International Water Management Institute

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RESILIENT WATERS PROGRAM

E-FLOWS FOR THE LIMPOPO RIVER BASIN:

FROM VISION TO MANAGEMENT

E-FLOWS FOR THE LIMPOPO RIVER BASIN: FROM VISION TO MANAGEMENT

(Submitted in partial fulfilment of Milestone 2: Report on basin ecosystems, biophysical characteristics and risk regions mapping)

Citation: Dickens, C.; Mukuyu, P.; Ndlovu, B.; O'Brien, G.; Stassen, R.; Magombeyi, M. 2020. ***E-flows for the Limpopo River Basin: from vision to management.*** Project report prepared by the International Water Management Institute (IWMI) for the United States Agency for International Development (USAID). Colombo, Sri Lanka: International Water Management Institute (IWMI); Washington, DC, USA: USAID. 104p. (E-flows for the Limpopo River Basin: Report 3). doi: https://doi.org/10.5337/2022.218

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About IWMI

The International Water Management Institute (IWMI) is an international, research-for-development organization that works with governments, civil society and the private sector to solve water problems in developing countries and scale up solutions. Through partnership, IWMI combines research on the sustainable use of water and land resources, knowledge services and products with capacity strengthening, dialogue and policy analysis to support implementation of water management solutions for agriculture, ecosystems, climate change and inclusive economic growth. Headquartered in Colombo, Sri Lanka, IWMI is a CGIAR Research Center with offices in 13 countries and a global network of scientists operating in more than 30 countries.

USAID statement and disclaimer: *This report was produced under United States Agency for International Development (USAID) Prime Contract No. 720-674-18-C-00007 and was made possible by the generous support of the American people through USAID. The contents are the responsibility of IWMI and do not necessarily reflect the views of USAID or the United States Government.*

Acknowledgements:

This project was funded by the United States Agency for International Development (USAID). It was implemented by the International Water Management Institute (IWMI) as part of the CGIAR Research Program on Water, Land and Ecosystems (WLE). The CGIAR and WLE combine the resources of 11 CGIAR centers, the Food and Agriculture Organization of the United Nations (FAO), the RUAF Foundation, and numerous national, regional and international partners to provide an integrated approach to natural resource management research. WLE promotes a new approach to sustainable intensification in which a healthy functioning ecosystem is seen as a prerequisite to agricultural development, resilience of food systems and human well-being. Special thanks go to Mayford Manika and Nkobi Moleele from USAID and Simon Johnson from JG Africa who managed the contract and provided project oversight. We would also like to thank representatives from LIMCOM especially Sergio Sitoe, Ebenizario Chonguica, and Zvikomborero Manyangadze, who will be the ultimate beneficiaries, and also Eddie Riddell and Robin Petersen from SANParks who helped so much both inside the Kruger Park and outside. Lastly, we would like to thanks the members of the Steering Committee, largely members of LIMCOM, for their participation and perspectives.

Cover picture: Groot Letaba River (picture G. O'Brien)

Collaborators:

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International Water Management Institute, Colombo, Sri Lanka

Limpopo River Commission, Mozambique

Rivers of Life located in the University of Mpumalanga, South Africa

South African National Parks, Kruger National Park, South Africa

Donor:

Donor agency, Washington DC, USA, Contract No. 720-674-18-C-00007 Subcontract No. FPSC-02-SWER; Grant Agreement No.: RWP-G5-IWMI

Project:

This project was part of a Resilient Waters Project https://chemonics.com/projects/natural-resources-management-and-water-security-in-southern-africa/ entitled *Natural Resource Management and Water Security in Southern Africa*.

This specific project undertaken by IWMI was titled *Environmental flows for the Limpopo River - building more resilient communities and ecosystems through improved management of transboundary natural resources*

The project was funded by USAID Contract No. Contract No. 720-674-18-C-00007

Subcontract No. FPSC-02-SWER, Grant Agreement No.: RWP-G5-IWMI

Below is the list of Project Reports. This report is highlighted

Report number	Report title E-FLOWS FOR THE LIMPOPO RIVER BASIN:
1	Inception Report
2	Basin Report
3	From Vision to Management
4	Specialist Literature and Data Review
5	Present Ecological State - Drivers of Ecosystem Change
6	Present Ecological State - Ecological Response to Change
7	Environmental Flow Determination
8	Risk of Altered Flows to the Ecosystem Services

PROJECT TITLE:

Environmental flows for the Limpopo River - building more resilient communities and ecosystems through improved management of transboundary natural resources

REPORT TITLE:

E-flows for the Limpopo Basin: From Vision to Management

PROJECT OBJECTIVES:

This project will provide the necessary evidence to secure environmental flows (e-flows) for increasing the resilience of communities and ecosystems in the Limpopo Basin to changes in streamflow resulting from basin activities and climate change.

TERMS OF REFERENCE:

USAID has funded Chemonics to implement the Resilient Waters Program. In turn this project was a response to a Grant call that had as its overall goal "*to build more resilient communities and ecosystems through improved management of transboundary natural resources*……".

The International Water Management Institute (IWMI) was commissioned by Resilient Waters to undertake a project titled: *Environmental flows (e-flows) for the Limpopo River - building more resilient communities and ecosystems through improved management of transboundary natural resources*. The study incorporated the PROBFLO method to determine e-flows and eveluate the risk of altered flows and non-flow variables to the ecosystems services in the Limpopo Basin. The project has resulted in two final reports including:

- Environmental flow determination in the Limpopo Basin.
- Risk of altered flows to the ecosystems services of the Limpopo Basin.

This report presents the description of establishing a vision for the basin.

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ACRONYMS

BN	Bayesian Network
CPT	Conditional Probability Table
DWS	Department of Water and Sanitation South Africa (=DWA)
DRM	Desktop Reserve Model (Hughes, 1999)
E-flow	The quantity, timing, and quality of freshwater flows and levels necessary to sustain aquatic ecosystems which, in turn, support human cultures, economies, livelihoods, and well-being (Arthington et al., 2018).
EF	Environmental flows (=E-flow)
EI	Ecological importance
ES	Ecological sensitivity
EWR	Environmental Water Requirement (=E-flow)
GW	Groundwater
IWMI	International Water Management Institute
LIMCOM	Limpopo Watercourse Commission
LoE	Line of Evidence
MAR	Mean Annual Runoff
PES	Present Ecological State
PROBFLO	E-flow method (O'Brien et al, 2018)
RW	Resilient Waters Program of USAID
SW	Surface water
VEGRAI	Riparian Vegetation Response Assessment Index

1. SUMMARY

Ecosystem services describe the relationship between what is provided by the natural ecosystems of the Limpopo River Basin, and the people who benefit from those ecosystems. E-flows (environmental flows) describe the flows that are needed to maintain the ecosystems on which people depend. Thus, ecosystem services (ES) are used here in this project as the currency on which to base the determination of e-flows.

The logic of the process to evaluate this has been:

- Describe the **stressors** on the system i.e. those factors that will be reducing the ability of ecosystems to function
- Document the **present state** of the river ecosystems as impacted by the stressors
- Describe the **ecosystem services** (ES) used in each Risk Region (RR)
- Extract from policy statements, **vision and management objectives** which may describe from the significance of each ecosystem service
- **Recommend the ecological state** in the river that will provide the required ecosystem services, and will at least maintain the river in its present ecological state or better.

A wide range of data and information has been compiled into this evaluation, some of it the result of intensive studies which can be taken to be accurate, while others are speculative, extracted from other documents. Much of this information is compiled in the Basin report (2020) and also in Annexure A to this report.

Below is a short summary of each of the steps followed:

Stressors – some regions of the basin are heavily stressed, in particular RR1 (Crocodile) and also the RR7 (Olifants), by a mixture of urban developments and mining. The rest of the basin suffers from general development, agriculture and rural living, much of which has transformed and degraded the land.

Present ecological state (PES) – the state of river ecosystems reflects the above stressors. Some of the rivers are in good condition (e.g. the Marico, the Mwenezi, the Shingwedzi) while others are in a state below what is acceptable for any level of management where the ecosystem can already by concluded to be in an unsustainable state (e.g. Crododile, Shashe, Upper Olifants and Elefantes). The latter rivers all need urgent attention to return them to a sustainable state.

Ecosystem services – the ES in each RR have been evaluated in terms of their importance to local inhabitants. There are a wide range of ES including provisional, regulatory, cultural and supporting services. A simple summation of the ES per RR

shows that the Lower Limpopo has the greatest value of services, followed by the Olifants and Middle Limpopo. There are the least ES in the Luvuvhu.

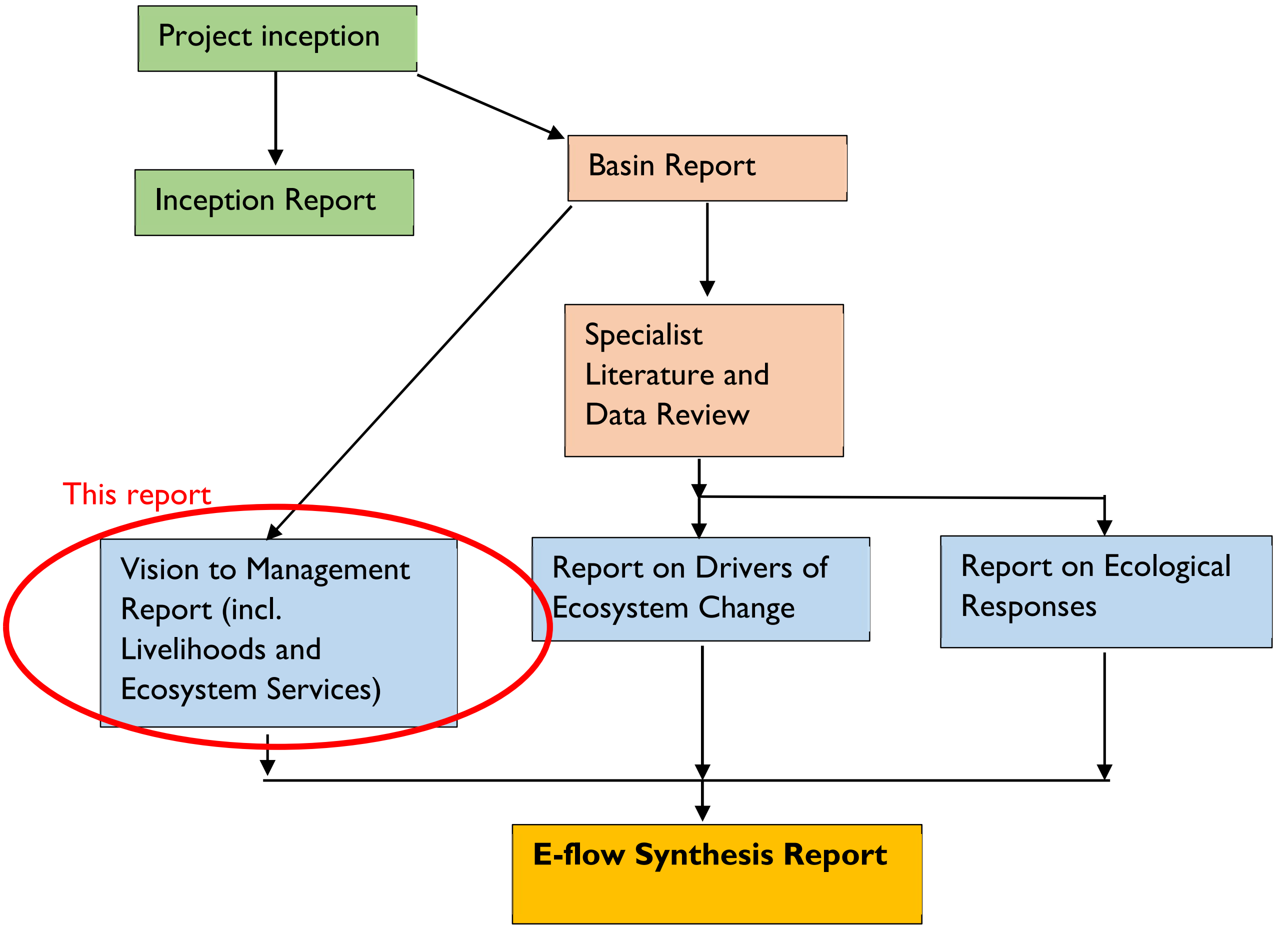
Vision and management objectives – a range of pertinent policy documents has been reviewed and a number of supporting statements and quantitative requirements are available. Most of the policies from the SADC to the country level, have statements requiring that ecosystems are protected, and in some cases stipulating that e-flows are provided to support ecosystems.

More detailed management reports give numerical data that describes aspects of the ecosystems in reach RR in considerable detail. While this varies between RR and between countries, sufficient information has been gathered to provide an indication of the type of ecosystem conditions that should be achieved by management of river flows.

The recommended ecological categories (REC) – these summarise the type of river ecosystem that should be maintained in each RR. These categories will be used to structure the e-flows that are determined for each RR, with additional information given as flows that would improve the REC to the next level above. Note that these recommendations will be updated after establishing e-flows as part of this study, and based on first-hand data and information collected.

2 INTRODUCTION

2.1 PROJECT REPORTING STRUCTURE



E-flows can only be set in relation to a vision and management objective for the condition of the river and for the communities that the river supports. Visions and management objectives already exist in various formats in different parts of the basin as part of policy strategies and resource objectives within riparian governments. Additionally, LIMCOM has recently completed a study on the vision for the basin.

For this project, these will be harmonized into a format that provides the vision for different sub-sections of the basin and thus a context for the e-flows evaluation to follow. A vision and objectives for the river will be established separately for each Risk Region (RR) and will be considered from both a surface and groundwater perspective, taking into account the reality that the river today is ephemeral in places including along the main stem river. If the existing vision or objectives are inadequate for setting of e-flows, then the e-flows will be determined for the present day flows and modelled for an improved ecological condition to provide decision makers with alternative options. Thus, the boundaries of the e-flow recommendation would be existing policy statements and/or the PES of the river.

For the project to assume a vision or objectives, and thus set an e-flow, that is at odds with the new LIMCOM vision, and also with present day policy at regional and country level, would not be possible as such changes would require extensive consultation and also the mandate of riparian governments.

This report presents the process to convert the gathered information on the vision and management objectives as provided in the Basin Report (IWMI 2020) and the Flow Related Livelihoods and Ecosystem Services Report, into management objectives expressed as the recommended ecological management class that will then set direction for the e-flows assessment.

In the Basin Report the following scales were used to gather vision and management objectives:

1. Regional level
2. Basin level
3. Country level
4. Risk region level

The vision is presented, where possible, at each of these levels.

2.2 SYNTHESIZING BASIN VISION AND OBJECTIVES

A process to gather the required information, to synthesise and provide statements on the vision and management objectives for the different regions of the Limpopo Basin has been developed and is illustrated in Figure 2.1. This report follows this procedure.

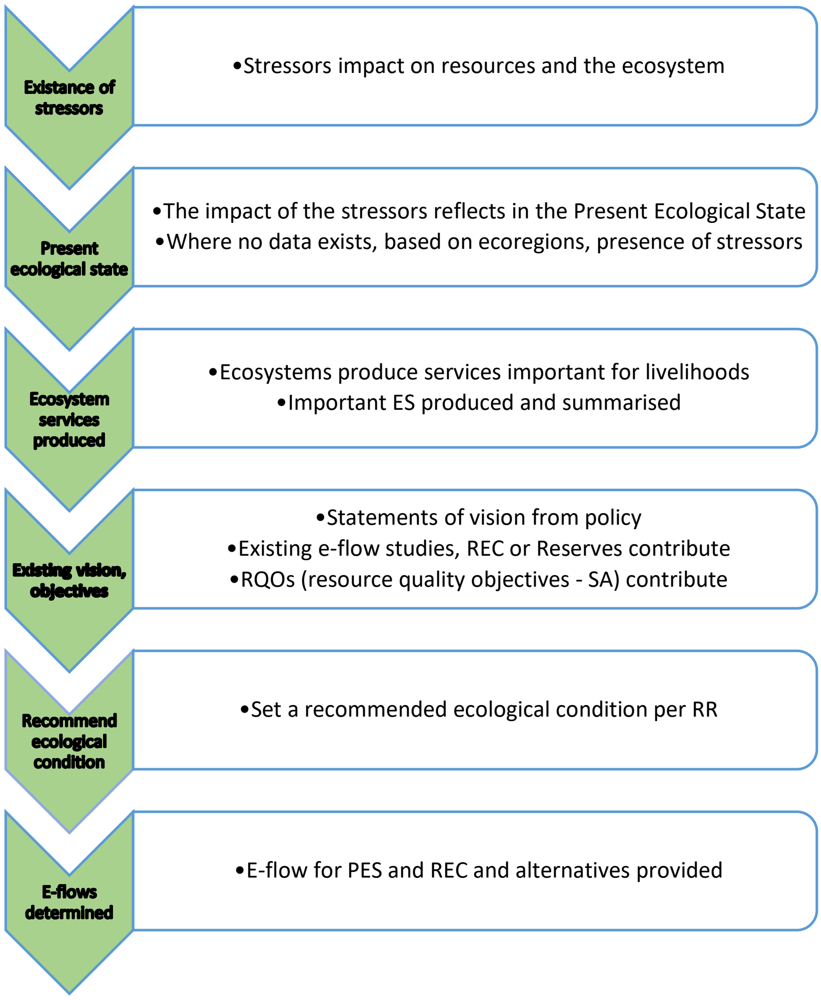
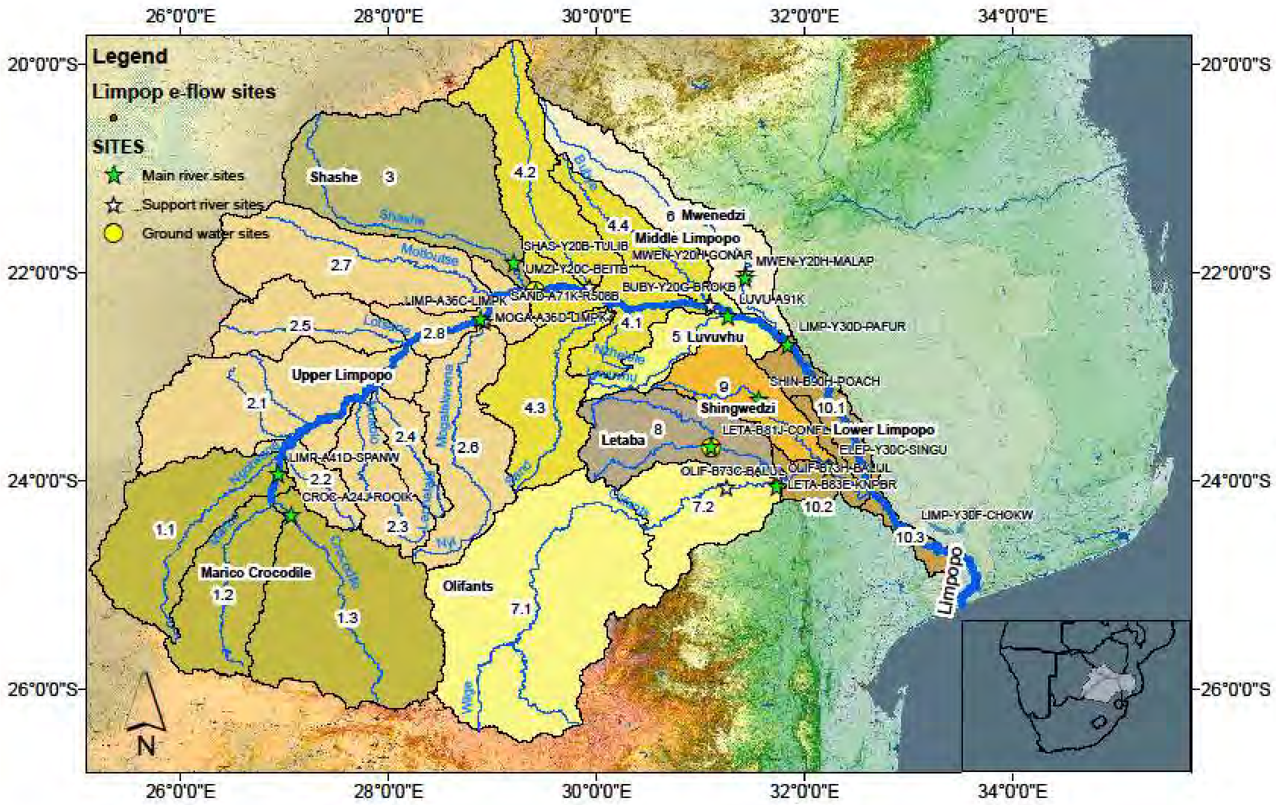


FIGURE 2.1: SCHEMATIC SHOWING LAYOUT OF THIS REPORT FOLLOWING THE PROCESS TO ARRIVE AT THE RECOMMENDED CONDITION FOR THE RIVER

Two project reports provided data and information that informed this process, providing a synthesis of data and information at a regional, basin and RR scale. These reports were:

- **Basin Report** (2020)
  - This report describes the Limpopo Basin and its people by providing a baseline description of the basin from a river flow perspective.
  - The report was structured to include the following:
    - Socio-economic conditions and livelihoods
    - Basin vision and management objectives
    - Physical characteristics
    - Water resources
    - Water resources availability (for each Risk region)
    - Water quality
    - River ecosystems
- **Flow Related Livelihoods and Ecosystem Services** (See Annexure A to this report)
  - This report presents the different river-flow related ecosystem services (ES) and where possible illustrates their occurrence across the RR in the Basin. A discussion of ES and livelihoods follows, punctuated by examples of how people in the basin are using the river and the resultant ES.
  - The report aims to paint a picture of how essential ES are sustained by e-flows in the Limpopo River system, and how these services are central to the livelihoods of local communities in the basin.
  - The report has been structured to include the following:
    - Introduction to aquatic ecosystem services
    - Regulating services
    - Cultural services
    - Provisioning services
    - Supporting services



1. Marico Crocodile
2. Upper Limpopo
3. Shashe
4. Middle Limpopo
5. Luvuvhu
6. Mwenezi
7. Olifants
8. Letaba
9. Shingwedzi
10. Lower Limpopo

FIGURE 2.2: MAP OF RISK REGIONS AND SURVEY SITES IN THE LIMPOPO RIVER BASIN

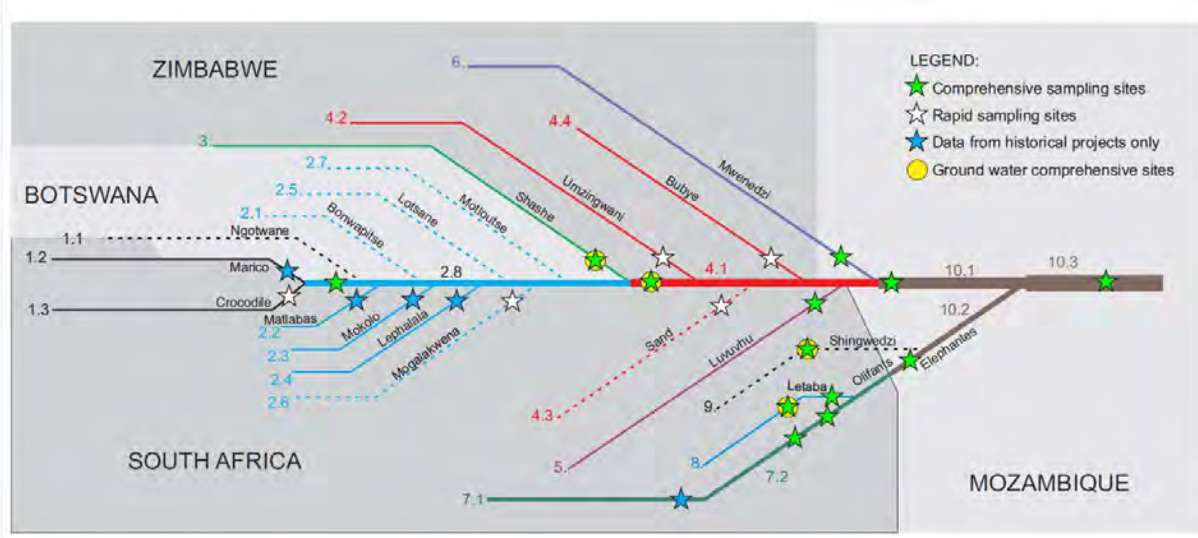


FIGURE 2.3: SCHEMATIC SHOWING RISK REGIONS, SUB-REGIONS AND SITES IN THE LIMPOPO RIVER BASIN

2.3 STRESSORS IN THE BASIN

The Basin Report (IWMI, 2020) and Livelihoods and Ecosystem Services Report (Annexure A) both document many of the stressors that are at play in the basin. These stressors impose stress on the river ecosystem as shown in Figure 2.4, which in turn influences the delivery of ecosystem services that ultimately influence the management of the river. Depending on the vision for the river, the stressors will have to be managed in such a way that impacts on the receiving ecosystems are "acceptable" so that anticipated services can be delivered. This is the hard reality of the trade-offs that need to be made. For example, if the vision for a river is to achieve a high delivery of ecosystem services, then the ecosystems will need to be maintained in their best condition which would mean reducing the stressors in a way that maintains ecosystem condition. This may mean a reduction in water withdrawals.

The information presented here tries to cover the wide nature of stress on the ecosystem, with the emphasis being on the scope of stressors rather than on accuracy of component information, so that later investigations into the e-flows can consider the extent and nature of the stress in terms of understanding the changes to the ecosystem that are detected.

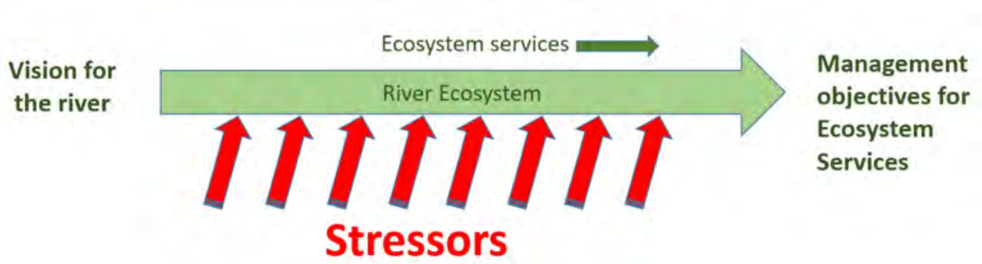


FIGURE 2.4: ILLUSTRATION OF HOW STRESSORS IMPACT ON THE RIVER ECOSYSTEM IN RELATION TO THE VISION AND OBJECTIVES

Figure 2.5 shows the distribution of human populations in the basin, which can be associated with many forms of stress on the river ecosystem and provides a good proxy for the total stress. Table 2.1 provides a summary of some of the most important water users in the basin.

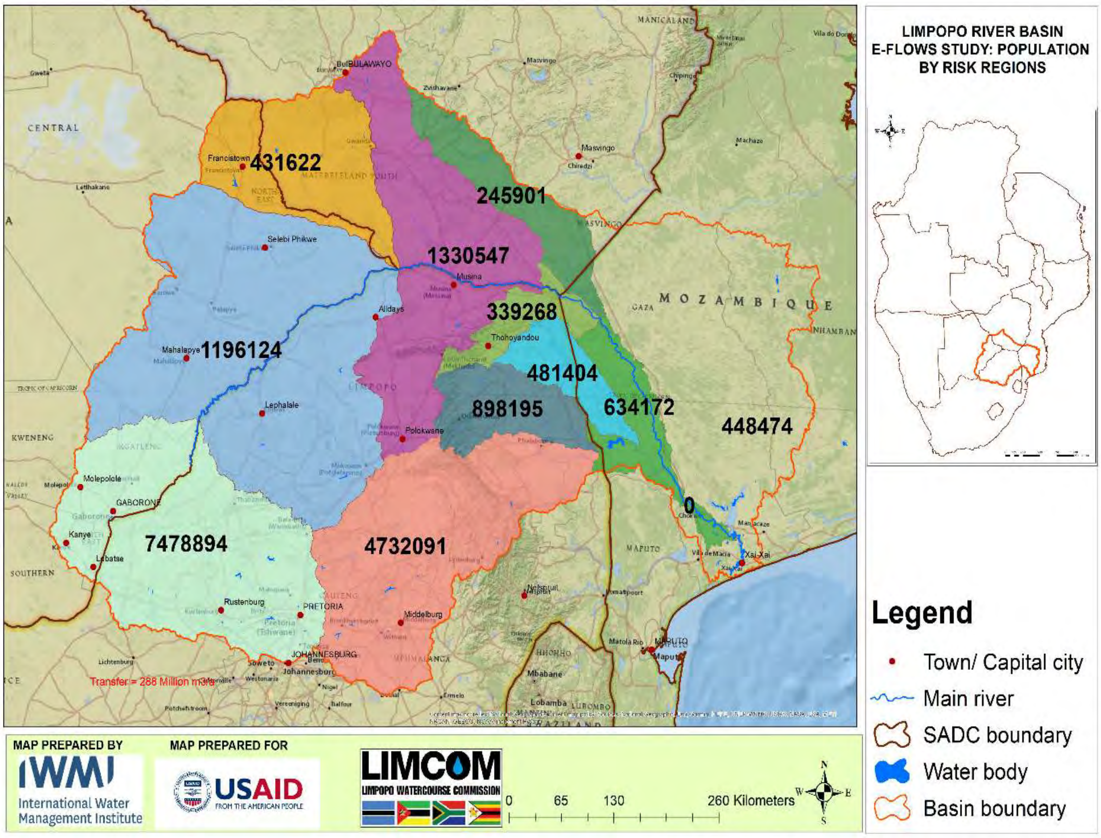


FIGURE 2.5: DISTRIBUTION OF HUMAN POPULATION - ALLIED TO MOST STRESSORS

Table 2.1 presents a summary of the intensity of stress on the ecosystems of each RR. Each of these stressors has been evaluated in a different way depending on the nature of the stress and the data and information available to describe it. The evaluation, either quantitative or qualitative, allocates a stress ranking as shown in Table 2.1that ranges from the stress not present (1) to a high level of stress (4).

The source of the data is shown. Note that these stress values are not aligned between stressors, for example, the stress of "alien fish" is not compared in terms of its impact on the aquatic ecosystem against the stress of "dryland agriculture", or any other stressor. Such an evaluation would be the subject of a different study and was not necessary here.

TABLE 2.1: SUMMARY OF INFORMATION ON THE INTENSITY OF STRESS IN EACH RR

Risk Region activities that impact on water resources 1= not present 2= not important 3= important 4= very important (important = quantity and quality)	RR1 Marico Crocodile	RR2 Upper Limpopo	RR3 Shashe	RR4 Middle Limpopo	RR5 Luvuvhu	RR6 Mwenedzi	RR7 Olifants	RR8 Letaba	RR9 Shingwedzi	RR10 Lower Limpopo	Source of data
Afforestation	2	1	1	2	3	1	3	4	1	1	Map of plantations
Rehabilitation activities	3	2	2	2	3	2	3	3	3	2	Working for Water Programs - clearing of invasive plants in Olifants and Marico Crocodile RR, especially in South Africa
Alien vegetation	3	2	2	2	4	2	3	4	3	2	Combine afforestation and rehabilitation - evaluate in terms of alien infestation
Dams	3	2	4	3	2	2	4	4	1	3	Number of dams in each risk region, and for the Massingir dam- the largest dam - dam size was also considered.
Dryland agriculture (including sugarcane & other crops)	2	3	3	3	2	3	2	2	2	4	Landuse map
Industrial areas	4	3	3	3	3	2	4	2	2	2	Urban areas -assummed to be similar to industrial areas
Infrastructure (including roads, powerlines etc)	4	2	2	3	3	2	4	3	2	3	Urban areas and road network
Inter-basin transfers	4	1	1	1	1	1	4	1	1	1	There are 4 interbasin transfers: 3 into Olifants and 1 into Marico Crocodile RR.
Intra-basin transfers	4	1	4	4	4	1	4	4	1	1	There are 11 intra-basin transfers: 4 from Letaba, 2 from Olifants, 2 from Middle Limpopo, 1 from Marico Crocodile, 1
Irrigated agriculture	3	3	1	3	3	1	4	3	1	3	Percent of irrigated area from irrigated map
Livestock grazing	3	4	2	4	1	2	3	1	1	1	Proportion of grassland from the landuse map
Mining activities	4	2	2	4	2	2	4	3	2	1	Number of mines in each RR from map of mines
Rural Settlements practicing subsistence resource use	2	3	3	3	2	3	2	2	2	4	Populations excluding urban
Sewage works and solid waste sites	4	3	3	3	3	2	4	3	2	3	Combination of urban areas and the number of mines
Population density (persons/km2)	4	2	2	2	2	2	3	3	2	2	Population and area of RR to calculate population density
Urban areas	4	3	3	3	3	2	4	3	2	3	Landuse map
Urban Informal settlements	4	3	3	3	3	2	4	3	2	2	Proportion of urban area
Barriers to fish migration (flow, physical & chemical)	4	1	4	1	2	2	4	4	2	1	Olifants acid mine; Crocodile and sewage from urban areas; Shashe and middle Limpopo (esp. in Zimbabwe) gold panning,; dams and weirs
Alien fish	3	2	3	3	3	2	4	4	2	3	Alien fish distribution, Bass (4 species), Carp, Silver Carp, Grass Carp, Mosquito fish, Placostamus, Nile Tilapia, Three spot Tilapia, Nembwe, etc
TOTALS	64	43	48	52	49	36	67	56	34	42	

The total stress is estimated by simple addition and shows that the most stressed RR are RR1 Marico Crocodile and the RR7 Olifants while the least stressed is the Shingwedzi.

Table 2.2 provides some explanation of the sources of stress in each RR and is not an exhaustive assessment but a representation of the wide range of issues at play.

TABLE 2.2: EXPLANATION OF SOME OF THE STRESS IN EACH RR

RISK REGION	SUMMARY
RR I Marico Crocodile	• Intensive water use both urban, industrial and agricultural. • Notwane catchment contains Gaborone and 30% of the population. Two dams the Gaborone and Mogobane (mainly irrigation) used for domestic and industrial water supply. Flows to the Gaborone Dam are sporadic so transfers from Marico sub-basin. • Marico sub-basin mostly South Africa. The Upper Groot Marico River a National Freshwater Ecosystem Priority Area (NFEPA) and is the last free flowing river in the northwest of SA. Communities depend on this river for game reserves, ecotourism and livestock farming. • Crocodile sub-basin - high levels of land degradation, polluted industrial waste from Tshwane, high unemployment, frequent fires and poor spatial planning which aggravate flooding risks.
RR2 Upper Limpopo	• In the South African portion mostly developed and heavily utilized for mining, irrigation and supply to power stations. • The Mogalakwena catchment has approximately 700 farm dams in addition to three large dams providing water for irrigation. • There is also extensive groundwater exploitation. • In Botswana mainly cattle and game farming.
RR3 Shashe	• Greater Mapungubwe Transfrontier Conservation Area. • Firewood in short supply in parts. • Pastures for livestock and domestic water. • Small scale irrigated agriculture and livestock production support the livelihoods of many of the households in the risk region. • Drought prone – loss of agriculture impacts on ecosystem. • 9 dams and 30 mines.
RR4 Middle Limpopo	• Spans across South Africa and Zimbabwe. • Zimbabwe - smallholder irrigation schemes as well as gold panning along river beds • ~60% of the domestic water in Bulawayo is supplied from the Mzingwane Catchment. • Zhovhe Dam supplies water for domestic and irrigation use. • Sand dams are a common feature in the Upper Mzingwane Catchment providing irrigation and domestic water to local rural households. • South African side - the Sand river sub catchment is considered dry and dependent on groundwater. • Significant mining and irrigation activities. • Many rural communities in the Sand rely on groundwater. • The water demand introduced by the proposed Musina Special Economic Zone and Limpopo Eco-Industrial Park may have to be met by water transfers from Zimbabwe. • Rural communities of the Nzhelele demand for grazing land and wood for fuel.

RISK REGION	SUMMARY
	• Half of the population here is unemployed and are mostly women – with severely limited access to basic services like water and electricity.
RR5 Luvuvhu	• Large scale agriculture of citrus, fruit and grains, afforestation and ecotourism. • Local communities are rural, the majority of them poor and dependent on social grants. • Over 20 000 hectares of land are under irrigation • Fertile land below Soutpansberg mountains but however rural communities contend with poverty and poor infrastructure for basic services. • Proliferation of alien vegetation.
RR6 Nuanetzi/Mwenezi	• Seasonal river with sandy alluvial soils that can store large volumes of water. • The Manyuchi Dam is the largest dam in the sub-basin with three quarters of its water allocated to irrigated sugar cane. • The lower reaches of the river are critical the Gonarezhou National Park. • Local communities are mostly rural and depend on livestock farming and to a lesser extent crop agriculture.
RR7 Olifants	• Important for flows to Mozambique to support the livelihoods of nearly 10 000 small-scale farmers. • Irrigated commercial farming and subsistence agriculture important. • Rural communities directly fetch water from the river for domestic use in the Lower and Middle Olifants. • Nearly 70% of the population is rural relying on ecosystem services. • 25% of the population relies on wood as a source of energy. • Tourism in the Kruger National Park also supports informal crafters. • Mining and acid mine drainage as well as untreated sewage a major issue.
RR8 Letaba	• 20 dams constructed on the Groot Letaba • Tzaneen and Giyani are larger town centers. • Water for domestic, industrial and agricultural needs. • The largely rural communities engage in smallholder agriculture dependent. • Large-scale commercial farms also rely on surface water for irrigation. • Livestock grazing and clearing of vegetation leading to siltation of rivers. • Sand mining for building and construction leading to negative impacts on ecosystems.
RR9 Shingwedzi	• Mostly in Kruger National Park and Greater Limpopo Transfrontier Park. • Communities outside the national park practice subsistence agriculture. • Informal urban settlements and poor land use practices on the flood plains of concern. • Small dams are dotted within the region including the Kanniedood and Sirheni dams within the KNP.

RISK REGION	SUMMARY
RR10 Lower Limpopo	• Parts in the Great Limpopo Transfrontier Park. • Low lying and flood prone. • Significant water quality and flow regime changes due to upstream development activities. • Mineral sand mining activities occur at the edge of the risk region. • Floodplain agriculture a key economic activities for local communities. • Irrigation schemes at Chokwe, termed the 'granary of the nation' have potential for further growth. • Concerns around the availability of water to support expansion • Proposed Mapai dam would serve to mitigate some of the flooding associated with this region as well as deliver on hydropower. • Climate variation and increased incidence of flooding coupled with upstream development add to uncertainties that surround water availability in the Lower Limpopo.

In summary, the stress that is imposed on aquatic ecoregions in the basin is in places severe. The Olifants has the reputation of being the most polluted and stressed basin in South Africa, and probably in the region. At the same time water shortages are rapidly becoming an issue of great importance for life and developments in the Limpopo basin. The variability of the natural flows in the river, now subject to increasing levels of stress, is meaning that parts of the river have changed from perennial to ephemeral which will be having a substantial impact on the delivery of ecosystem services. Detail on this is presented below.

2.4 PRESENT ECOLOGICAL STATE

Dickens and McCartney (2020) define a water related ecosystem as "a dynamic complex of plant, animal, and microorganism communities and the non-living environment dominated by the presence of flowing (lotic) or still (lentic) water, interacting as a functional unit."

The aquatic ecosystems of the Limpopo have been described in summary in the Basin Report (IWMI, 2020a), and in greater detail in the Specialist Report (IWMI, 2020b). The ecosystem services are described in the attached Annexure A. The purpose of this section of the report is to document the PES of the ecosystems in a way that can be helpful in setting the e-flows and ultimately in management of objectives for the whole basin. The reason to present this information is that there is the assumption, well supported by evidence, that maximum ecosystem services are delivered by ecosystems in the best condition, and that as ecosystems degrade, so do the services associated with them. This relationship is by no means linear, for example a small amount of nutrient added into a pristine lake will raise its productivity and similarly most of the ecosystem services provided by the lake. However, once the nutrients increase beyond a certain amount and the lake becomes polluted, then the benefits from the lake begin to decline and will continue to do so until there is an almost total collapse of services. A total collapse is not possible, for example, a river can be used to carry raw sewage from a city, however the degraded ecosystem that will result while providing only one service of getting rid of waste will mean that all of the other services of the river (e.g. drinking water, irrigation, recreation etc.) will be severely compromised. Society then needs to evaluate this trade-off and hopefully choose in favour of a wider range of benefits.

The Aquatic Ecoregions for the Limpopo Basin (Figure 2.6) were derived from extrapolating the Department of Water and Sanitation South Africa (DWS) Level I Ecoregions to neighbouring countries (see Basin report, IWMI, 2020a). This information is useful in that it can be assumed that any river within a single ecoregion will have a similar ecological structure. This means that data can be inferred from one site to another within each Ecoregion.

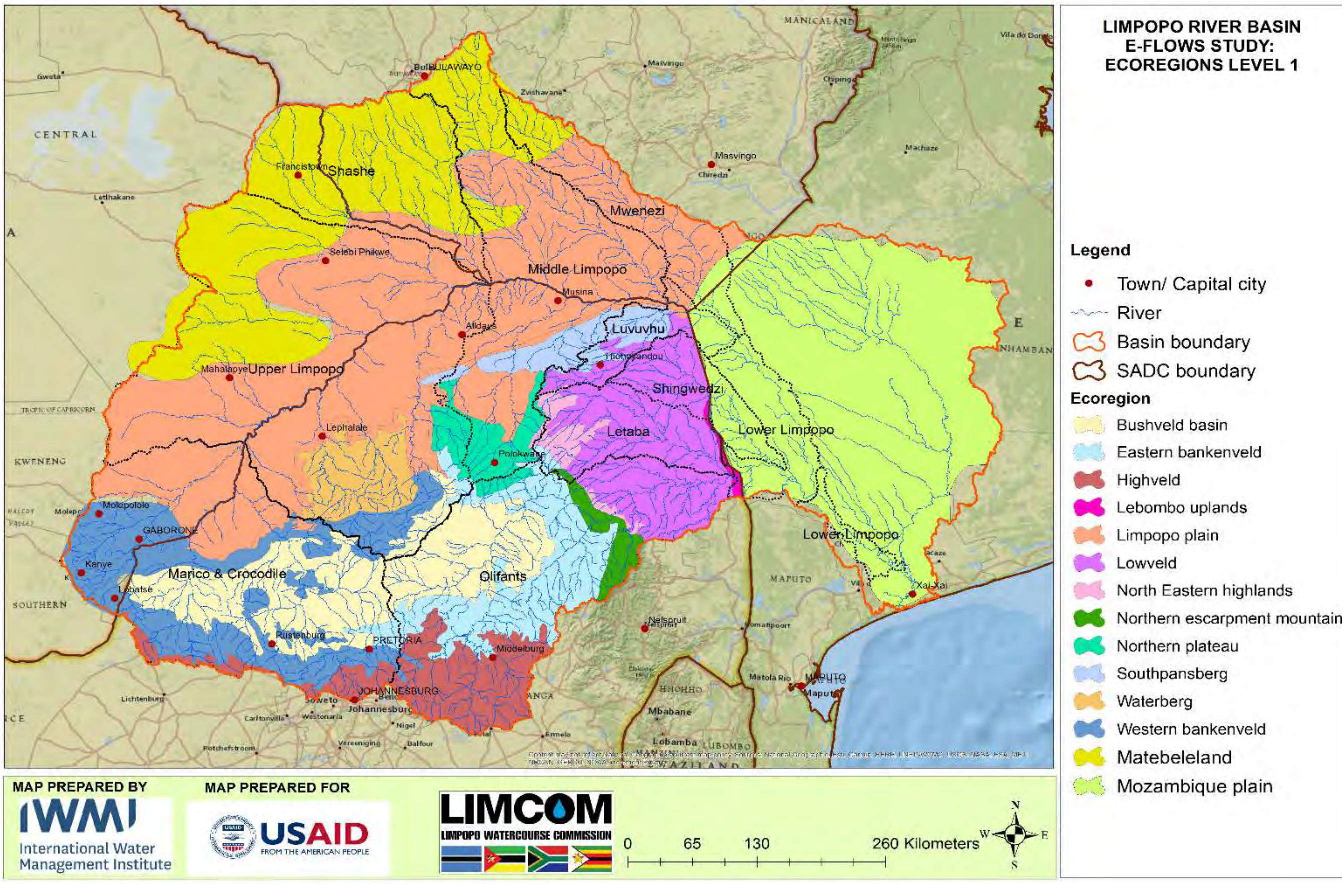


FIGURE 2.6: AQUATIC ECOREGIONS OF THE LIMPOPO RIVER BASIN

At the time of writing, there was varied data on the PES of each RR. Those areas within South Africa are well documented by the PES-EIS programme (DWS, 2014), while those in neighbouring countries had, at times, to be inferred in a process that was based on available biodiversity information, and an understanding of the stressors in the region. Table 2.3 provides a summary of the PES, greater detail is provided later in the report where it is summarised per risk region.

TABLE 2.3: SUMMARY OF KNOWN INFORMATION ON THE PES, THE ECOLOGICAL IMPORTANCE (EI) AND THE ECOLOGICAL SENSITIVITY (ES). DATA IS SUMMARISED FROM THE BASIN REPORT (2020)

	Risk Region Ecosystem Ranking **A = Pristine** **B = Almost natural** **C = Moderately modified** **D = Largely modified** **E = Seriously modified**																									
Ecosystem	**1.1-Ngotwane**	**1.2-Marico**	**1.3-Crocodile**	**2.1-Bonwapitse**	**2.2-Matlabas**	**2.3-Mokolo**	**2.4-Lephalala**	**2.5-Lotsane**	**2.6-Mogalakwena**	**2.7-Motloutse**	**2.8-Upper Limpopo**	**3-Shashe**	**4.1-Middle Limpopo**	**4.2-Umzingwani**	**4.3-Sand**	**4.4-Bubye**	**5-Luvuvhu**	**6-Mwenedzi**	**7.1-Upper Olifants**	**7.2-Lower Olifants**	**8-Letaba**	**9-Shingwedzi**	**10.1-Lower Limpopo**	**10.2-Elephantes**	**10.3-Lower Limpopo**
PES (present ecological state)	C	BC	DE	CD	CD	C	CD	CD	D	D	D	DE	D	DE	D	C	D	BC	DE	D	DE	BC	D	DE	CD
EI (ecological importance)	L	M	M	L	M	M	M	L	M	L	H	M	H	M	L	M	H	H	H	H	M	H	H	H	H
ES (ecological sensitivity)	L	H	M	L	M	M	M	L	H	L	M	M	M	M	L	L	H	M	H	H	M	M	H	H	H

3 AQUATIC ECOSYSTEM SERVICES

A review of the aquatic ES that are at play in the Limpopo Basin is provided in Annexure A.

In summary, the ES are divided into the following categories:

1. Regulating services
2. Cultural services
3. Provisioning services
4. Supporting services

3.1 REGULATING SERVICES

There is a general lack of understanding of the regulating processes occurring in the basin. This is due mostly because of their dynamic nature and also because of the complex interactions that occur between ecosystem functions. There is thus little quantitative data to support these ES, even though these are one of the most important of all ES, and for this reason Regulating Services are seldom given the appreciation they deserve when it comes to catchment planning.

Flow regulation and flood control

There is a complex relationship between the storage of rainwater on land and the runoff to river, with the nature and condition of the vegetation and soil, and the interaction with the groundwater, being key issues that affect the runoff. Wetland areas in the landscape are key focal points of this service, pointing to their value in the catchment; however, all areas vegetated will be contributing this service to a greater or lesser degree. Flooding rivers also expand onto floodplains and even just up onto flood benches that run parallel to the river, where water may be stored and slowly released back to the river, reducing the overall size and impact of the mainstream flood.

Even in the driest periods of the year, the continued flow of water in the river comes from groundwater seepage, all contributing to the ability of the ecosystem to regulate river flow. Where the land-cover is in poor condition, or if the groundwater is decimated, then this service may be most, with flood intensities increasing resulting in increased damage downstream. Because of the rapid run-off associated with increased flooding, the land dries out more rapidly, and rivers may even cease flowing during the dry season, a common problem in the Limpopo basin (see Section 6).

Society has attempted to replicate regulating service by building dams. While these are very efficient at providing some aspects of the regulating service, they may compromise the provision of other services (e.g. supporting services through biodiversity). Importantly, they also reduce the impetus to manage the landscape well and thus to keep the water in the basin.

The Limpopo River Basin has an approximately 5.2 million hectares of wetland area which is 12 .5 percent of the total area of the basin (Kulawardhana et al. 2006). The RESILIM program, highlighted that in the Limpopo River Basin the mean annual runoff (MAR) per unit area from the upland catchments is up to 100 times that of the low-lying areas and they propose that the mist-belt forests and upland grasslands of the basin, which maintain a significant baseflow during the dry season, are of exceptional value to the hydrological resilience of the Basin. These grasslands and forests are however abused, the grass cover reduced by grazing, converted to cropland, while the natural forests have to a large extent given way to plantations which do not share the regulation characteristics of the natural forests. Such degradation of the natural vegetation has contributed to a lessening of this ES.

Water purification

Many of the rivers in the Limpopo are polluted, with the Olifants being in particularly poor condition. River ecosystems are powerful agents in the purification of waste, in particular nutrient waste coming from people and animals, where the complex of biota ranging from bacteria to protozoans to invertebrates to fish and even riparian vegetation will all be working to recycle pollutants and lessen their impact on the ecosystem. These ecological processes may even have positive impacts on the cycling of heavy metals and other toxic pollutants. All of the rivers and wetlands in the entire Limpopo Basin will be providing this service. It is well known that upstream sources of pollutant can be mitigated with distance down river as the ecosystem recycles the pollutant; witness that the quality of the water in the Lower Limpopo is much better than in many parts of the upstream basin.

Carbon storage and climate regulation

All vegetation, both terrestrial and aquatic, will be accumulating carbon and storing this often below ground in the roots or as wood and above-ground growth. Wetlands that accumulate peat are particularly important at long-term storage of carbon. Wherever there is a healthy vegetation, this service will be provided, with more being stored in vegetation types with a higher biomass per area such as forests and peat.

3.2 CULTURAL SERVICES

Cultural ES are the non-material benefits that people obtain from nature which include recreation, aesthetic enjoyment, physical and mental health benefits and spiritual experiences. These services are difficult to value, as a result they are often overlooked in development planning. Indications of the extent of their value can be seen in the high prices paid for water-side or river-view developments. However, there are many other cultural benefits to being near rivers, and in this project, an assumption is made that people living in rural areas are more likely to be using the rivers for cultural activities on a daily basis, as people in urban areas may be detached from contact with the environment.

Spiritual

Freshwater ecosystems provide important sacred sites for many religions and spiritual belief systems making water central to the way that people live, work, create and relax. An example from the basin is the Bapedi tribe who practice a way of encouraging rain by drawing water from the river under spiritual guidance (see Annexure A). Another example was that during the development of Resource Quality Objectives for the Olifants River in 2014, stakeholders requested that consideration be given to water depth and quality in large pools used for spiritual use (Dickens, *pers com*).

Recreation and tourism

The Limpopo River Basin is one of the key focal points for eco-tourism and nature reserves in the SADC region as it includes many large and famous parks such as Kruger, Limpopo, Gonarezhou, Manjinji Pan, Malipati, Madikwe, Pilanesberg, Mapungubwe, Mashatu, Soutpansberg and Sabi-Sand (RAK 2020), many of which have rivers at their centre. There are also large wetland systems such as Nylsvlei in the Upper Limpopo. Artificial dams or reservoirs also provide these services, with angling ranging from trout in higher elevation dams to yellow fish and carp in the lower dams, with whole towns built to support the tourism around these dams. Recreation using rivers will also be important for rural communities, with swimming in clean rivers an important activity with multiple benefits for healthy communities.

3.3 PROVISIONING SERVICES

Provisioning services are the tangible products that people obtain from ecosystems and they include food, water, raw materials, energy and genetic resources and are most often considered as the most fundamental benefits of nature to livelihoods. These are thus key services that support all of the people in the Limpopo Basin but particularly those who live in intimate contact with the ecosystem such as small scale farmers.

Water provision

There are a number of man-made infrastructures within the basin designed to retain, abstract and convey water to users for multiple purposes e.g. domestic use, mining, irrigation and power generation as well as direct river abstractions and use for poor communities (RAK 2020). Figure 3.1 illustrates the distribution of 4750 Mm^3/year water in the Basin, with boreholes providing 506 Mm^3/year. Noteworthy is the dominance of irrigation (51%) in the use of water, which may also be underreported as a recent IWMI report showed some 70,000ha informal irrigation in South African Limpopo section alone (van Koppen et al., 2017). The FAO predicted that the irrigation extent would reach 295,400 ha (LBTC 2010), but this was not accounting for the unregistered users.

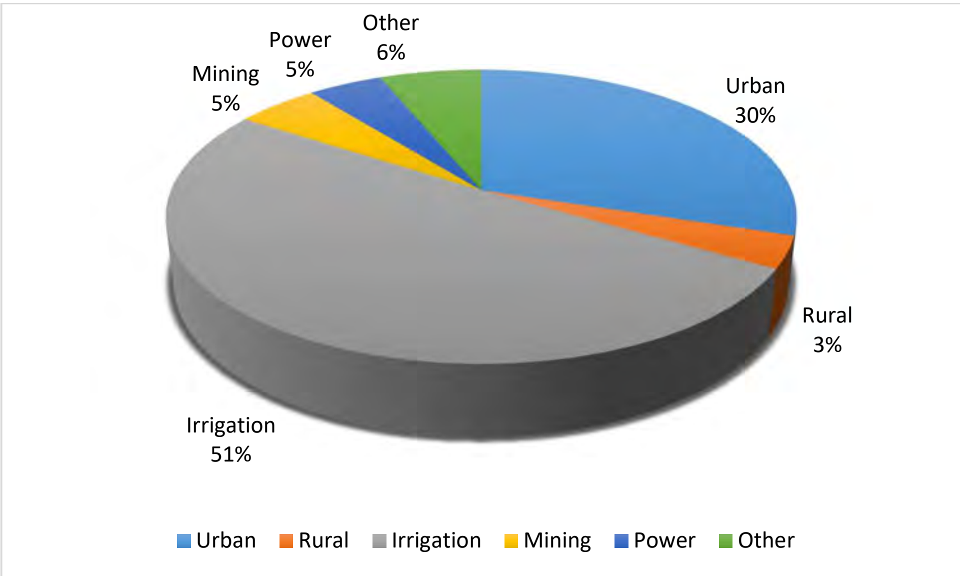


FIGURE 3.1: WATER USES IN THE LIMPOPO BASIN

Small – scale, rainfed and irrigated agriculture

Irrigation is the major user of water in the basin (Figure 3.1) although Figure A8 in Annexure A shows that the majority of this occurs in South Africa. Small-scale irrigation is a lot more common in the Limpopo than officially acknowledged as a result of many unregistered users. Flood recession agriculture is also common in the floodplain areas, in particular in the lower reaches of the river where there are large numbers of small-scale farmers on the floodplains adjacent to the Chokwe irrigation scheme.

Large-scale irrigation farming

Large irrigation estates occur in Botswana, Zimbabwe, South Africa and Mozambique, with a variety of abstraction and irrigation systems ranging from centre-pivots pumped from the river or groundwater, to the canal system at Chokwe in Mozambique. The latter produces more than half Mozambique's rice production, while also producing vegetables. Upland irrigation schemes grow a range of crops from citrus to maize, with sugarcane for biofuels now also planned for the Elefantes River.

Riparian small-scale agriculture and livestock grazing

The riverbanks provide some of the only green foliage during the winter months in the upper parts of the basin and are thus important for livestock. Riparian crops are also cultivated and watered directly from the rivers.

Fish

Fish and molluscs are harvested by local subsistence gathers directly from all of the rivers in the Basin. The floodplains are particularly important for production of fish stocks, being the site of much breeding and growth of the juvenile fish. The rivers are variable as a source of fish, because of intermittent flows, but during the wet season will be providing protein for local people. The many dams provide a more stable fish environment and thus provide greater stocks, some used for recreational angling but other for food.

Harvesting of riparian plants, reeds and medicinal herbs

There will be some harvesting of reeds at all places in the river where these occur and where there are people. Reeds may be used for craft work and also construction. Woody plants from the riparian zones will be used for construction and fuel and medicinal plants will also be sourced.

Gold panning, sand and gravel mining

Minerals, sand and gravel in river beds and deposited by river floods, provide a source of construction material as well as support substantial informal gold panning activities (particularly in Zimbabwe). Demand for sand and gravel is likely higher closer to urban developments where construction activities are prevalent.

3.3.1 SUPPORTING SERVICES

Supporting ES are services that are necessary in the production of other ES and play a crucial role in maintaining them. They also contribute directly and indirectly to the wellbeing and livelihoods of people. The ability of ecosystems to provide habitat for species, produce biomass, soil and atmospheric oxygen are some of the likely supporting services, while the abundance of biodiversity may also be considered a supporting ES.

Primary production and maintenance

The extensive vegetation biomes in the Limpopo Basin, i.e., savanna forming more than 60% on the western side, coastal vegetation on the eastern side with grassland and wetlands more in the southern regions, means a huge production of biomass, as well as production of atmospheric oxygen which is a by-product of the process of photosynthesis. This vegetation is the foundation of all ecosystems, and aids in soil formation and retention and nutrient cycling as the biomass decomposes. Hydrologically, vegetation through transpiration also helps in water cycling (hydrological cycle) and also facilitates groundwater recharge.

Provision of habitat and biodiversity support

Biodiversity primarily provides its service by supporting all other ecosystems and their services. None of the services above would be possible without biodiversity, with the greater the diversity the greater the range of services provided. Biodiversity thus supports tourism, livelihoods, spiritual and emotional fulfilment; supporting and regulating services such as nutrient cycling and soil fertility, pollination, and carbon sequestration. It also plays a substantial role in regulation of water flow off the land and for infiltration into the soil, and for regulation of flooding and many other services.

3.3.2 VALUATION OF THE CONTRIBUTION OF ECOSYSTEM SERVICES

Estimating the value of ES has been a major topic of research reviewed in detail by the TEEB reports (TEEB, 2010). Subsequently models have been developed to direct the valuation of ES, for example a scoping of values could have been done in this project making use of models such as InVEST Model (InVEST - Integrated Valuation of Ecosystem Services and Tradeoffs).

For this e-flows project however a detailed valuation of the ES was not practical within the constraints of the project, it being more important to scope the full range of ES rather than to establish actual dollar values. A process has been followed instead to roughly estimate their importance. Each service was evaluated depending on the type of data that was available (see Table 3.1). The importance of each ES was ranked from 1 to 4, where 4 represents a very important ES in the Basin. The importance rating is later used to contribute to definition and assessment of the objectives of e-flow establishment. This is described in the next section.

TABLE 3.1: SUMMARY OF INFORMATION ON THE VALUE OF ECOSYSTEM SERVICES IN EACH RR

Groups of Ecosystem Services	Risk Region Ecosystem Service Ranking 1= not present 2= not important 3= important 4= very important (important = user demand)	1 - Marico Crocodile	2 - Upper Limpopo	3 - Shashe	4 - Middle Limpopo	5 - Luvuvhu	6 - Mwenezi	7 - Olifants	8 - Letaba	9 - Shingwedzi	10 - Lower Limpopo	Potential to be mitigated by e-flows 1= none 2= minor 3= good 4= high	Rationale for rating importance of Ecosystem Service
Provisioning Services	Fresh Water supply	3	3	3	3	2	3	3	4	3	3	4	Key population and water supply
	Small scale irrigation and agriculture	3	3	2	3	3	2	4	3	2	3	4	Irrigation and agriculture mapping
	Livestock grazing	3	4	2	4	2	2	3	2	2	2	2	Grassland map
	Food (edible plants)	2	3	3	3	2	3	2	2	2	4	2	Population density excluding urban areas
	Fisheries and fish farming	3	2	2	2	3	2	4	3	4	4	4	river characteristics and some available data from interview #1 and #4 on fishing and fish farming
	Plant based building materials	2	2	3	2	2	2	2	2	3	3	3	Poor data - derived from susistance living
	Medicinal plants for people	2	3	3	3	2	3	2	2	2	4	2	Population density excluding urban areas
	Gold panning, sand and gravel mining	2	2	2	3	2	2	2	3	2	2	2	information from Interview #2 and #3
Regulating Services	Regulation of diseases	2	3	3	4	4	4	3	3	3	4	4	Combination water purification, bilharzia and malaria from WRC report Dicke
	Flood attenuation	2	2	2	2	2	2	3	2	2	3	3	Flooding history and areas with high flooding risk - to protect against
	Flow regulation	2	3	2	3	2	2	3	2	3	4	2	Wetlands, conservation areas and vegetation
	Water purification	4	2	2	3	2	2	4	3	2	2	3	Combination of sewage and population and mining
Supporting Services	Provision of habitat and biodiversity support	3	3	4	4	3	4	3	3	4	4	4	Biodiversity and land cover conservation ares
	Carbon storage	3	2	3	4	3	3	4	4	3	3	2	Land cover, vegetation
	Hydrological cycle	2	2	3	3	4	3	3	4	4	4	4	March 2020 MOD_NDVI was used and this changes in the dry season
	Soil stabilisation	3	2	2	3	2	3	3	3	3	3	2	Soil erosion map
	Primary production and maintainace	3	3	3	3	2	4	3	3	3	4	4	Biodiversity and land cover NDVI
	Nutrient and water cycling	4	2	2	3	2	2	4	3	2	2	4	Same as water purification
Cultural Services	Tourism, recreation and aesthetic value	3	2	3	2	3	2	3	3	4	3	3	Game parks and conservation areas - have excluded local recreation
	Spiritual enrichment	2	3	3	3	2	3	2	2	2	4	3	Same as Stressor Rural Settlements practicing subsistence resource use
	Education congnitive development	4	2	2	2	2	2	3	3	2	2	2	Proportional to population
	TOTAL	57	53	54	62	51	55	63	59	57	67		

3.4 ECOSYSTEM SERVICES TO ENDPOINTS

E-flows can only be set in relation to a vision and management objective for the condition of the river within the basin and for the communities that the river supports.

In Task 3 of the PROBFLO framework that is being followed in this assessment, the vision and objectives are matched to the requirements of local stakeholders for flow-related ecosystem services (as derived from both surface and groundwater systems). The requirements of stakeholders are provided by ecosystem services. These requirements become the endpoints (see definition below) of the e-flows study, the endpoints that the e-flows must deliver, in order to continue to provide flow-related ecosystem services. The project facilitates consideration of trade-offs between these endpoints. Endpoints have been defined as “specific entities and their attributes that are at risk and that are expressions of a management goal” (USEPA, 2003).

Using the ES that have been established above, and the requirements of stakeholders, the relationship between ES and endpoints is shown in Table 3.2.

TABLE 3.2: RELATIONSHIP BETWEEN ECOSYSTEM SERVICES AND ENDPOINTS USED IN THIS PROJECT

ECOSYSTEM SERVICES	ENDPOINTS
Provisioning	**Livelihoods**
Fresh Water supply	Domestic water (drinking and washing)
Small scale irrigation and agriculture	Water for small-scale agriculture
Livestock grazing	Riparian non-woody plants (grazing)
Food (edible plants)	Edible plants for people
Fisheries and fish farming	Fish stocks as food for people
Plant building materials	Woody plants (fuel, construction)
	Reeds for building etc.
Medicinal plants for people	Medicinal plants for people
Gold panning, Sand and gravel mining	Building sand supply from instream
Regulatory	**Regulatory**
Regulation of diseases	Water borne diseases
Flood attenuation and prevention	
Flow regulation – water security	
Water purification	
Supporting	**Biodiversity**
Provision of habitat and biodiversity support	Protection of fish biodiversity
	Protection of the riparian ecosystem
	Protection of the river benthos (algae and invertebrates) for the ecosystem
	Protection of bird biodiversity
	State of the Ecosystem
	Protection of the state of protected water-related ecosystems
	Protection of the state of all other water-related ecosystems
Carbon storage	
Hydrological cycle,	
Climatic condition and extreme weather conditions	
Soil stabilisation	
Primary production and maintenance	
Nutrient and water cycling	
Cultural	**Health & Culture**
Tourism, recreation and aesthetic value	Recreation/Spiritual use of the river
Spiritual enrichment	Tourism
Cognitive development / education	

4 EXISTING VISION AND OBJECTIVES

The vision can be described as "an aspirational description of what an organization would like to achieve or accomplish in the mid-term or long-term future. It is intended to serve as a clear guide for choosing current and future courses of action" (Business Directory). Objectives for water resources are "something that you are planning to do or achieve", (Cambridge English Dictionary) i.e. things that need to be done to achieve the vision. No independent study has been done to clearly define the latter in the Limpopo, however there are a number of documents at different levels of governance, that provide insight into both the vision and objectives for water resource management in each RR, and also give indications at the wider basin and regional level. These are summarised below, with greater detail given in the Basin report (IWMI, 2020a)

The following statements are all of a general nature and apply to the scale indicated i.e. the whole basin, or country portions of the basin, or risk region. They are statements that express commitment to management of water resources and where possible e-flows. The following are perspectives of SADC and LIMCOM and are a summary of the details in the Basin Report (IWMI, 2020a).

4.1 REGIONAL SUMMARY

4.1.1 SADC

Supporting documents: *2000 Revised Protocol of Shared Watercourses, SADC Regional Strategic Action Plan on Integrated Water Resources Development and Management Phase IV 2016-2020, SADC Regional Infrastructure Development Master Plan – Water Sector Plan 2012.*

1. Protect, preserve and conserve ecosystems
2. Sustainable and equitable utilization of resources for social and environmental justice
3. Building capacity to assess e-flows (does not mention implementation)

These tables are summaries of those that appeared in the Basin Report, extracting only that information that is directly relevant.

TABLE 4.1: SADC ENVIRONMENTAL FLOW RELATED REGIONAL VISIONS, OBJECTIVES AND PRIORITY INTERVENTIONS (SOURCE: SADC, 2016)

SADC REGIONAL AGREEMENT	Provisions in the SADC Revised Protocol on Shared Watercourses	(2) (a) Protection and preservation of ecosystems. - protect and preserve the ecosystems of a shared water course. (2) (d) Protection and preservation of the aquatic environment - protect and preserve the aquatic environment, including estuaries.
	SADC Water Vision	An equitable and sustainable utilization of water for social and environmental justice, regional integration and economic benefit for present and future generations
PRIORITY INTERVENTIONS	Ecological Water Requirement	Capacity building programme for methodologies for determining EWR developed.
		- capacity building programme for Member States on the methodologies for determination of environmental flows /ecological water requirements and river health classification.

4.1.2 LIMCOM

Supporting documents: *LIMCOM 2003 Agreement, Integrated Water Resources Management Plan 2018-2022, 2019 LIMCOM Vision and Principles*

1. Vision - A DYNAMIC, PROSPEROUS AND SUSTAINABLE RIVER BASIN FOR ALL.
2. IWRM Plan Vision - Sustainable water security for improved livelihoods in the Limpopo River Basin.
3. Sustainable development is a priority
4. Use of water resources together with protection, conservation and preservation of resources
5. Fairness between different uses for the benefit of the environment and the longevity of the natural resource base for future generations
6. Sustainable water security for improved livelihoods
7. Protect fragile ecosystems

TABLE 4.2: LIMCOM RIVER FLOW RELATED BASIN VISION STATEMENTS ARTICULATED IN THE BASIN AGREEMENT AND VISION DOCUMENTS (LIMCOM, 2003; LIMCOM, 2019)

LIMCOM basin vision	A DYNAMIC, PROSPEROUS AND SUSTAINABLE RIVER BASIN FOR ALL
Key principles supporting the vision	The principle of sustainable development shall apply to ensure fairness between different uses for the benefit of the environment and the longevity of the natural resource base for future generations
Immediate actions	Environmental water requirements Protect fragile ecosystems (aquatic and terrestrial) Improve groundwater resources management in the Limpopo River Basin Watershed Conservation (Catchment protection)
IWRM Plan	*Vision*: Sustainable water security for improved livelihoods in the Limpopo River Basin. *IWRM Programme Goal*: sustainable management and development of the Limpopo River Basin.

Activities for specific immediate actions outlined in Table 4.2, such as environmental water requirements and protection of fragile ecosystems (aquatic and terrestrial) are indicated as follows:

1. Environmental water requirements
    a. Develop initiatives that will update and strengthen assessment of environmental water requirements in the basin
    b. EWR basin assessment
2. Protect fragile ecosystems (aquatic and terrestrial)
    a. Develop basin wide programmes to demonstrate the value of ecosystems and protection for identified priority fragile ecosystems (LIMCOM, 2018)

Comment

While the above statements taken from SADC and LIMCOM documents are inspiring, they do not set targets for natural resources other than by providing an upward motivation. They do provide commitment to sustainable development that balances use and protection, with e-flows as one priority. Protection of ecosystems and natural resources is also a priority

4.1.3 COUNTRY SUMMARIES OF VISION STATEMENTS

TABLE 4.3: NATIONAL VISIONS AND WATER MANAGEMENT OBJECTIVES FOR WATER RESOURCES IN THE LIMPOPO BASIN RIPARIAN COUNTRIES

COUNTRY	VISION AND MANAGEMENT OBJECTIVE STATEMENTS
BOTSWANA	• Pursue and promote IWRM strategies, including policy instruments and public education that encourage water efficiency and conservation efforts, conjunctive use of surface and groundwater and promotion of artificial recharge for groundwater (GoB, 2016) • Cognizance shall be taken for the environment and ecosystem requirements to receive priority when planning and allocating water among competing uses and users (GoB, 2016a) • The protection of water resources must be promoted and the conservation and sustainability of ecosystems and the goods and services they provide must be ensured (GoB, 2016a) • Assess and operationalize an ecological reserve and requirements for all catchments and water resources infrastructure (GoB, 2016a)
MOZAMBIQUE	• Article 13 of the Water Act of 1991Provides for the protection of the environment, ensuring that uses and use of water take place without damage to the minimum flow and the ecological flow (RdM, 1991) • Common uses are made according to the regime traditional use and without significantly changing the quality of water and its flow. (RdM, 1991) • Ensure ecological flows according to water needs downstream (RdM, 2006) • The conservation of the free flow of waters includes, in particular, the duty to: (a) not degrade the watercourses (RdM, 1991) • Develop capacity to deal with water quality issues, ecological flows, infestations of aquatic plants, monitoring of pollution (RdM, 2006) • Water resources must be managed in a sustainable manner to ensure the development of fisheries. (RdM, 2006) • Ensure ecological flows according to water needs downstream, and avoid the total elimination of low flows or compensate with flow releases regularly reviewing the rules of dam operation (RdM, 2006)

COUNTRY	VISION AND MANAGEMENT OBJECTIVE STATEMENTS
SOUTH AFRICA	• Water resources are protected, used, developed, conserved, managed and controlled in ways that take into account amongst other factors—… (g) protecting aquatic and associated ecosystems and their biological diversity (RSA, 1998) • The determination and preservation of the ecological Reserve and the classification of our river fresh water systems will be a priority (DWA, 2013) • The objective of managing the quantity, quality and reliability of the nation's water resources is to achieve optimum, long-term, environmentally sustainable social and economic benefit for society from their use. (DWA, 2013) Approximately 25% of the MAR of 49 000 million m3/a needs to remain in the rivers and estuaries to support ecological functioning of the catchments, depending on the specific river systems. (DWA, 2013) • By 2030, water in, or from water resources shall be fit for use. Fitness-for-use may relate to the water quality requirements of the aquatic ecosystem (DWS, 2018) • Review and promulgate aggressive restrictions within the legislation to restore and protect ecological infrastructure (DWS, 2018) • The PES and/or REC for all river Freshwater Ecosystem Priority Areas (FEPAs) needs to be maintained or improved. (DWS, 2018) • Declare strategic water source areas and critical groundwater recharge areas and aquatic ecosystems recognized as threatened or sensitive as protected areas (DWS, 2018)
ZIMBABWE	• Before issuance of an effluent discharge license …Take into consideration the water requirements of riparian residents, ecosystems, human settlements, and agricultural schemes (GoZ, 2002) • Ensure the availability of water to all citizens for primary purposes and to meet the needs of aquatic and associated ecosystems particularly when there are competing demands for water. (GoZ, 2012) • The Environment is a legitimate and important user of water. Therefore, sufficient quantity of water of adequate quality will be allocated to meet the requirements riverine and aquatic eco systems, wildlife, wetlands, bird life etc., based on sound professional assessment. These allocations will be specifically accommodated in Catchment Outline Plans when allocations for other purposes are made (GoZ, 2012)

Botswana – ecosystem protection and requirements a priority within the context of sustainable development.

Supporting documents: 2016 National Water Policy, 2016 Government of Botswana Vision 2036, National Development Plan 2017-2023

Environmental and ecosystem requirements take priority when planning and allocating water – Reserve to be operationalised

- Promote protection of water resources and ensure conservation and sustainability of ecosystem services

South Africa – ecosystem and basic human needs a priority within the context of resource protection and sustainable development. Commitment to maintaining present ecological or recommended state at all FEPA sites.

Supporting documents: 1998 National Water Act and related gazettes on resource quality objectives and the ecological reserve; 2013 Water Resources Strategy 2; 2018 National Water and Sanitation Master Plan; National Freshwater Ecosystem Priority Areas

- Policy of resource protection to ensure sustainable use
- Reserve (e-flow) and basic human needs the only right to water
- Protect biodiversity ecological infrastructure of aquatic ecosystems
- Classification and determination of Reserve a priority
- Long-term environmental sustainability for use and benefit
- Fitness-for-use may relate to the water quality requirements of the aquatic ecosystem
- PES and/or REC need to be maintained or improved for all FEPA sites

Zimbabwe – ecosystems and basic human needs take priority.

Supporting documents: 1998 Zimbabwe National Water Act; 2002 National Environmental Management Act; 2012 National Water Policy; 2018-2020 Transitional Stabilization Programme; Mzingwane Catchment Council Strategic Plan 2019-2023; Mzingwane River System Outline Plan 2009.

- Take into account ecosystems and other users
- Ensure the needs of basic human needs and ecosystems are met when there are competing needs
- sufficient quantity of water of adequate quality will be allocated to meet the requirements riverine and aquatic ecosystems, wildlife, wetlands, bird life etc.

Mozambique – priority given to maintaining ecosystem in service of users. Sustainable fisheries and avoiding zero flow in rivers a priority.

Supporting documents: Water Act No. 16/91, National Water Resources Management Strategy 2006, Flood Management Plan 2018, Recognize minimum flow for ecosystem not to be damaged by users

- Manage ecological flows according to downstream users
- Conserve free flow of rivers
- Sustainable management to ensure fisheries
- Avoid zero flow rivers or plan for additions from upstream dams
- Do not degrade water courses

4.2 NATIONAL DEVELOPMENT VISIONS AND WATER POLICY OBJECTIVES

The text below is a summary of what is contained in Table 4.3.

All the four countries sharing the Limpopo Basin have an understanding of the importance of ecosystems and their connection to overall water resources management. However, the specific protection of eflows is addressed to varying degrees. In the Botswana National Water Policy of 2016, environmental requirements are recognised and should take priority over other competing use. The country has set an objective to "assess and operationalise an ecological reserve and requirements for all catchment" which is still to be implemented. There are however no basin specific management objectives set for water resources in Botswana, therefore such a statement would apply across all basins in Botswana.

Similarly, in Mozambique, there is no basin specific management objectives given within legal and policy frameworks outside of the broader policy statements. The guidance provided is overarching and contained in the national water law which recognises that water use should not negatively impact environmental flow, promoting the conservation of the free flow of rivers. How this would be implemented at a practical; level is not provided for within the policy and legal documents reviewed.

The South African policy and legal framework provides for eflows through various policy and legal frameworks such as the 1998 National Water Act and the National Water Resources Strategy 2. Detailed management objectives for stretches of rivers within the Limpopo Basin are provided for more explicitly. Through the Resource Quality Objectives set for the different tributaries, specific targets of recommended ecological conditions and eflows were determined and gazetted.

In Zimbabwe, the 2012 National Water Policy and Environmental Management Act of 2002 recognises the importance of water requirements for ecosystems. While there are no basin specific objectives outlined, a river system operation plan for the Mzingwane catchment provides some guidance on the flows that should be maintained in certain stretches of the Limpopo tributaries.

5 RISK REGION SUMMARIES – FLOW RELATED MANAGEMENT OBJECTIVES

This section presents flow related management objectives in each Preliminary Risk Region and associated sub-basins.

5.1 MARICO CROCODILE

NB: Important ecosystem services are summarised in Table 3.1.

Botswana – ecosystem protection and requirements a priority within the context of sustainable development.

South Africa – ecosystem and basic human needs a priority within the context of resource protection and sustainable development. Commitment to maintaining present ecological or recommended state at all FEPA sites.

Aquatic Ecoregion: The majority of the upper portion of the RR is made up of Western Bankenveld and Bushveld. The lower portion of the RR is on the Limpopo Plain.

State of the Rivers:

While the Marico is reputed to be in much better condition than the Crocodile, it is only by the percentage of river in a C category, containing almost similar amounts of B category. The Crocodile has 15% in a failed condition (E & F).

TABLE 5.1: MARICO CROCODILE MANAGEMENT OBJECTIVES

Sub-basin	WRC	REC TO BE MAINT.[1]	E-Flows as % of natural Mean annual runoff	Visions statements / management objectives
Crocodile	II - III	B-D	7.48 -45.93	Available groundwater resources should be utilised in all areas and opportunities for conjunctive surface / groundwater utilisation should be explored. (DWS, 2018)
Marico	I - III	B - D	7.96 – 76.32	Groot Marico flagged as FEPA PES for the Marico to be maintained (DWA, 2013) Importance of implementing an Ecological Reserve monitoring programme (DWA, 2013) It is not in any way practical to release upstream flows for the management of low flows in the Limpopo. Water released from the tributaries might reach the main stem but would never get beyond the first weir. Botswana does not have legal obligations to the Reserve of this common river, complicating the task. It is nevertheless recommended in the NFEPA report that a portion of the Marico River be protected in its current, relatively pristine condition.
Notwane	Cognisance shall be taken for the environment and ecosystem requirements to receive priority when planning and allocating water among competing uses and users (GoB, 2016)[2] Assess and operationalize an ecological reserve and requirements for all catchments and water resources infrastructure. (GoB, 2016)			

In the table below the PES figures are from the PES project, the WRC and EWR% are from the WRC/RQO documents. The WRC (e.g. IIx3) indicates that three reaches of that river were in a Class II.

[1] Data for REC, WRC and E-Flows as % of Natural Mean Annual Runoff obtained from (DWS, 2015)

[2] Basin management statements in the Botswana National Water Policy applies as no specific objectives were available.

TABLE 5.2: PES WITH THE WATER RESOURCE CLASSIFICATION (WRC) AND EWR % OF THE MARICO CRODILE RR (%)

SECONDARY	WRC	CAT A%	CAT B %	CAT C %	CAT D %	CAT E %	CAT F %	EWR %
A1(Ngotwane)		0,0	6,2	20,6	73,3	0,0	0,0	
A2 (Crocodile)	II x3 III x5	0,0	12,5	37,2	35,2	14,6	0,4	25
A3 (Marico)		0,3	14,5	64,3	20,9	0,0	0,0	

TABLE 5.3: E-FLOW STUDIES FROM THE RISK REGION

EWR site	River	Quat catchment	PES	EIS	REC	nMAR ($10^6 m^3$)	%EWR (REC)	LatDD	LongDD
LmEWR1r	Limpopo at Spanwerk	A41D	B/C	High	B/C	591.49	27.60	-23.9447	26.9308

EWR site	River	Quat	RR	PES	EIS	REC	nMAR ($10^6 m^3$)	%EWR (REC)	LatDD	LongDD
MAR_EWR 1	Kaaloog-se-Loop: Below gorge	A31A	1	B	Very high	B	10.539	76.32	-25.7770	26.4330
MAR_EWR 2	Groot Marico: Upstream confluence with Sterkstroom	A31B	1	B	Very high	B	42.08	50.26	-25.6690	26.4350
MAR_EWR 3	Groot Marico: Downstream Marico Bosveld Dam	A31F	1	C/D	High	C/D	65.083	23.62	-25.4610	26.3920
MAR_EWR 4	Groot Marico: Downstream Tswasa Weir	A32D	1	C	High	C	153.251	7.96	-24.7060	26.4240
MAR_EWR 5	Klein Marico Downstream Klein Maricopoort Dam	A31E	1	C	Moderate	C	29.8	4.67	-25.5160	26.1590
MAR_EWR 6	Polkadraaispruit before confluence with Marico	A31B	1	B/C	Moderate	B	9.866	31.87	-25.6469	26.4893
MAT_EWR 1	Matlabas Zyn Kloof	A41A	1	B	Very high	A	5.23	57.07	-24.412	27.60324
MAT_EWR 2	Matlabas at Haarlem East (A4H004)	A41C	1	C	High	B/C	32.8	33.23	-24.1601	27.47971
MAT_EWR 3	Mamba River Bridge	A41B	1	B/C	Moderate	B/C	9.54	35.49	-24.2127	27.50718

EWR site	River	Quat	RR	PES	EIS	REC	nMAR (106m³)	%EWR (REC)	LatDD	LongDD
MAT_EWR 4	Matlabas at Phofu	A41C	1	B	Moderate	B	35.58	33.42	-24.0516	27.35922
CROC_EWR 1	Crocodile: Upstream of the Hartbeespoort Dam	A21H	1	D	Moderate	D	231.1	24.07	-25.80040	27.896
CROC_EWR 2	Jukskei: Heron Bridge School	A21C	1	E	Moderate	D	139.9	29.19	-25.95390	27.9621
CROC_EWR 3	Crocodile: Downstream of Hartbeespoort Dam in Mount Amanzi	A21J	1	C/D	High	C/D	143.3	25.02	-25.71680	27.8431
CROC_EWR 4	Pienaars: Downstream of Roodeplaat Dam	A23B	1	C	High	C	28.2	20.98	-25.41550	28.312
CROC_EWR 5	Pienaars/Moretele: Downstream of the Klipvoor Dam in Borakalalo National Park	A23J	1	D	High	C	113	11.82	-25.12657	27.80457
CROC_EWR 6	Hex: Upstream of Vaalkop Dam	A22J	1	D	Moderate	D	26.9	14.96	-25.52140	27.3749
CROC_EWR 7	Crocodile: Upstream of the confluence with theBierspruit	A24C	1	D	Moderate	D	463.4	9.14	-24.88661	27.51743
CROC_EWR 8	Crocodile downstream the confluence with Bierspruit in Ben Alberts Nature Reserve	A24H	1	C	Moderate	C	559.9	14.22	-24.64476	27.32569
CROC_EWR 9	Magalies: Downstream of Malony's Eye	A21F	1	B	Very high	B	14.7	45.58	-26.01689	27.56581
CROC_EWR 10	Elands: Upstream Swartruggens Dam	A22A	1	C	High	B/C	10.1	30.48	-25.72655	26.72044
CROC_EWR 11	Sterkstroom: Upstream Buffelspoort Dam	A21K	1	C	High	C	14	28.41	-25.80739	27.47848
CROC_EWR 12	Buffelspruit before confluence with Plat	A23G	1	B/C	Moderate	B/C	3.14	35.85	-24.8304	28.22240
CROC_EWR 13	Elands downstream Lindleyspoort Dam	A22E	1	C	Low	C	18.77	21.90	-25.4811	26.69039
CROC_EWR 14	Waterkloofspruit downstream	A22H	1	B/C	Low	B/C	5.469	28.27	-25.4811	26.69039

EWR site	River	Quat	RR	PES	EIS	REC	nMAR (106m³)	%EWR (REC)	LatDD	LongDD
	Rustenburg Nature Reserve									
CROC_EWR 15	Lower Magalies before confluence with Skeerpoort	A21F	I	C/D	Low	C/D	21.899	21.18	-25.8969	27.59820
CROC_EWR 16	Rietvlei upstream Rietvlei Dam	A21A	I	C	Low	C	4.788	27.83	-26.0189	28.30442

5.2 UPPER LIMPOPO

NB: Important ecosystem services are summarised in Table 3.1.

Botswana – ecosystem protection and requirements a priority within the context of sustainable development.

South Africa – ecosystem and basic human needs a priority within the context of resource protection and sustainable development. Commitment to maintaining present ecological or recommended state at all FEPA sites.

TABLE 5.4: UPPER LIMPOPO MANAGEMENT OBJECTIVES

Sub-basin	REC to be maintained[3]	WRC	E-Flows as % of natural Mean annual runoff	Visions statements / management objectives
South Africa sub basins				
Mokolo	B-D	II	8.65-52.63	
Matlabas	A-B/C	II	5.23-35.58	
Lephalale	There are no significant developments expected in the Lephalale catchment due to the limited water available and the high conservation importance of the Wilderness area in the middle reaches of the catchment (DWS, 2016).			
Mogalakwena	Additional water to support the rapid expanding mining activities in the vicinity of Mokopane needs to be augmented by transfers from the Flag Boshielo Dam in the adjacent Olifants River catchment (DWS, 2016)			
Botswana sub basins				
Bonwapitse Mahalapswe Lotsane Motloutse	Cognizance shall be taken for the environment and ecosystem requirements to receive priority when planning and allocating water among competing uses and users (GoB, 2012)[4] Assess and operationalize an ecological reserve and requirements for all catchments and water resources infrastructure (GoB, 2012)			

Aquatic Ecoregion: Dominated by the Western Bankenveld with Matabeleland in Botswana and Zimbabwe.

State of the Rivers:

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[3] Data for REC, WRC and E-Flows as % of Natural Mean Annual Runoff obtained from (DWS, 2017)

[4] Basin management statements in the Botswana National Water Policy applies as no specific objectives were available.

TABLE 5.5: PES OF THE UPPER LIMPOPO RR

SECONDARY	CAT A% LENGTH	CAT B % LENGTH	CAT C % LENGTH	CAT D % LENGTH	CAT E % LENGTH	CAT F % LENGTH
A4 MOKOL	1,4	16,5	59,0	22,0	1,1	0,0
A5 LEPHAL	0,0	25,4	32,4	42,2	0,0	0,0
A6 MOGAL	1,6	12,4	44,4	37,8	3,9	0,0
Total % for Secondaries	1,3	15,9	48,4	32,2	2,2	0,0

TABLE 5.6: E-FLOW STUDIES FROM THE RISK REGION

EWR site	River	Quat	RR	PES	EIS	REC	nMAR ($106m^3$)	%EWR (REC)	LatDD	LongDD
MOK_EWR 1a	Mokolo at Vaalwater	A42C	2	C/D	High	B	84.84	22.60	-24.2894	28.0924
MOK_EWR 1b	Mokolo at Tobacco	A42E	2	B/C	High	B	135.03	17.60	-24.1783	27.9777
MOK_EWR 2	Mokolo at Ka'ingo	A42F	2	B/C	Very high	B	196.2	19.80	-24.0650	27.7872
MOK_EWR 3	Mokolo below Mokolo Dam in the Gorge	A42G	2	B/C	Very high	B	214.5	12.50	-23.9680	27.7269
MOK_EWR 4	Mokolo: Malalatau	A42G	2	C	Very high	B	253.3	16.50	-23.7712	27.7553

5.3 SHASHE

NB: Important ecosystem services are summarised in Table 3.1.

Botswana – ecosystem protection and requirements a priority within the context of sustainable development.

Zimbabwe – ecosystems and basic human needs take priority.

TABLE 5.7: SHASHE MANAGEMENT OBJECTIVES

Sub-basin	Visions statements / management objectives
Shashe	Shashe West development of 1.50 MAR will be required to cater for the increases in water usage to the planning horizon, this includes a reserve of 3% of MAR. (ZINWA, 2009) Agriculture will be the predominant user taking up 75% of the developed yield. An environmental flow of 4% has been allowed (ZINWA, 2009) Tuli river catchment - a development of only 0.50MAR will be required to cater for the planning horizon, this includes a reserve of 4% of MAR. (ZINWA, 2009) Tuli-Manyange Dam 33 million m^3 dam and 2 saddle dams with earth fill volume of 110 000 m^3 to be 40% complete by 2020 (GoZ, 2018)

Aquatic Ecoregion: Matabeleland in Zimbabwe then Western Bankenveld down to the Limpopo River.

State of the Rivers: No detailed information was available.

5.4 MIDDLE LIMPOPO

NB: Important ecosystem services are summarised in Table 3.1.

Botswana – ecosystem protection and requirements a priority within the context of sustainable development.

Zimbabwe – ecosystems and basic human needs take priority.

South Africa – ecosystem and basic human needs a priority within the context of resource protection and sustainable development. Commitment to maintaining present ecological or recommended state at all FEPA sites.

TABLE 5.8: MIDDLE LIMPOPO MANAGEMENT OBJECTIVES

Sub-basin	Visions statements / management objectives
Mzingwane	A dynamic, sustainable and prosperous Catchment area by 2023. (MCC, 2018) A further 3000ha has been proposed for irrigation and a canal is under construction. An environmental flow of 10% MAR has been allowed in Lower Mzingwane Catchment (ZINWA, 2009). Upper Mzingwane - Development to 2,40 MAR for the Mzingwane dams will be required to cater for the increased usage over the planning horizon. An environmental flow of 4% MAR has been allowed. (ZINWA, 2009)
Bubi	Environmental flows reserved at 4% of MAR (ZINWA, 2009)

Sub-basin	Visions statements / management objectives
Nzhelele	Approximately 25% of the MAR of 49 000 million m^3/a needs to remain in the rivers and estuaries to support ecological functioning of the catchments, depending on the specific river systems. (DWA, 2013)[5]
Sand	A joint water commission has been stablished to conduct studies to investigate potential supply from Zimbabwe into the Sand catchment (DWS, 2018)

Aquatic Ecoregion: With Matabeleland at the top in Zimbabwe, moving to Western Bankenveld that crosses the Limpopo River, with Soutpansberg and Northern Plateau to the south in SA.

State of the Rivers:

TABLE 5.9: E-FLOW STUDIES FROM THE RISK REGION

EWR site	River	Quat catchment	PES	EIS	REC	nMAR (106m3)	%EWR (REC)	LatDD	LongDD
LmEWR2r	Limpopo at Poachers Corner	A71L	B/C	Moderate	B/C	1683	30.90	-22.1842	29.4052

TABLE 5.10: PRESENT ECOLOGICAL STAE (PES) OF THE MIDDLE LIMPOPO RR

SECONDARY	CAT A%	CAT B %	CAT C %	CAT D %	CAT E %	CAT F %
A7 SAND	4,7	21,5	51,9	21,9	0,0	0,0
A8 Nzhelele Nwanedi	0,0	11,7	51,6	31,5	5,2	0,0
Total % for Secondaries	5,8	16,0	52,9	24,3	1,1	0,0

5.5 LUVUVHU

NB: Important ecosystem services are summarised in Table 3.1.

Zimbabwe – ecosystems and basic human needs take priority.

South Africa – ecosystem and basic human needs a priority within the context of resource protection and sustainable development. Commitment to maintaining present ecological or recommended state at all FEPA sites.

[5] Basin management statements in the South Africa National Water Resources Strategy II applies as no specific objectives were available.

Mozambique – priority given to maintaining ecosystem in service of users. Sustainable fisheries and avoiding zero flow in rivers a priority.

TABLE 5.11: LUVUVHU MANAGEMENT OBJECTIVES

Sub-basin	Vision statements / management objectives
Luvuvhu	Investigate and implement groundwater developments. The Luvuvhu and Letaba Water Supply System (DWS, 2018) Investigate the possible increase of the Nandoni sub-system yield by improved utilising of downstream incremental flows (DWS, 2018).

Aquatic Ecoregion: Lowveld and Soutpansberg

State of the Rivers:

TABLE 5.12: E-FLOW STUDIES FROM THE RISK REGION

EWR site	River	Quat catchment	PES	EIS	REC	nMAR (106m3)	%EWR (REC)	LatDD	LongDD
LmEWR4r	Limpopo at Pafuri	Mozambique	C	Moderate	C	2792	30.90	-22.4596	31.5030

TABLE.5.13 PRESENT ECOLOGICAL STAE (PES) OF THE LUVUVUHU RR

SECONDARY	CAT A%	CAT B %	CAT C %	CAT D %	CAT E %	CAT F %
A9 LUVUVH	10,6	9,4	55,0	24,2	0,7	0,0

TABLE 5.14: E-FLOW STUDIES FROM THE RISK REGION

EWR site	River	Quat	RR	PES	EIS	REC	nMAR (106m3)	%EWR (REC)	LatDD	LongDD
LUV_EWR	Mutshindudi	A91G	-	C	High	B/C	47.47	29.86	-22.9147	30.48838

5.6 MWENEZI

NB: Important ecosystem services are summarised in Table 3.1.

Zimbabwe – ecosystems and basic human needs take priority.

Mozambique – priority given to maintaining ecosystem in service of users. Sustainable fisheries and avoiding zero flow in rivers a priority.

TABLE 5.15: MWENEZI MANAGEMENT OBJECTIVES

Sub-basin	Vision statements / management objectives
Mwenezi	Additional potential yield of this catchment that could be made available for agricultural use until the early part of the next century is 54 900 ML/annum (ZINWA, 2009) 10% MAR has been allowed for environmental flows (ZINWA, 2009)

Aquatic Ecoregion: Matabeleland in Zimbabwe then Western Bankenveld down to the Limpopo River

State of the Rivers:

TABLE 5.16: E-FLOW STUDIES FROM THE RISK REGION

EWR site	River	Quat catchment	PES	EIS	REC	nMAR (106m3)	%EWR (REC)	LatDD	LongDD
LmEWR3r	Mwanedzi at Malapati	Zimbabwe	C	Moderate	B/C	282.73	22.00	-22.0639	31.4231

5.7 OLIFANTS

NB: Important ecosystem services are summarised in Table 3.1.

South Africa – ecosystem and basic human needs a priority within the context of resource protection and sustainable development. Commitment to maintaining present ecological or recommended state at all FEPA sites.

Mozambique – priority given to maintaining ecosystem in service of users. Sustainable fisheries and avoiding zero flow in rivers a priority.

Overall statement of vision and objectives

TABLE 5.17: OLIFANTS MANAGEMENT OBJECTIVES

Sub-basin	REC TO BE MAINTAINED[6]	WRC	E-Flows as % of natural Mean annual runoff
Upper Olifants	B - D	III	4.67 – 13.90
Middle Olifants	B - D	III	3.81 - 13.90
Steelpoort	B - D	III	7.43 - 20.78
Lower Olifants	A - D	II	4.30 - 27.9

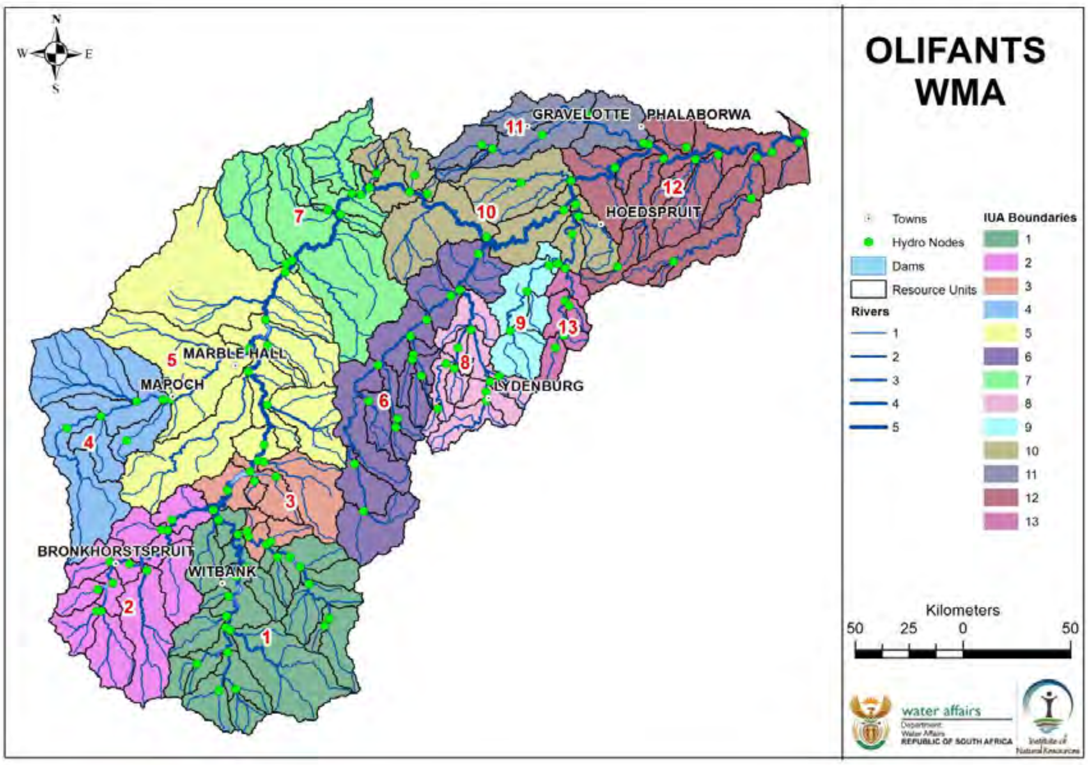

FIGURE 5.1 INTEGRATED UNITS OF ANALYSIS (IUA) FOR THE OLIFANTS RQO DETERMINATION (DEPARTMENT OF WATER AFFAIRS SOUTH AFRICA, 2012)

The procedure to determine Resource Quality Objectives (RQOs) in South Africa produced the above map of Integrated Units of Analysis (IUAs) for the Olifants River. Table 5.18 reproduces the summary of the RQOs per IUA but much greater detail is also provided at a river reach level. Note that in IUA 12 special consideration is given to the international obligations but this is not shown here.

TABLE 5.18: RQOS FOR OLIFANTS RIVER IUAS (THE REC OF ANY RIVER REACH AS DESCRIBED IN THE CLASSIFICATION (ANNEXURE A) MUST BE ADHERED TO UNLESS

[6] Data for REC, WRC and E-Flows as % of Natural Mean Annual Runoff obtained from (DWS, 2015)

SUPERSEDED BY THE DETAILED RESOURCE QUALITY OBJECTIVES FOR THE RUS PUBLISHED IN THE GAZETTE.)

IUA	RQO
1	The water quality, quantity and habitat of the headwater streams in this IUA are heavily impacted on by landuse and mining activities. Increasing nutrients, salts and likely toxins are having a negative impact on the ecosystem and need to be managed at a D or better ecological category so that instream ecosystem structure and functioning is not suppressed. The loss of alkalinity in the water as a result of mining activities poses a threat of acidification of the ecosystem, thus alkalinity concentrations must be kept high enough to prevent this from happening. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health. Riparian habitat is also negatively impacted in the IUA and needs to be maintained in a D or better ecological category.
2	The rivers in this headwater catchment IUA are being negatively impacted on by landuse activities, where the habitat in particular, but also the water quality, needs to be maintained in a D ecological category or better if the river is to continue to provide ecosystem services. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health.
3	Upstream mining and wastewater impacts are placing pressure on the system which is also impacted by the upstream dam. Increasing nutrients, salts and likely toxins are having a negative impact on the ecosystem and need to be managed so that instream ecosystem structure and functioning is not suppressed below a D category. The loss of alkalinity in the water as a result of mining activities poses a threat of acidification of the ecosystem, thus alkalinity concentrations must be kept high enough to prevent this from happening. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health.
4	The rivers in this IUA are generally in a suitable state with limited agriculture and urban area impacts. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health.
5	Upstream activities are stressing the ecosystem through the reduction of flows and pollution of the water. Flows need to be maintained in a D or better ecological category. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health. The instream and riparian habitats as well as the consequent biota are also important in this IUA and must be improved in most cases to a D or better ecological category from present conditions.
6	Many of the streams in this IUA are stressed in almost all respects, having inadequate flow, poor water quality (mostly due to salt contamination but also nutrients) with poor habitats and associated biota. Many of these systems are presently at below the sustainable level and no sub-component should be allowed to be below a D category. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health.
7	The consumption of fish harvested from rivers in the IUA must not pose a threat to human health.
8	In this IUA the consumption of fish harvested from rivers in the IUA must not pose a threat to human health.
9	Low flows in particular in this IUA are under stress and must be maintained at least at a category D level if the habitat is to be maintained in a condition sufficient for the important

IUA	RQO
	fish populations which must be also at least at a category D level. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health.
10	Many of the smaller tributaries in this IUA contain ecologically important fish species that must be maintained by maintaining the instream habitat of the tributaries in the IUA in at least a D category. In the larger rivers, inadequate flows and excessive sediments are impacting negatively on the instream habitat which is in turn impacting negatively on the instream biota. The flows and water quality must be maintained in a D ecological category or better in this IUA. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health.
11	Upstream activities are having an impact on the system via the lack of low flows, build-up of toxics and salt and sedimentation of the instream channel. All of these aspects should be managed to be at least at a D category as must the stream habitats. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health.
12	This lowermost IUA exists partly in the Kruger National Park where special protection conditions are necessary. The upstream activities have reduced flows and increased sedimentation to unacceptable levels and both of these must be increased to at least a D category. The riparian habitat is one zone that can be managed partly by non-instream controls of the water flow and quality and must be improved in some areas to at least a D category but should be nearly natural in the Park. Fish are important in the instream and must be managed to at least a D category. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health.
13	In this IUA the consumption of fish harvested from rivers in the IUA must not pose a threat to human health.

Aquatic Ecoregion: The top catchment areas of the RR are in the Highveld, dropping down first into the Eastern Bankenveld and then Bushveld in the lower reaches and Lowveld before crossing the border.

State of the Rivers:

The main channel of the Olifants is largely in a failed state (E & F), totalling some 700km and is worst in the upper reaches in the vicinity of many of the mines. The tributaries are generally in a better state.

TABLE 5.19: PRPES OF THE OLIFANTS RR

SECONDARY	CAT A%	CAT B %	CAT C %	CAT D %	CAT E %	CAT F %
OLIFANTS (combined with tributaries)	1,8	20,2	39,2	29,3	9,1	0,4

OLIFANTS main channel	2	18	35	33	12	1

TABLE 5.20: E-FLOW STUDIES FROM THE RISK REGION

EWR site	River	Quat	RR	PES	EIS	REC	nMAR (106m3)	%EWR (REC)	LatDD	LongDD
Olifants_EWR1	Olifants	B11J	7.1	E (D)	Moderate	C	184.52	18.60	-25.75944	29.31250
Olifants_EWR2	Olifants	B32A	7.1	C	High	B	500.63	23.80	-25.49567	29.25411
Olifants_EWR3	Klein Olifants	B12E	7.1	D	Moderate	C	81.54	27.00	-25.67358	29.31680
Olifants_EWR4	Wilge	B20J	7.1	C	High	B	175.5	29.90	-25.61994	28.99881
Olifants_EWR5	Olifants	B32D	7.1	C	High	C	570.98	19.10	-25.30400	29.42200
Olifants_EWR6	Elands	B31G	7.1	E (D)	Moderate	D	60.3	17.90	-25.11600	28.95650
Olifants_EWR7	Olifants	B51G	7.1	E (D)	Moderate	D	726.52	12.70	-24.52889	29.54639
Olifants_EWR8	Olifants	B71B	7.1	E (D)	Moderate	D	813.04	15.20	-24.23889	30.08194
Olifants_EWR9	Steelpoort	B41J	7.1	D	High	D	120.17	15.20	-24.77500	30.16500
Olifants_EWR10	Steelpoort	B41K	7.1	D	High	D	336.63	12.10	-24.49650	30.39900
Olifants_EWR11	Olifants	B71J	7.2	E (D)	High	D	1321.8	13.70	-24.30719	30.78608
Olifants_EWR12	Blyde	B60J	7.2	B	High	B	383.7	34.50	-24.40861	30.82639
Olifants_EWR13	Olifants	B72D	7.2	C	Moderate	B	1760.7	23.60	-24.12667	31.01694
Olifants_EWR14a	Ga-Selati	B72H	7.2	C	Moderate	C	52.2	31.20	-23.99139	30.68333
Olifants_EWR14b	Ga-Selati	B72K	7.2	E (D)	Moderate	D	72.74	24.80	-24.02250	31.14667
Olifants_EWR16	Olifants	B73H	7.2	C	Very high	B	1916.9	21.60	-24.05117	31.73231
TREUR	Treur	B60C	7.2	A/B	Very high	A/B	49.28	45.40	-24.70967	30.81792
DWARS	Dwars	B41H	7.1	B/C	High	B/C	31.43	25.90	-24.84392	30.09189
NPS	Noupoortspruit	B11G	7.1	C/D	Moderate	C/D	4.28	25.90	-29.7554	30.60588

EWR site	River	Quat	RR	PES	EIS	REC	nMAR (106m3)	%EWR (REC)	LatDD	LongDD
OLI-EWR1	Upper Klein Olifants	B12C	7.1	C	Low	C	44.46	28.90	-25.81690	29.5904
OLI-EWR2	Upper Steelpoort	B41B	7.1	C	Moderate	C	63.46	29.80	-25.38310	29.8383
OLI-EWR3	Kranspoortspruit	B32A	7.1	B	Very high	A/B	4.71	30.50	-25.43760	29.4758
OLI-EWR4	Klip	B41F	7.1	C	Moderate	B/C	5.2	27.50	-25.22490	30.0523
OLI-EWR5	Watervals	B42G	7.1	C	Moderate	C	36.39	23.50	-24.89120	30.3105
OLI-EWR6	Upper Spekboom	B42D	7.1	C	High	B/C	28.04	28.10	-25.00940	30.5003
OLI-EWR7	Klaserie	B73A	7.2	B/C	High	B	25.54	33.10	-24.54270	31.0349
OLI-EWR8	Ohrigstad	B60H	7..2	C	Moderate	C	65.49	21.50	-24.54030	30.7223

5.8 LETABA

NB: Important ecosystem services are summarised in Table 3.1.

South Africa – ecosystem and basic human needs a priority within the context of resource protection and sustainable development. Commitment to maintaining present ecological or recommended state at all FEPA sites.

The bulk of ecosystems are in the C and D category.

TABLE 5.21: LETABA MANAGEMENT OBJECTIVES

Sub-basin	REC to be maint.[7]	WRC	E-Flows as % of natural Mean annual runoff	Vision statements / management objectives
Letaba	A-E	I - III	11.8 – 14.1	Groot Letaba Water Development Project (GLeWAP): Phase 2 Construction of Nwamitwa Dam in the Groot Letaba River to meet the projected growing primary requirements to the year 2025, to improve the water availability for the riverine ecosystem and to make provision for new resource poor farmers by 2020 (DWS, 2018) Investigate and implement groundwater developments. The Luvuvhu and Letaba Water Supply System (DWS, 2018)

The highest recommended ecological class in the sub-basin is A in the Lower Klein Letaba tributaries while the poorest REC of E is maintained for two of the biophysical nodes in the middle Letaba.

Aquatic Ecoregion: Norther Eastern Highlands and Lowveld.

State of the Rivers:

TABLE 5.22: PES OF THE LETABA RR

SECONDARY	CAT A%	CAT B %	CAT C %	CAT D %	CAT E %	CAT F %
B8 LETABA	14,1	14,3	35,2	32,8	3,6	0,0

5.9 SHINGWEDZI

NB: Important ecosystem services are summarised in Table 3.1.

South Africa – ecosystem and basic human needs a priority within the context of resource protection and sustainable development. Commitment to maintaining present ecological or recommended state at all FEPA sites.

Mozambique – priority given to maintaining ecosystem in service of users. Sustainable fisheries and avoiding zero flow in rivers a priority.

[7] REC, WRC and E-Flow as % of Natural Mean Annual Runoff obtained from (DWS, 2016)

TABLE 5.23: SHINGWEDZI MANAGEMENT OBJECTIVES

Sub-basin	Visions statements / Management Objectives
Shingwedzi	Efficient use of water for economic development, water for environmental conservation (RdM, 2006) Approximately 25% of the MAR of 49 000 million m3/a needs to remain in the rivers and estuaries to support ecological functioning of the catchments, depending on the specific river systems. (DWA, 2013)

Aquatic Ecoregion: Lowveld in the Kruger Park then Mozambique plain.

State of the Rivers:

The Shingwedzi in particular is in good condition being inside the Kruger Park, with 32% of the river in natural condition. 96% is in the C category and better.

TABLE 5.24: E-FLOW STUDIES FROM THE RISK REGION

EWR site	River	Quat catchment	PES	EIS	REC	nMAR (106m3)	%EWR (REC)	LatDD	LongDD
LmEWR6r	Shingwedzi d/s Kanniedood Dam	B90H	B/C	Moderate	B	81.63	28.80	-23.1441	31.4728

TABLE 5.25: PES OF THE SHINGWEDZI RR

SECONDARY	CAT A%	CAT B %	CAT C %	CAT D %	CAT E %	CAT F %
B9 SHINGWEDZI	32,0	28,7	35,7	3,6	0,0	0,0

5.10 LOWER LIMPOPO

NB: Important ecosystem services are summarised in Table 3.1.

Aquatic Ecoregion: Mozambique plain

TABLE 5.26: LOWER LIMPOPO MANAGEMENT OBJECTIVES

Sub-basin	Visions statements / management objectives
Lower Limpopo	Improving the resilience and reducing risk of damage to the communities, infrastructure ad livelihoods in the lower Limpopo River Basin (ADB, 2014) Efficient use of water for economic development, water for environmental conservation ((RdM, 2006))

State of the Rivers:

TABLE 5.27: E-FLOW STUDIES FROM THE RISK REGION

EWR site	River	Quat	PES	EIS	REC	nMAR (106m3)	%EWR (REC)	LatDD	LongDD
LmEWR 5r	Limpopo at Combomune	Mozambique	C	Moderate	C	3087	26.20	-23.4717	32.4438
# LmEWR 7r	Limpopo at Chokwe	Mozambique	C	Moderate	C	5572	20.60	-24.5002	33.0104
EWR1	Elephantes below Massingir Dam	Mozambique	C	High	C	ND	14.77	-23.88005	32.253306
# EWR2	Limpopo at Chokwe	Mozambique	C	High	C	ND	14.05	-24.29825	32.818611

6 RECOMMENDED ECOLOGICAL CATEGORY

6.1 KEY ISSUE – CHANGE OF PERENNIAL TO EPHEMERAL RIVERS

A key part of the vision for the Limpopo Basin is the perennial nature of the river flows. The Marico, Lephalale, Mogalakwena and Nzhelele Rivers have changed from perennial to ephemeral systems because of upstream offtakes. However, the mainstem Limpopo River is still a perennial system (flows each year) but with increased zero flows in the lower sections. Figure 6.1 represents an example from Combumune (lower Limpopo) and shows the decline in flows over the full year. Table 6.1 shows how this translates into zero flows during the dry months, where for example, over all of the September months the number of times the river has stopped flowing has increased from 22% of years to 48%. This means that historically the river stopped flowing in the driest month of September one year in five, whereas this is now every second year. This will be having a large impact on the ecosystem as well as on the livelihoods of people who depend on the river.

It will be necessary for governance of the river system to make decisions on the perenniality of these rivers. To assist with this decision, this project will provide e-flows that will maintain the present impacted state (showing the consequences), but will also provide e-flows at higher levels that will go part way to restoring the flows.

Restoring the flows of the Limpopo would require management plans to reduce withdrawals in combination with releases of water from dams. While the lower Limpopo discharge may be replenished using water from the planned Mapai Dam that will be built in the upper reaches of the Limpopo River in Mozambique, this will require dedicated management attention. It also will not address the change to ephemeral of the upstream sub-basins and also the Limpopo above Mapai Dam.

TABLE 6.1: PERCENTAGE OF ZERO FLOW PER MONTH IN THE MAINSTEM LIMPOPO AT COMBOMUNE (NAT = NATURAL, PRS = PRESENT DAY)

MAJOR TRIBUTARIES	PERCENTAGE ZERO FLOWS PER MONTH												
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Limpopo @ LmEWR05	NAT	19	3	1	0	0	0	1	2	4	11	16	22
	PRS	35	12	4	4	2	1	2	4	11	23	41	48

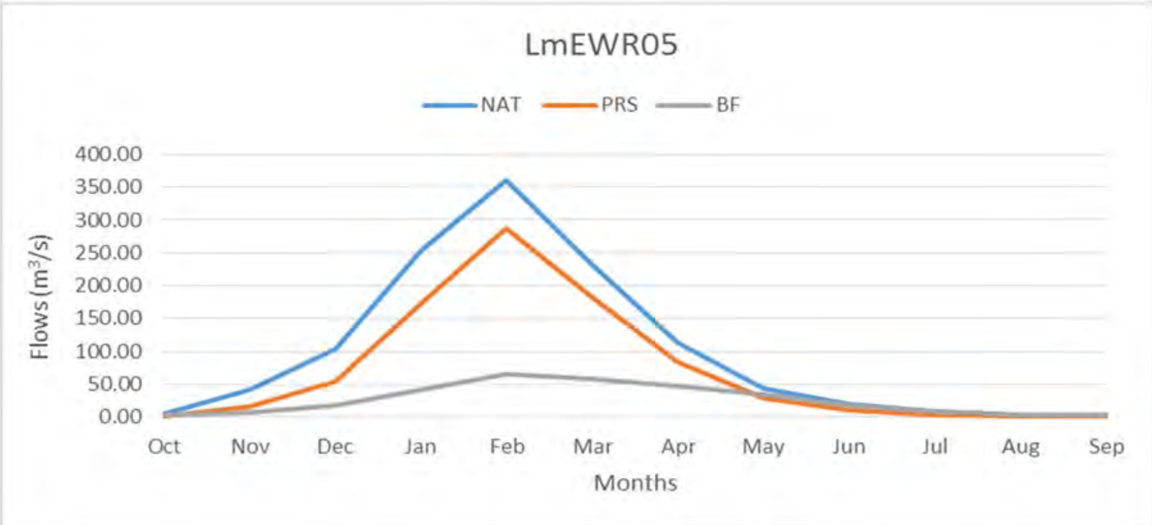

FIGURE 6.1: DISCHARGE OF MAINSTEM LIMPOPO AT COMBOMUNE

6.2 RECOMMENDED ECOLOGICAL CATEGORIES

Within South Africa, the standard approach to determination of e-flows has included the determination of the REC for sites or river reaches. This is done following a process described by Kleynhans and Louw (2008). Table 6.2 shows a summary of all of the data and information that was provided for each RR leading to a general REC for each RR. It should be recognised that the aggregation for sub-basins requires an averaging, as some sections would be in a better condition than others.

TABLE 6.2: SUMMARY OF RECOMMENDED ECOLOGICAL CATEGORIES (REC) PER RR

	PES	REC	REC updated for the following reasons.
1.1-Ngotwane	C	C	N/A
1.2-Marico	BC	BC	N/A
1.3-Crocodile	DE	C	Mandatory and lift to meet BC at Spanwerk
2.1-Bonwapitse	CD	B	Spanwerk was a BC - close location
2.2-Matlabas	CD	B	WRC was A-BC
2.3-Mokolo	C	B	REC from Reserves were B
2.4-Lephalala	CD	CD	N/A
2.5-Lotsane	CD	CD	N/A
2.6-Mogalakwena	D	C	EWR studies
2.7-Motloutse	D	D	N/A
2.8-Upper Limpopo	D	BC	Spanwerk was a BC and Poachers also a BC
3-Shashe	DE	D	Mandatory
4.1-Middle Limpopo	D	C	REC of BC in places incl Poachers Corner
4.2-Umzingwani	DE	D	Mandatory
4.3-Sand	D	C	PES was mostly C in PES project
4.4-Bubye	C	C	N/A
5-Luvuvhu	D	C	PES project mostly C and Pafurie EWR also C
6-Mwenedzi	BC	BC	N/A
7.1-Upper Olifants	DE	D	Mandatory
7.2-Lower Olifants	D	C	ERW and RQO data have several Cs and Bs
8-Letaba	DE	C	Mandatory - and PES in PES project mostly C
9-Shingwedzi	BC	B	REC documented by EWR study
10.1-Lower Limpopo	D	C	EWR REC was a C
10.2-Elephantes	DE	D	Mandatory
10.3-Lower Limpopo	CD	C	EWR REC was a C
			Mandatory change is where the PES is in a DE or E which is below what is sustainable so must be improved to a D

Figure 6.2 provides two maps, the top showing the PES and the bottom the REC.

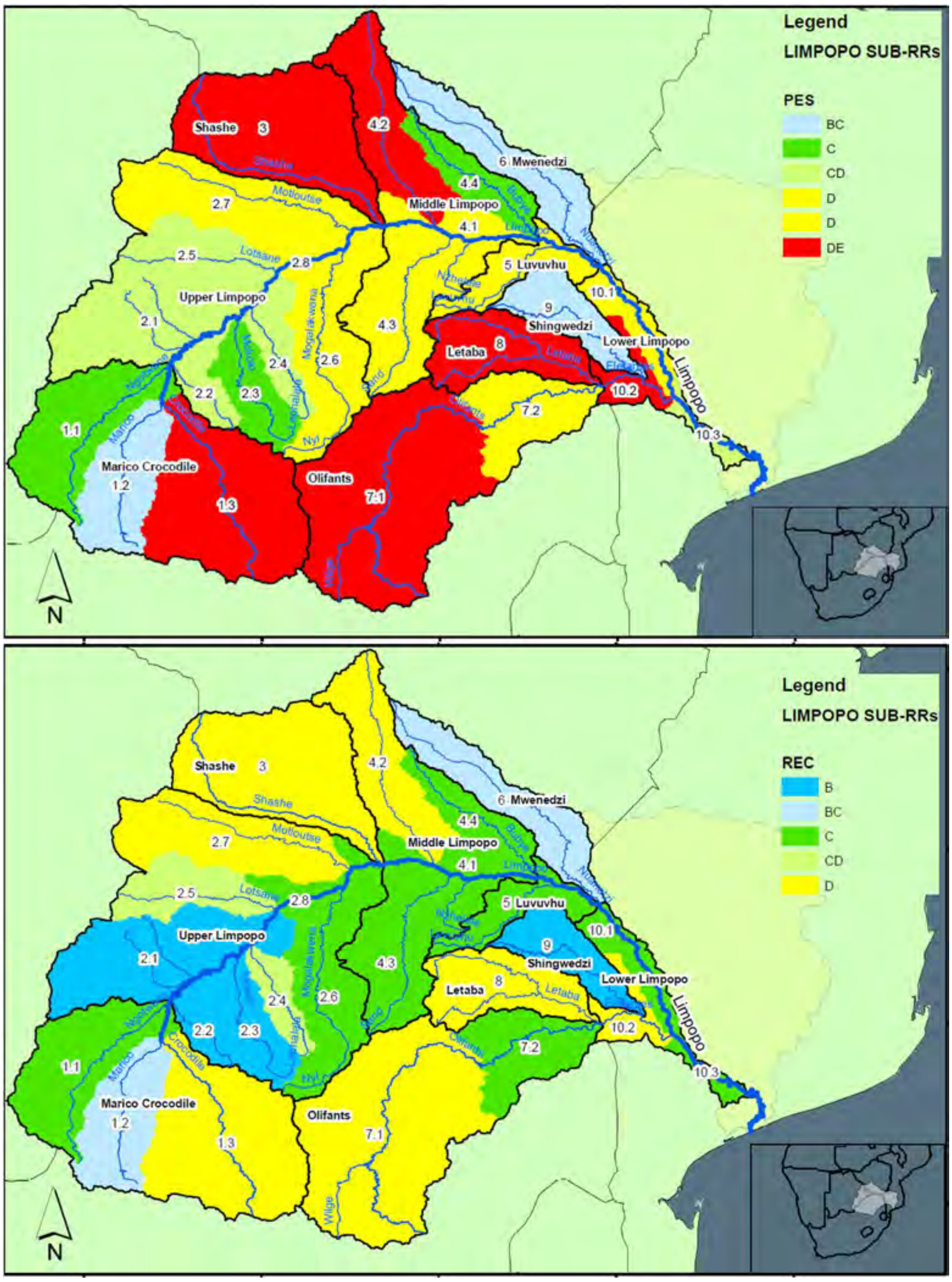

FIGURE 6.2: THE PES (TOP) AND REC (BOTTOM) FOR THE LIMPOPO RIVER. NOTE THAT BOTH OF THESE MAPS WILL BE AMENDED BY ADDITIONAL INFORMATION GATHERED IN THIS PROJECT.

CONCLUSION

What has been presented in this report is the data and information that has helped to frame the desired outcomes for the river ecosystem that will subsequently be achieved by implementation of e-flows.

E-flow assessments will be carried out in each RR to achieve the REC, many of which are the same as the present state. Additional e-flow values will also be provided to achieve ecological states that maintain the river in states that are better and in some case worse than present. This will provide management in the future with options to manage the system to a better or worse state, as required to satisfy management requirements.

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ANNEXURE A: LIVELIHOODS AND ECOSYSTEM SERVICES

Irrigation using groundwater in HaGumbu Village near Musina South Africa: (Photo by Manuel Magombeyi)

THIS REPORT

E-flows can only be set in relation to a vision and management objective for the condition of the river within the basin and for the communities that the river supports.

In Task 3 of the PROBFLO framework that is being followed in this assessment, the vision and objectives clarified in Task 2 are matched to the requirements of local stakeholders for flow-related ecosystem services (as derived from both surface and groundwater systems). In order to do this, a process is followed where the vision and objectives in policy are tested to achieve the following understanding:

a. The activities occurring in the basin that threaten the flow-related ecosystem services to communities along the river
b. The requirements these communities have for flow-related ecosystem services, and the relative dependence on groundwater and surface water for these services.
c. The above requirements become the endpoints the e-flows study, the endpoints that the e-flows must deliver, in order to continue to provide flow-related ecosystem services. The project facilitates consideration of trade-offs between these endpoints. Endpoints have been defined as "*specific entities and their attributes that are at risk and that are expressions of a management goal*" (USEPA, 2003)

Endpoints need to be coupled with a preliminary economics and livelihoods assessment related to streamflow, based largely on literature and limited stakeholder representative consultation, consultation with NGOs and riparian government agencies and also with LIMCOM. This report is of that assessment. Following this report, a process will be followed to merge the vision and management objectives, with the livelihood requirements into the endponits of the study.

STRUCTURE OF THIS REPORT

This report first presents the different river-flow related ecosystem services (ES) and where possible illustrates their occurrence across the risk regions in the Basin. A discussion of ES and livelihoods follows, punctuated by examples of how people in the basin are using the river and the resultant ES. Finally, some key messages from this report are synthesized in the concluding section.

Ultimately, this report aims to paint a picture of how essential ES are sustained by e-flows in the Limpopo River system, and how these services are central to the livelihoods of local communities in the basin. The e-flows will ultimately be set according to ecological needs and also the needs for livelihoods of dependent communities.

LIMITATIONS OF THE REPORT

The scope covered by this report in determining ES and their contribution to livelihoods has been limited by the following factors:

- Stakeholder consultation to obtain on-the-ground information on what ES are used by communities in the Limpopo River Basin was constrained. A full stakeholder survey would have substantially increased project cost and thus only literature and a few selected indiviuals were consulted. Those persons who were consulted were selected from key national government institutions, local government and NGOs that operate in the basin. Undoubtedly, they will not have fully represented the diversity of ecosystem users in the basin, nor activities in all the risk regions and sub-basins of the Limpopo River Basin. However, their holistic perspective on the basin was useful in obtaining essential information on the use of flow related ES, and together with information from the literature, was considered sufficient for implementation of PROBFLO.

  - A description of key informants interviewed - their countries of origin and designation - is provided in Annex 1.

- Similarly, no attempts to estimate the value of ES were made, this not being necessary for implementation of PROBFLO.
- Examples presented in this report provide a snapshot of what people in the basin use flow related ES for and are by no means fully representative of the situation across the basin.

1 INTRODUCTION

Contributions of ecosystems to human well-being and livelihoods are indisputable, with fundamental benefits derived from ecosystem services (ES) perceived to contribute significantly to making human life possible and worth living (Costanza et al., 1997; MEA 2005). The Millennium Ecosystems Assessment (MEA 2005) classified ES into four major categories namely; **provisioning services**, **regulating services**, **supporting services** and **cultural services**, which although the subject of some criticism, continue to be widely used. These services are explained in Table 1. Burkhard and colleauges defined ES as the contributions of ecosystem structure to human well-being (Burkhard & Maes Eds. 2017; Burkhard et al. 2012). The TEEB Synthesis report added the *indirect* to the *direct* contributions of ecosystems to human well-being in its definition of ES (TEEB, 2010), while most recently, the Inter-governmental Panel on Biodiversity and Ecosystem Services (IPBES) have publicised the term for ES as "natures contributions to people" (IPBES 2018).

TABLE 3: CLASSIFICATION OF DIFFERENT TYPES OF ECOSYSTEM SERVICES (MEA 2005)

PROVISIONING SERVICES	Tangible products obtained from ecosystems, including for example, genetic resources, food and fibre and freshwater.
REGULATING SERVICES	The benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water and some human disease
CULTURAL SERVICES	The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including, e.g., knowledge systems, social relations and aesthetic values.
SUPPORTING SERVICES	Ecosystem services that are necessary for the productions of all other ecosystem services. Some examples include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling and provision of habitat

The value of ES have for long been unrecognized in policy and decision making, including economic and financial decisions, and they tended to be overlooked or viewed simply as 'free' or 'public goods' (TEEB 2010; IUCN 2015). This has led to irrational plunder and misuse of these resources with little attention paid to maintaining them. Recently however, ES have risen to become one of the global policy focal points (for example the IPBES, the Sustainable Development Goals and the Convention on Biological Diversity) with an increasing recognition of their importance to human wellbeing as well as their economic value. This has been met by growing effort to maintain and invest in the 'natural capital' to ensure that there is continued human benefit derived from ES (MEA 2005; Hejnowicz and Rudd 2017; Costanza et al. 2014).

Approximately 20 million people live in the Limpopo River Basin and the population is expected to grow by 10% by 2040 (Resilim O, 2013). Many of these people are directly or indirectly dependent on the flows of the Limpopo, its associated groundwater system and the ES they provide (IWMI 2020). However, due to weak governance structures and other pressures such as a growing population, increased development and climate change, maintaining the ES is a challenge, putting a strain on resources, especially water, and further exacerbating the threat to ecosystems, biodiversity and human wellbeing (Petrie et al. 2014).

This report describes flow related services and benefits obtained from ecosystem processes and biodiversity linked to livelihoods and social wellbeing of the people living within the Limpopo River Basin. Presentation of information where possible follows the risk region definitions developed and described in the Basin Report (IWMI, 2020) (see Figure 1).

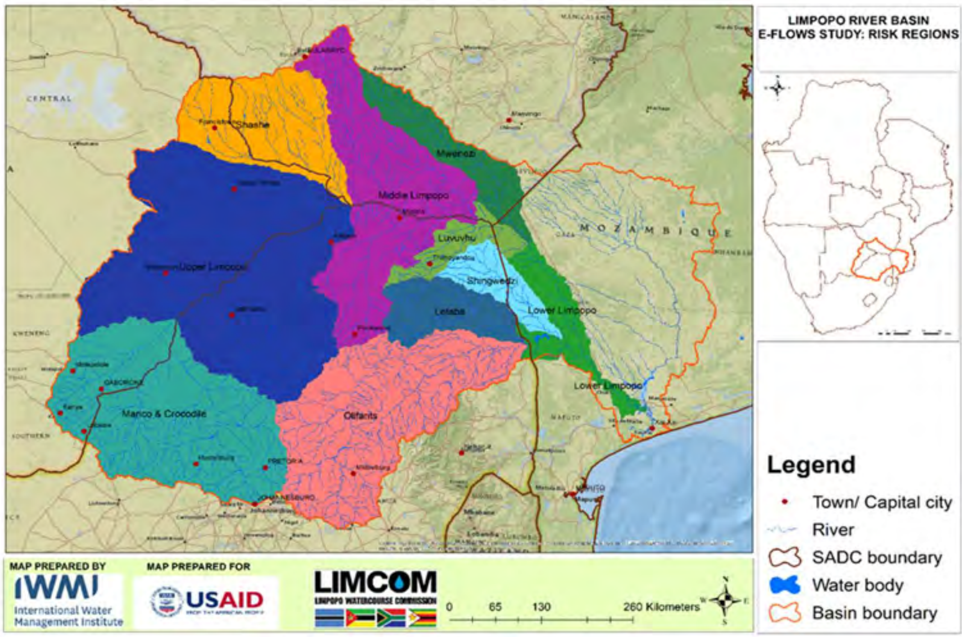


FIGURE 3: MAP OF THE LIMPOPO BASIN INDICATING PRELIMINARY RISK REGIONS AND SUB-BASINS (IWMI, 2020)

2 WATER-RELATED ECOSYSTEMS

What is an ecosystem and in particular a water-related ecostem? A water-related ecosystem is *a dynamic complex of plant, animal, and microorganism communities and the non-living environment dominated by the presence of flowing (lotic) or still (lentic) water, interacting as a functional unit.*" (Dickens and McCartney, 2020).

From the above definition, it is clear that biodiversity is central to the functioning of ecosystems and thus for the delivery of ES, even though the potential of biodiversity to contribute to ES is not always obvious (Haines-young and Potschin 2010). Some have suggested a linear relationship between species diversity and ecosystem productivity (Fagan et al. 2008), although it is more likely that this linear relationship is between species diversity and resilience, a factor documented in the Convention of Biological Diversity.

It is generally recognised that it is necessary to consider a wide range of ES in order to appreciate the full value of an ecosystem e.g. soil formation, biomass production and erosion control, especially where the role of biodiversity may be unclear. In many cases species may play a role that supports ecosystems to continue supplying services and thus it is regarded that it is the functional diversity of species and communities that plays the most important role in delivery of ES (De Bello et al. 2008). It is often the combined contribution of biodiversity and the different ecosystem processes that may eventually result in an appreciable contribution of an ecosystem to society.

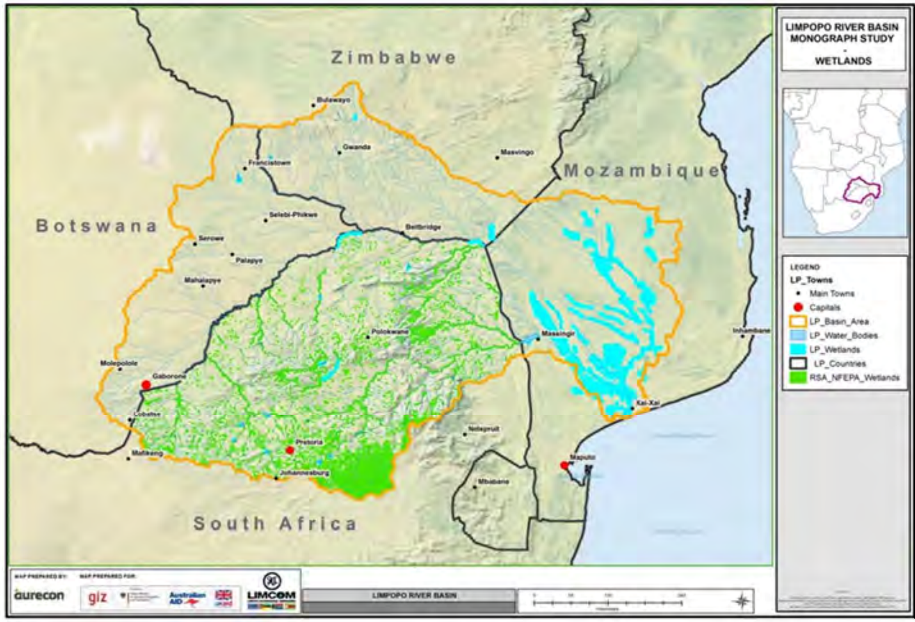
Petrie et al. (2014) describes the Limpopo River Basin as a complex transboundary system with an exceptionally rich biodiversity including its wetlands (see Table 2 and Figure 2). Wetlands in the basin are hydrologically complex and they cover approximately 12.5% of the landscape and play important roles in ecosystems functioning and biodiversity of the basin. They play provisioning, regulatory, and habitat roles in the landscape, with McCartney et al. (2005) highlighting the importance of wetlands in attenuating floods, recharging groundwater sources, regulating river flow, water purification, biodiversity protection, tourism, grazing, and subsistence agriculture and as a source of food and plant materials for rural communities.

The biodiversity of the Limpopo will be described in detail in the subsequent Specialist Literature and Data Review for the Limpopo that follows this report. However it has been noted that there are two recognized Biodiversity Hotspot areas in the Limpopo River Basin: I) small remnants of the Coastal Forests of Eastern Africa hotspot that extends mainly to the north; and II) the Maputoland-Pondoland-Albany that extends from the south and ends its range at the Limpopo mouth; these hotspots have been described in the basin report (IWMI, 2020).

From a terrestrial perspective, the catchment is dominated by 2 vegetation Biomes: Savannah (more than 60%) on the western side and Indian Ocean Coastal Belt on the eastern side (Mucina & Rutherford 2006; 2012). A small amount of Grassland Biome occurs in the southern regions and supports a high density of seep wetlands, which are vital for base flow maintenance. Several reaches of lowland rivers are characterized by a zonal Lowveld Riverine Forest (IWMI, 2020). Land cover areas per risk region in the Limpopo River Basin are shown in Table 3 and Figure 3.

TABLE 2: WETLAND AREAS IN THE LIMPOPO RIVER BASIN

RISK REGION	Marico-Crocodile	Olifants	Upper Limpopo	Shashe	Middle Limpopo	Mwenezi	Luvuvhu	Letaba	Shingwedzi	Lower Limpopo	Total
WETLAND AREA (KM²)	529	877	903	152	219	292	194	92	29	4534	7821
WETLAND AREA / RISK REGION (%)	6.8	11.2	11.5	1.9	2.8	3.7	2.5	1.2	0.4	58.0	100



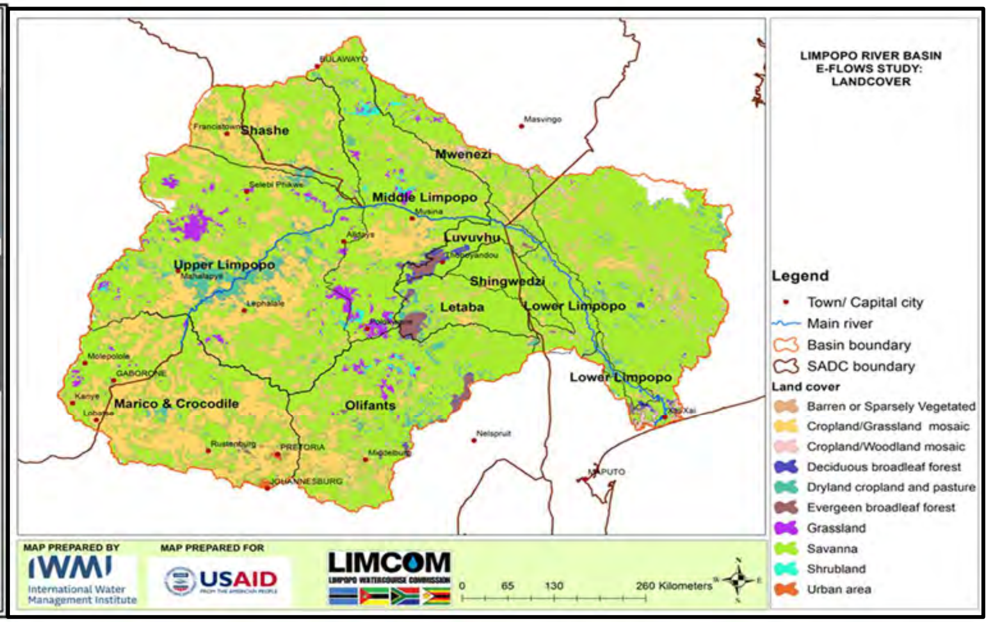


FIGURE 2 (LEFT): LOCATION OF WETLANDS IN THE LIMPOPO RIVER BASIN (AURECON, 2013A) FIGURE 3 (RIGHT): LAND COVER MAP FOR THE LIMPOPO RIVER BASIN

TABLE 3: LAND COVER AREAS (KM²) FOR THE RISK REGIONS OF THE LIMPOPO RIVER BASIN

LAND USE (KM²)/ RISK REGION	MARICO-COCRODILE	OLIFANTS	UPPER LIMPOPO	SHASHE	MIDDLE LIMPOPO	MWENEZI	LUVUVHU	LETABA	SHINGWEDZI	LOWER LIMPOPO	TOTAL
BARREN OR SPARSELY VEGETATED	127	94	52	139	74	62	65	6	16	391	1026
CROPLAND/GRASSLAND MOSAIC	39710	42154	69740	12688	10712	3753	5530	1946	1124	904	188261
CROPLAND/WOODLAND MOSAIC	13	24	43	211	239	591	1	24	36	245	1427
DECIDUOUS BROADLEAF FOREST	34	328	9		354	9	888	446	17	159	2244
DRYLAND CROPLAND AND PASTURE	575	1966	6804	943	1039	201	146	718	189	676	13257
EVERGEEN BROADLEAF FOREST	197	2075	33	9	2126	12	1064	2109	5	74	7704
GRASSLAND	467	1624	4563	61	2864	221		1		3	9804
SAVANNAH	19409	5651	11980	14886	30011	9650	96	8519	7807	9938	117947
SHRUBLAND	7	375	399	28	1198	486					2493
URBAN AREA	531	26	44	13	41		5				660
TOTAL	61070	54317	93667	28978	48658	14985	7795	13769	9194	12390	344823

3 ECOSYSTEM SERVICES AND LIVELIHOODS IN THE BASIN

This section presents the description and occurrence of ES in the Limpopo River Basin as well as examples of how the inhabitants of the Basin benefit from them - what they use the flow related ES for, and what role such services play in their daily lives. As established in the basin report (IWMI, 2020), the Limpopo is a semi-arid basin, prone to droughts and floods. There is high biodiversity and abundant wildlife which forms the backbone of numerous conservation areas and game farms such as the Kruger National Park, Greater Limpopo Transfrontier Park, Gonarezhou National Park and Mapungubwe National Park, among others. The basin however suffers from considerable socio - economic disparities with high poverty levels and large proportions of the population living in rural areas. Provisioning services in rural Africa are particularly important and central to livelihoods, where the majority of the population directly relies on natural resources for daily living (Egoh et al. 2012; Ryan et al. 2016). This report is mostly focused on surface and groundwater flow-related ES such as, drinking water, riparian cultivation and grazing, fishing, and recreation. Where possible attempts were made to reach community level specificity, detailing actual use and significance of ES, however where this was not possible due to data limitations, a broad framing of ES was used.

The ES of the Limpopo River Basin are presented in the following sections:

5. Regulating services
6. Cultural services
7. Provisioning services
8. Supporting services

3.1 THE SCALE OF SERVICES CONSIDERED IN THIS REPORT

It is important to be clear on the scale of the ecosystem services that will be considered as part of the e-flow analysis. The concept of e-flows is illustrated (Figure 4), showing how livelihoods-use forms part of the e-flow volume in the river, which is distinct from the large-scale allocations of water that may be for commercial irrigation, urban withdrawal etc. The latter all form part of the allocation of resources that is the essence of a resource management plan.

The livelihood uses of water that are included are those community uses that are directly linked to the flow of the river. Thus direct withdrawals of small-scale irrigation water, fisheries, building materials etc. Withdrawal from boreholes that are within the influence of the surface water in the river are also included in this, while recognizing the difficulty in establishing this relationship.

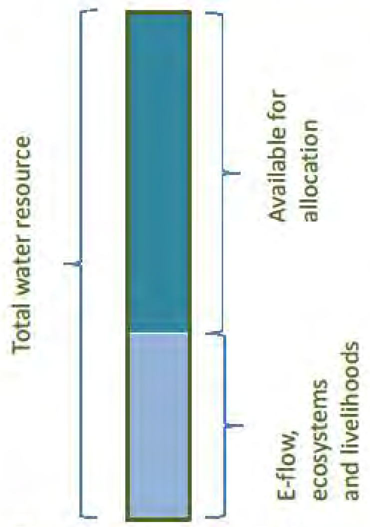


FIGURE 4 THE SPLIT OF THE TOTAL WATER RESOURCE INTO THAT PORTION WHICH IS THE E-FLOWS, WHICH INCLUDES WATER FOR ECOSYSTEMS AND LIVELIHOODS. THE AMOUNTS AVAILABLE FOR ALLOCATION ARE FOR LARGE-SCALE IRRIGATION, URBAN DOMESTIC ETC.

3.2 REGULATING SERVICES

The prevention and mitigation of natural disasters such as floods and human induced impacts like pollution of water bodies are some of the regulating service benefits that are derived from ecosystems (MEA 2005). Natural infrastructure supports human wellbeing by moderating natural and human induced impacts, which would otherwise inflict devastating costs on society that is vulnerable to such impacts (Gupta and Nair, 2012). Even though regulating services play an important role to livelihoods, when compared to provisioning services, they are less understood and usually neglected in policy appraisal and natural resources development planning and management (McCartney and Nyambe, 2017). These authors also suggest that lack of detailed understanding of the processes occurring, their dynamic nature and the interactions of these functions with the catchments within which the ecosystems are located, is one of the major reasons as to why these services are not well understood. The Limpopo River Basin, like many other basins in southern Africa, is not spared in this regard, so that little quantitative information on ecosystems regulatory services is available for the basin. This has had the outcome that regulating services are often missing from policy and management plans. Through a general understanding of ES using information sourced from the literature, regulatory ES of the Limpopo River Basin can be understood as described below.

3.2.1 FLOW REGULATION AND FLOOD CONTROL

Forests, wetlands and riparian habitats play a key service in the regulation of river flows and to a certain extent the control of flood (McCartney and Nyambe, 2017; Shackleton et al. 2008). As floods spread out over wetland areas (Figure 5) the downstream threat of flooding and its damaging impact is reduced as river flows are regulated by storage of water in the wetlands, marshes and forests. Flooding of wetlands also facilitates recharge of groundwater aquifers. Water from the wetlands and aquifers is released when the river returns to lower levels, and continues even into dry periods ensuring the continual supply of water downstream, even though some of this water may be lost by evapotranspiration. This water maintains biodiversity and ecosystem function and provides support to livelihoods (e.g. through supply of water for domestic use, agriculture and by maintaining other resources such as building materials and fish) of people living around these areas, which otherwise would not have been available (Blumenfeld et al. 2009; Shackleton et al. 2008). Emerton and Boss (2004) have proposed to look at natural ecosystem as performing functions similar to human-made reservoirs, supporting the suggestion that natural ecosystems should be considered as natural infrastructure and incorporated into water resources planning.

FIGURE 5: WETLAND IN NYLSVLEY NATURE RESERVE. SOURCE NIGHTJAR TRAVEL GUIDE ACCESSED AT HTTPS://WWW.NIGHTJARTRAVEL.COM/PARKS/NYLSVLEY-NATURE-RESERVE

The Limpopo River Basin has an approximately 5.2 million hectares of wetland area which is 12.5 percent of the total area of the basin (Ranjani et al. 2006) and includes predominantly dambos in the upper catchment, and riverine wetlands and floodplains in the lower catchment in Mozambique. Dambos and flood pans occur in the upper Olifants catchment in South Africa; the Mwenezi, Shashe, Umzingwane, Tuli, and Bubi catchments in Zimbabwe; and the tributaries of the Changane catchment in Mozambique (the Changane is not included in the Risk Regions of this project). Riverine wetlands/swamps are found along the lower reaches of the main stem of the Limpopo River and the Changane tributary (IWMI 2003). Amaral and Sommerhalder (2004) and Leira et al. (2002) have argued that poor land management, including land-clearing and poor agricultural practices in the upper river basin, and a lack of integrated management of upstream dams and wetlands have contributed to flooding in the Limpopo River Basin. They suggest that if the natural systems had been present and unaltered then they would be playing a crucial role of mitigating floods.

Tropical forests have been described by Bruijnzeel (2004) to play a crucial role in moderation of streamflow, it is argued that they maintain a high infiltration rate because of the thick vegetation cover, and store water to be released later during the dry season hence maintaining baseflow. The Limpopo River Basin does indeed contain tropical forests, the ES of modifying hydrological behavior being important for the basin and thus highly valued (Bruijnzeel, 2004). Petrie et al., (2014) in a synthesis report for the USAID Southern Africa "Resilience in the Limpopo River Basin" (RESILIM) program, highlighted that in the Limpopo River Basin the mean annual runoff (MAR) per unit area from the upland catchments is up to 100 times that of the low-lying areas and they propose that the mist-belt forests and upland grasslands of the basin, which maintain a significant baseflow during the dry season, are of exceptional value to the hydrological resilience of the Basin.

3.2.2 WATER PURIFICATION

High levels of pollution in many tributaries of the Limpopo are threatening communities throughout the basin. Acid mine drainage from defunct coal mines on the Mpumalanga Highveld, effluent from industrial processes, overloaded waste-water treatment plants which release raw sewerage in the North West, Limpopo and Gauteng regions of South Africa, as well as agricultural runoff, have created a toxic mix of organic and inorganic pollution in the Limpopo River (Petrie et al. 2014). The Limpopo Basin Permanent Technical Committee (LBPT) described the overall water quality situation in the Limpopo River Basin as "impacted, but not severe" (LBPTC 2010). The same cannot however be said for some of its tributaries e.g. the Olifants, which is well known to be highly polluted with both acid mine drainage and sewage effluent, while in Mozambique there are also sources of pollution related to the intense agricultural activities in the Chókwè region (Ashton et al. 2001; De Villiers & Mkwelo 2009).

Aquatic ecosystems including rivers and wetlands with different geomorphological features and biodiversity (especially plants and macro and microbiological organisms), have the ability to purify water. The natural purifying process includes dilution, sedimentation, filtration, physical and chemical immobilization, microbial interaction and uptake by vegetation and aquatic organisms (Dordio et al., 2008; Kadlec and Knight 1996; Jingmei et al. 2016). Given the existing levels of pollution in the basin, the presence and maintenance of ecosystems that provide water purification services is essential. The benefits of this would accrue to all water users in the basin but are especially relevant to rural populations that make use of water direct from the rivers. The presence of wetlands in every risk region (see Table 2 and Figure 2) as well as the thousands of kilometers of river channel therefore present an important ES that is purifying water. Proper management and maintenance of these aquatic ecosystems is thus crucial.

3.2.3 CARBON STORAGE AND CLIMATE REGULATION

Biological carbon sequestration is the assimilation and storage of atmospheric carbon initially in photosynthetic plants and algae, ultimately accumulating in vegetation, soils, woody products and aquatic environments (Land Trust Alliance 2020). Fluxes of carbon dioxide and other greenhouse gases (GHG) in ecosystems are a function of natural ecosystem processes as well as anthropogenic activities, which makes grasslands, forests and wetlands an important element of the biosphere as they buffer these changes, absorbing excess carbon.

Even though not much quantitative information is available on carbon storage/sequestration in the Limpopo River Basin, understanding the potential of ecosystems within the basin to store carbon is important, especially as we now need to consider burgeoning atmospheric carbon due to climate change, and are presented with the need to respond by developing climate change mitigation and adaptation strategies. Masike (2014) carried out an economic valuation of the 465 ha of mangroves in the Limpopo estuary and estimated the carbon stored and its economic value (Tables 4 and 5). The authors provide no reason that growth was not recorded for the Dense Mangroves, but perhaps this was as the forest was in a stable state with no room for addition of biomass.

TABLE 4: ESTIMATED CARBON STORED AND SEQUESTERED IN THE MANGROVES (MASIKE 2014)

	CATEGORY	TOTAL BIOMASS	BIOMASS GROWTH	CARBON STOCK (MT)	CARBON SEQUESTERED (MT)
DENSE MANGROVE	Above ground biomass	12 972.69	0	6486.35	0
	Below ground biomass	22 561.20	0	11280.6	0
DISPERSED MANGROVE	Above ground biomass	27 910.84	984.20	13 955.42	492.10
	Below ground biomass	48 540.60	3937	24 270.30	1 969.50
DEGRADED MANGROVE	Above ground biomass	5 506.20	486.6	2 753.10	243.30
	Below ground biomass	9 576	1942	4788	971
	Total Carbon			63,533.72	3,675.90

TABLE 5: ECONOMIC VALUE OF MANGROVES IN US DOLLARS AS SOURCE OF CARBON STORE (CONVERTED TO USD SEPTEMBER 2020 FROM MASIKE 2014)

TOTAL CARBON (MT)	PRICE (USD/MT)	VALUE OF CARBON (USD)
63,533.72	8.35	530,506

3.2.4 OTHER REGULATING SERVICES

Studies in other river basins have investigated and valued a number of regulatory services that are provided by various ecosystem (Brauman et al., 2017; Brils, 2010; Goulder and Kennedy 1997; Lele, 2009; Hein et al., 2006). However, there is no extensive data on regulatory services in the Limpopo River Basin, but they should nonetheless be considered important. Below (see Table 6) are examples of such services.

TABLE 6: OTHER POSSIBLE REGULATING ECOSYSTEM SERVICES

REGULATION OF THE HYDROLOGICAL CYCLE	Vegetation affecting transpiration and evaporation and stabilising soils enhancing infiltration of rainfall.
STABILIZING OF CLIMATE AND MODERATION OF WEATHER EXTREMES	Plants alter the energy balance by changing the albedo (reflective properties) of the surface and by transpiring water which absorbs energy from the atmosphere and also buffer the impact of storm winds
REGULATION OF DISEASES AND PESTS	Some animals and plants species are important controllers of natural pests and diseases

3.3 CULTURAL SERVICES

Cultural ES are the non-material benefits that people obtain from nature which include recreation, aesthetic enjoyment, physical and mental health benefits and spiritual experiences (MEA 2005). They contribute to a sense of place whilst fostering social cohesion and are essential for human health and well-being (IUCN 2015). There is a deep connection between cultural services which hare often connected to other ES i.e. provisioning and regulating services, e.g. small-scale fishing is not only about food and income, but also about the fishers' way of life. In many situations, cultural services are among the most significant values people associate with Nature hence it is of paramount importance to understand them (FAO 2020). It is however challenging to quantitatively measure and monitor cultural services, as perceptions of the value of cultural ES may differ amongst individuals and communities, be locally specific, and change through time. This difficulty in quantifying the value of cultural ES may mean that the least prominent or less visible services are overlooked in decision making, particularly when compared to provisioning services (MARS, 2016).

3.3.1 SPIRITUAL

According to MARS (2016), freshwater ecosystems provide important sacred sites for many religions and spiritual belief systems making water central to many religious and spiritual practices and shaping the way that people live, work, create and relax. This means that freshwater ecosystems are important contributors to cultural diversity, artistic and literary forms and practices, and so can shape local and regional identities.

BOX 1: SPIRITUAL PRACTICES IN LIMPOPO RIVERS

An example of the spiritual value of water ecosystems comes from the Bapedi tribe in the Limpopo Province, South Africa, where "village girls who are still virgins and have not, as yet, gone through the rights of passage into womanhood or adulthood are gathered and draw water from the river using containers made of clay, called *'meetana'* (*'moetana'* – singular) (Harries, 1929). This water is carefully mixed with rain-medicine to sprinkle the earth (Hammond-Tooke, 1974) under the careful guidance of the chief traditional healer for that particular village called *'Ngaka ya Moshate'* in Sepedi. It is believed that the rain will come down as soon as the girls arrive back from the river having performed the necessary rituals" (Mokgobi 2014). During the development of Resource Quality Objectives for the Olifants River, stakeholders requested that consideration be given to water depth and quality in large pools used for spiritual use (Dickens, *pers com*). Another example of a spiritual use is where Christian christenings are carried out in rivers by some faith members.

3.3.2 RECREATION AND TOURISM

Freshwater ecosystems attract a range of diverse user groups including; sightseers and walkers who may use bankside paths, trails and viewpoints, drawn by a landscape's aesthetic appeal (MARS 2016). The Limpopo River Basin is one of the key focal points for eco-tourism and nature reserves in the SADC region as it includes many large and famous parks such as Kruger, Limpopo, Gonarezhou, Manjinji Pan, Malipati, Madikwe, Pilanesberg, Mapungubwe, Mashatu, Soutpansberg and Sabi-Sand (RAK 2020). Many of these parks focus on wetlands as presenting the best opportunities for viewing animals and birds that inhabit these ecosystems. A good example is the Nylsvley Nature Reserve (a Ramser designated wetland) which is one of the top birding spots in Southern Africa, with more than 400 species recorded (Figure 6). It is also recognized as one of Birdlife SA's Important Birding Areas (IBA SA008). The floodplain occasionally erupts with bird-activity, supporting up to 80,000 birds in years of high rainfall.

FIGURE 6: NYLSVLEY NATURE RESERVE. (SOURCE: SOUTHERN AFRICA RAMSAR SITES. ACCESSED AT HTTP://WWW.SARAMSAR.COM/2015/06/NYLSVLEY-NATURE-RESERVE.HTML)

BOX 2: ECOTOURISM, RECREATION AND LIVELIHOODS – EXAMPLES FROM THE BASIN

Major conservation areas in the Limpopo River Basin are home to different wildlife species whose continued survival is linked to the flows of rivers in the basin. Consequently, these conservation activities support eco-tourism and provide employment opportunities for local communities. While the contribution of conservation activities to local livelihoods is an area of debate (Musakwa et al. 2020), they nonetheless are dependent on the flow related ES of the Limpopo system by providing drinking water for the wildlife and sustaining riparian vegetation that completes the ecosystem. In Botswana, the Tuli Block at the confluence of the Shashe and Limpopo River, is a narrow stretch of scenic views and biodiversity where a number of game farms form tourist attractions, these include Notugre and the Mapungubwe Transfrontier Conservation Area. The Luvuvhu, Letaba, Olifants and Sabie-Sand are important river systems that support the Kruger National Park ecosystem, maintaining the international tourist destination and many people that depend on the resultant revenues for their livelihood. Disturbance in river flow regimes as well as increasing water demand and abstraction are cited as some of the potential threats to the functioning of the KNP (SANPARKS 2018). In Mozambique, the Limpopo National Park which borders the KNP and through which the Shingwedzi river flows, sustains a diversity of wildlife and plant species.

Dams for recreation and fishing

By their very nature dams become sought after places for recreation that includes water-sports and angling or fishing. The Loskop Dam located in the upper Olifants catchment, is an established tourist attraction, and allows for freshwater angling activities, fishing competitions and other water sports. There is even cold-water trout fishing in small dams in the upper Olifants Basin where whole town economies have built up around the industry. Dams however are largely designed for the supply of other ES namely provisioning and regulating services (see later).

3.4 PROVISIONING SERVICES

Provisioning services are the tangible products that people obtain from ecosystems and they include food, water, raw materials, energy and genetic resources and most often considered as the most fundamental benefits of nature to livelihoods (Shackleton et al. 2008; RAK 2020; Darwall et al. 2009). Most studies on ES have focused on provisioning services due to their extractive nature and hence they are easily quantified and valued. In the Limpopo River Basin, the majority of the population, just like the rest of rural Africa, depend on ES for their livelihoods with provisioning services being the core of these services.

3.4.1 WATER PROVISION

Water is a fundamental human need required to support all life in the Limpopo River Basin. There are a number of man-made infrastructures within the basin designed to retain, abstract and convey water to users for multiple purposes e.g. domestic use, mining, irrigation and power generation as well as direct river abstractions and use for poor communities (RAK 2020). Water use by various sectors in the Limpopo River Basin is presented in Table 7.

TABLE 7: PRESENT WATER USE BY SECTOR IN THE LIMPOPO RIVER BASIN FOR EACH RIPARIAN COUNTRY (MM3/YEAR). SOURCE: LBPTC 2010

COUNTRY	URBAN	RURAL	IRRIGATION	MINING	POWER	OTHER	TOTAL
BOTSWANA	60	12	20	9	*	0	101
MOZAMBIQUE	4	9	270	0	0	0	283
SOUTH AFRICA	665	140	1,485	230	215	295	3,030
ZIMBABWE	690	6	640	*	*	0	1,366
TOTAL	1,419	167	2,415	239	215	295	4,750

Groundwater abstraction is also common in the basin, with an estimated 70,000 boreholes reported in the Limpopo Basin Report (IWMI, 2020). Cobbing et al. (2008) claimed that sustainable utilization of groundwater is dependent on the management of surface water. In the Limpopo Basin groundwater abstraction is common and draws a substantial amount of water from the basin, (Table 8. and Figure 7).

TABLE 8: ESTIMATED ANNUAL GROUNDWATER ABSTRACTIONS IN THE LIMPOPO RIVER BASIN. SOURCE: ENVIRONMENTEK, CSIR 2003

COUNTRY	ESTIMATED ANNUAL GROUNDWATER ABSTRACTION (MM3/YEAR)	SECTOR USE
BOTSWANA	23	Domestic, Irrigation
MOZAMBIQUE	15	Domestic
SOUTH AFRICA	462	Domestic, Irrigation, Mining,
ZIMBABWE	6	Irrigation

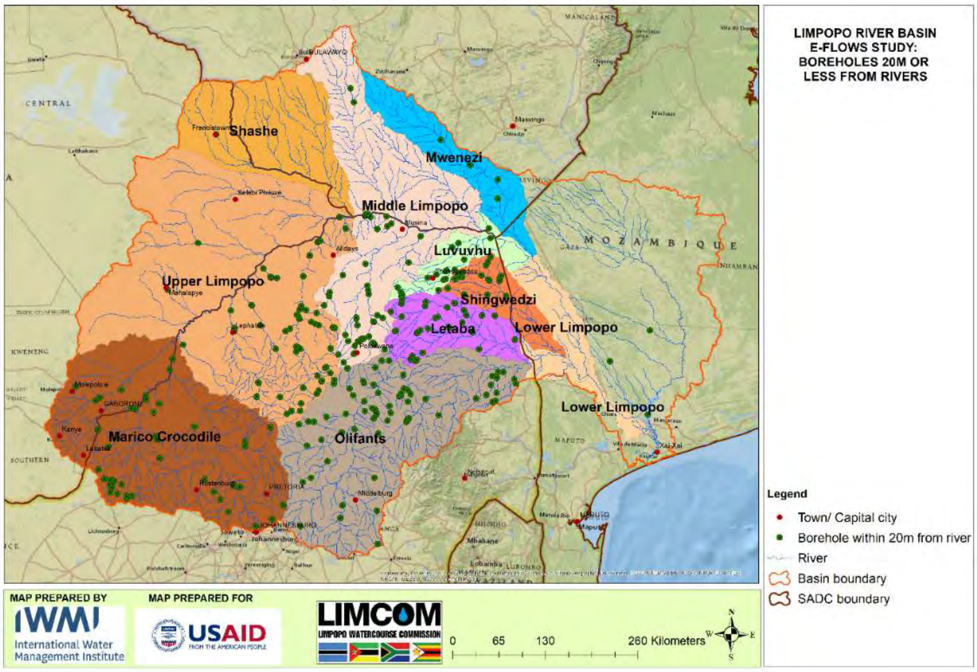


FIGURE 7: MAP OF THE LIMPOPO RIVER BASIN SHOWING BOREHOLES THAT ARE 20 METERS OR LESS FROM THE RIVERS.

BOX 3: DOMESTIC WATER PROVISION - EXAMPLES FROM THE SHASHE, MIDDLE LIMPOPO, OLIFANTS AND MWENEZI RISK REGIONS

Water abstraction for domestic use directly from the river, is a common practice in parts of the basin. In the Shashe, Middle Limpopo risk region and Mwenezi risk regions, in the Mzingwane, and parts of the Mwenezi sub basins, communities along the major rivers such as the Makakavhule, Umzingwane, Kwalu, Bgwemula, Zezani, Vutulula in Zimbabwe all get their water from Umzingwane River and directly from the Limpopo main stem. The Shashe, Jalukanga, Bili and Malibeng communities rely on water from the Shashe River (Interview #4). The Intunjambili wetland in the Tuli River sub basin supports just over 100 households supplying domestic water (Ndlovu, 2009; Interview #2). There are undoubtedly other numerous examples dotted throughout the Basin.

In the Olifants basin, the Mohlapitsi River, a tributary of the Olifants River, while not befitting significantly from the nearby GaMampa wetland dry season flows despite claims to the contrary (McCartney et al., 2011), communities here fetch water from the wetland and the river, the Mantlhane village particularly relies on the GaMampa wetland for domestic water supply (Adekola et al. 2008). In the Crocodile Marico risk region, communities are mobilising for the protection of the pristine Groot Marico – one of the last free flowing rivers in South Africa, which has been declared a National Freshwater Ecosystem Priority Area (NFEPA). This declaration ensures that people of the Koffiekraal community continue to benefit from the river's headwaters which are still clean and unpolluted (WRC 2012). In the lower Limpopo the Mabalane, Mapai, Chibuto communities abstract water for drinking from the minor tributary Jatingue (Interview #5).

3.4.2 SMALL - SCALE RAINFED AND IRRIGATED AGRICULTURE

Agriculture (commercial as well as small-scale farming) is one of the major activities in the Limpopo River Basin and uses more than half of the water abstracted making it the number one direct and indirect beneficiary of a combination of ES provided by ecosystems. There are a number of linkages to other ES that are necessary for agriculture to be possible; supporting services such as maintenance of soil fertility and biodiversity including micro-organisms and insects that pollinate plants; regulating services such as flood attenuation and flow regulation; and most importantly provisioning of water for irrigation are some of the significant ES that make agriculture possible. Rural people of the basin are predominantly dependent on small-scale agriculture such as floodplain cultivation for their livelihoods (see Box 4). Wetlands play a role in providing fertile and arable land that supports small-scale agriculture and irrigation activities. Wetland and irrigation areas in the Limpopo River Basin are shown in Figure 8.

3.4.3 LIVESTOCK FARMING

The Limpopo River Basin outside the protected and conservation areas is used mainly for livestock grazing and nearly half of the land area located in the basin in Zimbabwe and South Africa is classified as commercial farmland used for cattle ranching (FAO 2004). In Botswana and Mozambique communal grazing is dominant and usually uncontrolled (FAO 2004). Wetlands, rivers and streams support livestock farming and more especially rural livelihoods as expressed in Box 4, with these water-related ecosystem often providing the last remaining green vegetation during dry periods. Wetlands are also amongst the most nutritious of grazing destinations.

BOX 4: AGRICULTURE EXAMPLES FROM THE BASIN

Small-scale irrigated farming

Rural communities in the Limpopo rely significantly on small scale crop cultivation and livestock rearing for food and income generation. In a basin where over half of the population is rural, agriculture is a backbone for survival (Aurecon 2013). In Zimbabwe, irrigated small scale agriculture is dotted around the Mzingwane catchment. For example, Ndambe I is an irrigation scheme of 7 ha which draws water from boreholes drilled along Mzingwane River, and Ndambe II (18 ha) uses canals to draw water from the Zhovhe dam (Magombeyi, 2020; Figure 8). In the Shashe sub-basin small scale agriculture is prevalent both in Botswana and Zimbabwe.

CANAL IRRIGATION AT THE NDAMBE II SMALLHOLDER PLOT, ZIMBABWE (SOURCE: IWMI 2019)

In the lower Limpopo which lies mainly in the Gaza Province of Mozambique, flood recession agriculture is an important subsistence and economic activity. Fertile soils transported by the river support cultivation of crops such as tomatoes and maize. In downstream Mozambique, riparian and smallholder farming by rural households depend on river flows. In the flood plain wetlands of the Changane River, the Chibuto wetland (Mozambique) is used for agriculture producing vegetables, bananas, maize, and rice (Nagabhatla et al. 2008).

BOX 4: AGRICULTURE EXAMPLES FROM THE BASIN

Large scale irrigated farming

Along the Limpopo River main stem, irrigation supports large scale commercial agriculture in all four riparian countries. Large estates include the Nottingham Citrus Estate in Zimbabwe and Talana farms in Botswana. Talana farms are commercial farms located in the fertile Tuli Block region. Water for irrigation is pumped at the confluence of the Limpopo and Motloutse rivers through the Talana farms wellfield (Lentswe and Molwalefhe 2020). Within the Mapungubwe National Park, 10 commercial farms separated by fences from conservation areas depend solely of water directly from the Limpopo River main stem (Sinthumule 2014).

WATER BEING EXTRACTED FROM LIMPOPO RIVER INTO A NEARBY COMMERCIAL FARM, SOUTH AFRICA (SOURCE: SINTHUMULE 2014)

The state managed Chókwè irrigation scheme is the largest irrigation scheme in Mozambique. It is irrigated by water transported through a gravity system from the Massingir and Macarretane dams to sustain rice production making up over half of the nation's rice produce (Kajisa and Payongayong 2011). The Chokwe is thus of strategic importance to Mozambique from a food security perspective. The Government of Mozambique is committed to making the Limpopo Valley (100,000 ha), the country´s First Special Agricultural Economic Zone (Interview # 4). Irrigation schemes (Regadio do Baixo Limpopo) at Chókwè and Xai-Xai, presently cover 70,000 ha (Interview # 5). Under the controversial ProCana biofuels project, which has received scrutiny (Borras et al. 2011), 30,000 ha of sugarcane will be cultivated on the banks of the Elefantes River (Olifants River) (Interview # 5).

The Mwenezana Sugar Estate is a large Tongaat Hullet irrigation establishment supplied by water from the Manyuchi Dam on the Mwenezi River in Zimbabwe. It is worthwhile to note planned irrigation expansion both in Zimbabwe and Mozambique (Interview # 1; Interview # 5). In 1997, the Food and Agricultural Organization estimated total area under irrigation in the Limpopo to be around 244,000 ha with a potential to reach 295,400 ha (LBTC 2010), a development which may improve livelihoods but also potentially impact water availability in the Basin. However, a report by the International Water Management Institute (van Koppen et al., 2017), recorded in excess of 70,000 ha of informal irrigation in the Limpopo Province of South Africa, which falls largely within the Limpopo River Basin, suggesting that the FAO figure may be an underestimate. This informal irrigation was reported in the former homeland areas, made up mostly of black small-scale farmers.

Riparian small-scale agriculture and livestock grazing

Riparian (relating to the banks of a river) grazing is widespread along the banks of the Olifantes, Mzingwane, Shashe and Limpopo where during the winter months the riparian zones provide the only green foliage. River bank cultivation is a widespread livelihood activity for the Makakavhulele, Mzingwane, Kwalu, Bgwemula Zezani villages along the Mzingwane river in Zimbabwe. Some of this produce supplies the nearby Beitbridge urban market with fresh vegetable produce (Interview #4). Communities around the GaMampa wetlands (South Africa) practice small-scale agriculture and rely on the wetland and nearby rivers for watering livestock and crops.

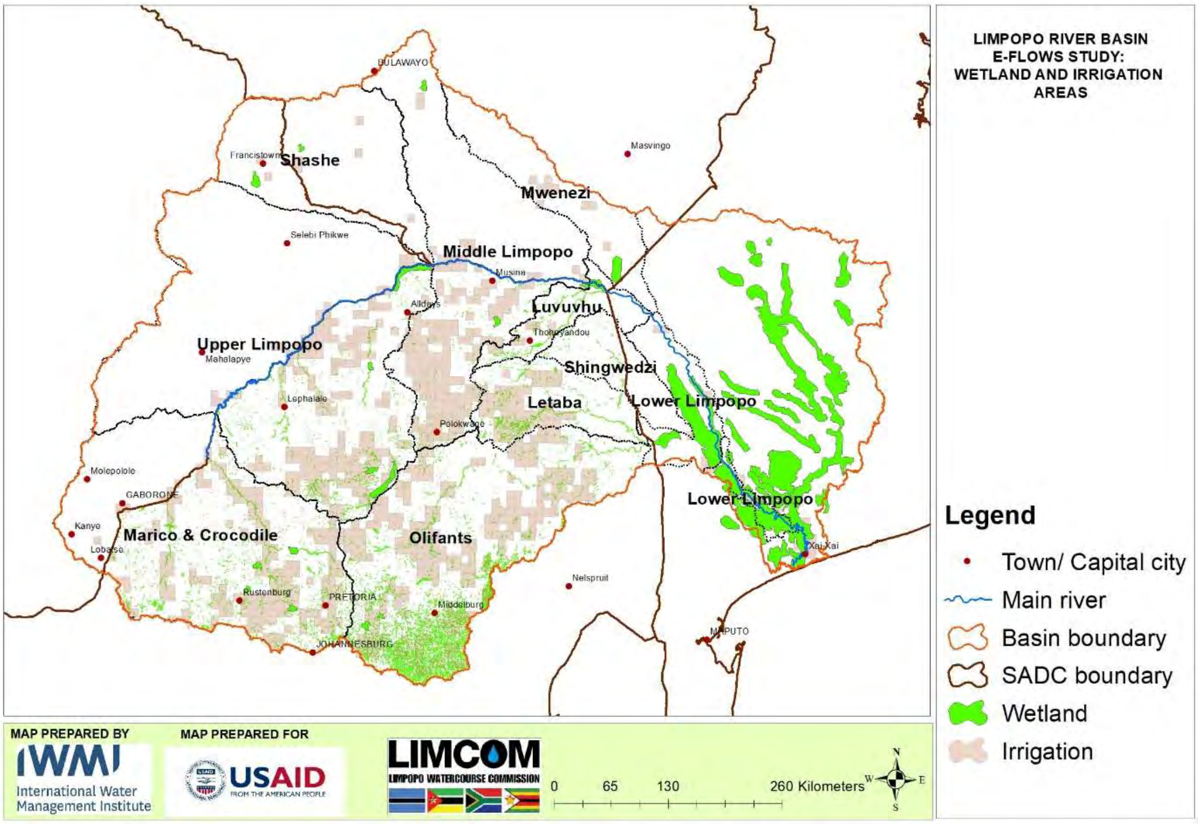


FIGURE 8: MAP OF THE LIMPOPO RIVER BASIN SHOWING WETLANDS AND IRRIGATED AREAS

3.4.4 FISHERIES

Cyprinids, catfish, tilapia, trout and several brakish-water species (found in the estuary in Mozambique) are the most common fish found in the Limpopo River Basin, which provide a source of income and protein to the basin people living near these watercourses (RAK 2020). The Limpopo River also supports a large number of mollusk species that can be harvested (Darwall et al. 2009). Seasonal flooding, river fluctuations and prolonged dry periods are major drivers of ecological transformation and fisheries productivity (FAO 2004). Many fish migrate onto the floodplains to breed during the first floods, spawning on the floodplains to provide juveniles with plenty of food and well oxygenated water and a secure habitat (World Bank 2015). The floodplain thus supports an abundant supply of fish which then supports local livelihoods as it becomes their major source of protein and income.

Fishing activities, both recreational and commercial are more extensive in dams. The Zimbabwe government has embarked on a project of introducing fish into reservoirs to stimulate aquaculture and foster livelihoods. The Zhovhe Dam on the Mzingwane is such an example where fish catch yields of up to 1,000 tonnes/annum are anticipated[8]. In Botswana,

[8] State media report: https://www.herald.co.zw/zhovhe-estate-eyes-1-000-tonnes-of-fish-annually/

fish, mainly bream species from the Gaborone, Letsibogo, Bokaa and Shashe dams contribute about 20% of the total national catch (FAO 2007). Mozambique has the highest per capita fish consumption at 11.4 kg per person per annum while Botswana has the lowest (Table 9), but all reflect a generally non-fish dependent population. The variable temperatures and water levels make Botswana less favorable for supporting a large fish poplulations. The lower zone of the Limpopo River system is important to Mozambique as its flows contribute to the productivity of the coastal brackish water area, where fish and shrimp production is significant. Subsistence and commercial fishing are carried out in the river basin at Rio dos Elefantes (Olifants River) -Massingir dam and estuary.

TABLE 9: COUNTRY LEVEL PER-CAPITA FISH CONSUMPTION IN THE LIMPOPO BASIN COUNTRIES (SOURCE FAO 2019, 2018, 2016)

LIMPOPO BASIN COUNTRY	PER CAPITA FISH CONSUMPTION IN KG/ANNUM
Botswana	3.7
Mozambique	11.4
South Africa	6.1
Zimbabwe	2.2

BOX 4: FISHING AND LIVELIHOODS - EXAMPLES FROM THE BASIN

The majority of tributaries of the Limpopo including the main stem itself are ephemeral, flowing only seasonally. Fishing actvities occur at local scale to a limited extent. In the Upper Mzingwane catchment, local communities continue to fish even as the river turns into puddles during the dry season and when there is still water in isolated ponds within the river (Interview #1; Interview #4). However, the amounts of fish obtained during the wet seasons are too low to contribute meaningfully to livelihoods and food requirements. Fishing is a widespread activity in the villages around the Shashe, Mzingwane and Mwenezi sub basins. Seasonal fishing in the Mutale and Limpopo Rivers were central to the livelihoods of people in the Bennde Mutale village before the communities were displaced by conservation activities (Whande 2007). With increasing loss of access to the river, fishing has become a restricted and illegal activity enforced by both security and conservation agencies (Whande 2007). In the Olifants catchment, local villages around the small GaMampa wetland harvest a total of about 70 kg of fish every year from the wetland for household consumption (Adekola et al. 2008).

3.4.5 OTHER PROVISIONING SERVICES

Besides the aforementioned, other provisioning services support rural livelihoods throughout the basin. Services such as fuel wood provide a primary energy source, which is crucial especially to the poor who cannot afford other forms of energy like electricity for domestic use like meal preparation. Services such as gold panning, sand and gravel mining and harvesting of riparian plants, reeds and medicinal herbs, provide the locals with some level of income and materials for construction of shelters and other life demands. Wild foods including honey, vegetables, wild fruits, mushrooms, certain grasses, roots and insects provide a good source of food and income. While the “Mopane worm” is a common food source across the region, its host the mopane tree cannot really be considered as riparian.

BOX 5: OTHER PROVISIONING SERVICES- EXAMPLES FROM THE BASIN

Gold panning, sand and gravel mining

Minerals, sand and gravel deposited by river floods, provide a source of construction material as well as support substantial informal gold panning activities along the riverbeds. While these activities have a detrimental effect on the river channel and for both aquatic and terrestrial ecosystems, their practice nonetheless supports the livelihoods of local communities. Gold panning is prevalent in the upper reaches of the Upper Mzingwane in the Zezani and Vutulula areas (Interview #2; Interview #3), while an increasing trend of sand and gravel mining to supply the construction industry has been observed along the Nzhelele river (Kori and Mathada 2012). Sand mining is common in the Makakavhule area on the Umzingwane River supplying construction works in the Beitbridge urban area. In Mozambique, sand mining takes place in Chibuto, while in South Africa it takes place along the Selati River, a tributary to the Olifants River.

Harvesting of riparian plants, reeds and medicinal herbs

Evidence of harvesting riparian vegetation for medicinal herbs and reeds in the Limpopo River Basin is limited. A few examples noted through stakeholder interactions suggest that these are not widespread activities. Harvesting of *ilala* for basket weaving and sweeping broom making is common in Shashe sub-basin but also not a widespread activity (Interview # 4). In Botswana, the Babirwa women engage in basket weaving using palm reeds (*Hyphaene petersiana*), a plant which grows in riparian areas (Blach-Overgaard et al. 2009).

BASKET WEAVING IS COMMON IN THE SHASHE SUB-BASIN, BOTSWANA (SOURCE: JULIA DAVIES, UNIVERSITY OF CAPE TOWN)

3.5 SUPPORTING SERVICES

Supporting ES are the services that are necessary in the production of other ES and play a crucial role to maintain them (Rodríguez 2005). They also contribute directly and indirectly to the wellbeing and livelihoods of people. The ability of ecosystems to provide habitat for species, produce biomass, soil and atmospheric oxygen are some of the likely supporting services, while the abundance of biodiversity my also be considered a supporting ES. However, there is little understanding and literature available on the interaction and quantification of supporting ES in relation to other ES. Based on a general understanding of supporting ES and evidence from the literature in areas with similar characteristics to the Limpopo River Basin, extrapolation of data and understanding to the Limpopo can be done.

3.5.1 PRIMARY PRODUCTION AND MAINTENANCE

The extensive vegetation biomes in the Limpopo Basin, i.e., as already mentioned earlier; Savanna (more than 60%) on the western side and Indian Ocean Coastal Belt on the eastern side (Mucina & Rutherford 2006; 2012) and Grassland occurring in the southern regions with a high density of seep wetland vegetation means a huge production of biomass, as well as production of atmospheric oxygen which is a by-product of the process of photosynthesis. This vegetation aids in soil formation and retention and nutrient cycling as the biomass decomposes and become part of the soil. Hydrologically, vegetation through transpiration also helps in water cycling (hydrological cycle) and also facilitates groundwater recharge.

3.5.2 PROVISION OF HABITAT AND BIODIVERSITY SUPPORT

Biodiversity (Box 6) is essential for the delivery of many ES and supports ecosystems functions and processes (Shackleton et al. 2008). The benefits of biodiversity and the support it provides to other ES cannot be overstated as it forms the very basis for nature-based tourism whilst providing important services that support livelihoods, including spiritual and emotional fulfilment; supporting and regulating services such as nutrient cycling and soil fertility, pollination, and carbon sequestration (Shackleton et al. 2008). Diversity at the genetic level, at species level and of ecosystems and habitats with predators and prey relations provide a level of organization and biological interaction that is important to ecosystems and their services (Coad et al., 2008). Implementation of e-flows is recognised as a powerful way of ensuring the continued supply of these vital ES, with biodiversity at the core.

BOX 6: BIODIVERSITY IN ARID AND SEMI-ARID SOUTHERN AFRICA. SOURCE (SHACKLETON ET AL. 2008).

Southern Africa is well known as a region of high biodiversity. This is hardly surprising given its large size and wide range of biomes and habitats; from coastal deserts in Namibia to tropical forests in Mozambique, large inland deltas and pans in Botswana and Namibia, to high mountains of Lesotho and South Africa. It is also home to the Cape Floral Kingdom, and many internationally recognised centres of endemism and species richness such as the Karoo and the Maputuland centre (e.g. Myers et al. 2000; van Wyk & Smith 2001). The southern African region south of the Zambezi and Kunene rivers as a whole comprises only 2.5 % of the world's terrestrial surface area, but boasts over 10 % of the world's vascular plants (approximately 30,000 species), of which over 60 % are endemic to the region (van Wyk & Smith 2001). Southern African savannas harbour approximately 8,500 plant species, more than half of which are endemic. Similarly, the Karoo and Kaokoveld contain over 7,000 plant species of which over two-thirds are endemic. Considering both richness and endemism of plants and vertebrates together, the arid ecoregion is classified as globally outstanding, and the savannas as bioregionally outstanding from a conservation perspective (Burgess et al. 2004). This overwhelming concentration of species offers unique potential for use of genetic and species diversity to support local livelihoods and alleviate poverty, whilst simultaneously posing many challenges for the seven developing countries charged with conserving such a rich and globally renowned heritage. Some 90 % of

4 SUMMARY

ES are vital to the livelihoods of people living in close association to the Limpopo River, while the millions of other inhabitants of the Basin who live some distance from the river, are ultimately also dependent in some way or other, even if this dependence is not obvious. Big cities such as Pretoria in South Africa, Gaborone and Francistown in Botswana, Bulawayo in Zimbabwe which is just outside the basin, and many more industrial and other economically important areas within the basin, benefit substantially from the ES provided by the Limpopo River Basin through the provision of services such as water, waste treatment, the well-being of the ~20million inhabitants who contribute to the economy of the basin, and so on. Some of these services are obvious and may attract more attention (especially the provisioning services), while others are less so but ultimately are just as important.

It is due to the complexity in understanding these other ES and how they interact with each other and contribute to livelihoods that has made them look less important. This perception is to be guarded against in the Limpopo Basin if true sustainable development is the vision (see Basin Report, IWMI 2020). It is thus important to preserve ecosystems and their associated biodiversity in order to continue benefiting in all of the ways illustrated above. Provision of e-flows is recognised as possibly the most powerful form of protecting aquatic ecosystems and the bulk of the ES that come from water-related ecosystems.

The lack of data on the scale and value of each of the ES in the Limpopo River Basin potentially impacts negatively on decision making regarding water-resource management in the basin. In the long run this might affect the sustainability of ecosystems and their potential to supply services to people living within the basin, thus posing a threat to livelihoods, socio-economic development and the environment at large. This e-flows project will contribute substantially to the development of the necessary data, but will only be valuable if taken futher into influence of policy and management plans.

5 KEY MESSAGES

- Wetlands, vegetation and the complex biodiversity existing in the Limpopo River Basin provide much of the ES that are of importance to the people living in it. These services include fresh water, food and genetic resources under **provisioning**; regulation of flow, floods and climate, water purification and carbon storage under **regulating**; social relation and aesthetic values under **cultural**; biomass and oxygen production, water cycling, provisioning of habitat and soil formation under **supporting** services.
- Across the Limpopo River Basin, rural communities primarily depend on provisioning ES, obtaining such products as drinking water, water for crop and livestock agriculture as well as for fishing and aquaculture. Riparian agriculture as well as small-scale, irrigated agriculture form an important means of food and income in the Mzingwane, Shashe and Lower Limpopo sub basins. The highly developed (agriculture, mining, urban areas) areas of the Marico Crocodile risk region have resulted in significant pollution downstream (wastewater discharge and agriculture return flows) and as such only a few communities e.g. around the Groot Marico, directly abstract water from the river for domestic use.
- Large scale irrigation is prevalent along the main stem of the Limpopo, with both surface and groundwater being abstracted to support commercial agriculture in the Lower and Middle Limpopo risk regions. Wells near to the river may affect the subsurface flow contribution to environmental water requirements.
- The prevalence of certain activities is more in some areas of the basin than others for example, reed harvesting for basket weaving is mostly reported in the Shashe risk region.
- River fishing is limited due to the ephemeral nature of the tributaries in the Limpopo River Basin, while most fishing activities are economically significant in the many man-made reservoirs.
- Dams in the basin also support recreation and tourism activities e.g. Loskop and Zhovhe Dams.
- Ecotourism is an important livelihood activity in the basin owing to its rich animal and plant biodiversity. Conservation activities are thus widespread attracting tourists and generating income.
- In order to have a clear picture of the status and value of the ES there is need for census data at the basin scale including but not limited to; remote sensing, field-based estimations, community monitoring, stakeholder consultations and models.

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ANNEXURES

STAKEHOLDER ENGAGEMENT REGISTER

NAME	DESIGNATION	ORGANISATION	COUNTRY	DETAILS OF MEETING	RISK REGION / SUB-BASIN OF FOCUS
Interview #1	Coordinator Transboundary Water Resources Management	Ministry of Land Agriculture and Climate Change	Zimbabwe	MS Teams 18 August 2020	Mzingwane/Shashe/Mwenezi
Interview #2	Director	Dabane Trust NGO	Zimbabwe	Zoom meeting 9 August 2020	Mzingwane
Interview #3	Scientist: Aquatic Ecology	SANPARKS, Kruger National Park	South Africa,	WhatsApp call 21 August 2020	Olifants
Interview # 4	Rural District Council (Head of Technical/Engineering Services	Beitbridge Rural District Council	Zimbabwe	Questionnaire Received 26 August 2020	Mzingwane
Interview #5	Biologist	Ministry of Public Works Housing and Water Resources	Mozambique Department of River Basin Management (DGBH)	Questionnaire Received 1 September 2020	Lower Limpopo

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