet light and further exacerbate faecal pollution.

Figure 3, on the following page, presents an illustration of some of these issues and linkages between plastic and various socio-ecological systems based on typical flow paths of waste through the environment.

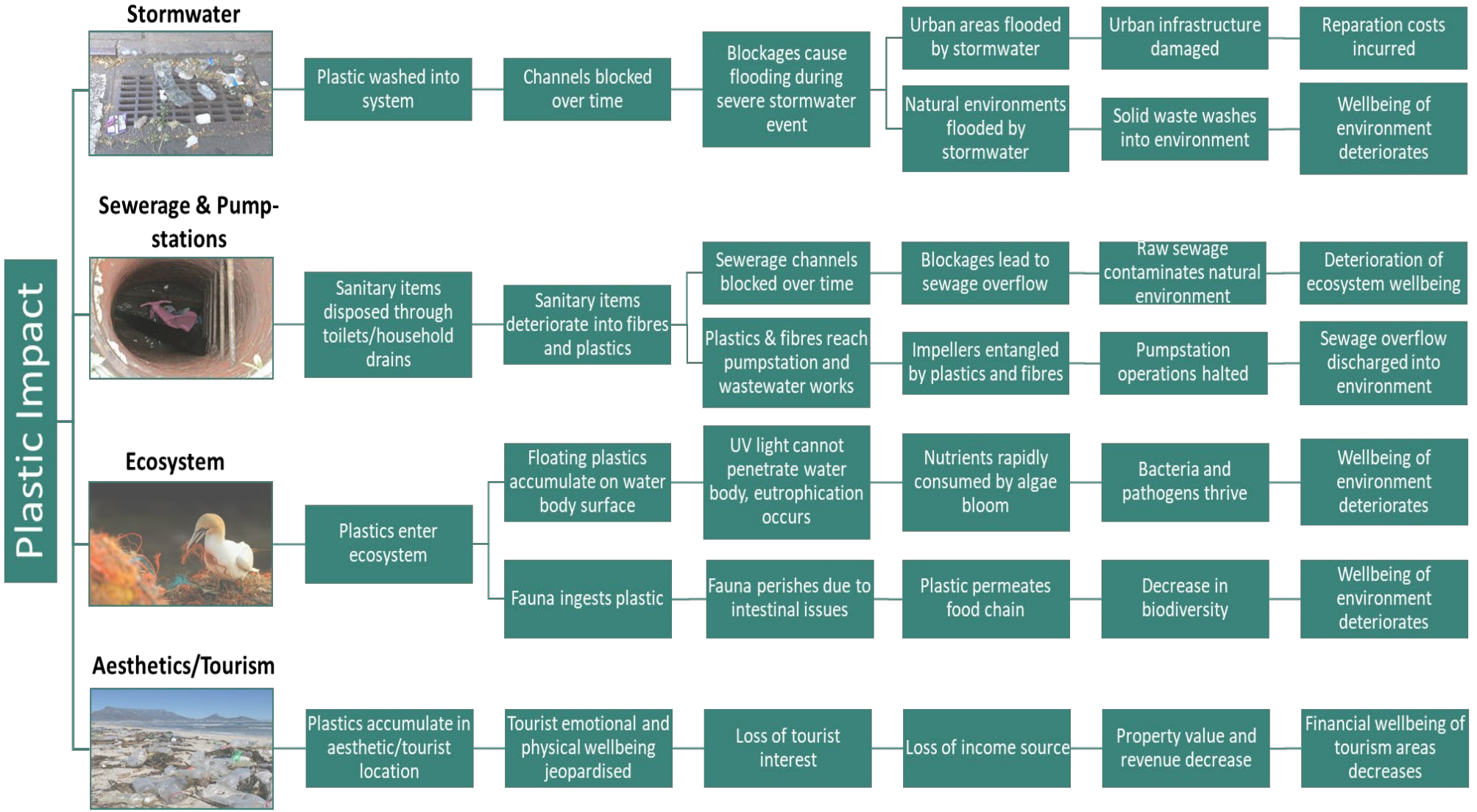

Figure 3 Direct, perverse and compounding aspects of plastic waste along different flow paths in the environment and how it affects various endpoints

2.2 Method

A literature survey (using an internet search, Google Scholar, online journals and articles, and information from various local professionals) to source as much information as possible on the known monetary costs of plastic waste in Durban was undertaken. This initially focussed on searching for information from studies that may have been undertaken in or close to the study area, and then expanded to the rest of South Africa. It was then broadened to include global studies. Despite this broad review, very little information was found on direct monetary costs of plastic waste in the Durban environment. Finding information about the indirect costs of plastic proved to be even more challenging, as even international literature did not provide substantial information about these costs. However, it was assumed that examples of international events that lead to plastic monetary costs would also occur in Durban. For example, if marine plastic debris was known to foul ship propellers entering Hong Kong's harbour, then it was also assumed that such an event might occur in Durban Harbour too).

The information sourced from the literature survey was supplemented with unpublished data and information on monetary costs provided during the stakeholder engagement process and scoping of stakeholder perceptions of the costs of plastic waste. A few stakeholders, particularly those from NGOs and the Municipality, did have some quantitative data on costs, calculated from current and historical projects. However, this data was also extremely limited and largely anecdotal. It has become evident that there is little data and information being collected on the monetary costs of plastic waste, and even less information that is being published in literature or reports.

2.3 Results

a. The known monetary costs of plastic waste

The monetary costs of plastic waste in the environment may include:

- clean-up costs of plastic litter in the environment – such as beach and mangrove clean-ups, and operation of litter booms in rivers;
- damage to municipal infrastructure – such as the destruction of culverts, roads, sewer and water pipelines, and electrical and communication cables;
- decline in tourism revenue – due to the cancellation of visits or shifting of holiday destinations to other regions due to poor quality beaches and their associated quality;
- health and psychological costs – such as a reduction in outdoor activities with associated health losses to individuals, or the exposure to cuts and infections by recreating in polluted locations;
- recreation value losses – the loss of opportunities for residents or visitors to enjoy water or beach related recreational activities; and
- property value declines – such as the loss in growth potential in property prices of beach, river or estuary neighbouring locations, and the associated stagnation of municipal rates/taxes.

These points are described in more details in the following sections (b-g)

b. Municipal clean-up costs associated with beaches and rivers

The eThekwini municipality undertakes regular beach clean-ups to deal with the daily or weekly discard of litter into the environment. After intense seasonal rainfall events and floods, the city must undertake large-scale clean-ups due to the large volume of waste that flows downstream to beaches. Costs pertaining directly to Durban beach clean-ups have not been made available to this project. However, a study conducted by S. Arabi (2020) estimated the removal cost of plastic from Cape Town beaches to be R3000 per ton. The City of Cape Town spent R2.7

million on beach clean-ups during 1992-1993, which is equivalent to a present-day value of R12 million ($808,000). It can be assumed that plastic clean-ups along Durban's beaches would cost eThekwini Municipality just as a similar amount and based on the large number of popular beaches along the Durban coastline.

c. River pollution and clean-up costs

The Transformative River Management Programme (TRMP) spends R35.5 million ($2.4 million) a year to clear litter and alien plants on 450 kilometres of urban rivers (Business Case for Durban's Transformative Riverine Management Programme 2021). It is estimated that 30% of costs (R10.6 million, or $721,000) could be attributed to waste, largely plastic waste (Geoff Tooley pers comm. 2022). A cost of R23 556/km ($1,600/km) per year is incurred to clear waste from Durban streams to avoid damage to municipal culverts, roads and water and sewer infrastructure.

d. Private sector clean-up costs along rivers and beaches

Private sector action includes clean-ups by landowners or property owners on their own properties and associated public property. Special rating areas have management agents who also undertake clean-up action paid for by property owners within the special rating areas.

There are several non-profit organisations (NPOs) in Durban that undertake clean-ups in rivers and on the beaches, for example the Adopt a River programme. Some of these operations are funded through the private sector and through government programmes and create jobs for local communities to collect plastic waste, operate litter booms, and undertake small-scale recycling initiatives. Several NPOs also arrange many volunteer clean-up activities every year. The total number of these actions and their associated costs are unknown.

The total costs associated with the private sector clean-up costs have not been published.

e. Changes in tourism revenue

Tourists typically vote with their feet and beaches or other sites with declining quality are avoided by discerning visitors or beach users. For example, the Mercury Newspaper reported on 7 May 2008 that the loss suffered by Durban because of losing its Blue Flag status for the Durban beaches was up to R100 million ($6.8 million) per year with visitors choosing alternative beaches WITH an accredited Blue Flag status (McKenna *et al.* 2011).

Tourism's contribution to Durban's GDP (Gross Domestic Product) in 2019 was R19 billion ($1.3 million) with 37 622 jobs (eThekwini Municipality Report on Economic Impact of Tourism for 2019). A visitor survey in 2020 indicated that 55% visitors come for leisure and 70% of these visitors use the beach (eThekwini Municipality Report on Economic Impact of Tourism for 2020).

In the absence of any specifics for eThekwini/Durban, a Cape Town beach user survey (Balance *et al.* 2000) found that 85% of visitors indicated they would not visit the beaches that had more than 2 waste items per square meter and that 97% of visitors would not visit beaches with 10 waste items per square meter – leading to a loss of R27 million ($520,000) to the regional economy (Arabi & Nahman, 2020). The Cape Town survey estimated that tourist numbers could decline by 52% if the beaches were not cleaned. Furthermore, tourists spent longer time on clean beaches and cleanliness ranked the highest attribute for beach attractiveness.

Assuming the Cape Town predictions as a worst-case scenario, Durban could lose 50% of its visitors, significantly threatening the R19.5 billion ($1.3 million) tourism industry and 37 622 associated jobs.

f. Health, cultural, spiritual and recreational costs

Plastic waste degrades rivers, estuaries and ocean experiences. This implies that users who benefit from health, cultural, spiritual and/or recreational uses would experience losses. There is little available data on these costs but some indicators are noted below.

In 2018 the Duzi Canoe Marathon involved 2 894 people with an economic impact of between R4million to R6 million ($272,000 - $410,000) (KwaZulu-Natal Tourism). Recreational events such as this are threatened (with fewer participants) by water quality issues – such as plastic pollution and sewerage. Canoeists rate clean water quality as one of the most critical factors influencing their choices around engaging in this sport.

Selected sites on rivers, estuaries and ocean are also used by many for cultural and spiritual ceremonies (e.g. cleansing ceremonies, baptisms, etc.). Contamination of preferred sites with plastic waste results in users having to incur costs (time and money) to travel further to alternative areas to practice their important ceremonies.

g. Property values and the business case

Real estate stakeholders highlight that plastic waste pollution reflects badly on the Municipality's functional capacity and reduces confidence of residents and potential buyers of property in the area. The public perception is that excessive plastic waste is an indicator of the Municipality’s ability to maintain other essential services in the area and drives people to look to buy property elsewhere. However, it is not possible to apportion property value changes to plastic waste currently. Plastic pollution is important because it affects people's perceptions, but it is hard to say currently what the overall impact is. There is a relationship between waste on the beaches, perceptions of municipal service delivery effectiveness, confidence in a property’s (or the area where properties are located) attractiveness, demand for houses and therefore price. Property prices shape future developments, municipal service revenue and the municipal rates base. How the Municipality treats plastic waste will influence how buyers perceive the security of long-term property investments in Durban.

The Business Case for Durban’s Transformative Riverine Management Programme (2021) estimated that without effective river management, the Durban rivers, estuaries, and ocean could see an average 11% decline in ecosystem services supplied to some 2.2 million beach users. Furthermore, using GDP per capita as a proxy for the value of life and human wellbeing and assuming the inconvenience of disrupted access to services on the beach for one month (over a year period), the potential loss of value to users was estimated to be R87 million ($6 million) a year.

In addition, plastic litter in the ocean may leach toxic chemicals into the environment which marine organisms may concentrate, and this may be harmful to humans (UNEP 2014).

h. Shipping industry

Plastic debris may end up floating into harbours or ports – areas that typically experience increased volumes of ship traffic. Plastic has been known to damage ships by fouling propellers and anchors, damaging drive shafts, clogging intake pipes, ultimately increasing ship maintenance and repair costs. Costs are therefore incurred by port authorities to conduct plastic clean-up activities, to reduce the likelihood of plastic damaging ships visiting the port.

These costs are particularly relevant to Durban, which has a port of its own, one of the busiest and strategic ports on the southern African continent – and as a major trade artery into the interior of southern Africa. The plastic clean-up costs for the Port of Durban were not made available for this report, and because the primary focus was on the uMngeni catchment below Inanda Dam, which does not directly affect the Port of Durban. However, clean-up costs at the

Port of Durban for the stormy April/May 2019 period totalled R4.35 million ($296,000) .(Arabi & Nahman, 2020). Plastic accumulation in the port can incur a large financial debt to shipping companies for the repair and maintenance of their ships, and a running cost for the Port of Durban authorities to continually remove marine plastic debris from the port. Furthermore, consistent damage to ships could eventually discourage shipping companies from returning to the Port of Durban, resulting in a huge loss in revenue, goods and services for the Port of Durban, and for South Africa as a whole.

CHAPTER 3: SUPPLY AND DEMAND OF ECOSYSTEM SERVICES IN THE LOWER UMNGENI RIVER CATCHMENT

3.1 Introduction

Services are useful inputs that make the lives of people living in Durban better. South African's are familiar with electrical infrastructure, roads and water pipes as key municipal services, and also know that the size and condition of this municipal infrastructure influences the service levels that the residents may access.

Similarly, ecosystems - such and rivers, estuaries and beaches - are ecological infrastructure that supply services to society, such as beach recreation, storm damage reduction, water quality maintenance and scenic beauty.

Unmanaged plastic waste impacts on functionality of both built infrastructure (such as roads and storm water drains) and ecological infrastructure such as rivers and the beaches. The loss or reduction of services to humans results in the loss of wellbeing and or the creation of costs. When roads and stormwater drains are blocked, or unusable, then human wellbeing suffers because of reduced access or greater access costs. Furthermore, the repairs and clean -up also generate costs. These costs are understood in urban management.

Similarly, when ecological assets are choked with plastic waste, they cannot function and the service benefits lost to society, and clean-up costs are incurred. However, while the impacts of unmanaged plastic waste in the built environment are well known, the impacts of plastic in the natural environment and their costs to society are not well known.

To understand the local impacts of plastic litter in the case study area are on human wellbeing, one needs to understand:

- what ecological infrastructure is present in the lower uMngeni River Catchment and what the size, condition and connectivity of the assets are,
- what services do they supply and what are the relative volumes of those services,
- which Durban residents use the services, how many people use the services and how important are these services in their lives, and
- how might the ecological infrastructure change or degraded in response to a range of plastic waste scenarios.

As social ecological systems are complex and very much integrated, keeping track of all the interconnections and understanding how services and benefits may change in the future scenarios requires decision support tools, such as computer aided modelling.

A proprietary expert spreadsheet model[3] was used to assist in visualising and sharing understandings of plastic litter impacts on the lower uMngeni social ecological system, and to develop new insights.

The section below outlines the supply of ecosystem services, the demand for ecosystem services and a suite of plausible future plastic management scenarios.

3.2 Method

The modelling process combined both available empirical data and local knowledge to understand system linkages and to predict future changes in the social-ecological system. The process included the development of a systems model to outline the status-quo situation (the baseline) of the lower uMngeni catchment area, in terms of ecosystem services, and then modelled the implications of several plausible scenarios that could emerge in the catchment area. The modelling process generated indicators of:

- the ecological infrastructure (or natural assets) and other landscape assets in the uMngeni catchment (its size and condition),
- the ecosystem services supplied and their relative supply levels (not actual levels),
- the number of service users and the benefits generated through use (using a Human Benefit Index),
- the direction and magnitude of ecosystem services change in different plastic waste management scenarios.

The process uses ecosystem services as the currency of measuring change – as it is through changes in ecosystem services that humans experience landscape changes. Ecosystem services are the outputs of nature that generate services for people and are generated by both natural and transformed landscapes. A recent article on the BBC (BBC, March 2022) highlights this in useful colloquial terms “Biodiversity is the variety of all life on Earth - animals, plants, fungi and micro-organisms like bacteria. Animals and plants provide humans with everything needed to survive - including fresh water, food, and medicines”.

It is important to note that ecosystem services are not the same as ecosystem functions. Functions are the biological, chemical and physical processes associated with natural ecosystems. Services are the results or outputs of those processes which people use – either directly or indirectly.

The modelling process combined both the expertise of the consulting team and key stakeholders (interviewed independently or in a workshop) in assessing the supply of and demand for ecosystem services in the uMngeni catchment. The process used is outlined below:

- Collated available data on land cover in the area into a Geographic Information System.
- Built a social-ecological systems model using Excel.
- Mapped the land cover types to determine their geographic location and size (in hectares).
- Demarcated the boundaries of the affected area.

[3] The model and associated process is called ECOFUTURES and has been developed by FutureWorks, myles@futureworks.co.za

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- Populated the model with available data and prepared several scenarios to share with stakeholders.
- Based on these scenarios, the consulting team then estimated changes in terms of:
    - Switching the allocation of areas between different land cover types, such as reducing wetlands and replacing them with informal waste dumps.
      Changing the condition of the built and ecological infrastructure in response to the likely future land uses and their associated management efficiencies / approaches and local population pressures.
      Systematically reflecting on the consequences of changes in the catchment in relation to hydrological systems, such as when an upstream wetland degraded, with the impacts on downstream rivers and estuaries identified and scored.
- Held a workshop with a range of local stakeholders and experts in Durban (10th March 2022) to outline the likely supply and demand for ecosystem services. The workshop process shared understandings of stakeholders and experts (See appendix number 4: The list of participants), and developed new insights in terms of:
    - Ecosystems' and transformed landscapes' conditions and functionality.
    - The numbers of ecosystem services' users in terms of river communities, beach users, and catchment and city level users.
    - The relative dependency of the users on the selected ecosystem services.

- The workshop process focussed on adapting the plausible future scenarios which Durban may experience in the future. The following scenarios were proposed and described:

1. Maximum scenario – to define the upper boundary of possible improvement benefits
2. High Road scenarios – the best plausible option for Durban to work towards
3. Low Road scenarios – a plausible scenario if business-as-usual continues

All three scenarios used the same 10 years' timeframe, that is, the scenarios described a situation in the year 2032.

The outcomes, in terms of services supply and their associated demands were then modelled and reviewed.

a. The key land cover types and ecosystem services supplied

For modelling purposes, a land cover map was developed using the 2018 South African National Land Cover (SANLC) as the principal layer (Figure 4). Other spatial layers were used to improve the resolution of certain ecosystem assets, namely the National Wetland Map 5 for South Africa, river management corridor layer developed for the C40 Cities TRMP Business Case study, the South African Estuaries coverage, the eThekwini informal settlement programme layer, and the road network of eThekwini.

The key land cover categorised, and their respective areas are outlined in Figure 444 and summarised in Figure 5 in terms of their relative composition within the lower uMngeni River catchment. The total area of the lower uMngeni River catchment and associated coastline is estimated at 37,704 hectares. Approximately 56% of the study area has been transformed by urban development (e.g., settlement, industry, roads, etc.), while a small (2%) area comprises agricultural land (largely sugarcane). The natural assets make up the remaining area with

terrestrial ecosystems (forest, thick, grassland), freshwater ecosystems (rivers and wetlands), the uMngeni Estuary, and beach/near shore occupying 21%, 17%, 1%, and 3% respectively. Note that assets such as agriculture and dams also hold ecological and hydrological processes which benefit society, such as soil stability and flood risk reduction, and are therefore included in the ecosystem services analysis.

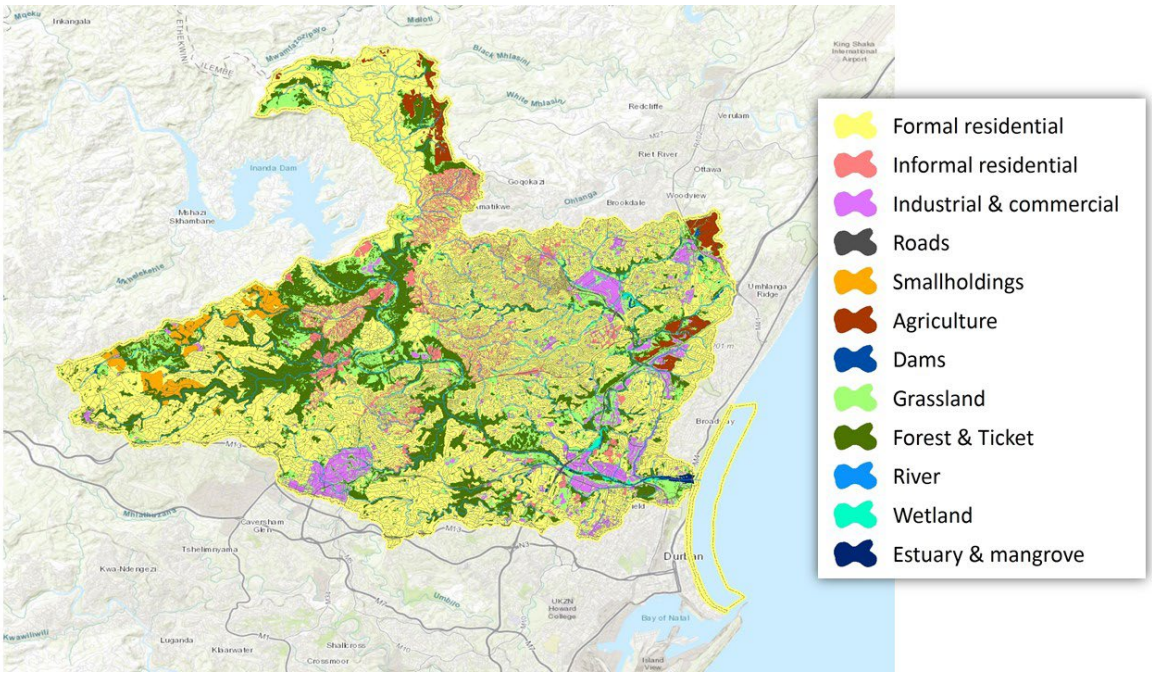

Figure 4 Land cover map of the lower uMngeni River Catchment

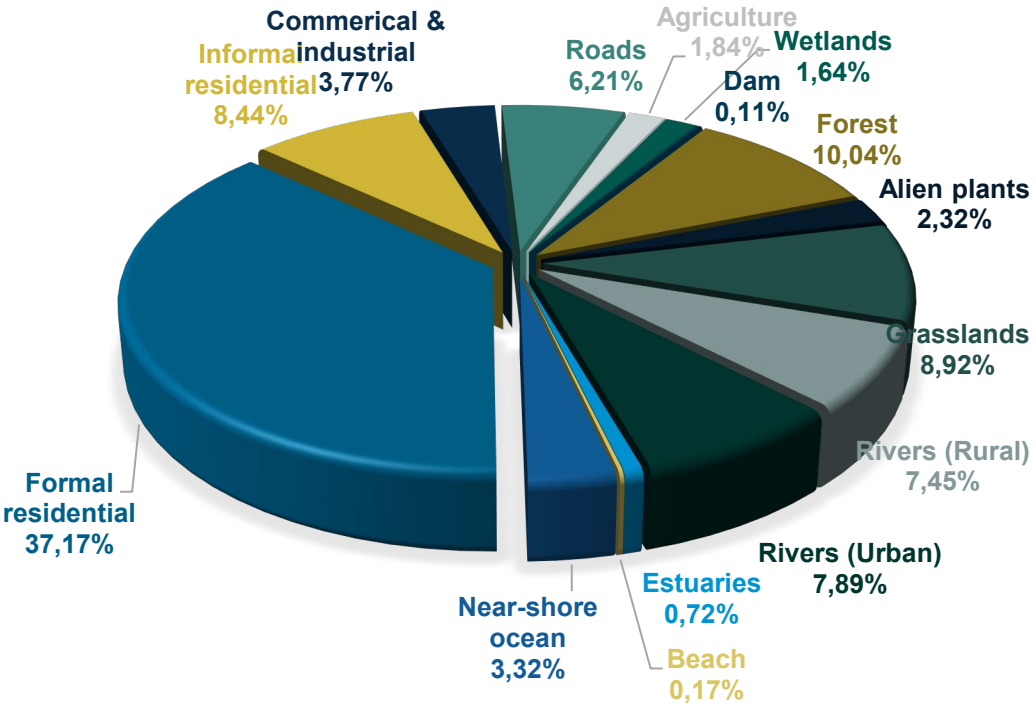

Figure 5 The relative size of the built landscape and ecological assets

The assets outlined above, generate a suite of ecosystem services which are used directly or indirectly by humans. The bigger and better the condition of the assets, the greater the level of services supplied. Not all ecosystem services supplied by assets were assessed. Only those services which are likely to be impacted by plastic waste were assessed and they are listed below:

- **Marketing icon** – the use of beaches and lush vegetation to market Durban as a national and international holiday destination and a life-style city
- **Beach recreation –** the recreation activities that beaches offer, such as playing, sunbathing, beach sports, etc
- **Water quality maintenance** – the assimilation and dilution of pollutants and the reduction in aquatic pathogens
- **Sense of place** – places or locations generate a unique atmosphere or quality that people relate to and value
- **Flood reduction** – the reduction of damaging peak water flows during high rainfall events
- **Transport access** – the ability to access transport opportunities due to intact river and stream crossings
- **Food production** – agricultural food production and fishing for consumption
- **Pest control** – the control of pests such as rodents and insects near to habitations or in agricultural fields
- **Solid waste capture** – the capture of plastic waste – intentionally or unintentionally by built or ecological assets
- **Refugia and nursery** – for replenishing fishing stocks or for bird watching
- **Water recreation** – activities such as swimming, surfing, canoeing, kayaking, sailing, etc
- **Visual amenity** – attractive views of the landscape or ocean that generate wellbeing and also elevate property values or tourism trade
- **Biodiversity conservation objectives** – meeting provincial or national conservation objectives
- **Ecotherap**y – engaging with natural environments in various ways (active or passive) to promote physiological and mental wellbeing
- **Carbon storage & sequestration** – for carbon in setting or offsets trading

b. The future land cover scenarios

A series of future scenarios were developed by the project team to analyse changes to ecosystem services and associated human benefits (see Table 2), and included a ‘maximum’ scenario, a ‘High Road’ scenario and a ‘Low Road’ scenario. In these scenarios, different plastic management options were developed, and any possible associated impacts extrapolated, resulting in associated changes to the size (in hectares), condition (scores) and connectivity (scores) of existing landscape assets.

Initially the modelling required an understanding of the current (or baseline) functionality of the land cover types, which required an analysis of the condition of the assets together with their size. Figure 66 illustrates the current condition of the assets. Areas were calculated using GIS (Geographical Information Systems), while condition scores were generated based on known data for the area. Condition scores relate to a baseline condition which in natural areas would be a pristine state and would score a 4, and in built or farmed areas the score would relate to ‘industry sustainable best practice’, for example, in agriculture, organic farming would be the best and score a 4.

Table 2: Future scenarios and their predicted changes to ecosystem services

Scenario	Description
Status Quo	Based on present day situation (baseline)
Maximum	Based on the Rwanda Model (in 2008, Rwanda's anti-plastic bag legislation, which banned the importation and use of non-biodegradable packaging bags, became among the most severe globally): • Use of plastic is banned through policy development and enforcement (waste by laws). • Population grows (12% over 10 years), but with little plastic pollution, except during extreme events; and • Strong focus on informal areas - improved awareness, better services, green economies linked to waste, etc.
High Road	Best case scenario for Durban: Population still grows with higher volumes of plastic/solid waste generation; • Develop a value chain for plastics and develop waste recycling businesses and innovations to collect waste; • Expanding Durban's Transformative Riverine Management Programme (TRMP); • Improved socioeconomic conditions (similar to "Maximum" scenario); • Reduced solid waste entering rivers, estuaries and beaches; • Reduced sewage pollution from better functioning sewer systems; • Environmental conditions and ecosystem health maintained/improved; • Gains from tourism and revenue; • Solid waste services have more time and resources to maintain systems; and • Durban becomes a "city of choice" as a healthy and safe place.
Low Road	Status Quo 10 years from now (Durban's Worst Case): • Population growth greatly exceeds the City's ability to manage and deliver basic services (e.g. solid waste); • Plastic pollution grows significantly, and beaches not useable for 80% of year (similar to what is occasionally experienced in Durban); • Increased informal settlement with socioeconomic conditions worsening; • increased waste generation with high volumes of solid waste entering river systems; • Increase in illegal dumping of solid waste in environment; • Expect increased blockages in sewer systems and WWTW failures to the detriment of water quality in rivers and on near shore beaches environments and on river health; • Road conditions and access deteriorate due to increased culvert jams and flood damage (with increased disaster management expenditure);

In addition, the plausible population growth (given published trends) over 10 years was estimated at 12%, with the possible changes in land cover type, size and condition proposed and inserted into the systems model. Importantly, the land area was always kept constant, so any increase in, for example settlements would require a concomitant reduction in another land asset, such as agriculture or forest. Note that scenarios were modelled to included linkages between habitat types. For example, when wetlands were negatively impacted, the downstream river condition would decline accordingly. For more details, see Appendix 5 for the land cover types' condition and size in the status quo and in the three alternative scenarios.

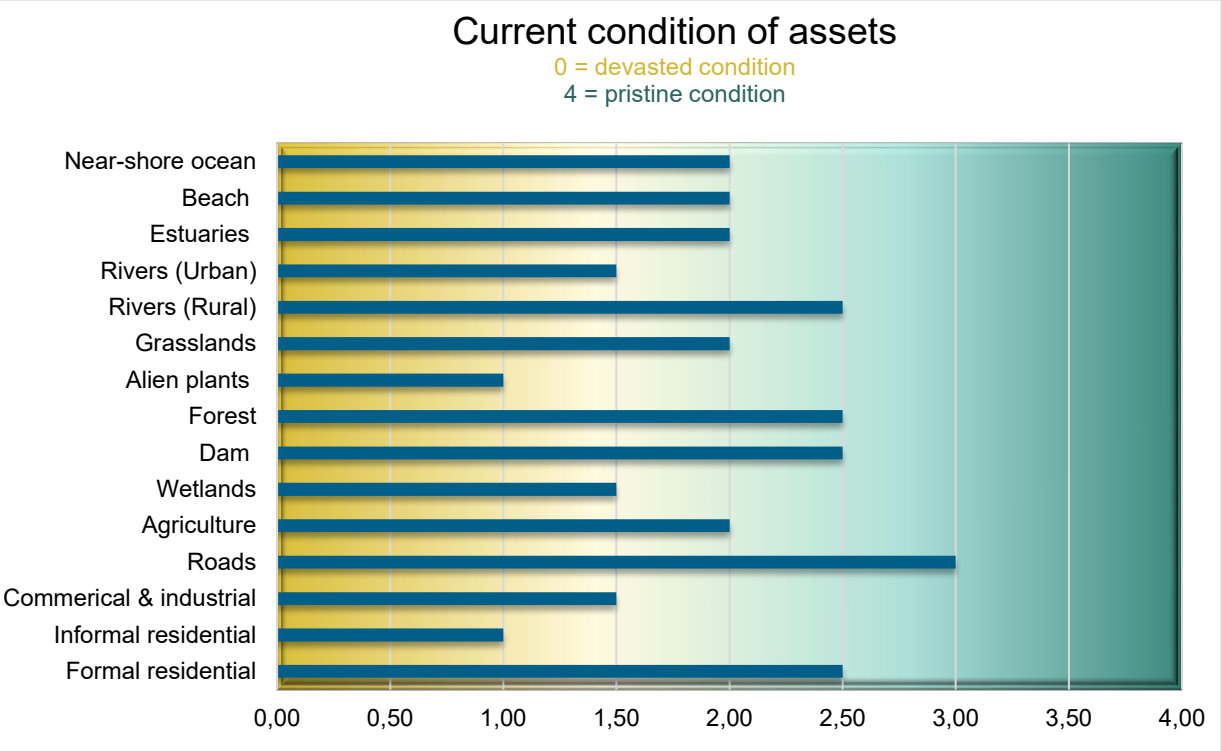

Figure 6 The condition of assets and state of the land cover types.

c. The magnitude and location of current services supplied

The modelling combined the land cover types' functionality (an indicator from the product of condition x size x connectivity) with the land cover's potential capability to produce ecosystem services (in ideal conditions), to predict relative service levels (e.g. service a supply level = habitat y area x condition score x connectivity x service supply capability score). A look-up table of service supply capability scores (again using a 1 to 4-point score – with 4=high, 3=medium high, 2=medium low and 1=low capability) was developed by the consulting team.

Figure 7 outlines the relative ecosystem service's supply levels in the catchment at the current time (March 2022). These levels are an index or indicator only. Note the highs (water quality maintenance, sense of place, biodiversity conservation objectives) and lows (beach recreation and food).

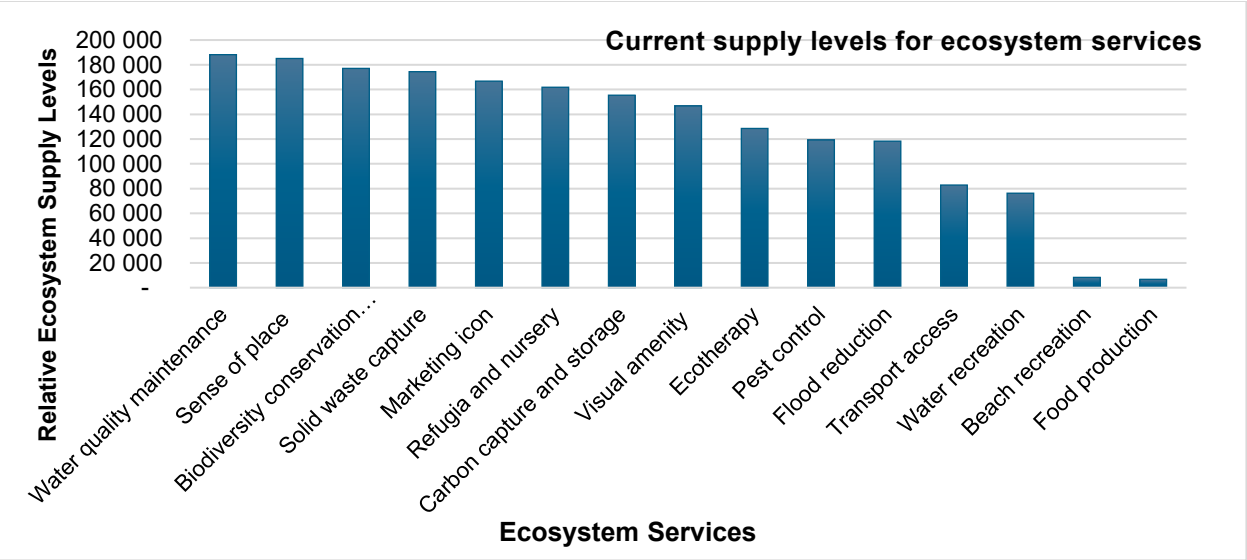

Figure 7 Relative ecosystem service levels in the catchment (the units are an index with the highest being relatively most abundant and the lowest being relatively least abundant)

Figure 8 below shows which land cover types are generating the greatest levels of services in total (based on total area of land cover) (the blue column) and the greatest services supply per hectare (the red line). This graphic illustrates that land cover such as formal residential, rural rivers and forests are currently generating the greatest volume of services. It also shows that estuaries, near shore, ocean, beach, and rural rivers generate the greatest service levels per hectare. These two factors highlight which land cover types, in general, show the maintenance priorities, and which land cover types offer the greatest benefits per hectare when managed effectively.

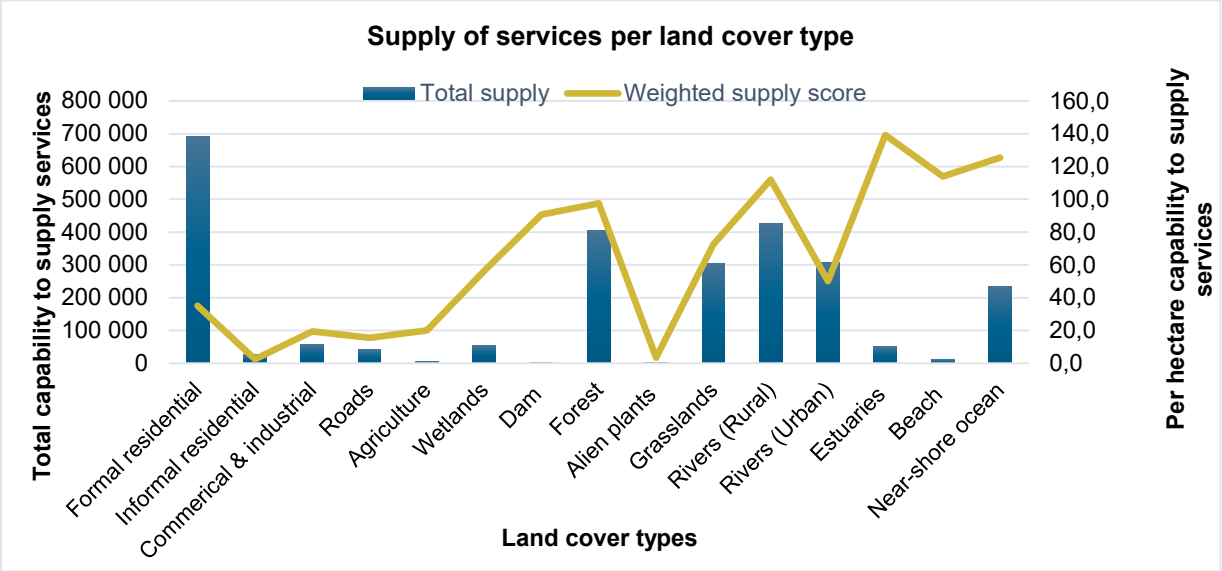

Figure 8 The total supply is the sum of all services for total area of a single land cover type (the column), while the per hectare capability is the average supply per hectare (total supply per hectare capability is the average supply per hectare (total supply per land cover divided by total area of a land cover)

d. Changes to services supply in different scenarios

In Figure 99 the yellow line constitutes the current supply level (with each service depicted as 100% of current supply levels). The percentage change in different scenarios is reflected by the different scenario lines. In the 'Low Road scenario, there is a serious decline in all services (between 20% to 80% decline) and warns against a future business-as-usual plastic waste management will lead to serious wellbeing losses for society. Such scenarios are evident in locations such as Conakry in the country of Guinea (in West Africa) where some beaches are not useable.

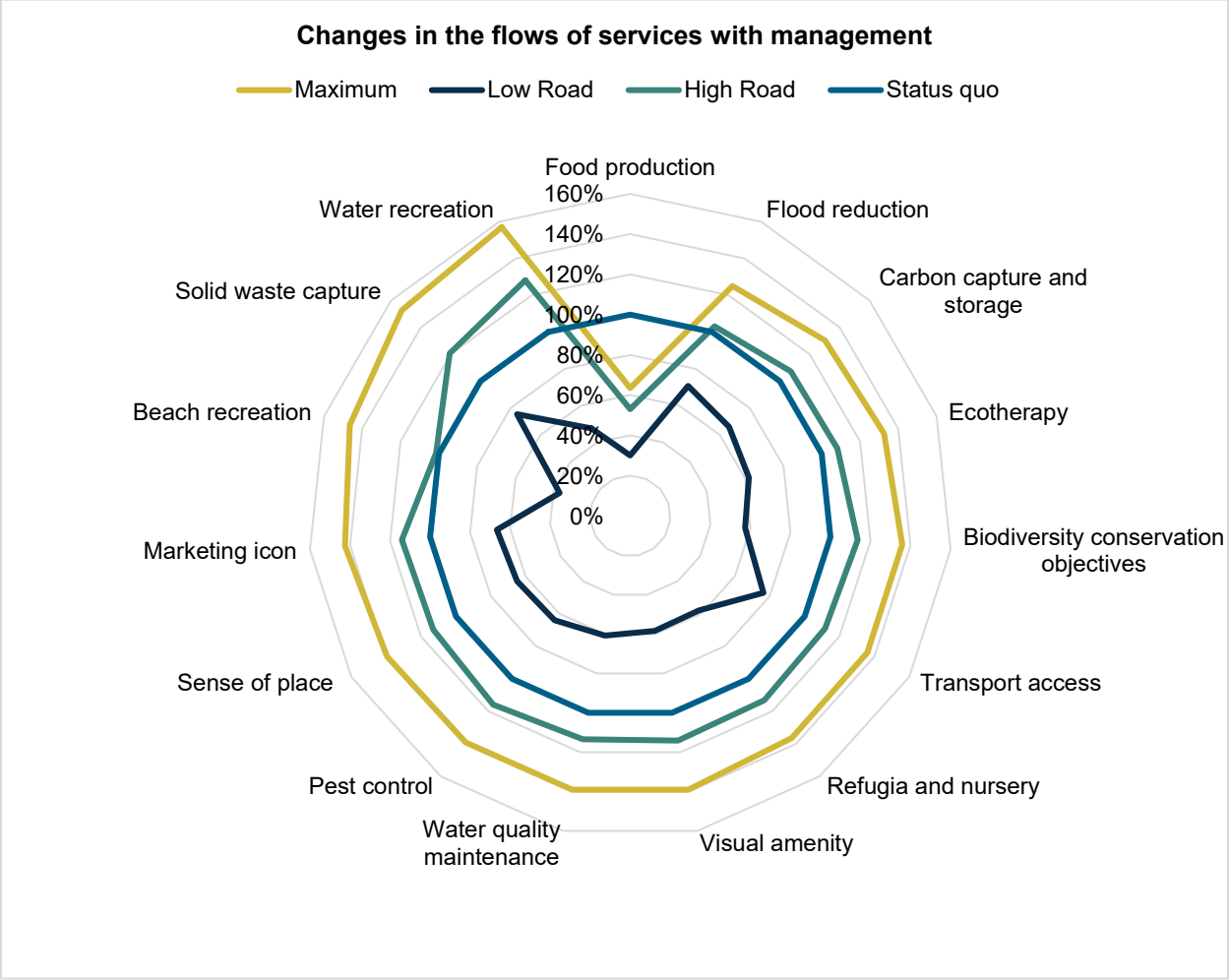

Figure 9 Changes in the supply of ecosystem services in different scenarios in the affected area (the red line shows supply at 100% of current levels)

Note that for the 'Maximum' scenario, which highlights the upper boundary of gains, there is a 30% to 60% possible growth in most service levels, except food production which declines. Note that food production declines in all scenarios due to the loss of agricultural land to informal settlement.

The 'High Road' scenario shows a range in service growth, from 0% to 30%, but importantly shows that such an intervention will be able to ensure that service levels generally grow and increase the service available per capita. This implies that even with population growth, it is feasible to improve on the current situation.

e. The demand for services

In considering the changes in services supply, the question that begs answering is – how significant are these changes to human welfare? To answer this question, the ECOFUTURES process captures the numbers of services users and their relative dependence on these services, and generates an index, the human benefit index, so that the trade-offs between choices can be compared from a human wellbeing perspective. A human benefit index is used as people may benefit very differently from services. For example, some beach users may be people who work in the hospitality industry and their livelihood depends entirely on a functional beach area. On the other hand, there may be beach users who only visit the beach twice a

year and they could have the option of going to other beaches north or south of Durban. Changes to the beach will have very different wellbeing implications for these two groups.

In developing an understanding of the user number and dependence on ecosystem services, the stakeholder interviews undertaken, GIS (Geographical Information Systems) estimates, Durban Tourism estimates, and other available data were used to estimate the numbers and the level of dependence for the following groups:

- The river community – the number of people living with 30 meters of river systems – this was based on the number of houses within the 30m zone and counted with GIS
- The off-river community – the number of people living in the catchment but excluding the river community above. This was based on Ward census data.
- The beach users - based on estimated tourism numbers on Durban beach front in 2019 (pre-covid numbers) (Durban Tourism).
- eThekwini municipality population estimate
- KwaZulu- Natal population estimate

The population of users, the weighting process and final index is provided in Table 2 and 3. Note that each service was estimated to have a particular number of users and each user group was also assumed to have different levels of dependence on the services. In this way, the user population consisting of part-time users and/or users of different intensity - are converted into an index representing fulltime users of high dependence. This index then allows the benefits to be compared - all having the same units of benefit.

Table 2 The population of ecosystem service users (total number of beneficiaries)

	River community	Off-river community	eThekwini	Coastal	KZN Population	
SERVICES	**212,074**	**844,382**	**3,500,000**	**2,200,000**	**11,500,000**	**Sub-total**
Marketing icon			100%	0%	2%	3,730,000
Beach recreation				100%		2,200,000
Water quality maintenance	50%			100%		2,306,037
Sense of place	50%	25%		100%		2,517,133
Flood reduction	50%					106,037
Transport access	50%	20%				274,913
Food production	2%	2%		0.8%		37,629
Pest control	50%					106,037
Solid waste capture	25%			100%		2,253,019
Carbon capture and storage			100%			3,500,000
Refugia and nursery			1%			17,500
Water recreation	20%			80%		1,802,415
Visual amenity	50%	25%	5%	100%		2,692,133
Biodiversity conservation objectives					100%	11,500,000
Ecotherapy	20%			100%		2,242,415

Table 3 The relative dependence on the services and a weighted benefit score (index)

SERVICES	% Very high dependence	% High dependence	% Moderate dependence	% Low dependence	
	1	0.5	0.1	0.05	Weighted benefit score
Marketing icon	10%	10%	40%	40%	783,300
Beach recreation	10%	30%	40%	20%	660,000
Water quality maintenance	10%	30%	40%	20%	691,811
Sense of place	1%	40%	40%	19%	653,196
Flood reduction	50%	50%			79,528
Transport access	25%	25%	25%	25%	113,402
Food production	100%				37,629
Pest control			25%	75%	6,627
Solid waste capture	5%	15%	20%	60%	394,278
Carbon capture and storage				100%	175,000
Refugia and nursery	25%	25%	25%	25%	7,219
Water recreation	0.2%	1%	50%	49%	146,897
Visual amenity	5%	33%	33%	29%	706,685
Biodiversity conservation objectives		0.5%	0.5%	99%	603,750
Ecotherapy	10%	20%	30%	40%	560,604

The levels of demand are outlined in Figure 10. The height of the graph indicates the Human Benefit Index, while the colours signify the relative levels of dependence.

The marketing icon service generates the greatest human benefit due to the large population (most of Durban) and it is also the service with the greatest level of ‘very high dependence’ – largely due to the large number of people associated with the tourism industry in Durban. Following closely in terms of benefits are visual amenity (tourists, tourism industry and property owners), water quality management, beach recreation and sense of place service users. All these users are strongly associated with the quality of the beach front. What is also important to note is that these users are associated with all social levels – poor to wealthy – as the beach front provides an important work opportunity and a relatively cheap and accessible recreation facility for Durban society.

The demand for services (using the human benefit index as a proxy) helps prioritise which services to focus on, and therefore what supporting natural capital to prioritise for management. The demand for services also shows which user groups could be engaged to access resources and political support for effectively managing the area. For example, engage with the tourism and property sector to leverage private and public resources to support for plastic waste management.

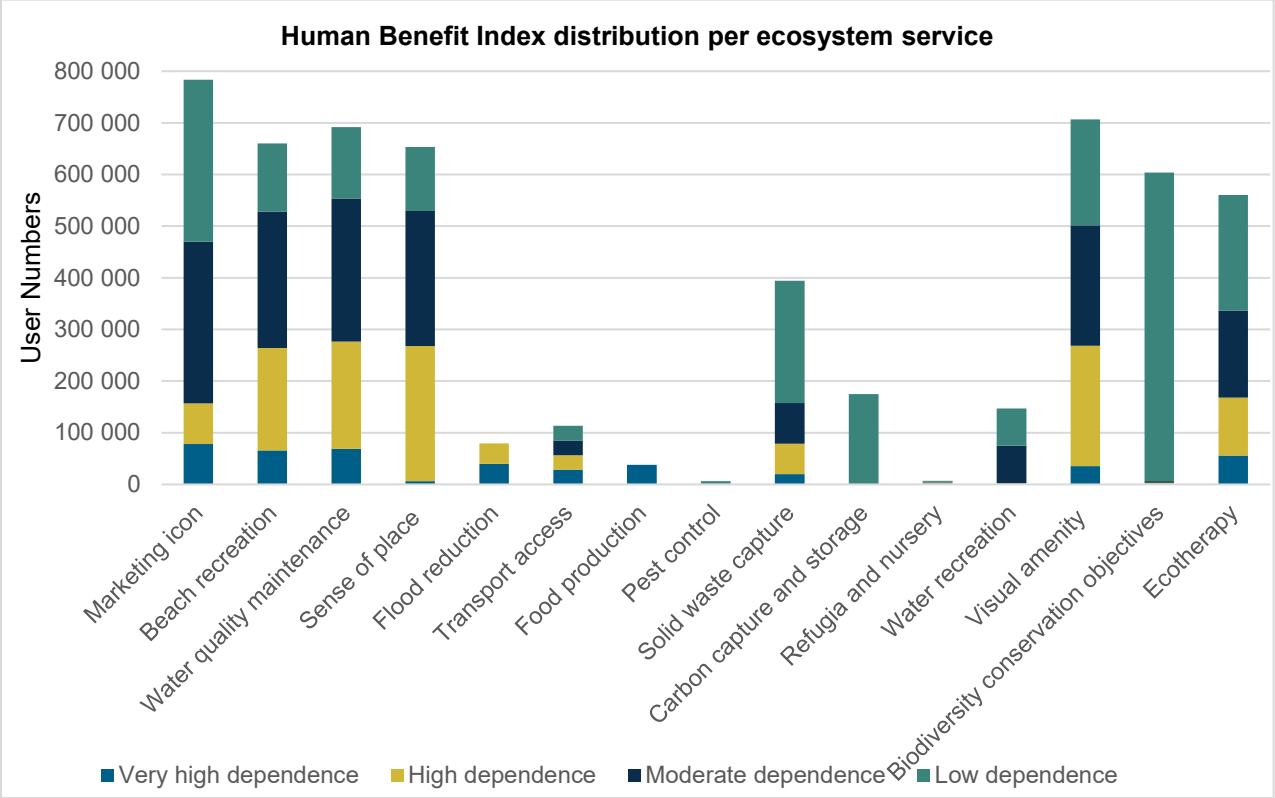

Figure 10 The human benefit index in terms of the product of estimated user numbers and the relative dependence on ecosystem services

f. The risks to services use

Comparing ecosystem services supply and demand levels provides an indication of the risks associated with each service, see Figure 11. In this analysis, risk is measured by dividing demand by supply, in other words, how much supply is there per user, and how might this change under different future scenarios.

The large numbers of beach recreation users (some 2.2 million users with a benefit index of 660 equivalent full-time users) are dependent on a limited beach area (0.17% of the catchment area or 63 ha) implying that any negative impacts to beach assets will pose a serious risk to wellbeing in Durban. Figure 11 illustrates the risk profile of the range of services. Note that the status quo is already risky for beach recreation users. In a 'Low Road' scenario, the risk index to users treble - implying that potentially high losses of wellbeing are plausible and investment is likely to be withheld. The 'High Road' scenario indicates that risks could be maintained at near to current levels, supporting ongoing investment in the area. The 'Maximum' scenario indicates that a lower risk is possible and could be pursued to attract further investment in the area.

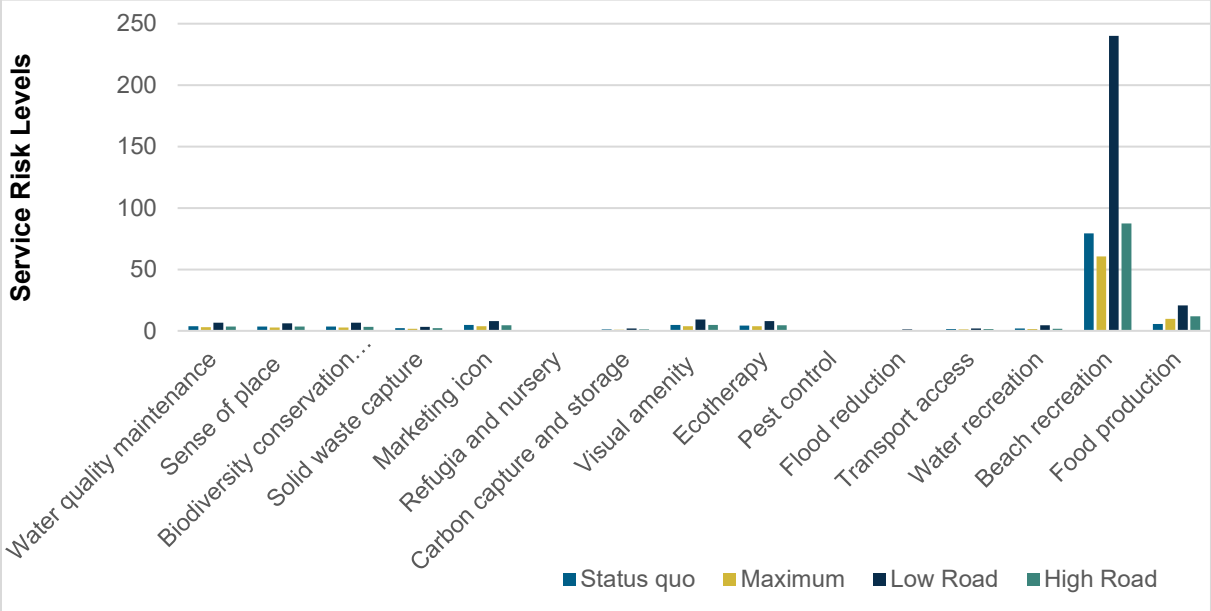

Figure 11 The risk profile of services supply in the current and future scenarios in the affected area

3.3 Results from modelling and analysis

- The catchment context:
  - The catchment is some 37,000 hectares in size, the greatest area being residential settlement, with aquatic assets making up 21% of the area. The condition of the aquatic assets are on average 50% of an ideal condition, indicating that the assets are performing well below their capabilities – half as well as they could be.
- The ecosystem services supplied:
  - The natural assets or ecological infrastructure produce a wide range of ecosystem services to society which may be impacted by plastic pollution. For example, the services may be a city marketing icon, beach recreation, water quality maintenance, flood reduction, transport access, visual amenity (and property value maintenance), biodiversity conservation objectives and ecotherapy.
- The value of ecosystem services impacted by waste:
  - The ecosystem services supplied generate a considerable amount of wellbeing. The marketing icon service generates the greatest human benefit due to the large population (most of Durban – over 3.5 million people) and it is also the service with the greatest level of 'very high dependence' – largely due to the large number of people associated with the tourism industry in Durban. Following closely in terms of benefits are visual amenity (tourists, tourism industry and property owners), water quality management, beach recreation and sense of place service users – as there are over 2 million annual beach users. All these users are strongly associated with the quality of the beach front. What is also important to note that these users are associated with all social levels – poor to wealthy – as the beach front provides an important work opportunity and a relatively cheap and accessible recreation facility for Durban society. There are also a range of other services, such as water quality maintenance and transport access (the

protection of culverts) – which benefit urban residents, which are also generated by the catchment ecosystems.
    - The benefits associated with the beach and river related services depend on the functionality of the associated ecosystems – the rivers, wetlands, estuary, beach and nearshore ocean – all of which function in an integrated way to generate good quality beach experiences and damage avoidance services in residential areas. Consequently, the levels and quantity of services supplied to urban residents, beach front properties, city beach users and visiting tourists – are important to society.
- The impacts of plastic pollution:
    - Plastic pollution degrades the functionality and consequently lowers the volume and quality of ecosystem services – with frequent flood damage to river related infrastructure – such as culverts and low lying houses, and unsightly pollution of estuaries and the beaches, which then discourage users and investors. Water quality pollution from compromised/blocked sewerage infrastructure may also manifest.
- The plastic waste management future scenarios:
    - The best case or 'Maximum' scenario was modelled to highlight the difference between the current ecosystem service levels and the potential service levels. In this scenario plastic was banned and consequently little plastic pollution arrived in the rivers, such as in Kigali City in Rwanda. In this scenario it was plausible that service levels could be 30% to 60% higher than current levels.
    - In the 'Low Road' scenario, there is a serious decline in all services - 20% to 80% decline – which warns against a future business-as-usual plastic waste management scenario which would lead to a serious wellbeing loss for society. Such scenarios are evident in locations like Conakry in Guinea where many beaches are not useable at all, and the beach has become a liability to its neighbours.
    - In 'High Road' scenario, favoured by the workshop participants, it was shown that it is plausible for Durban to achieve a growth in services of 0% to 30%. It shows that interventions, such as transformative river management, environmental education and extensive recycling, are able ensure that service levels generally grow and increase the service available per capita – despite population growth. This implies that even with population growth, it is feasible to improve on the current situation.

CHAPTER 4: DISCUSSION AND RECOMMENDATIONS

Proper waste management remains a serious challenge, particularly for developing countries, resulting in inappropriate and/or uncontrolled disposal (Hahladakis *et al*. 2020; World Bank Group, 2022). Factors such as poor waste management infrastructure and application of insufficient recycling technologies, together with the lack of public awareness and incentives, is cause for the growing concern of plastic waste entering the environment (Hahladakis *et al*. 2020). This is emphasised in the preceding chapters which highlight the threat that the current plastic waste problem has on socio-economic wellbeing and supply of ecosystem services for Durban, and its surrounding areas within the eThekwini Municipality. Managing plastic waste efficiently using innovative techniques is an essential step to ensure that the City of Durban is maintained as a sustainable and liveable city. This requires a multidisciplinary approach to handle the complexities of urban environments.

The 'high road' scenario presented for Durban includes a range of possible interventions that will help to deal with the plastic waste problem arising within the city. However, this all comes at a cost, and the only way to make this a sustainable development will be through creating a value chain for plastic waste, enabling the best possible scenario to be achieved.

A- Management Interventions and Costs for the 'High Road' Scenario

To develop the 'high road' scenario for the lower uMngeni River catchment, a range of interventions covering the various biophysical, social and institutional situations of the catchment will be required. This should include a strategy that involves all stakeholders (including primary, target, enabling, supporting, and external stakeholders) at various levels (or spheres) of influence that can integrate innovative waste management actions.

a. Provision of basic and efficient and maintained solid waste services

The installation and maintenance of a more efficient, far-reaching waste service system is the most basic and fundamental intervention for solving the plastic pollution problem in Durban. Providing more solid waste disposal services to an area, such as waste collection and recycling bins, should be relatively simple, and will promote the reduction in plastics entering the environment. However, it is important that these waste disposal services are accompanied by adequate waste collection services. Waste collection services will ideally operate throughout the area and collect as much solid waste as possible.

The provision of more waste disposal services, and waste collection services, will require substantial workforce. However, this is an opportunity to promote and increase community employment, involvement, and even skills transfer. Community members can be hired to deliver bins to an area, collect rubbish, and even be trained to become drivers of waste collection vehicles. The servicing and continued maintenance of the provided solid waste services is crucial to the long-term success of this intervention – providing bins that are not cleaned or emptied, and providing collection services that operate inefficiently, is counter-intuitive, and will end up being a burden on the municipality, instead of a viable solution.

b. Transformative Riverine Management Programme (TRMP)

The TRMP involves utilising community co-operatives to undertake riverine management, largely through the clearing of alien vegetation and removal of solid waste. The eThekwini Municipality is currently expanding the programme from the recent Sihlanzimvelo stream cleaning programme that was carried out for over seven years on 300 kilometres of river and the plan is to increase this to 1,000 kilometres of river, and ultimately 7,400 kilometres covering the full length of rivers that flow through the eThekwini Municipality.

The current costs required to support TRMP is approximately R80,000/km ($5,500/km) of river. The lower uMngeni River Catchment supports 425 kilometres of riverine habitat that can be covered by the TRMP co-operatives. The current estimated cost is therefore ~R40million ($2.7 million), which includes both removal of solid waste and clearing of alien vegetation.

c. Passive solid waste traps (biophysical interventions)

Various traps can be installed. It is is proposed that the eThekwini Municipality install various traps at throughout the study area to aid in trapping and collection of solid waste. These include:

- **Litter socks –** relatively novel structures that can be fitted onto culverts and stormwater drains on outflow points. They are relatively specialized and may need to be imported unless they can be made locally. Cost to import and install one sock is approximately

R100,000 ($6,800), and these would need to be placed in strategic solid waste 'hotspots'.

- **Litter booms (or trash booms) –** are installed diagonally across waterways to catch and direct floating material (debris or solid waste) towards the banks, thus preventing this material from travelling further downstream, and allowing waste to be removed from the river. The cost to install and service a litter boom ranges from approximately R35,000to R70,000 ($2,380 - $4,760) per year.
- **Groynes –** are structures that protrude from a bank into a river that are constructed using reinforced concrete, gabions or soil berms. They are generally used on floodplains and in lower-energy river systems. The primary purpose of a groyne is to direct high energy flows away from the bank to protect it from erosion, however, they also influence the hydraulics of a river by creating an eddy, encouraging sediment and solid waste deposition. The cost to design and install a single groyne is approximately R600,000 ($40,800).

Litter traps will require regular maintenance to remain effective, which will incur a running cost to the eThekwini Municipality. However, this is countered by the creation of an employment opportunity, as community members can be trained to clean. In the absence of known quantities of plastic waste it is difficult to provide an estimation of the number of units that would be required to for the lower uMngeni River Catchment. An amount of R4million ($272,000) is assumed, which will allow for ten litter socks, three large litter booms, ten small litter booms and two groynes to be installed.

d. Social and institutional interventions

Social interventions aimed at training of local communities and municipality officials in resource management practices, improved supply chains and access to market, new infrastructure, peer learning and user groups, financial investments, etc. Empowering people to take ownership and responsibility of their surroundings and giving them agency to take more in control of their own lives is an effective way instilling behavioural changes and encouraging people to take action. This is where the greatest change is needed that can have long-term positive impacts for the environment. The following types of social interventions can be considered for the study area, building on existing programmes:

- **Enviro-Champs training and monitoring –** The Enviro- Champs programme or model, pioneered by DUCT, has had great success in the various parts of KZN (including the Palmiet River within the study area) and has great potential for upscaling throughout the eThekwini Municipality. Enviro-Champs are essentially on-the-ground monitors that provide education and training to local communities on water quality issues (proper disposal of refuse, reporting of sewerage spills, proper sanitation and no illegal dumping of waste). They are trained to use citizen science tools to monitor water quality, and report issues to responsible authorities. Enviro-Champs can be selected from the number of informal settlements located within the lower uMngeni River Catchment. They can serve to help uplift the social wellbeing of communities while helping improve river health through water quality monitoring, reporting leakages, burst pipes and discharging sewers, and engaging in door-to-door initiatives to raise awareness about water and sanitation issues. Estimated cost of R600,000 ($40,800) to train and employ a team of 10 Enviro-Champs.
- **School environmental programmes –** Building awareness around river ecosystems through school environmental programmes and citizen science activities is a good way to get local schools to become involved in the ongoing monitoring of river health while instilling a healthy appreciation of the environment (including knowledge of solid waste impacts). A practical example here is to provide support to multiple schools that can

"Adopt-a-River" reach and undertake monitoring using various citizen science tools. School groups could also provide outreach around issues such as solid waste and sewerage pollution within respective reaches. There are up to 65 primary schools and 80 secondary schools in the study area that can be considered. Estimated cost of R60,000 ($4,080) to develop and run a school programme for one primary school and one secondary school.

- **River awareness and training –** Stakeholders that can significantly influence how rivers are managed and how clean-up operations are coordinated include municipal officials, ward councillors and private businesses. Key members from these groups can be trained to improve understanding of the linkages across these catchments, ecological infrastructure and enhance awareness regarding the importance of riverine ecosystems. Estimated cost of R300,000 ($20,400) to train 10 councillors/officials and 10 business members.

An amount of R5million ($341,000) is considered, which will allow for five teams of up to 50 Enviro-Champs, ten primary schools, ten secondary schools, ten councillors/officials and ten business members to be trained and educated to monitor river systems and build awareness around wise river management.

e. Develop a plastic value chain using waste recycling technologies

As of 2018, South Africa has been successful in diverting only 10% of waste from landfills to recycling facilities (Strydom, 2018). This low value can be attributed to the difficulty associated with accessing these facilities, which discourages South African citizens from recycling. South Africa has a heavy reliance on mechanical recycling facilities, which struggle with degradation, high costs, and the need to meticulously sort a wide variety of plastic products. These facilities also "down-cycle" plastic - producing a product worth less than the virgin material. As such, there is no "value chain" associated with recycling plastic. However, this creates an opportunity to explore alternative recycling technologies, such as reverse vending machines and chemical recycling technologies.

Reverse vending machines consume and crush plastic bottles in exchange for cash – effectively creating a simple plastic value chain. The machines themselves are mostly self-serviced (any Durban resident can collect plastic waste and bring it to the machine) as well as low-cost and automated, and crushing plastic products saves space (Sambhi & Dahiya, 2020). Reverse vending machines will need maintenance to remain effective. This provides an employment opportunity, as community members can be trained to operate and service the machines.

It should be mentioned that placing reverse vending machines on the streets will place them at risk to crime-related activities. Thieves may damage the machines whilst trying to gain access to the large quantity of cash kept within the machine, undermining the effectiveness of this intervention. It is therefore proposed that the eThekwini Municipality purchase a number of these machines and place them in secure areas with high plastic pollution density, such as schools, malls, food outlets or offices. Alternatively, machines could use of a token system – where plastic is exchanged for tokens that can be redeemed for cash at a separate location.

Chemical recycling technologies are more complicated. These technologies create value by consuming plastic to produce cheap fuel alternatives and are more resistant to the variety of plastics in the waste stream, mobile, cost-effective, and environmentally friendly compared to traditional landfill and incineration waste disposal methods.

There are several chemical recycling technologies available, the most promising of which are gasification and pyrolysis. Research has shown that small-scale pyrolysis units (which cost

approximately R1 million, or $68,000 per unit) can produce 400-500 litres of diesel per day processing between 600 and 700kg of plastic. Diesel produced in this way costs R7/litre ($0.5/litre, three times cheaper than current costs), which can be used to subsidise logistical expenses of other systems (e.g. waste collection system where fuel is the biggest expense) and power generation system (diesel used in peak power stations). Gasification technologies available internationally are modular and affordable, producing between 200kW and 1 megawatt output using an average of one tonne of plastic, per hour per megawatt. It is estimated that one plant can consume over 2 000 tons of plastic per year while saving costs on fuel imports.

These key potential power generation options articulate perfectly with the city's stated intentions in this area – as embodied in the eThekwini Integrated Resource Plan (EIRP) document (Link to the Energy policy for public comment document) This outlines the long-term, clean energy strategy for the eThekwini Municipality – and the milestones to accomplish this goal by 2050. The document aims to ensure that eThekwini Municipality can fulfil its constitutional mandate to transition to clean, sustainable, and cheap energy sources, whilst meeting climate change targets and bolstering economic growth through job provision.

Chemical recycling technologies, such as pyrolysis and gasification, may bolster South Africa's ability to achieve the goals set out in the EIRP by 2050. These technologies provide the means to reduce plastic pollution in the environment, produce clean, sustainable fuel and energy, and create jobs in the process – cohesive, clean, and contained systems that target all the elements of the EIRP.

Table 4: Waste recycling options based on current projected costs

Intervention	Set up and running cost per year	Waste consumed (tonnes of per annum)	Product Quantity	Product Unit	Return on Investment (months)
Pyrolysis (10 tonne plant)	R 18,000,000	2800	1188000	Litres of diesel	18
Pyrolysis (800L plant)	R 2,500,000	210	125000	Litres of diesel	24
Gasification (5MW plant)	R 350,000,000	84000	1610	Mega Watts of power	42
Gasification (1MW plant)	R 50,000,000	16000	306	Mega Watts of power	12
Glass aggregate (2 tonne plant)	R 3,150,000	4200	4200	Tonnes of aggregate	2

** RoI estimates based on specific project applications and should be calculated for local conditions, so above estimated are indicative only*

Small-scale gasification and pyrolysis units already exist and would be ideal for the study area. These units are mobile and can be moved between the plastic "hotspots" of the study area (i.e. where plastic waste generation is greatest). Community members can be paid to collect and sort plastics for the units. Although chemical recycling technologies are more resistant to mixed and layered plastics than mechanical recycling methods, sorting is still required to reduce contamination of wood and metal-related materials (Muhammad Saad Qureshi, 2020). Depending on the number of units, gasification and pyrolysis technologies can create jobs not just for the day-to-day operations, but also for teams/co-operatives removing and collecting waste from the environment.

The largest obstacles for these technologies are licensing, funding and the need for consistent feedstock. A blanket technical approval will be required to circumvent the need for each pyrolysis/gasification unit to receive an EIA (Environmental Impact Assessment) assessment – furthermore, the mobility of these units may be limited to the area wherein the license applies. Small-scale pyrolysis units have a relatively low environmental impact, which should ease the process of acquiring air emission and water use licensing. A viable strategy to overcome the

need for government funding would be for the private sector to handle the delivery of units (private sector will handle the capital cost, but will also monitor quality control) and sell the recycled product back to the government/municipality.

The use of plastic and glass as an ingredient in aggregate for retaining blocks and paving stones can also be explored as an alternative to the chemical recycling technologies mentioned above. Studies have shown that aggregate containing a 40% recycled plastic material holds very similar strength properties to conventionally mixed aggregate – and reduces the reliance on natural resources, such as sand (A Gupta, 2020). This technology is also reportedly cheaper than traditional methods, however; more research is required to define the exact degree of cost-effectiveness.

Hence, there is lots of potential for the implementation of waste recycling practices in the study area, which will not only reduce the volumes of solid waste entering the environment, but also create businesses and provide opportunities for employment. The ability for gasification and pyrolysis technologies to add value to the recycling of plastics is major, and these technologies provide elegant solutions to plastic pollution, unemployment and rising fuel prices. Although pyrolysis and gasification have some limitations, these can be overcome with the correct approach, and promote a relationship between government and the private sector.

Although the potential for developing innovative technologies to recycle plastic waste is justified, there is a distinct lack of information of plastic waste volumes that would enable the number and size of plants to be determined. For this study it has been assumed that three small (800L) pyrolysis plants, one small (1MW) gasification plant, and one glass aggregate plant would be a suitable starting point to pilot these innovations within the lower uMngeni River catchment. This would cost in the region of R60million ($4.1 million) to set up and run for one year.

B- Conclusions and summary of Plastic Waste Management Cost-benefit Overview for Durban

Based on the research conducted in this study, a conceptual model was developed that describes the effect that plastic accumulation has on societal costs and benefits of ecosystem goods and services. The figure below (Figure 12), shows this model. If Durban were to be ranked according to Figure 12, the state of the city work conducted during this project, it is suggested that Durban would most likely fall within Scenario C of this model: State of Malfunction with a rapid deterioration of systems, steep decline of ecosystems goods and services benefits, steep increase in demand and costs of management of plastic. (A more detailed description of each scenario is found in Appendix 6).

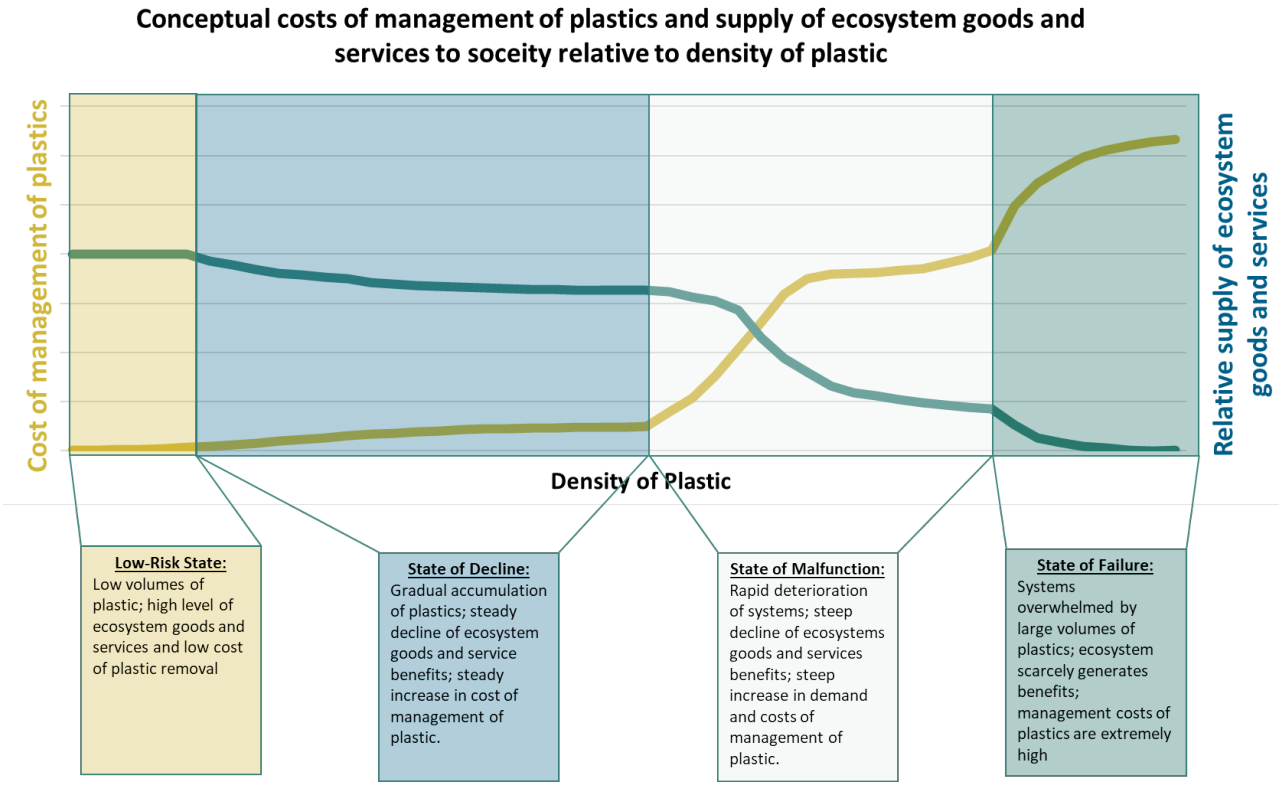

Figure 12: Conceptual Costs of management of plastics and supply of ecosystem goods and services relative to density of plastic

The greatest socio-economic benefit for the City of Durban sits within the revenue that is generated from an estimated R20billion ($1.4 billion) tourism industry, as well as from the incomes generated from rates and taxes. This has a significant amplification effect when combined with aspects of land values, a broad rates (local tax) base, and numerous goods and services etc., which are probably not accounted for in this figure. As such the above figure is therefore likely to be highly conservative and may in fact be much larger.

The plastics waste within and transported by the lower uMngeni River catchment alone has the potential to seriously jeopardise these extremely valuable revenue streams based solely on the threats posed from poor waste management, and the impacts that this plastic has on the supply of numerous key ecosystem goods and services.

To realise or achieve the 'high road' scenario as estimated in this work, the best possible scenario for the city will cost in the region of R110million ($7,5 million) to set up and run in the first year (based on current projected costs). These first-year costs will decrease substantially (by approximately 50%) into the second year, particularly for the plastic/waste recycling value chain innovations which have high initial set up costs. Compared to the benefits that are gained from the tourism industry, which is probably closer to R10billion ($680 million, and scaled from the R20 billion, or $1.4 billion, figure for the city of Durban and to the impact that the lower uMngeni River has to the broader study area), these costs are in the region of 1% in the first year dropping to 0.5% thereafter. Thus, the benefits from the tourism alone strongly outweigh the costs to implement actions that will bring about changes to the lower uMngeni River Catchment to reduce plastic waste within the environment and improve the wellbeing of socio-economic and ecological systems – and broadly enhance the delivery of key ecosystem goods and services from the area.

South Africa has signed and made a commitment to the UN Sustainable Development Goals (SDGs). The issue of plastic waste is crosscutting on numerous of those SDGs, and hence those commitments.

This study has highlighted the significant costs to a range of key stakeholders of inaction around plastic waste, whilst at the same time illustrating those most impacted by this issue. It also spatially and institutionally highlights key parts of the system that should be focused on going forward and to address this issue. Results have also highlighted the potential key linkages that could be achieved with a robust and resourced community-based recycling, jobs and skills development programme. This would achieve:

- Increased employment within the region;
- Power generation – in support of the city's own stated policy objectives to achieve greater power independence and generation;
- Ongoing and improved tourism revenues;
- Assisting in addressing well publicised negative aspects around water and sewage pollution in the city's rivers, estuaries and beach environments.

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Appendix 1. Background Information Document (BID) for the Stakeholder Engagement

Purpose of this document

The purpose of this background information document (BID) is to inform stakeholders about this study that will involve a socio-economic analysis of the costs of plastic debris pollution in the uMngeni River catchment, below Inanda Dam, in the region KwaZulu-Natal of South Africa. The purpose of the project is to investigate social and economic impacts of plastic waste on a range of stakeholders in government, private sector and civil society.

Stakeholders are invited to participate in the process by contributing information by corresponding with the project team at the address provided: Fonda Lewis, Cell: 0828038989, Email: Adrienne@Groundtruth.co.za.

Background to the project

Marine litter and debris, such as plastic items, lost fishing equipment, and thin plastic waste are an international concern not only because they wash up on beaches and shorelines worldwide and look unsightly, but also because debris impacts commercial fisheries, human health, marine ecosystems and other ecosystem services throughout the world. Investments in improved waste management practices on land are critical to reducing the amount of plastic waste entering the oceans.

A recent plastic pollution assessment by IUCN (International Union for the Conservation of Nature) in 2020, highlighted KwaZulu-Natal as a hotspot for plastic leakage in South Africa. The South African Department of Forestry, Fisheries and the Environment (DFFE) has also identified the heavy load of marine litter originating from the uMngeni River as a major problem. DFFE is therefore a strategic partner on the project both in terms of contributing to the study as well as potentially applying the outcomes.

The focus of the study

Plastic litter is discarded in streets, drains, storm-water channels and culverts in settlements and suburbs, either blocking these channels or discharging directly into the uMngeni River particularly during high rainfall events and floods. This is resulting in plastic litter moving along the uMngeni River system from source to sea. Recent flooding in the greater Durban area resulted in excessively high volumes of plastic waste being transported along the length of the uMngeni River and deposited into the marine environment along the beaches of Durban Bight.

GroundTruth in collaboration with NIRAS, and with support from the Swedish Agency for Marine and Water Management (SwAM) (the Sea and Water Authority specifically), are undertaking this project in strategic partnership with the South African Department of Forestry Fisheries and Environment (DFFE). The objective is to investigate both the social and economic impacts of plastic waste on a range of factors affecting a broad range of stakeholders. This includes:

- Analyzing the social impacts including for example, human health effects and public perception of plastic debris
- Identifying economic impacts, for example, loss of revenue for key industries/businesses along the catchment and, clean-up costs in and around the river and beaches.
- Estimating the magnitude of the impacts (under different scenarios) to different key user groups
- Identifying opportunities and provide motivations for the eThekwini Municipality to manage plastic pollution more effectively.

- Identifying additional potential solutions including for example innovative ideas and community driven initiatives to tackle land-based pollution of plastic into rivers.

The project approach

The study will apply an ecosystem services approach. The ecosystem services approach allows us to view natural systems as sources of services and goods for human well-being. Identifying the goods and services that are provided to us by the natural environment provides a way to assess the impacts and costs or benefits linked to changes in the condition of the natural environment. The ecosystems approaches being applied in this study has two key themes:

- Building a model of ecosystem goods and services (principally focused around the uMngeni River below Inanda dam, and how these are modified by the plastics within these systems),
- A social learning and stakeholder engagement process to allow a collective understanding of the key services and disservices which occur under different scenarios around plastics management.

The relative magnitude and change to the services under the different scenarios will be used to guide future engagement as well as the municipal focus areas that need to address the plastics issues within the eThekwini, and the study focus area in particular.

Some facts about the uMngeni river and catchment

The uMngeni River serves as the primary source of drinking water for an estimated 3.4 million people in the Kwazulu-Natal area. The same catchment also accounts for 65% of the economic production in Kwazulu-Natal, producing 20% of South Africa's gross national product.

Durban is known for its busy port and aesthetic beaches, making it an important economic hub for the region.

Plastic debris has negative impacts on many activities, such as aquaculture, fisheries, shipping, leisure boating, industrial use as well as coastal tourism, and this is a threat to production and revenue.

What are ecosystem services?

Ecosystem services are the benefits that humans get from the natural environment. Most of these services are usually taken for granted, but they lead to benefits that are essential for human wellbeing and quality of life. Ecosystem services can be divided into four categories:

- Provisioning services (e.g. water, food, drugs and genetic resources)
- Regulating services (e.g. flood attenuation, herbivory, pest control and pollination)
- Supporting services (e.g. primary production, nutrient cycling) and
- Cultural services (e.g. recreational, spiritual and cultural benefits)

Following an ecosystem approach means understanding these connections, and taking account of ecosystem services in how we manage land, freshwater and the sea.

Plastic pollution is a physical, chemical and biological threat to the environment and erodes ecosystem services. This creates risks for human well-being and quality of life.

Location of the study area

This study area consists of the lower reaches of the uMngeni River catchment, below the Inanda Dam, within the eThekwini Municipality. The uMngeni River system, is strategically

significant to KwaZulu-Natal in terms of water security, and it is also one of the most developed catchment regions in South Africa.

The uMngeni River has particular importance within the eThekwini Municipality, having several economic, ecological, recreational, and aesthetic properties that make it one of the most recognizable river systems in the region.

The uMngeni contributes a significant and large volume of plastic pollution to the river and marine environments from much of its urbanized catchment area within the eThekwini municipal area. The geographic scope for this study is therefore defined as the length of the uMngeni River below the Inanda Dam wall, to the estuary reach in the city of Durban and into the adjoining sea.

Appendix 2. Stakeholders engaged in the social assessment

With respect to the South African legislation: POPIA (Protection of Personal Information Act), the names of the stakeholders are not mentioned.

User Groups	Organisation	Department
Tourism Enterprise	Surf ski club and school	Paddling Academy DBN (uShaka Marine)
Tourism Enterprise	Surfing school	Living the Dream Surf School
Business	Key businesses	UrbanMGT
Real Estate	Harcourts Synergy	
Government	eThekwini Municipality	Climate and Environment
Government	eThekwini Municipality	Climate and Environment
Government	eThekwini Municipality	Economic development Unit
Government	eThekwini Municipality	Stormwater and Catchment management
Government	eThekwini Municipality	Durban Tourism
Government	eThekwini Municipality	Durban Tourism
Government	eThekwini Municipality	Project Executive: Coastal Policy
Government	eThekwini Municipality	Manager: Operation, Strategic and New Developments
Government	eThekwini Municipality	Manager: Education and Waste Minimisation.
Government	DFFE	Project Co-Ordinator: Source to Sea Regional Demonstration Project
Government	DFFE	Chief Directorate: Integrated Coastal Management
Government	DFFE	Chief Directorate: Integrated Coastal Management
Communities	Quarry Road West Settlement	Environmental Specialist
Communities	Enviro Champs	
Communities	Wise Wayz Water Care	
Research / Academic	The Ocean Clean-up	
Research / Academic	The Ocean Clean-up	
Research / Academic	UKZN Geography	
NGO / Private Sector	WildOCEANS	
NGO / Private Sector	WildOCEANS	
NGO / Private Sector	ORI	
NGO / Private Sector	Adopt a River Ecosolutions	
NGO / Private Sector	Litter Boom Project	
NGO / Private Sector	Refilwe Matlotlo Non-Profit Organisation (#justcleansa)	
NGO / Private Sector	Durban Green Corridor	

Appendix 3. Tables covering the social perception

Table A: Overview of perceptions of the social and monetary costs and impacts of plastic pollution across a range of stakeholder categories

ECOSYSTEM SERVICE	EXAMPLES	Informal settlement communities	Recreation Clubs and Businesses	NGOs and CSOs
Provisioning services	Food (crop production on river banks, fishing in rivers and sea) Water Consumption Harvesting natural resources (e.g. reeds, building materials	Not a lot of cultivation taking place on banks of rivers due to expansion of housing so no space for crops. But some reported to be starting in some areas again after clean-up/restoration activities (upstream near Molweni). Fishing not widely practiced mainly because of lack of fish (due to poor water quality, over catching?) but when fish were caught and in areas where still caught plastic waste not seen as a hazard to consuming the fish even when plastic found ingested by fish. River water not used for drinking - households have access to piped water. Not a lot of livestock kept so no issues raised about risks of plastic to livestock		
Regulating and Supporting services	Flood attenuation / Flood damage reduction Control of pests / disease reduction Nutriment cycling Habitat provision (biodiversity) Provincial and municipal biodiversity conservation objectives Residential land for settlements (e.g., informal settlements close to rivers)	Flooding of houses is perceived as a risk and 2019 floods flagged as impacting heavily on loss of houses. But not linked to impacts of plastic pollution. No perceptions of impacts of plastic on pests and diseases or to health. Water quality linked to E. coli and chemical pollution widely seen as the risk but not plastic. It is however perceived to be linked to mental health and well-being which is described below. Some people try to burn the waste to get rid of it (where no waste collection) but burning perceived to be bad for air quality and associated with respiratory illnesses so not a common practice.	There has been a substantial increase in plastic waste pollution over past years and it is impacting on recreational users (spear fishing, snorkelling, surfing, etc) in several wats. It is unsightly on beaches and breaks down into micro-plastics which then enter system and have health impacts. Littering intertidal zone and rock pools where it must be impacting light and fowling for marine life which must negatively affect marine biology.	A lot of plastic litter trapped in Mangroves and so looks like not much coming down the river. Mangroves act as a filter. But then rain event and it's flushed from the mangroves and deposited downstream and on beaches to amplifies the effect. No info on impact of plastic pollution on health and functioning of mangroves and socio-economic costs and consequences. Combination of human and 'non-human' cost of impacts of plastic. Detrimental impacts to biodiversity and environment (e.g., micro plastics impacts on earthworms etc).
Cultural services	Places for religious / traditional / spiritual ceremonies A place for recreation and sport (canoeing on river, swimming / surfing in rivers and along	Plastic is perceived to be a nuisance to the selection of sites for spiritual / cultural practices, but it is not a big problem that stops a site from being used. The key issues are volume of water flowing (e.g., waterfalls) so even if plastic	About 3500 – 4000 members of the Durban Undersea Club (surfers, divers, paddlers etc.). Plastic pollution affects well-being by negatively impacting on happiness	Impacts of plastic pollution on tourism e.g. on desirability of visiting beaches.

ECOSYSTEM SERVICE	EXAMPLES	Informal settlement communities	Recreation Clubs and Businesses	NGOs and CSOs
	beaches, sailing and fishing/diving in sea; Safe beaches for children Places for cultural practices and traditions Aesthetic / visual amenity value / scenic beauty	pollution at a site with good flow the site is still used (e.g., Rasta Falls). But water quality in terms of E. coli and chemical pollution is widely recognised so traditional/spiritual leaders will get people to take buckets of clean water from standpipes all the way to the river and still stand in the river of the ceremony but then bath/wash in the bucket water not river water. But presence of plastic pollution does not have impact on these practices. Children like to play and swim in river and adults may chase them out because of perceived health risk from water quality but not associated with plastic pollution. Negatively affects sense of place and dignity - solid waste and plastic undermine sense of self-worth and people start to believe that is all they are worthy of, and they deserve what they get. These perceptions negatively affect mental health and well-being, more so than physical health. Some recognition that plastic pollution is bad but most just don't care. Perceptions start to change when rehabilitation initiatives undertaken and sense of pride s re-instated. People start to take ownership again and start putting pressure on others not to dump in rehabilitated areas.	and seeing it and the impacts it has on marine life is upsetting and even makes people angry. Don't like to take people surfing / paddle-skiing when lot of plastic pollution as people perceive it to be dirty and unsafe, also attribute dead sea life to it. Negative impacts on sport and recreation because plastic is unsightly and so detracts from enjoyment. But people actually far more concerned about E. coli and water quality Not so much the direct effect plastic pollution has on people, but the impact is the psychological impact it has when people see the impact it has on marine life. Plastic pollution does not really result in a cost to the paddlers, divers or surfers - does not result in loss or damage to equipment. It is also not perceived to pose any health or safety risks to these user groups - just a nuisance impact. A lot of foreign tourists are very surprised when they see large quantities of plastic pollution in the sea as it's something that is very foreign to them - may affect their willingness to return? Reflects badly on the Municipality seeing all the plastic pollution and looks like municipality not doing anything about it. On the beaches, on the beautiful promenades etc.	Also loss of social/amenity value due to plastic pollution e.g. plastic pollution at special places like Rasta Falls. Combination of water quality issues such as E.coli pollution results in loss of open areas for social and recreation activities due to pollution. But people start to come back to use the areas once areas cleaned and this has positive impact on community (social capital) for example old women come and start using open areas for social and fitness groups and pocket parks for therapy areas for children. People start to take pride in restored areas and putting pressure on others not to dump waste. (Note - These areas lost for these activities when filled with plastic pollution - contributes to erosion of social capital and sense of community which increases risk of increase of other social ills).
Business / Economic	Property values Business operations	Plastic waste perceived by some to be an enterprise / income earning opportunity.		Picking up plastic pollution is recognised as an employment creation opportunity - Adopt a River Eco Solutions employs 5 people for 4 days a week for the past 2

ECOSYSTEM SERVICE	EXAMPLES	Informal settlement communities	Recreation Clubs and Businesses	NGOs and CSOs
	Repairs and maintenance	Most people don't really care about plastic pollution very much – "unless it's terrible its perceived to be acceptable".		years to pick up plastic at Blue Lagoon and surrounding beaches. But operating on a shoestring budget. Have had funding in the past through Amanzi ethu and EPWP and employed more people. Currently got a proposal in to the Presidential Fund for funding for 30 people who would work in teams of 4 or 5. Ideally want to divert the plastic that is collected from going into the landfill but very few options of what to do with it now. So it is taken to the south bank where agreement with Durban Solid Waste to collect it and take it to the land fill. But this is very far away and so very expensive. But plastic recycling opportunities currently very limited and typically focussed on (clean) PET. Most of the plastic that is collected does not meet this category so no operation but to send to landfill at present. However, are exploring opportunities to incorporate it into 'green cement' which will take all plastic and does not need to be cleaned. If successfully established this could increase potential for more employment and income generating opportunities. Mainly through corporate sponsorship several initiatives to address plastic pollution are being developed that also create employment and incomes e.g., 24 reclaimers working across 4 or 5 litter booms below Inanda Dam. Aim to establish SMEs (Small Medium Enterprises) though sponsorship that can reclaim plastics for recycling - but currently challenges with securing waste management licencing requirements from authorities. Intention to supply reclaimed

ECOSYSTEM SERVICE	EXAMPLES	Informal settlement communities	Recreation Clubs and Businesses	NGOs and CSOs
				plastic to commercial buyers for repurposing.
Governance	Jurisdiction Policy Costs and Operations			

Table B Overview of perceptions of the social and monetary costs and impacts of plastic pollution across a range of stakeholder categories

ECOSYSTEM SERVICE	Property / Real Estate Sector	Tourism Sector	Government/Municipality	Business and Economic Development
Provisioning services (e.g., water, food, drugs, and genetic resources)			- Crop production and residential not permitted below 100-year flood mark so theoretically not impacted by plastic pollution in river.	
Regulating and Supporting services	Impacts on our natural environment which is such an asset in the area - especially marine. Perceived link between plastic pollution and health but not sure of specifics		Contributes to loss of flood attenuation of ecosystems and built infrastructure due to plastic build up. Damage to roads and culverts when flooding as well as damage to economy as a result of damage to infrastructure and socio-economic consequences. Lessons learned from River horse valley wetland rehabilitation project (2014) - wetland act as very effective litter trap - provides motivation to manage and rehab wetlands to benefit from this service. This lesson is changing the narrative - need to see urban river and wetland systems differently and manage them for these types of services as well (as opposed to rural or pristine systems) - 2014 - 2018 River Horse wetland rehab project had budget of €500 000 over 4 years. About 50% on rehab and balance alien removal, water quality monitoring etc. 90% of plastic below surface and not visible - only 10% on surface can be captured by booms or picked up - what about impacts of other 90%?	

ECOSYSTEM SERVICE	Property / Real Estate Sector	Tourism Sector	Government/Municipality	Business and Economic Development
Cultural services	Plastic pollution is unsightly / detracts from aesthetics of the area Impacts on recreation opportunities and potential in the area because residents and visitors don't want to lie among litter on the beach. Strong link between tourism and property values – when tourism dips so does demand	2020/21 - activities undertaken by tourists visiting Durban indicates 70% tourists going to the beach. In the 2019 tourists going the beach was 76% (difficult to account for impact of Covid in 2020/21) In 2019, only 13 out of 1 713 respondents mentioned crime, grime, dirty or litter when asked about their views of Durban. - An estimated 922 748 visitors visited the Municipality during Easter Season 2021, compared to 254 966 in Easter Season 2020. - The total direct expenditure of visitors is projected at R1.6 billion ($110 million) for Easter Season 2021. - The total GDP contribution is projected at R3.9 billion ($265 million). - The direct spend increased by R1.1 billion ($75 million) compared to Easter Season 2020 where the country was under national lockdown. - The total employment contribution of Easter Season 2021 was 8 422 annualised employment opportunities. - The Easter Season 2021 contribution to government taxes was R292.6 million ($20 million).		Recreation - water and beaches less enjoyable and fewer domestic tourists on return visits International tourism negatively impacted as fewer tourists on return visits Impacts not extreme but they are pervasive and everywhere so get under your skin. Although also getting used to it which is not necessarily a good thing. Heavy rain and floods amplify the shock value of plastic pollution as its becomes concentrated in some areas when it is 'picked up' / washed from areas of relatively low concentration - but it's always there just more visible after storms so more aware.

ECOSYSTEM SERVICE	Property / Real Estate Sector	Tourism Sector	Government/Municipality	Business and Economic Development
Business / Economic	Plastic pollution reflects badly on municipality's capacity and reduces confidence of residents and potential buyers of property in the area fear that it's a reflection on the Municipality's ability to maintain other services in the area because concerns about their ability therefore Umhlanga is seen as the Monaco of Africa – because of amount of money being spent and earned and invested in the area, but this is very negatively affected when events like pollution or spills or loss of blue flag beach status. Unable to say what the exact impact is on property values because too many factors affecting it all at once, e.g. Covid-19 pandemic. So can't apportion value of impact of plastic on property prices specifically. However property prices are a function of demand and supply, and plastic pollution definitely negatively affects demand therefore affects price negatively too. Definitely important because it affects people's perceptions by hard to say overall impact. More concern about water quality and municipal service delivery.		Tourism and recreation very important and negatively impacted Property values negatively impacted by plastic pollution Positive impacts from job creation because someone has to pick it all up. But need to teach people and raise awareness about ecological impact- Currently setting up coops of 7-8 people on 5km stretch of river to clean river of litter and alien vegetation and about 30m each side of river on Palmiet and Aloe Rivers? Once solid waste and plastic pollution has been cleared : - People feeling safer. - See veg gardens being established. - Play parks for children - Community starting to take ownership and control to prevent dumping Eco Champs	Economic development unit trying to work with programmes like Use-It and Green Corridors to set up recycling and waste diversion value chain. Supporting informal waste pickers and clean ups through buy back centres. Paying to subsidise the cost for recycling material and trying to increase range of plastic recycling to include certain types of plastic currently not being recycled because of price. (i.e. price paid for product does not justify recycling). Trying to financially incentivise people to bring plastic in to collection depos (same way as cardboard) pay collectors so that the material then becomes available for beneficiation 'for free' to start production process. Thereby stimulating value chain and creating greater demand for recycles materials City currently paying about R1800/ton ($22.4/ton) to collect and dump waste material into landfill. Trying to motivate that recycling programme gets 50% of that cost per ton of plastic it collects and recycles to divert it from landfill. That R900/ton ($61,2/ton) can then be invested into subsidising informal pickers

Governance			Plastic pollution does not seem to be seen as much of an important issue as sewerage and chemical pollution by City managers. Not given as much priority. Liquid sewerage seen as very emotive and perceived as far worse than plastic. Perhaps because of smell, colour etc impacts. Coastal management department has no jurisdiction below low water mark, but this is also where clean-up is needed. So coastal management policy from a functional perspective extends to shark nets at about 400m offshore. So technically the impact of plastic on fish band marine environment is a National (Marine and Coastal Management) issue. - Coastal management responsible for cleaning the beach every morning = cost. Different floods and flow volumes have different impacts and effects: 2017 storm - port had to be closed because of debris in bay - 65% debris was vegetation; 35% debris was solid waste including plastic. Losses and costs not only associated with damage directly to infrastructure due to blockages but also upstream as rivers push back. E.g. walls at private homes 'popping' due to pressure and homes flooded and contents and infrastructure destroyed. Floods of 2008, 2017, 2019 all different type and intensity of events all resulting in different impacts and costs to range of affected people. Roads and stormwater infrastructure a cost to the city Homes and private businesses impacts to individuals / private people who often can't afford the repairs, or to private insurance industry - Cumulative damage costs estimated at R1.9 Billion cumulative over 20 Years for all infrastructure across city - would be avoided cost - Cost of R90 Million ($6.1 million) per year for city infrastructure repairs. Keeping plastic out of landfills is a key climate change mitigation target for eThekwini - therefore linked to some solid waste management interventions.ie focus on reducing emissions by reducing amount of plastic entering landfill by recycling and upcycling plastic waste programmes. Includes community-based river rehabilitation programs. "Blue flag beaches - certification incorporates water quality (plastic pollution) and waste management (bins and recycling). Blue Flag statis very important for	

ECOSYSTEM SERVICE	Property / Real Estate Sector	Tourism Sector	Government/Municipality	Business and Economic Development
			attracting tourists so plastic management is essential to maintain / attract tourists. City working on early warning system that includes circulation model to forecasting where plastic and waste will end up after storms/floods so inform/predict where clean-ups and repairs will be required. For example to clean up Blue Flag beaches straight after storms to protect status. Transformative River Management programme is a critical process in securing support / awareness among communities to take responsibility for cleaning/maintaining ""their"" stretch of the river. includes alien invasive plant clearing and solid waste management. Plastic pollution needs to be seen as a component of a bigger challenge - need to see it as a collective of issues and address them holistically and innovatively."	

Appendix 4. List of participants in the workshop

Name	Organization
Smiso Bhengu	eThekwini Municipality (Climate and Environment)
Geoff Tooley	eThekwini Municipality (Stormwater and Catchment management)
Mr Siphiwe Makhanya	eThekwini Municipality (Operation, Strategic and New Developments)
Sumaiya Arabi	Department of Forestry, Fisheries and Environment (DFFE): Integrated Coastal Management
Dr Yazeed Peterson	Department of Forestry, Fisheries and Environment (DFFE): Integrated Coastal Management
Mr Siraj Paruk	Transnet National Ports Authority: Environmental Specialist
Masha Ramsamooch	Wild Trust: Wild Oceans
Janet Simpkins / Azile	Adopt a River Ecosolutions
Chris Whyte	ACEN (Association of Consultants Engineers in Namibia) Foundation
Cameron Service	The Litterboom Project | Parley for the Oceans
Nick Swan	Durban Green Corridor
Dr Refiloe Mofokeng	Refilwe Matlotlo NPO
Maria Göthberg	SwAM
Claus Pedersen	NIRAS
Nathalie Pano	NIRAS
Mark Graham	GroundTruth
Myles Mander	GroundTruth
Gary de Winnaar	GroundTruth
Keanu Singh	GroundTruth

Appendix 5. Land cover types' condition and size in the status quo and in the three alternative scenarios

Land cover types showing existing and possible future conditions and size for the affected area (condition scores relate to pristine (for natural areas) and industry best sustainable practice (for human landscapes) 1=<25%, 2=25>50%, 3=50>75%, 4=>75%, hectares are measured)

Status quo

LANDSCAPE ASSETS	Formal residential	Informal residential	Commerical & industrial	Roads	Agriculture	Wetlands	Dam	Forest	Alien plants	Grasslands	Rivers (Rural)	Rivers (Urban)	Estuaries	Beach	Near-shore ocean
CONDITION - score relative to its potential - 4 to 0	2.50	1.00	1.50	3.00	2.00	1.50	2.50	2.50	1.00	2.00	2.50	1.50	2.00	2.00	2.00
SIZE - area in ha (rivers in km)	14013.0	3184.0	1421.0	2343.0	694.0	618.0	41.0	3784.0	874.0	3362.0	2810.0	2976.0	271.0	63.0	1250.0
Percentage of total	37.2%	8.4%	3.8%	6.2%	1.8%	1.6%	0.1%	10.0%	2.3%	8.9%	7.5%	7.9%	0.7%	0.2%	3.3%
LANDSCAPE CONTEXT - score 0 to 4 (major regional ecological linkages = 4)	0.00	0.00	0.00	1.00	0.00	2.00	1.50	1.00	0.00	1.50	2.00	1.50	2.00	3.00	3.00
OVERALL FUNCTIONALITY	35,033	3,184	2,132	9,138	1,388	1,483	149	12,298	874	9,750	11,240	6,473	867	239	4,750

Maximum

LANDSCAPE ASSETS	Formal residential	Informal residential	Commerical & industrial	Roads	Agriculture	Wetlands	Dam	Forest	Alien plants	Grasslands	Rivers (Rural)	Rivers (Urban)	Estuaries	Beach	Near-shore ocean
CONDITION - score relative to its potential	3.50	3.00	3.00	3.25	2.25	2.00	2.50	2.75	1.00	2.50	3.00	2.50	2.50	3.00	3.00
SIZE - area in ha (rivers in km)	14113.00	3434.00	1471.00	2343.00	294.00	668.00	41.00	3784.00	374.00	3362.00	2910.00	3326.00	271.00	63.00	1250.00
Percentage of total	37.4%	9.1%	3.9%	6.2%	0.8%	1.8%	0.1%	10.0%	1.0%	8.9%	7.7%	8.8%	0.7%	0.2%	3.3%
LANDSCAPE CONTEXT - score 0 to 4 (major regional ecological linkages = 4)	0.00	0.00	0.00	1.25	0.00	2.50	1.50	1.00	0.00	1.50	2.50	2.00	2.50	3.25	3.00
OVERALL FUNCTIONALITY	49,396	10,302	4,413	10,470	662	2,338	149	13,528	374	12,187	15,278	13,304	1,186	373	7,125

Low Road

LANDSCAPE ASSETS	Formal residential	Informal residential	Commerical & industrial	Roads	Agriculture	Wetlands	Dam	Forest	Alien plants	Grasslands	Rivers (Rural)	Rivers (Urban)	Estuaries	Beach	Near-shore ocean
CONDITION - score relative to its potential	2.00	0.50	1.00	2.50	1.50	1.00	1.50	2.00	1.00	1.00	1.50	0.50	0.50	0.50	1.00
SIZE - area in ha (rivers in km)	14113.0	3434.0	1471.0	2343.0	294.0	618.0	41.0	3784.0	874.0	3362.0	2810.0	2976.0	271.0	63.0	1250.0
Percentage of total	37.4%	9.1%	3.9%	6.2%	0.8%	1.8%	0.1%	10.0%	1.0%	8.9%	7.7%	8.8%	0.7%	0.2%	3.3%
LANDSCAPE CONTEXT - score 0 to 4 (major regional ecological linkages = 4)	0.00	0.00	0.00	0.75	0.00	1.50	1.50	1.00	0.00	1.25	1.75	1.50	1.00	1.00	3.00
OVERALL FUNCTIONALITY	28226	1717	1471	7175	441	896	89	9838	874	4623	6428	2158	176	41	2,375

High Road

LANDSCAPE ASSETS	Formal residential	Informal residential	Commerical & industrial	Roads	Agriculture	Wetlands	Dam	Forest	Alien plants	Grasslands	Rivers (Rural)	Rivers (Urban)	Estuaries	Beach	Near-shore ocean
CONDITION - score relative to its potential	2.75	2.50	2.00	3.00	2.00	1.50	2.50	2.50	1.00	2.00	2.75	2.25	2.00	2.00	2.00
SIZE - area in ha (rivers in km)	14113.0	3434.0	1471.0	2343.0	294.0	668.0	41.0	3784.0	374.0	3362.0	2910.0	3326.0	271.0	63.0	1250.0
Percentage of total	37.4%	9.1%	3.9%	6.2%	0.8%	1.8%	0.1%	10.0%	1.0%	8.9%	7.7%	8.8%	0.7%	0.2%	3.3%
LANDSCAPE CONTEXT - score 0 to 4	0.00	0.00	0.00	1.25	0.00	2.00	1.50	1.00	0.00	1.50	2.25	1.75	2.25	3.00	3.00
OVERALL FUNCTIONALITY	38811	8585	2942	9665	588	1603	149	12298	374	9750	13404	11412	908	239	4,750

Appendix 6. Detailed descriptions of plastic density vs plastic cost of removal vs ecosystem goods and services benefits

Scenario	Description
A – Low Risk State	• Citizens litter. • Industries and businesses release plastic waste into the environment through poor practises. • Plastic begins to accumulate in urban and natural areas. • Routine maintenance required to restore to original state, but no decline in service benefits.
B – State of Decline	• Rain, wind, and other means wash plastic into stormwater and sewerage systems. • Blockages start occurring over long periods of time. • Some natural aesthetic value lost as plastics accumulate on beaches and in other natural areas. • Decrease in tourist activities. • Fauna and flora populations decline as plastic is ingested and presence of eutrophication increases. • Pathogens breed and spread via plastic products. • Ecosystem service benefits begin to take strain as frequent maintenance required. • Specialised measures (plumbing services, environmental assessments) needed to mitigate further plastic accumulation.
C – State of Malfunction	• Major blockages to wastewater infrastructure. • Stormwater and sewerage systems surcharge during storm event • Flooding, washing of large volumes of plastic and raw sewage into receiving water bodies, infrastructure damage. • Rivers and wetlands contaminated. • Provisioning services of these bodies steeply declines. • Pathogens continue to spread. • Physical and mental health of humans declines. • Wellbeing of natural habitats deteriorates further. • Intense pressure placed on services as plastic accumulation affects efficiency of entire wastewater system. • Pump stations require maintenance as plastic tangles equipment and causes malfunctions. • Significant decline in service benefits such as tourism, as beaches (and other locations) see 10+ plastic items per meter, and tourists discouraged from returning to SA. • Major, high-cost interventions are needed (long-term river clean-ups, new wastewater works) to curb the rate of failure of the system
D – State of Failure	• Services completely overwhelmed. • Wastewater systems require constant maintenance, and some of these services have failed completely in several neighbourhoods. • Tourism sector becomes a liability as tourist destinations require intense clean-up and maintenance to generate any income whatsoever. • Sanitation and other basic service requirements cannot be met as stormwater and sewerage systems are beyond repair. • Pump stations fail. • Raw sewage surcharged into environment. • Physical health of humans at risk due to intense spread of pathogens such as E. coli, and mental health deteriorates as dissatisfaction of living conditions becomes the norm. • Total overhaul of systems required, and intense interventions needed (alternative technologies, redesign of system). • Certain solutions obsolete, and large amounts of funding required to implement any impactful solutions.

SOCIO-ECONOMIC ANALYSIS OF THE COSTS OF INACTION OF PLASTIC DEBRIS LEAKAGE INTO THE UMNGENI RIVER CATCHMENT IN KWAZULU-NATAL, DURBAN, SOUTH AFRICA

This report shows the results of a socio-economic analysis of plastic debris in uMngeni River catchment completed in April 2022 by GroundTruth and NIRAS Sweden AB with support from SwAM. The findings indicated that plastic debris already has high negative social and economic impacts in the catchment, but the study also suggested potential technical and managerial solutions. Decisions should be made, and actions are needed at different levels in the solid waste supply chain to avoid further negative implications. To make a positive change, all parties, including government, NGOs, businesses and citizens should act united.

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SwAM, The Swedish Agency for Marine and Water Management is the responsible government agency tasked to protect, restore and ensure sustainable use of freshwater resources and seas including fisheries management.