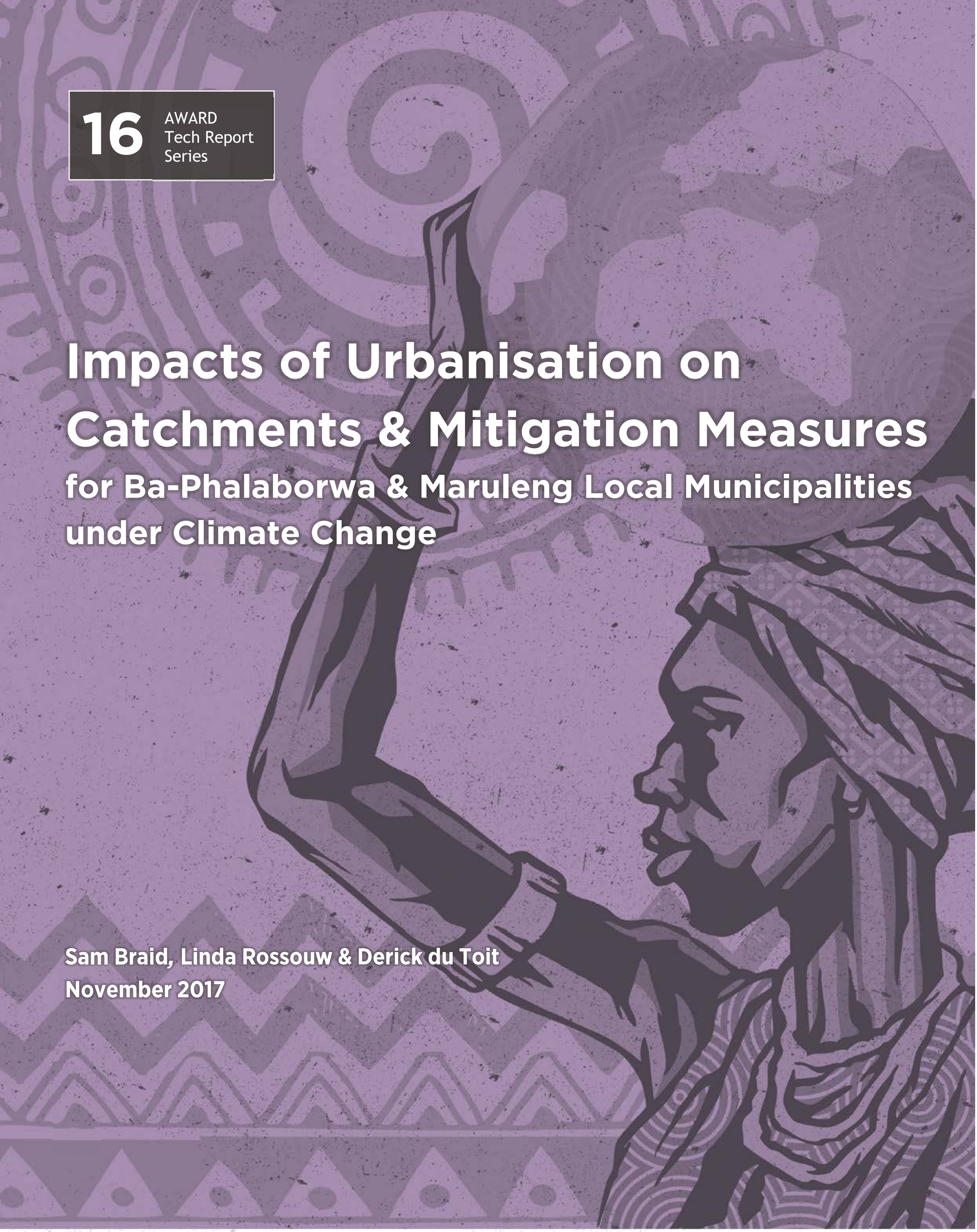
16 AWARD Tech Report Series



Impacts of Urbanisation on Catchments & Mitigation Measures

for Ba-Phalaborwa & Maruleng Local Municipalities under Climate Change

Sam Braid, Linda Rossouw & Derick du Toit

November 2017

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Abbreviations

AR4	Fourth Assessment Report of the IPCC
CEO	Chief Executive Officer
CMA	Catchment Management Agency
DEA	Department of Environmental Affairs
DM	District municipality
DWA	Department of Water Affairs
DWS	Department of Water and Sanitation
INR	Institute for Natural Resources
IPCC	International Panel on Climate Change
IRHI	Index of Reservoir Habitat Impairment
IUA	Integrated Unit of Analysis
LTAS	Long-term Adaptation Scenarios
RDP	Reconstruction and Development Plan
RQOs	Resource Quality Objectives
RWQOs	Resource Water Quality Objectives
SDF	Spatial Development Framework
SUDS	Sustainable Urban Drainage Systems
VIP	Ventilated Improved Pit latrine
WMS	Water Management System
WTW	Water Treatment Works
WUDS	Water Sensitive Urban Design
WWTW	Wastewater Treatment Works

1 Introduction

In terms of the Constitution (Schedule 4, Part B), Local Governments are responsible for landuse planning and management. As landuse activities directly impact on the environment, local government must consider these impacts, including water runoff, quantity and quality. The consequences of non- or poor management are impacts on our riverine systems and potential negative impacts on human settlements downstream. Land use planning is also set to have an impact on whether climate change scenarios will be experienced as severe or not.

Since municipalities span the full surface area of river catchments it is important that they are able to understand the importance of land use decisions on the catchment as a system. Furthermore it is upon them to plan and monitor so that the system is not adversely affected by poor land use decisions. For example, Local Governments are responsible for stormwater management, as such they are responsible to ensure the quality of the stormwater resulting from the landuse activities, and reaching the rivers or water resource body, does not degrade the quality of the resource.

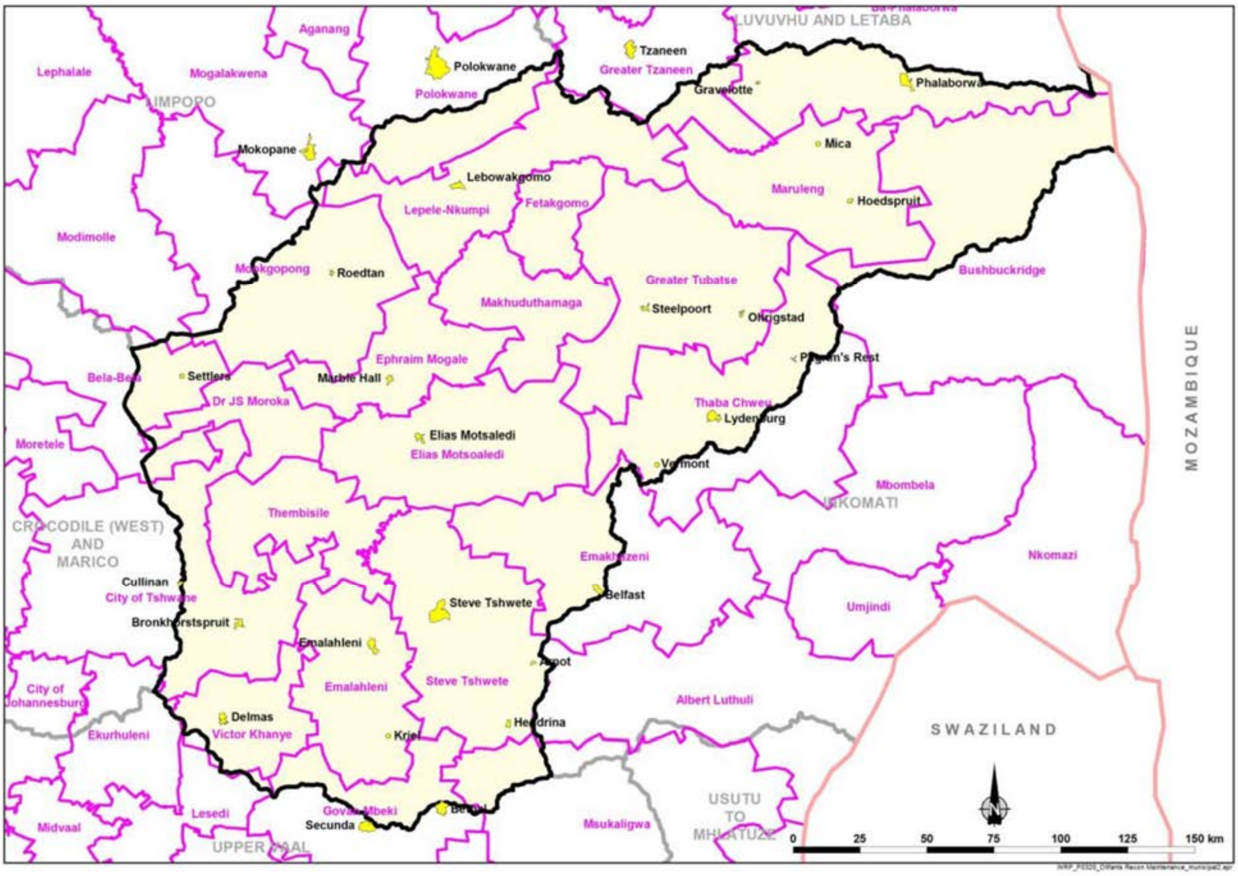

Figure 1: Local municipalities included in the Olifants Catchment (source WRP Consulting)

In order to manage the water resources of the country, both quality and quantity, a series of Resource Quality Objectives (RQOs) have been determined for various reaches of the rivers and resources of South Africa. The RQOs provide a set of targets and thresholds against which to manage the water resources, i.e. a volume of flow and level of acceptable pollution of the water resources at different locations. Water users and discharges, including stormwater runoff, must be managed in such a way that the national standards are met, i.e. that the pollution load reaching the water resource does not exceed the threshold set.

The Ba-Phalaborwa Local Municipality is currently (2019) updating their Spatial Development Framework (SDF) and together with Maruleng Local Municipality (both part of Mopani District Municipality) require advice on how to respond to resource management challenges in their landuse planning process. The scope of this 3-part MSI Series includes consideration of land use impacts to water quality, as well as water related risks (flooding, drought and pollution) as a result of climate change in the area; identification of pollution hotspots, applicable legislation to manage the pollution, spatial planning recommendations along riverine zones, and various mitigation recommendations.

1.1 Purpose of this report

This report sets out to outline the impacts of landuse on water quality especially taking into consideration the effects of climate change, specifically within the study area. The report identifies the applicable legislation for managing the landuses, and landuse planning practices that should be considered during the SDF process taking into consideration the impact of climate change. The report further outlines the resource quality objectives that fall within the study area before identifying the pollution issues and hotspots within the project area.

1.2 Introduction to the Mopani DM, Ba-Phalaborwa & Maruleng local municipalities

1.2.1 Mopani District Municipality

Mopani District Municipality (DM) is situated in the North-eastern part of the Limpopo Province, in South Africa. It is bordered in the east by Mozambique, in the north, by Vhembe District Municipality through Thulamela & Makhado Municipalities, in the south, by Mpumalanga province through Ehlanzeni District Municipality (Bushbuckridge, Thaba - Chweu and Greater Tubatse) and, to the west, by Capricorn District Municipality (Molemole, Polokwane & Lepelle - Nkumpi), in the south - west, by Sekhukhune District Municipality (Fetakgomo).

The district spans a total area of 2,001,100 ha (20,011 km^2), inclusive of a portion of Kruger National Park from Olifants to Shingwedzi camps or Lepelle to Shingwedzi Rivers. There are 16 urban areas (towns and townships), 354 villages (rural settlements) and a total of 125 Wards. Ba-Phalaborwa and Maruleng are two of the local municipalities serviced by the Mopani District Municipality.

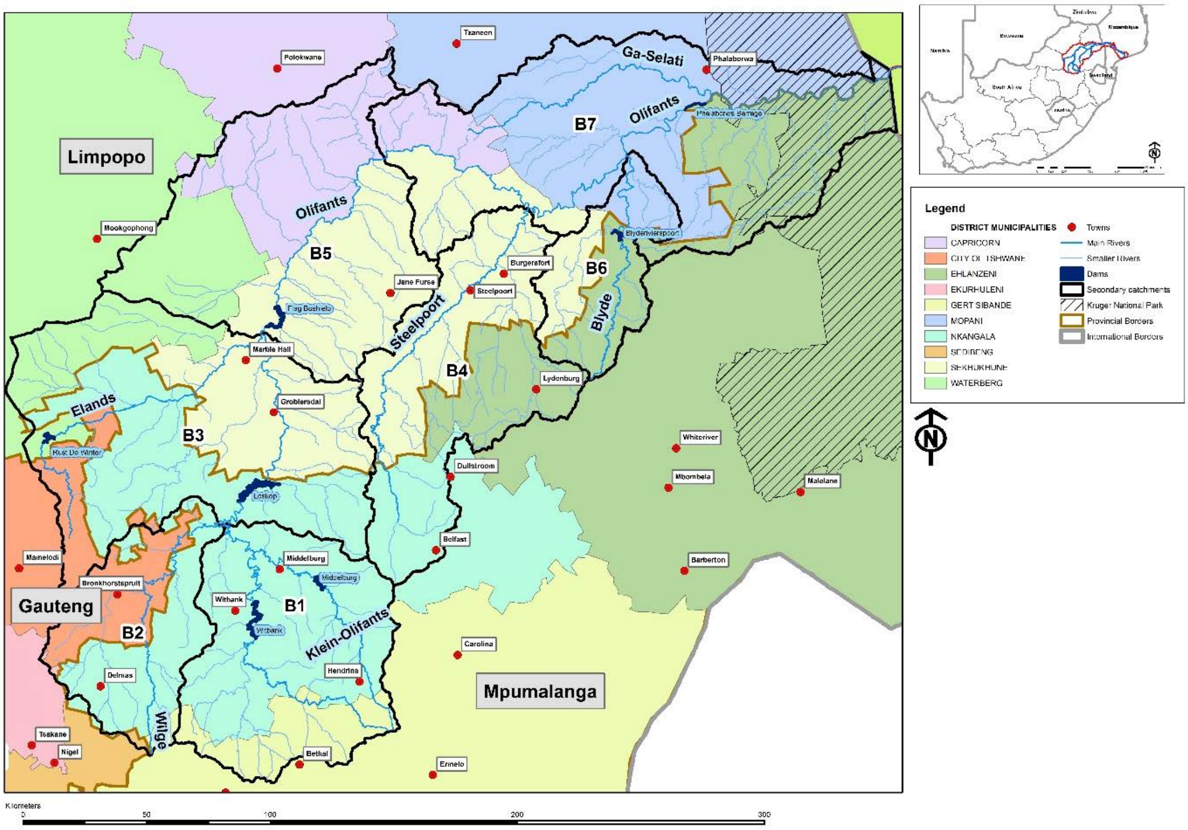

Figure 2: District municipalities within the Olifants Catchment

The key water resources in the Mopani DM consists of:

- Lower Olifants River from where it enters the Mopani DM near Ga-Mametsa up to the outflow from the DM and Kruger National Park at Olifants Gorge,
- Blyde River from downstream of the Blyderivierpoort Dam up to its confluence with the Olifants River,
- Selati River from its origin to its confluence with the Olifants River at Phalaborwa,
- Various smaller tributaries such as the Makhutswi and Klaserie rivers, and
- Letaba River which forms part of the northern border of the DM up to its confluence with the lower Olifants River in the Kruger National Park *(Although the Letaba is not part of the Olifants (East) catchment, the principles of this report still apply)*.
- The impoundments in the study area includes the Phalaborwa Barrage, Klaserie Dam (previously called Jan-Wassenaar Dam), and some smaller farm dams.

1.2.2 Ba-Phalaborwa Local Municipality

Ba-Phalaborwa Local Municipality (LM) is situated in the north-eastern part of South Africa, in the Mopani District of the Limpopo Province. It is one of the five local municipalities in the Mopani District. The municipality has a geographic area of 746,200ha) (7,462km2), with private farms covering a large proportion of the area, as well as commmunal land that is under the control of traditional leaders (namely, Ba-Phalaborwa Traditional Authority, Maseke Traditional Authority, Selwane Traditional Authority and Majeje Traditional Authority).

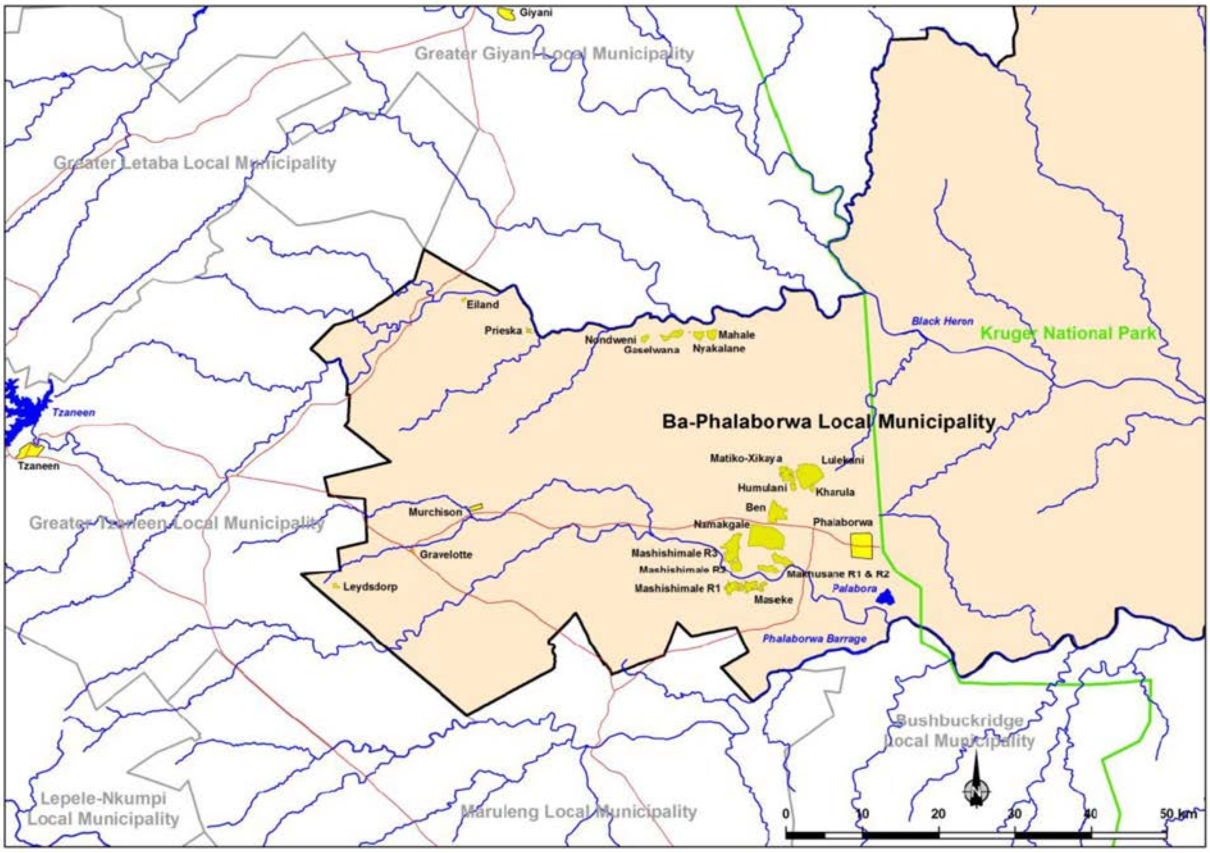

Figure 3: Ba-Phalaborwa Municipality showing high density residential including industrial and commercial areas (Source WRP consulting)

The other areas are proclaimed towns of Namakgale, Lulekani and Gravelotte. Farms constitute 27% of the total municipal area. Most of the farms in Ba-Phalaborwa belong to private owners and are used for game and citrus farming. Ba-Phalaborwa serves as a convenient gateway to the Kruger National Park and the Greater Limpopo Transfrontier Park through the Mozambique (Massingir-Xai-Xai) Channel. There are several mines operating within the municipal area.

Water is mainly supplied by Lepelle Northern Water at 334.94 c/kl (2015). Phalaborwa is supplied from the Phalaborwa Barrage with the remaining schemes relying on boreholes and springs. Ba-Phalaborwa LM is supplied by 8 reservoirs that are owned and managed by Lepelle Northern Water, these reservoirs supplies BPM Town, Namakgale, Lulekani, Benfarm and Mashishimale.

Water schemes (Water Infrastructure Status & Intervention Plans, DWS, 2012)

1. Phalaborwa / Namakgale / Lulekani RWS
2. Murchison WS
3. Gravelotte WS
4. Leydsdorp local WS
5. Eiland supply
6. Prieska supply

1.2.3 Maruleng Local Municipality

The Maruleng Local Municipality (LM) is situated in the south-eastern quadrant of the Limpopo Province within the Mopani District Municipal Area of Jurisdiction. The municipal area extends over 324,699ha (3,246.99km^2).

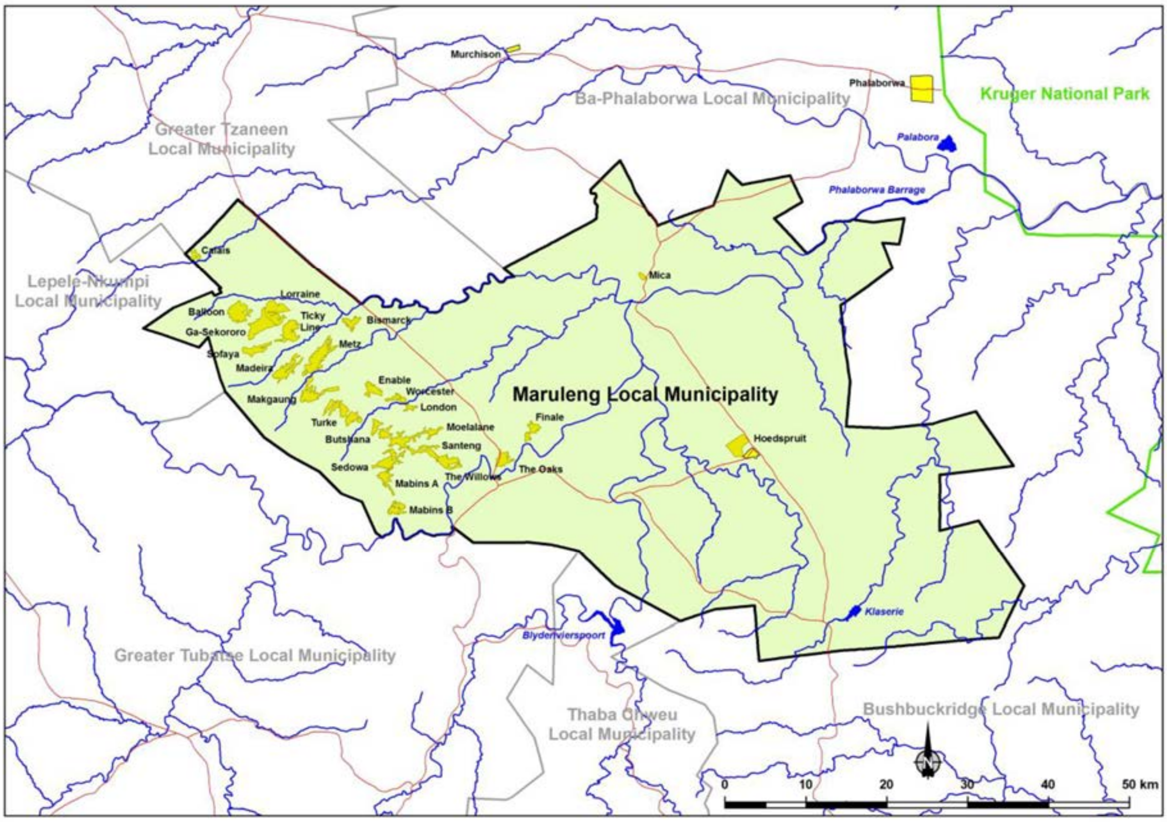

Figure 4: Maruleng Municipality showing high density residential including industrial and commercial areas (WRP Consulting)

The Maruleng LM is bordered by the Kruger National Park to the east, the Ba-Phalaborwa and Tzaneen Local Municipalities to the north, the Lepelle Nkumpi Local Municipality to the west, and the Tubatse Local Municipality and Bushbuckridge Local Municipality to the south.

Agriculture, especially commercial agriculture, is a key economic driver and employment generator in Maruleng LM. The area exports mango and citrus, but other crops such as vegetables are becoming increasingly important. Maize is also cultivated by both commercial and subsistence farmers. There are other agricultural activities such as livestock which focuses on cattle, goats and poultry, and game farms and marula fruit.

The Maruleng Local Municipality is characterized by low rainfall. This results in limited water resources culminating in severe water shortages and drought condition. Only 9% of the population have access to RDP standard water sources. The Municipality also provide free basic water (6000 litres per household per month).

Hoedspruit town is supplied by the Air Force base at Drakensig. The rest of the areas in Maruleng are supplied by boreholes.

Water schemes (Water Infrastructure Status & Intervention Plans, DWS, 2012)

1. Hoedspruit / Kampersrus WS
2. Mametje Sekororo Raw Water Scheme
3. Maruleng individual WS

Lack of access to basic sanitation services has created significant environmental and health problems. The fact that most villages in the municipality don't have RDP level sanitation constitutes a major risk in terms of ground water pollution. The main types of sanitary system used in the municipality are water borne sewerage (flush toilets), septic tanks, ventilated improved pit latrines (VIP), French drains and ordinary pit latrines to no basic services at all.

2 Landuse Planning

Landuse involves the changing or modification of natural environment/vegetated land into built environment such as settlements, agriculture, mining and other activities that transform and use the land. Landuse planning is the design or layout of such activities and the management of the activities to mitigate impacts to the community and environment by such land use activities.

How the land is used changes the vegetation cover e.g. removal of trees, grass and shrubs to create barren land or resurfacing the land; permeability of the land surface e.g. pervious (rain water drains into the ground) or impervious, harden surface and rain water runs off the land; occurrence of wastes and pollutants e.g. solid waste, effluent (liquid waste), etc.

Therefore, when designing or planning the layout of land use activities it is important to understand the impacts of these activities and the transformation of the land by the development activities on the receiving environment, and impose conditions for the sustainable management of the land to reduce these impacts. In particular the impacts on water e.g. by rainfall runoff from the land. Similarly the landuse planning must be cognisant of the impacts of the environment on the land e.g. floods, erosion, landslide.

2.1 Anticipated climate change scenarios for the Mopani District Municipality

In order to assess the potential impacts of climate change on water availability and quality, we assumed that ambient air temperatures would increase over time and water temperatures would also increase in step with the air temperatures, that rainfall would be within the range of present-day climate variability but that rainfall intensity would increase, and an increase in air temperatures would result in increased evaporation, and therefore the rate at which dissolved salts and other constituents would be concentrated in a mass of water. Increased rainfall intensity poses a risk of increased occurrence of flash flooding.

The Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) that was undertaken for South Africa (DEA, 2013), divided the country onto six hydrological zones based on their climatic and hydrological characteristics. The Mopani DM falls within Zone 1 –i.e. the Limpopo, Olifants and Inkomati WMAs in the northern interior (Limpopo/Olifants and Inkomati).

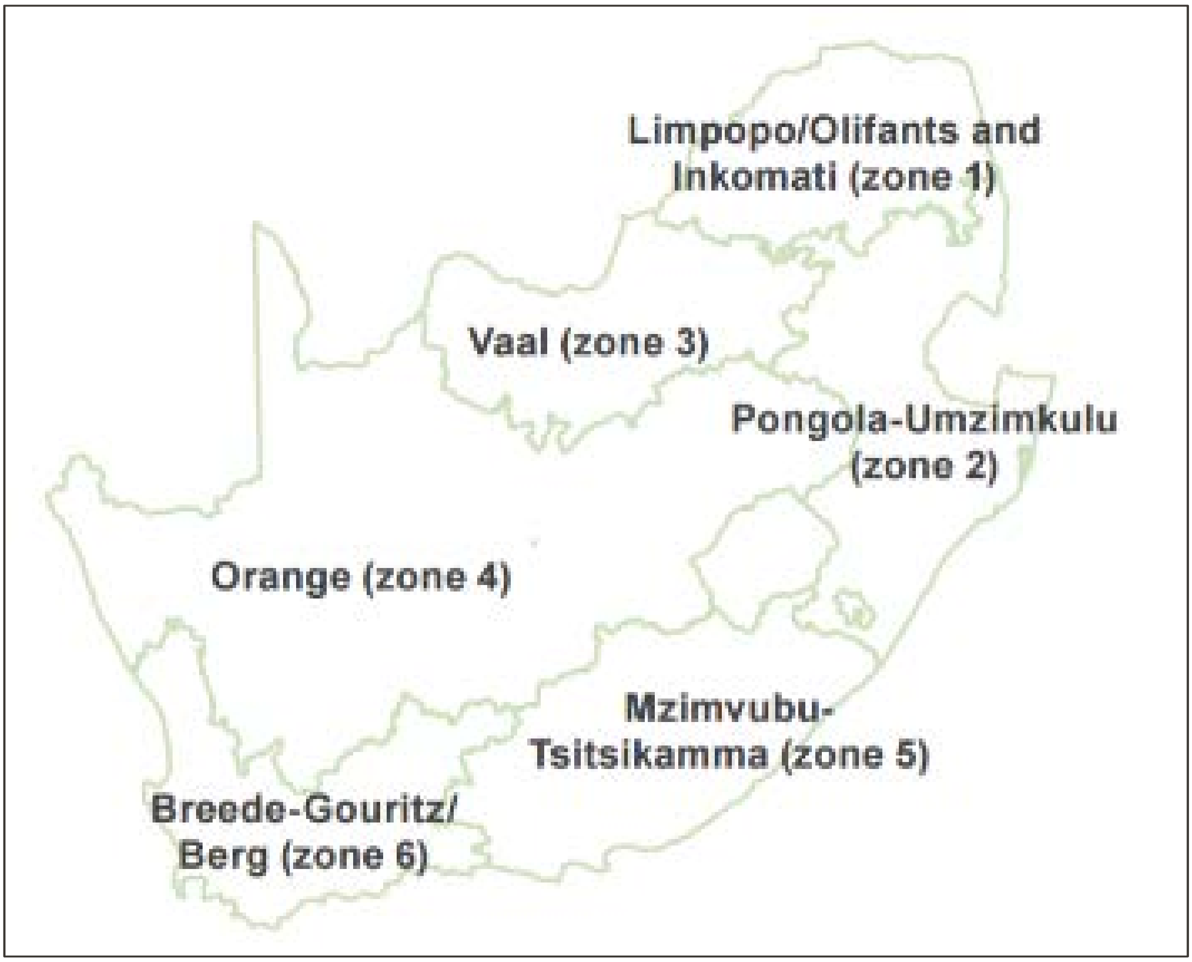

Figure 5: Map showing the six hydrological zones used in the LTAS project (DEA, 2013). These zones are based on Water Management Areas (WMAs) and grouped according to their climatic and hydrological characteristics.

The LTAS study summarised the observed climate trends for South Africa (1960–2010) and stated that over the last five decades the following climate trends have been observed (DEA, 2013):

- Mean annual temperatures have increased by at least 1.5 times the observed global average of 0.65°C reported by the Fourth Assessment Report (AR4) of the International Panel on Climate Change (IPCC) for the past five decades.
- Maximum and minimum daily temperatures have been increasing annually, and in almost all seasons. A notable exception is the central interior (zone 3, Vaal), where minimum temperatures have been increasing less strongly, and some decreases have been observed.
- High and low temperatures (i.e. hot and cold extremes) have respectively increased and decreased in frequency in most seasons across the country, particularly in the western and northern interior.
- The rate of temperature change has fluctuated, with the highest rates of increase occurring from the middle 1970s to the early 1980s, and again in the late 1990s to middle 2000s.
- Rainfall has shown high inter-annual variability, with smoothed rainfall showing amplitude of about 300 mm, about the same as the national average.
- Annual rainfall trends are weak overall and nonsignificant, but there is a tendency towards a significant decrease in the number of rain days in almost all hydrological zones. This implies a tendency towards an increase in the intensity of rainfall events and increased dry spell duration.

- There has also been a marginal reduction in rainfall for the autumn months in almost all hydrological zones.
- Extreme rainfall events show a tendency towards increasing in frequency annually, and especially in spring and summer, with a reduction in extremes in autumn.
- Overall, rainfall trends are similar in all the hydrological zones, with rainfall being above average in the 1970s, the late 1980s, and mid to late 1990s, and below average in the 1960s and in the early 2000s, reverting to the long-term mean towards 2010.

The downscaled sub-regional projections for Zone 1 (Limpopo/Olifants and Inkomati) is as follows:

- Annual average temperature increases of 3-6°C (4–7°C) are projected for Limpopo for the period 2080–2100, relative to the baseline period. These anomalies are well beyond the natural temperature variability of the region. That is, temperatures over Limpopo are projected to increase drastically, reaching a regime never observed before in the recorded climate of the region.
- For the mid-future period (2040–2060) temperature anomalies of between 1 and 3°C (2 to 5°C) are projected. The mid-future anomalies are already beyond the range of present day climatology.
- For the near-future period (2015–2035), annual temperature anomalies are mostly within the realm of present-day climate, although drifting out of it towards the end of the period, reaching values of about 2°C.
- Rainfall anomalies projected for Limpopo exhibit a clear pattern of drying, which strengthens over time. However, even for the far future (2080–2100) the anomalies are within the range of present-day climate variability.

These insights are based on the downscaled and localised climate analysis provided by the Climate System Analysis Group (CSAG) from the University of Cape Town (UCT) on behalf of AWARD[1]. This analysis was conducted both at a catchment level (Table 3), and at the local municipal level (Table 1 and Table 2)[2].

- For both local municipalities, the analysis indicated a strong signal of change for temperature, showing significant increases over the past decades, and projections for a continued increase into the future for annual mean daily maximum temperatures and the number of very hot days.
- For rainfall, the results are less clear. No statistically significant change was found for historical trends in any of the rainfall variables for either local municipality. Furthermore, overall, most models projected no change in rainfall patterns into the future. However, there were discrepancies amongst the models with several of these projecting increases and other decreases in the rainfall variables. Therefore, projected future rainfall patterns are uncertain.

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[1] See AWARD's technical brief series on historical trends and projected climate changes in the local municipalities of the Olifatns River Catchment, as well as the brochure *How is the climate changing in the Olifants River Catchment?*

[2] The analysis used two scenarios for future greenhouse gas (GHG) concentrations for the climate projections: the optimistic RCP 4.5 under which GHG emissions are stabilised by mid-century and fall sharply and therefore reducing the severity of climate changes; and the worst-case RCP 8.5 under which GHG emissions continue to increase until the end of the 21st century (i.e. no mitigation or business-as-usual) leading to the acceleration of climate change and increased severity of impacts.

TABLE 1: SUMMARISED RESULTS OF THE HISTORICAL TRENDS AND FUTURE PROJECTIONS FOR THE MARULENG LOCAL MUNICIPALITY. THESE RESULTS WERE DERIVED FROM GRAPHS PRODUCED BY CSAG (KONG ET AL., 2017).

	Historical trends from 1979 to 2014	Future projections for 2040	
		Optimistic scenario	Worst-case scenario
Temperature			
Annual mean of daily maximum	Increase of 1.3ºC	Increase of 0.75 to 2ºC	Increase of 1 to 2.1ºC
Annual mean of daily minimum	Increase of 1.5ºC		
annual number of days with maximum temperatures over 36C (very hot days)	No statistically significant change	Increase of 11 to 40 days	Increase of 18 to 48 days
Seasonal mean of daily maximum temperatures	Increase, especially winter and spring	Increase pronounced in summer and autumn	Increase across all seasons
Rainfall			
All climate variables related to rainfall	No statistically significant change	No change	No change

TABLE 2: SUMMARISED RESULTS OF THE HISTORICAL TRENDS AND FUTURE PROJECTIONS FOR THE BA-PHALABORWA LOCAL MUNICIPALITY. THESE RESULTS WERE DERIVED FROM GRAPHS PRODUCED BY CSAG (KONG ET AL., 2017).

	Historical trends from 1979 to 2014	Future projections for 2040	
		Optimistic scenario	Worst-case scenario
Temperature			
Annual mean of daily maximum	Increase of 1.3ºC	Increase of 0.75 to 2ºC	Increase of 1 to 2.1ºC
Annual mean of daily minimum	Increase of 1.5ºC		
Annual number of days with maximum temperatures over 36C (very hot days)	No statistically significant change	Increase of 11 to 40 days	Increase of 18 to 48 days
Seasonal mean of daily maximum temperatures	Increase, especially winter and spring	Increase pronounced in summer and autumn	Increase across all seasons
Rainfall			
All climate variables related to rainfall	No statistically significant change	No change	No change

TABLE 3: SUMMARISED RESULTS OF THE HISTORICAL TRENDS AND FUTURE PROJECTIONS FOR THE CLIMATE REGIONS IN THE LOCAL MUNICIPALITIES.

Climate regions are areas that have distinct temperature and rainfall characteristics because of natural variability in the local climate and heterogeneity of a landscape, meaning that observed and projected changes differ between the climate regions. The Olifants river catchment has five such climate regions, with each being impacted differently by climate change. The lower Limpopo occurs in both Maruleng and Ba-Phalaborwa local municipality, with the escarpment climate region occurring along the foothills of the Drakensburg mountains in Maruleng local municipality. These results were derived from the analysis conducted by CSAG (Kong et al., 2018).

		Historical trends from 1979 to 2014	Future projections for 2040	
			Optimistic scenario	Worst-case scenario
Lower Limpopo	**Temperature**			
	Mean daily max temperature	Increase of 0.25°C	Increase of 1 to 2°C	Increase of 2°C
	Annual number of days with maximum temperatures over 36C (very hot days)	No significant change	Increase of 30 to 37 days	Increase of 46 to 54 days
	Rainfall			
	All climate variables related to rainfall	No significant change	Mostly no change	Mostly no change
Escarpment	**Temperature**			
	Mean daily max temperature	Increase of 0.33°C	Increase of 2°C	Increase of 2°C
	Annual number of days with maximum temperatures over 36C (very hot days)	No significant change	Increase of 4 to 11 days	Increase of 9 to 13 days
	Rainfall			
	All climate variables related to rainfall	No significant change	Mostly no change	Mostly no change

2.2 How landuse activities associated with urbanisation impact water & its management

Urbanisation on land results in different impacts on river ecosystems. Different landuses such as Industrial, Commercial, Settlements and Agriculture, although different activities can result in the same impacts to the environment, for example surface hardening. Surface hardening results in increased runoff and erosion at discharge points and instream as well as increased risk of flooding by decreasing the time period over which runoff enters rivers. These same landuses can also cause pollution through application of fertilizers, pesticides and herbicides in gardens/fields or effluent discharge or leaching from a polluted site, and washing of solid waste and litter into water resources. Pollution can change the temperature, nutrients, salinity, dissolved oxygen, turbidity, metals, toxins and carbons in the water which in turn disturbs the ecosystem.

In this report we will look at the effects of urbanisation on 4 main categories:

A] Undeveloped land and upsteam activities

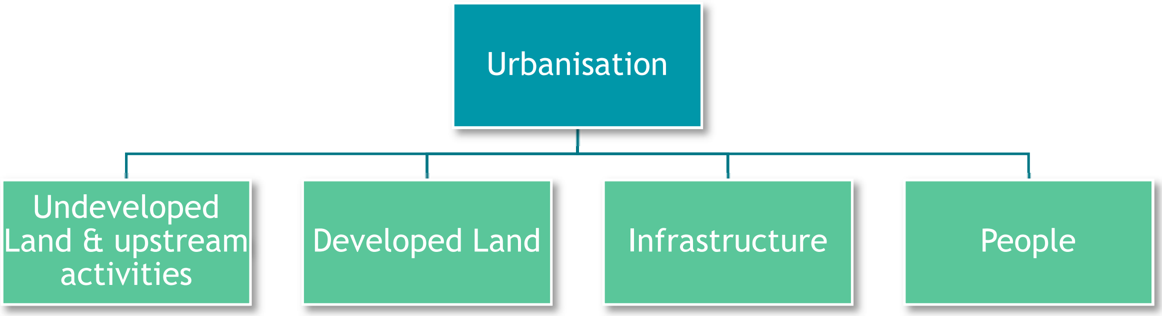
B] Developed land

C] Infrastructure

D] People

We will use a number of diagrams to show the linkages using the follow diagrammatic model:

DIAGRAM 1: THE EFFECTS OF URBANISATION



Disturbed ecosystems are more easily affected by climate change (less able to regulate increasing temperatures through loss of shade plants resulting in the loss of in-stream fauna such as fish which local people may rely on. The loss of instream plants would increase the flow of water through the ecosystem as well as increase evaporation, which could result in longer dry periods of the river, resulting in a lowering of the groundwater table and a potential loss of a water source for people using surface and groundwater. Polluted water is not suitable for irrigation and may pose health risks for washing, drinking, cooking and recreation.

Sanitation and landfill sites can both cause pollution when mismanaged or when the population is not adequately supplied with these facilities, especially where there are informal settlements. Inadequate stormwater facilities as well as leaking water supply infrastructure can also cause erosion, resulting in sedimentation of the river which alters the flow regime of the river and may result in increased occurrence of flooding or an increased area being affected by flooding.

People can cause pollution through traffic (exhaust fumes contaminants in rain) as well as direct pollution from informal ablutions and poor waste disposal e.g. disposing chemicals down stormwater drains instead of through formal procedures.

Even if land is undeveloped the natural vegetation may be removed which increases runoff and results in erosion, which in turn causes sedimentation (which can suffocate plants and sessile animals as well as cause blockages) and increased carbon and nutrients in the ecosystem. Vegetation encourages infiltration of rainfall whilst the lack thereof increases the flood risk as water runs off the land as sheet wash into the river. The following diagrams show how land uses and activities impact riverine environments.

As can be seen in the diagrams above, impacts on rivers usually entail changes to

A] Flood risk

B] Ecosystems stability

C] erosion profiles

DIAGRAM 2: THE IMPACTS OF URBANISATION ON UNDEVELOPED LAND IN A CATCHMENT (ADAPTED FROM H. VAN DEN BERG AND S. BRAID, 20170

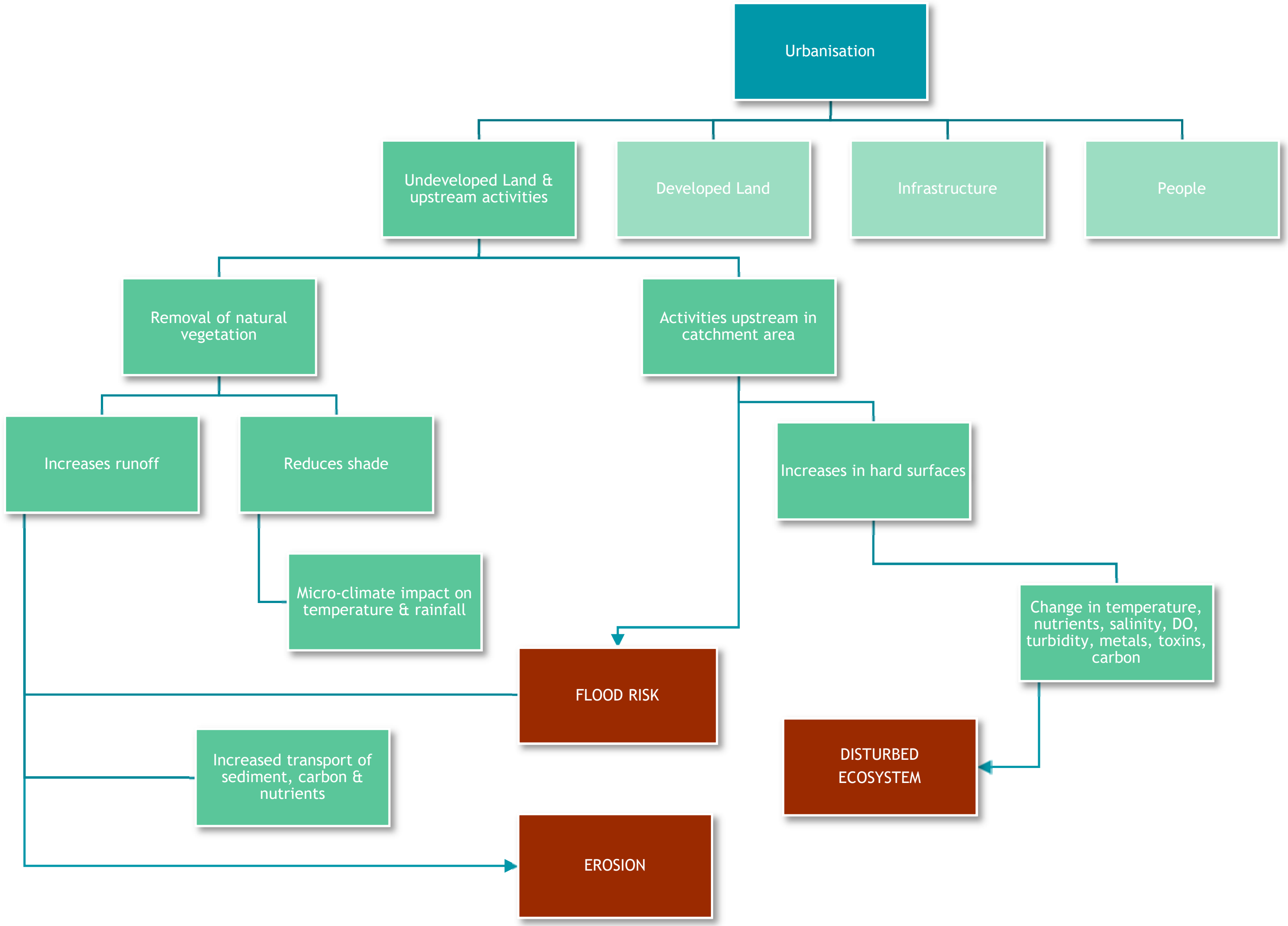


DIAGRAM 3: THE IMPACTS OF URBANISATION (DEVELOPED LAND) ON THE RIVERINE ECOSYSTEM (H. VAN DEN BERG AND S. BRAID, 2017)

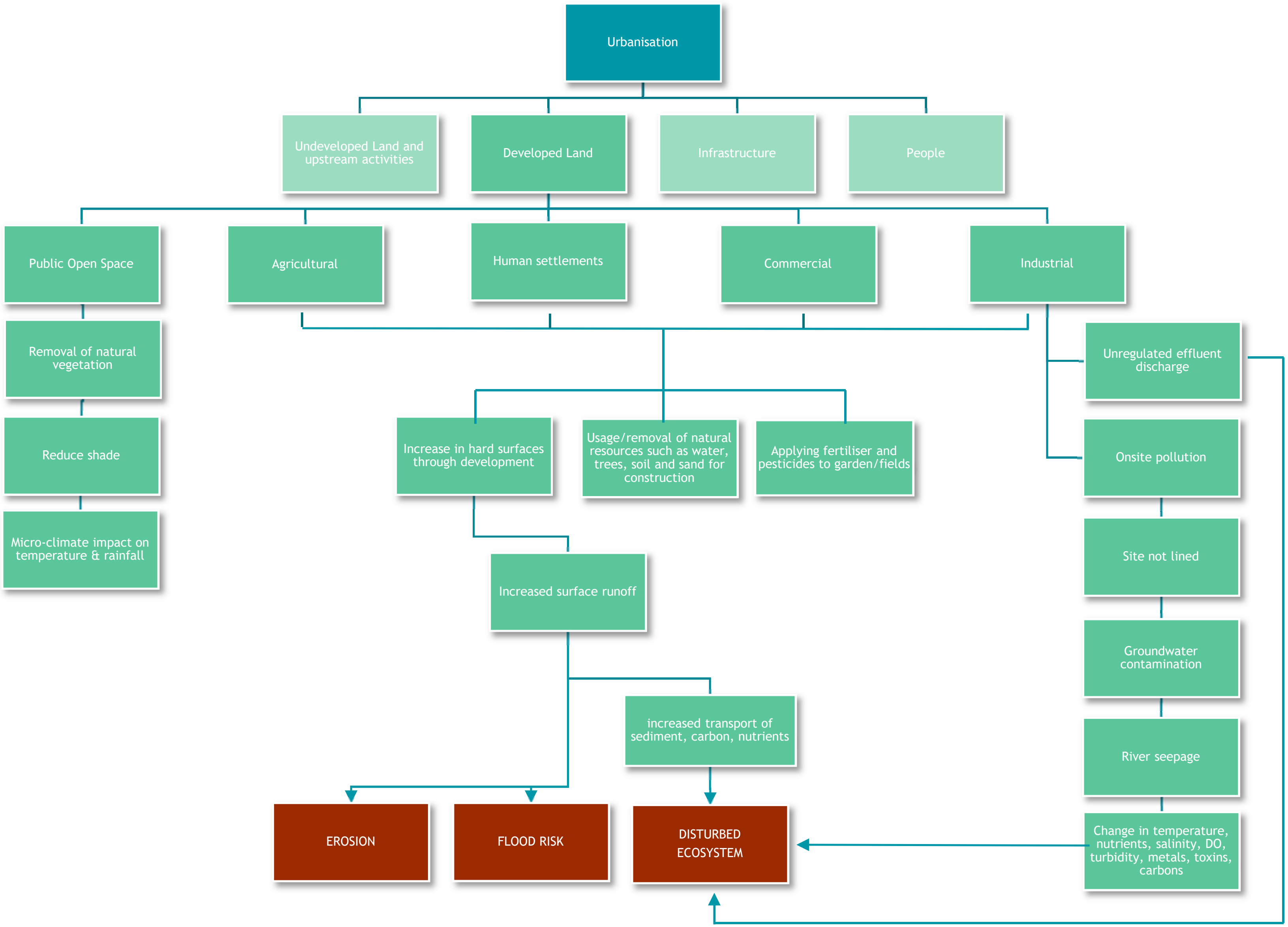


DIAGRAM 4: THE IMPACTS OF URBANISATION (INFRASTRUCTURE) ON THE RIVERINE ECOSYSTEM (ADAPTED FROM H. VAN DEN BERG AND S. BRAID, 2017)

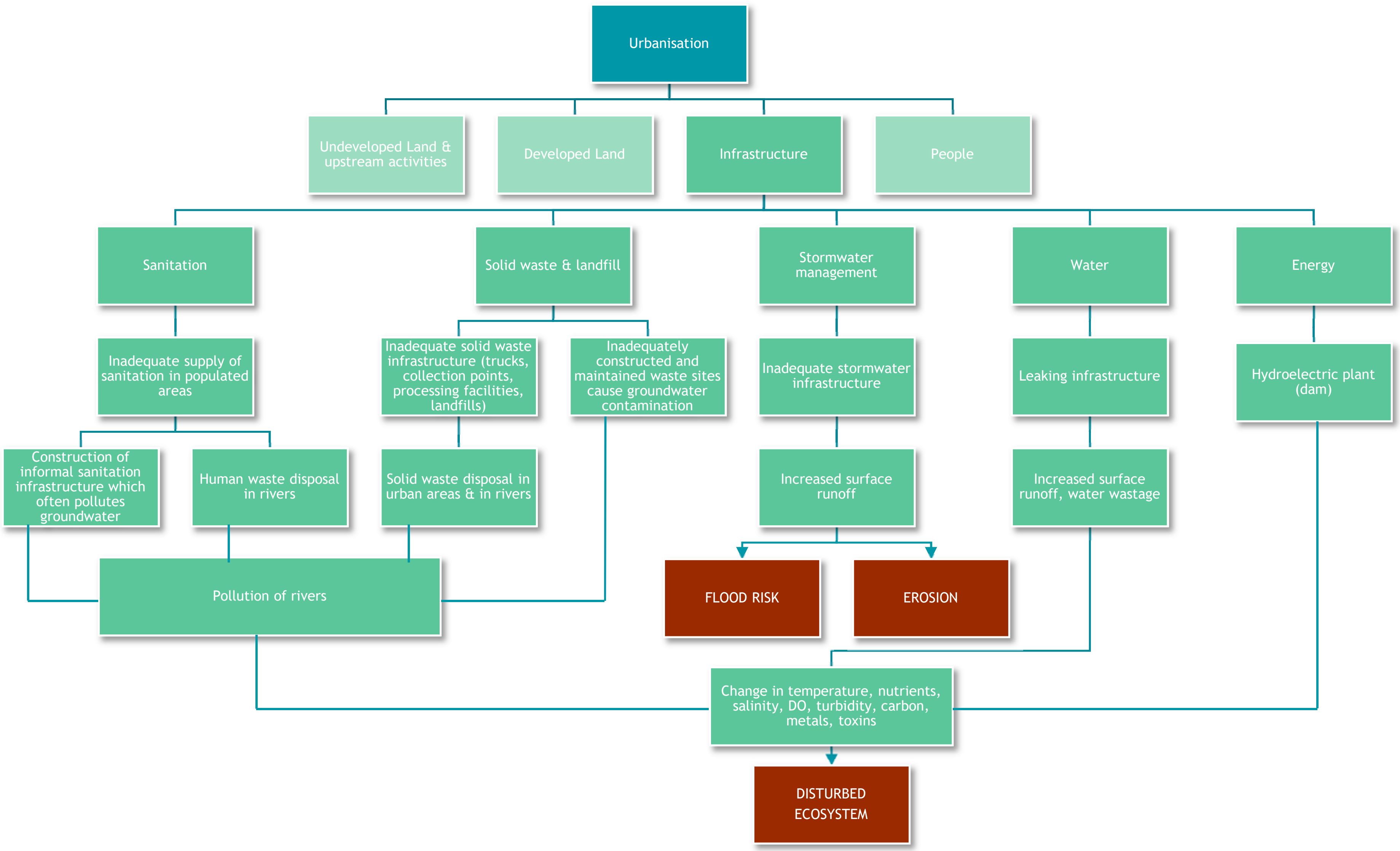
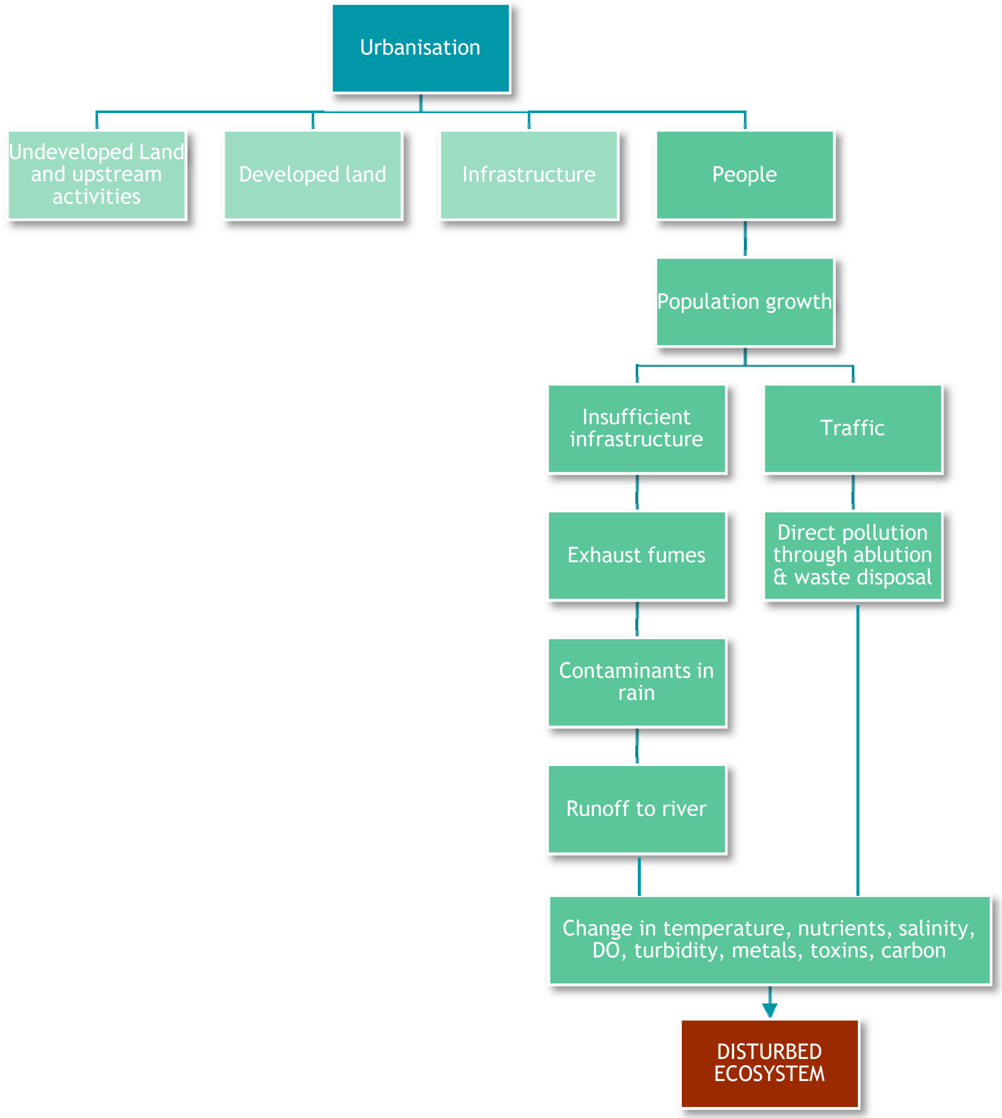


DIAGRAM 5: THE IMPACTS OF URBANISATION (PEOPLE) ON THE RIVERINE ECOSYSTEM (ADAPTED FROM H. VAN DEN BERG AND S. BRAID, 2017)



A number of mitigation measures exist to these landuse problems. A list of additional mitigation measures can be found in the table below.

TABLE 4: GUIDELINE: LANDUSE MITIGATION MEASURES FOR WATER QUALLITY IN LANDUSE ZONES

Landuse Zone	Impact	Mitigation		Strategies
		In landuse zone	**In River zone**	
Residential	Faecal pollution due to block, damaged, vandalised, absent sewer system	Install composting toilets as minimum sanitation standard	- Re-instate river buffer - Constructed wetlands at discharge points - Stormwater discharge set back from river with constructed wetland between active channel and outlet. - Outlets at max 45° angle to flow of water - Litter traps at selected points in the river - Regular litter / solid waste clean-up. - Clearing of alien and invasive vegetation and replace with indigenous - Re-vegetation of river zones - Include aeration of water with green infrastructure - Rehabilitate river functions	- Improved sanitation, including composting toilet
		Regular maintenance, emptying of sanitation points		
	Increased nutrient loads from faecal pollution, fertilizers and pesticides	Install formal holding pits in informal areas where sewerage can be pumped from for disposal		
	Increased runoff from hardened surfaces, and directed stormwater, blocked drains	Stormwater attenuation on site, e.g. holding ponds, water harvesting		- Bi-law for onsite stormwater management, including water harvesting and attenuation, WSUDS
	Solid waste from poor waste management, litter removal	Regular litter clean up and waste collection		- Implement recycling programmes e.g. pay per *kg* of tins, glass, plastic, etc.
		Litter traps on stormwater drains		
	Poor water quality from contaminated runoff	SUDs		- By-law on SUDs
	Spread of invasive, opportunistic and alien vegetation from landscaped gardens (seeds in runoff)	Promote planting and landscaping of indigenous vegetation		- Bi-laws of landscaping plants - Livelihood; removal and maintenance of alien and invasive vegetation
	Reduced shade from vegetation clearing	Promote tree planting		- By-law for minimum tree coverage
	Increased sediment load from cleared vegetation, exposed soil, building materials, blocked drains	Building materials to have berm around to reduce runoff		- Bi-law for building material management, and dumping in stormwater drains
	Reduced dissolved oxygen in water from contaminants and solid waste	reduce contamination and solid waste reaching receiving waters		
	Reduced biodiversity as result of reduced habitat provision function			

Landuse Zone	Impact	Mitigation: In landuse zone	Mitigation: In River zone	Strategies
Business/ Commercial Zones	Faecal pollution due to block, damaged, vandalised, absent sewer system	Install composting toilets as minimum sanitation standard Regular maintenance, emptying of sanitation points	- Re-instate river buffer - Constructed wetlands at discharge points - Stormwater discharge set back from river with constructed wetland between active channel and outlet - Outlets at max 45° angle to flow of water - Litter traps at selected points in the river - Regular litter / solid waste clean-up - Clearing of alien and invasive vegetation and replace with indigenous - Re-vegetation of river zones - Aeration of water in green infrastructure - Rehabilitate riverine functions	- Improved sanitation, including composting toilet
	Increased nutrient loads from faecal pollution, fertilizers and pesticides	Install formal holding pits where sewerage can be pumped from for disposal		
	Increased runoff from hardened surfaces, directed stormwater, and blocked drains	Stormwater attenuation on site, e.g. holding ponds, water harvesting SUDS for stormwater management		- Bi-law for onsite stormwater management, including water harvesting and attenuation, WSUDS
	Solid waste from poor waste management, litter removal, packaging	Regular litter clean up and waste collection Litter traps on stormwater drains		- Implement recycling programmes e.g. pay per *kg* of tins, glass, plastic, etc.
	Poor water quality from contaminated runoff, including phosphate from carwash, garage, paint, laundry, etc.	Basic water treatment on site to reduce phosphates		- Bi-laws regulating phosphate and effluent discharge limits
	Spread of invasive, opportunistic and alien vegetation from landscaped gardens (seeds in runoff)	Promote planting and landscaping of indigenous vegetation		- Bi-laws of landscaping plants - Livelihood; removal and maintenance of alien and invasive vegetation
	- Reduced shade from vegetation clearing - Increased temperature of micro-climate from hard surfaces, reduced shade, leads to increase evaporation	Promotion of shade e.g. tree planting, per m^2 of hard surfacing		- Bi-law planting trees per *x* parking bays
	Increased sediment load from cleared vegetation, exposed soil, building materials, blocked drains	Soil cover management, promote pervious ground cover		- Bi-law promoting pervious ground cover - Bi-law about dumping in stormwater drains
	Reduced dissolved oxygen in water from contaminants and solid waste	reduce contamination and solid waste reaching receiving waters		
	Changes in temperature and aeration of receiving water from contaminants e.g. cooking fats and effluent	Basic water treatment on site		- Bi-laws regulating phosphate and effluent discharge limits
	Reduced biodiversity as result of reduced habitat provision function			

Landuse Zone	Impact	Mitigation		Strategies
		In landuse zone	In River zone	
Industrial Zones	Faecal pollution due to block, damaged, vandalised, absent sewer system	Install composting toilets as minimum sanitation standard	- Re-instate river buffer - Constructed wetlands at discharge points - Stormwater discharge set back from river with constructed wetland between active channel and outlet - Outlets at max 45° angle to flow of water - Litter traps at selected points in the river - Regular litter / solid waste clean- up - Re-vegetation of river zones - Aeration of water in green infrastructure - Rehabilitate riverine functions	* Improved sanitation, including composting toilet
	Increased nutrient loads from faecal pollution	Regular maintenance, emptying of sanitation points Install formal holding pits where sewerage can be pumped from for disposal		
	Increased runoff from hardened surfaces, and directed stormwater, blocked drains	Stormwater attenuation on site, e.g. holding ponds, water harvesting SUDS for stormwater management		* Bi-law for onsite stormwater management, including water harvesting and attenuation, WSUDS
	Solid waste from poor waste management, litter removal	Regular litter clean up and waste collection Litter traps on stormwater drains		* Implement recycling programmes e.g. pay per *kg* of tins, glass, plastic, etc.
	Poor water quality from contaminated runoff especially toxic chemicals	Basic water treatment on site to reduce contamination of receiving waters Sumps to collect hydrocarbons		* Bi-laws regulating contaminants and effluent discharge limits; installation of sumps to collect hydrocarbons
	Changes in p.H of receiving water from chemical contaminants			
	Changes in temperature and aeration of receiving water from contaminants			
	Reduced shade from vegetation clearing	Promotion of shade e.g. tree planting, per m^2 of hard surfacing		* Bi-law planting trees per *x* parking bays
	Increased sediment load from cleared vegetation, exposed soil, building materials, blocked drains	Promote planting and landscaping with indigenous vegetation Soil cover management, promote pervious ground cover		* Bi-law promoting pervious ground cover * Bi-law about dumping in stormwater drains
	Reduced dissolved oxygen in water from contaminants and solid waste	reduce contamination and solid waste reaching receiving waters Basic water treatment on site		* Bi-laws regulating contaminant and effluent discharge limits
	Reduced biodiversity as result of reduced habitat provision function			Improve water quality

<table>
<tr><th rowspan="2">Landuse Zone</th><th rowspan="2">Impact</th><th colspan="2">Mitigation</th><th rowspan="2">Strategies</th></tr>
<tr><th>In Landuse zone</th><th>In River Zone</th></tr>
<tr><td rowspan="6">Recreation / Open zone</td><td>Reduced shade and biodiversity from clearing of natural vegetation</td><td>Promote planting and landscaping with indigenous vegetation</td><td rowspan="6">- Re-instate river buffer
- Constructed wetlands at discharge points
- Stormwater discharge set back from active channel with constructed wetland between active channel and outlet.
- Outlets at max 45° angle to flow of water, discharging downstream
- Litter traps at selected points in the river
- Regular litter / solid waste clean-up
- Clearing of alien and invasive vegetation and replace with indigenous
- Re-vegetation of river zones
- Include aeration of water with green infrastructure
- Rehabilitate river functions</td><td>- Bi-laws of landscaping plants
- Livelihood; removal and maintenance of alien and invasive vegetation</td></tr>
<tr><td>Increased runoff from hardened surfaces and compacted soils e.g. soccer field and path ways</td><td>Stormwater attenuation on site, e.g. holding ponds, water harvesting</td><td>- Bi-law for onsite stormwater management, including water harvesting and attenuation, WSUDS</td></tr>
<tr><td>Increased sediment load from exposed soil, sand mining, building materials</td><td>Soil cover management, promote pervious ground cover</td><td>- Bi-law promoting pervious ground cover
- Bi-law about dumping in stormwater drains</td></tr>
<tr><td rowspan="2">Increased solid waste (and leachate) due to poor solid waste management, litter clean-up</td><td>Regular litter clean up and waste collection</td><td rowspan="2">- Implement recycling programmes e.g. pay per kg of tins, glass, plastic, etc.</td></tr>
<tr><td>Litter traps on stormwater drains</td></tr>
<tr><td>Install composting toilets as minimum sanitation standard</td><td>Install composting toilets as minimum sanitation standard</td><td>- Improved sanitation, including composting toilet</td></tr>
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<table>
<tr><th rowspan="2">Landuse Zone</th><th rowspan="2">Impact</th><th colspan="2">Mitigation</th><th rowspan="2">Strategies</th></tr>
<tr><th>In Landuse zone</th><th>In River Zone</th></tr>
<tr><td rowspan="14">Education Zone</td><td rowspan="2">Faecal pollution due to blocked, damaged, vandalised, absent sewer system</td><td>Install composting toilets as minimum sanitation standard</td><td rowspan="14">- Re-instate river buffer
- Constructed wetlands at discharge points
- Stormwater discharge set back from river with constructed wetland between active channel and outlet.
- Outlets at max 45° angle to flow of water, discharging downstream
- Litter traps at selected points in the river
- Regular litter / solid waste clean-up
- Clearing of alien and invasive vegetation and replace with indigenous
- Re-vegetation of river zones
- Include aeration of water with green infrastructure
- Rehabilitate river functions and catchment areas
- Adopt a river initiatives</td><td rowspan="3">- Improved sanitation, including composting toilet</td></tr>
<tr><td>Regular maintenance, emptying of sanitation points</td></tr>
<tr><td>Increased nutrient loads from faecal pollution, fertilizers and pesticides</td><td>Install formal holding pits where sewerage can be pumped from for disposal</td></tr>
<tr><td>Increased runoff from hardened surfaces, and directed stormwater, blocked drains</td><td>Stormwater attenuation on site, e.g. holding ponds, water harvesting
Promote greywater harvesting and other water reuse activities</td><td>- Bi-law for onsite stormwater management, including water harvesting and attenuation, WSUDS</td></tr>
<tr><td rowspan="2">Solid waste from poor waste management, litter removal</td><td>Regular litter clean up and waste collection</td><td rowspan="2">- Implement recycling programmes e.g. pay per kg of tins, glass, plastic, etc.</td></tr>
<tr><td>Litter traps on stormwater drains</td></tr>
<tr><td>Poor water quality from contaminated runoff</td><td>reduce contamination and solid waste reaching receiving waters e.g. filtration trench.</td><td></td></tr>
<tr><td>Spread of invasive, opportunistic and alien vegetation from landscaped gardens (seeds in runoff)</td><td>Promote planting and landscaping with indigenous vegetation
promote school vegetable/permaculture gardens</td><td>- Bi-laws of landscaping plants
- Livelihood; removal and maintenance of alien and invasive vegetation</td></tr>
<tr><td>Reduced shade from vegetation clearing</td><td>Promote tree planting</td><td></td></tr>
<tr><td>Increased temperature of micro-climate from hard surfaces, reduced shade, leads to increase evaporation</td><td>Promote planting of trees</td><td></td></tr>
<tr><td>Increased sediment load from cleared vegetation, exposed soil, building materials, blocked drains</td><td>Soil cover management, promote pervious ground cover</td><td>- Bi-law promoting pervious ground cover
- Bi-law about dumping in stormwater drains</td></tr>
<tr><td>Reduced dissolved oxygen in water from contaminants and solid waste</td><td>reduce contamination and solid waste reaching receiving waters</td><td></td></tr>
<tr><td>Reduced biodiversity as result of reduced habitat provision function</td><td>Restore biodiversity corridors</td><td></td></tr>
</table>

Landuse Zone	Impact	Mitigation		Strategies
		In Landuse zone	In River Zone	
Agriculture	Faecal pollution due to block, damaged, vandalised, absent sewer system	Install composting toilets as minimum sanitation standard	- Re-instate river buffer - Constructed wetlands at discharge points - Rehabilitate erosion rill, channels and gullies in streams, fields, paths, roadsides, etc. * Promote natural farming and climate smart farming practices - Litter traps at selected points in the river - Regular litter / solid waste clean-up - Clearing of alien and invasive vegetation and replace with indigenous - Re-vegetation of river zones - Include aeration of water with green infrastructure - Rehabilitate river functions and catchment areas	- Improved sanitation, including composting toilet
		Regular maintenance, emptying of sanitation points		
		Install formal holding pits where sewerage can be pumped from for disposal		
	Increased nutrient loads from faecal pollution (human and livestock), fertilizers and pesticides	Promote use of organic fertilisers and pesticides rather than chemical ones		- Make and sell organic compost, green manure, natural seeds, as income generation
	Salinization of soil due to over irrigation	Promote good irrigation practices		
	Loss of soil fertility from poor nutrient management	Promote soil fertility management practices e.g. mulching, compost, minimal/no tillage,		
	Solid waste from poor waste management, litter removal	Regular litter clean up and waste collection		- Implement recycling programmes e.g. pay per *kg* of tins, glass, plastic, etc.
	Poor water quality from contaminated runoff	Implement water harvesting and water attenuation in field to reduce runoff and erosion		
	Spread of invasive, opportunistic and alien vegetation from gardens (seeds in runoff)	Promote planting and landscaping of indigenous vegetation		- Bi-laws of landscaping plants - Livelihood; removal and maintenance of alien and invasive vegetation
	Reduced shade from vegetation clearing and deforestation	Promote planting of beneficial trees e.g. fruit trees, agroforestry, nitrogen fixing, etc.		- Seed collection and tree nursery as income activities

Landuse Zone	Impact	Mitigation In Landuse zone	Mitigation In River Zone	Strategies
Agricullture (continue)	Increased sediment load from cleared vegetation, exposed soil	Implement sediment trapping activities e.g. vegetation barriers, silt curtains, check dams; mulching; plant beneficial ground covers on exposed soils		
	Reduced dissolved oxygen in water from contaminants and solid waste	reduce contamination and solid waste reaching receiving waters		
	Reduced biodiversity as result of reduced habitat provision function			
	Reduced turbidity from cattle crossings and watering points	Identify set cattle watering/crossing points, construct formal crossing points to reduce turbidity and erosion of river banks		
	Erosion long cattle pathways causing increased sediment load and runoff	Raise pathways, conduct regular erosion inspection and rehabilitation activities, implement swales along pathways, cattle paths to zigzag upslopes.		
	Overgrazing of catchment area causing increased runoff and erosion leading to increased sediment loads to receiving water	Implement a grazing plan to prevent overgrazing. Implement overgrazing rehabilitation plan including covering/fencing with brushwood to prevent access to rehabilitation areas.		
	Loss of riparian buffer due to farming practices	Implement buffer set back area.		
	Reduced food security due to increased impact of flooding to farmed areas along river banks	Promote good farming practices in zone of integration e.g. regular vegetation barriers perpendicular to flow of water using vetiver grass; plant flood hardy crops e.g. sugar cane or beneficial trees., promote minimal/no tillage in this area.		

<table>
<tr><th rowspan="2">Landuse Zone</th><th rowspan="2">Impact</th><th colspan="2">Mitigation</th><th rowspan="2">Strategies</th></tr>
<tr><th>In Landuse zone</th><th>In River Zone</th></tr>
<tr><td rowspan="11">Rural / Communal land</td><td rowspan="3">Faecal pollution due to block, damaged, vandalised, absent sewer system</td><td>Install composting toilets as minimum sanitation standard</td><td rowspan="11">- Re-instate river buffer
- Constructed wetlands at discharge points
- Rehabilitate erosion rill, channels and gullies in streams, fields, paths, roadsides, etc.
- Promote natural farming and climate smart farming practices
- Litter traps at selected points in the river
- Regular litter / solid waste clean-up
- Clearing of alien and invasive vegetation and replace with indigenous
- Re-vegetation of river zones
- Include aeration of water with green infrastructure
- Rehabilitate river functions and catchment areas</td><td rowspan="3">- Improved sanitation, including composting toilet</td></tr>
<tr><td>Regular maintenance, emptying of sanitation points</td></tr>
<tr><td>Install formal holding pits where sewerage can be pumped from for disposal</td></tr>
<tr><td>Loss of soil fertility from poor nutrient management</td><td>Promote use of organic fertilisers and pesticides rather than chemical ones</td><td rowspan="2">- Make and sell organic compost, green manure, natural seeds, as income generation</td></tr>
<tr><td>Increased nutrient loads from faecal pollution (human and livestock), fertilizers and pesticides</td><td>Promote soil fertility management practices e.g. mulching, compost, minimal/no tillage,</td></tr>
<tr><td>Salinization of soil due to over irrigation</td><td>Promote good irrigation practices</td><td></td></tr>
<tr><td>Solid waste from poor waste management, litter</td><td>Regular litter clean up and waste collection</td><td>- Implement recycling programmes e.g. pay per kg of tins, glass, plastic, etc.</td></tr>
<tr><td>Poor water quality from contaminated runoff</td><td>Implement water harvesting and water attenuation in field to reduce runoff and erosion</td><td></td></tr>
<tr><td>Spread of invasive, opportunistic and alien vegetation from disturbed vegetation</td><td>Promote planting and landscaping of indigenous vegetation</td><td>- Bi-laws of landscaping plants
- Livelihood; removal and maintenance of alien and invasive vegetation</td></tr>
<tr><td>Reduced shade from vegetation clearing, deforestation</td><td>Promote planting of beneficial trees e.g. fruit trees, agroforestry, nitrogen fixing, etc.</td><td rowspan="2">- Seed collection and tree nursery as income activities</td></tr>
<tr><td>Increased sediment load from cleared vegetation, exposed soil, compacted soil areas e.g. soccer field and pathways</td><td>Implement sediment trapping activities e.g. vegetation barriers, silt curtains, check dams; mulching; plant beneficial ground covers on exposed soils</td></tr>
</table>

Landuse Zone	Impact	Mitigation In Landuse zone	In River Zone	Strategies
Rural / Communal land (continue)	Reduced dissolved oxygen in water from contaminants and solid waste	reduce contamination and solid waste reaching receiving waters		
	Reduced biodiversity as result of reduced habitat provision function			
	Reduced turbidity from cattle crossings and watering points	Identify set cattle watering/crossing points, construct formal crossing points to reduce turbidity and erosion of river banks		
	Erosion long cattle pathways causing increased sediment load and runoff	Raise pathways, conduct regular erosion inspection and rehabilitation activities, implement swales along pathways, cattle paths to zigzag upslopes.		
	Overgrazing/ disturbance/ deforestation of catchment area causing increased runoff and erosion leading to increased sediment loads to receiving water	Implement a grazing plan to prevent overgrazing.		
		Implement overgrazing rehabilitation plan including covering/fencing with brushwood to prevent access to rehabilitation areas.		
	Loss of riparian buffer due to farming practices, sand mining	Implement buffer set back area.		
	Reduced food security due to increased impact of flooding to farmed areas along river banks	Promote good farming practices in zone of integration e.g. regular vegetation barriers perpendicular to flow of water using vetiver grass; plant flood hardy crops e.g. sugar cane or beneficial trees., promote minimal/no tillage in this area.		

<table>
<tr><th rowspan="2">Landuse Zone</th><th rowspan="2">Impact</th><th colspan="2">Mitigation</th><th rowspan="2">Strategies</th></tr>
<tr><th>In Landuse zone</th><th>In River Zone</th></tr>
<tr><td rowspan="4">Conservation / Protection / Tourism zone</td><td>Increased biodiversity due to habitat provision and protection</td><td>Restricted landuse activities to promote natural vegetation and ecosystem function</td><td rowspan="4">- Re-instate / preserve river buffer
- Constructed wetlands at discharge points
- Rehabilitate erosion rill, channels and gullies in streams, fields, paths, roadsides, etc.
- No farming practices in this area
- Litter traps at selected points in the river
- Regular litter / solid waste clean-up
- Clearing of alien and invasive vegetation and replace with indigenous vegetation
- Re-vegetation of river zones
- Include aeration of water with green infrastructure
- Rehabilitate river functions and catchment areas</td><td rowspan="4">- Improved sanitation, including composting toilet
- Formally declare conservation / protected areas to prevent illegal development</td></tr>
<tr><td>Carbon sequestration from natural vegetation</td><td>No vegetation clearing or mining activities, no deforestation</td></tr>
<tr><td>Sediment trapping by natural vegetation</td><td>Manage soil erosion. Promote good soil management</td></tr>
<tr><td>Seed bank</td><td>Collection indigenous seeds for re-instating natural vegetation in other areas and rehabilitation projects</td></tr>
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<table>
<tr><th rowspan="2">Landuse Zone</th><th rowspan="2">Impact</th><th colspan="2">Mitigation</th><th rowspan="2">Strategies</th></tr>
<tr><th>In Landuse zone</th><th>In River Zone</th></tr>
<tr><td rowspan="5">Transport Zone</td><td>Increased runoff from increased hardened surfaces, directed stormwater, blocked drains</td><td>Stormwater attenuation on site, e.g. holding ponds, water harvesting
WSUDS for stormwater management</td><td rowspan="5">- Stormwater discharge set back from river with constructed wetland between active channel and outlet
- Outlets at max 45° angle to flow of water
- Litter traps at selected points in the river
- Re-vegetation of river zones
- Re-instate river buffer
- Constructed wetlands at discharge points
- Regular litter and waste clearing from riverine zones
- Regular clearing of waste accumulated around bridges and culverts</td><td rowspan="3">- Bi-law for onsite stormwater management, including water harvesting and attenuation, WSUDS</td></tr>
<tr><td>Increased sediment from soil washed in stormwater</td><td>WSUDS for stormwater management</td></tr>
<tr><td>Reduced water quality from contaminants e.g. hydrocarbons from road and parking</td><td>Sumps installed at parking areas, garages, etc.</td></tr>
<tr><td>Increased pollution from solid waste washed down stormwater conduits and drains from roads, pavements and walkways.</td><td>Regular litter clean up and waste collection
Litter traps on stormwater drains</td><td>- Implement recycling programmes e.g. pay per kg of tins, glass, plastic, etc.</td></tr>
<tr><td>Alteration of natural flows from infrastructure e.g. bridges, culverts.</td><td>Single span / piered bridges rather than culverts
include riparian corridor under bridges</td><td></td></tr>
</table>

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The Association for Water and Rural Development

AWARD is a non-profit organisation specialising in participatory, research-based project implementation. Their work addresses issues of sustainability, inequity and poverty by building natural-resource management competence and supporting sustainable livelihoods. One of their current projects, supported by USAID, focuses on the Olifants River and the way in which people living in South Africa and Mozambique depend on the Olifants and its contributing waterways. It aims to improve water security and resource management in support of the healthy ecosystems to sustain livelihoods and resilient economic development in the catchment.

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About USAID: RESILIM-O

USAID: RESILIM-O focuses on the Olifants River Basin and the way in which people living in South Africa and Mozambique depend on the Olifants and its contributing waterways. It aims to improve water security and resource management in support of the healthy ecosystems that support livelihoods and resilient economic development in the catchment. The 5-year programme, involving the South African and Mozambican portions of the Olifants catchment, is being implemented by the Association for Water and Rural Development (AWARD) and is funded by USAID Southern Africa.

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