Republic of Mozambique and Republic of Zimbabwe

The Save River basin – a shared water resource

Monograph

December 2011

Supported by

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The consultancy for the project is carried out by COWI A/S in association with SWECO International, Interconsult Zimbabwe, CONSULTEC Consultores Associados and AustralCOWI.

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Acronyms and abbreviations

AGEP Annual Groundwater Exploitation Potential

ARA Regional Water Administration (Mozambique)

ARD Acid Rock Drainage

ARDA Agricultural Rural Development Authority (Zimbabwe)

AREX Agricultural Extension Service (Zimbabwe)

ASM Artesanal and Small-scale Mining

BOD Biological oxygen demand

CAN National Water Council

COD Chemical oxygen demand

CSO Central Statistics Office (now ZimStats)

DEM Digital Elevation Model

DNA National Water Directorate (Mozambique)

DWR Department of Water Resources (Zimbabwe)

EIA Environmental Impact Assessment

EKIS Enhanced Knowledge and Information System

EMA Environmental Management Authority (Zimbabwe)

FIPAG Water Supply Investment and Assets Fund (Mozambique)

GCM Global climate model

GIS Geographic Information System

IWRM Integrated Water Resources Management

MAR Mean Annual Runoff

$Mm^3 = Hm^3 = 1000$ Ml

MOPH Ministry of Public Works and Housing

NGO	Non-Governmental Organisation
RMF	Regional Maximum Flow
RSOP	River system outline plan
SADC	Southern African Development Community
TDS	Total dissolved solids
TSS	Total suspended solids
ZINWA	Zimbabwe National Water Authority

Executive summary

The monograph

The aim of this monograph is to present an overview of the characteristics of the Save River basin and highlight the issues that are of basin-wide importance. The monograph was presented to the PSC and accepted at a workshop that concluded the first phase of the project. Development scenarios will be examined in the next phase and eventually lead to the formulation of a joint strategy for the basin.

The monograph consists of this document and four annexes that provide detailed information on the environment, the socio-economic profile, the water resources and an assessment of the current water use and future demand.

The basin

The Save River originates in the Hwedza Mountain Range just south of Marondera town while the Odzi River, a major tributary begins in Zimbabwe's Eastern Highlands. The river runs south and merges with the Runde coming from the west before it passes through Mozambique on its way to the sea. The basin is 102,000 km^2 of which 83% lies in Zimbabwe.

The people

The population numbers 3.2 million of which 97% live in Zimbabwe. Most people are occupied in subsistence agriculture, commercial agriculture and mining. In Zimbabwe the basin hosts cities like Mutare and Masvingo and the economy and the infrastructure is more developed than in Mozambique. However, poverty is widespread in both countries.

Land use

Analysis of Landsat imagery established that 33% of the land is used for agriculture, while the remainder is largely forest (26%) or different forms of bush, scrub or grassland (38%). There are two national parks in the basin (Gonarezhou and Zinave) and a number of other protected areas. Dambos and other wetlands are particularly valuable for biodiversity.

Surface water

The mean annual rainfall is 685 mm. For most of the basin, rainfall is highly variable and unpredictable, but in general the dry season is about 8 months and dry season river flows are low. The total surface water resource was estimated at 6,885 Mm^3/yr, which is the amount of water that would enter the sea if there were no abstractions. The estimate is about 10% lower than the estimates currently used by ZINWA.

Groundwater

Groundwater is widely used for household supply and small water works. In the mid Save alluvial deposits groundwater is also used for irrigation. 79% of the

basin has a very low groundwater potential. The exploitable groundwater resource is estimated at 1,900 Mm^3/yr.

Climate change

The impact of climate change is uncertain, but it appears most likely that rainfall will decrease in Zimbabwe and increase in Mozambique. Contrary to recent experience climate models predict that the frequency of cyclones will decrease.

Water use

Access to safe water and sanitation is expanding, but remains a problem in many parts of the basin.

The water resources are well developed in Zimbabwe where a number of reservoirs and canals deliver water to intensive commercial agriculture such as sugar cane, to smaller irrigation schemes and to urban water supply. Further schemes have been proposed and feasibility studies have previously been carried out to different levels. In Mozambique the natural conditions are less suited for construction of reservoirs and the basin is currently undeveloped with hardly any irrigation. Overall irrigation accounts for 87% of the water consumption and livestock for another 8%.

The current water demand, exclusive of environmental flow, is estimated at sub-zone level and the total is 4,114 Mm^3/yr. For irrigation, this estimate is partly based on the 10%-yield of the large reservoirs. The 10%-yield is the amount of water the reservoir can deliver in 9 years out of 10, and most irrigation projects are designed based on this. Due to the economic situation in Zimbabwe the present water use is somewhat lower, but it is expected that the yield will be fully utilised by 2015. A map shows areas where the estimated resource exceeds demand and where there is a deficit.

The projected increase until 2030 is 53%. The demand can only be met if there is a large investment in storage capacity. The figure is also very high in comparison with the estimated surface water resource and needs to be examined more closely in the scenario phase.

Water quality

Surface water quality is good in parts of the river system, but generally it is not. The main causes are non-functioning urban wastewater treatment plants and inadequate sewerage which results in discharge of very polluted water that is a health hazard for downstream water users and affects the environment. Mining is in many places associated with acid rock drainage and artisanal gold panning causes pollution with mercury, which also is a health hazard to the miners. Other sources of pollution are the intensive agricultural production in parts of the basin.

Floods

The basin has experienced devastating flood as those caused by Cyclone Eline in 2000 when more than 30,000 inhabitants had to be evacuated from the coastal part of the basin.

Water governance

In terms of water governance both countries base water resource management on integrated river basin management principles and include stakeholder in-

volvement. At regional level both countries are committed to the SADC protocols and policies for shared watercourses.

Key issues

The monograph concludes with a list of issues that may be examined during the scenario development phase:

- Access to safe water
- Water resources development and water balance
- Flood and drought management
- Urban wastewater management
- Mining impacts
- Erosion and sedimentation

1 Introduction

1.1 Background

The Southern Africa Development Community (SADC) and its member states are convinced of the need for co-ordinated and environmentally sound development of the shared watercourses in the region in order to support sustainable socio-economic development. This is expressed in a protocol and in strategies and action plans.

In line with this, SADC has received a grant from the African Development Fund to finance the Shared Water-Courses Support Project for the Buzi, Ruvuma and Save River basins.

The Development of a Monograph and Strategy for the Save River Basin is one of the components of this project. It is executed by the SADC Secretariat through its Water Division, and implemented through ZINWA Runde and ZINWA Save in Zimbabwe, and ARA Centro in Mozambique.

1.2 Process

The project consists of three phases. The preparation of the monograph is the first phase as the monograph will constitute the basis for the subsequent work on scenarios and formulation of a development strategy for the shared water resources.

In addition the project works on an Enhanced Knowledge and Information System, EKIS, and on community based mini-projects.

1.3 Content

The monograph describes the basin, the socio-economic setting, the water resources, the water uses and the environmental issues in the basin that relate to water.

The monograph is structured as a main report which provides an overview and identifies key issues pertaining to water resources management that may be addressed in the strategy.

Four annexes cover specific subjects in more detail:

- Environmental profile
- Socio-economic profile
- Water resources
- Water demand

The annexes have been written so that they can be read as stand-alone documents. At the same time they provide the documentation for the main report and contain full references, while in the main report references have been kept to a minimum.

A geographic database has also been developed by the team.

1.4 Contributors

The monograph has been prepared by a team of consultants from Mozambique and Zimbabwe and international specialists.

The team has benefitted from consultations with a great number of government officials and others in the two basin countries. The assistance rendered is highly appreciated.

2 The Save River basin

2.1 Overview

The Save River basin has a total area of 102,000 km^2 of which 83% lies in Zimbabwe and the remainder in Mozambique[1]. A map of the basin is shown in Figure 1 below.

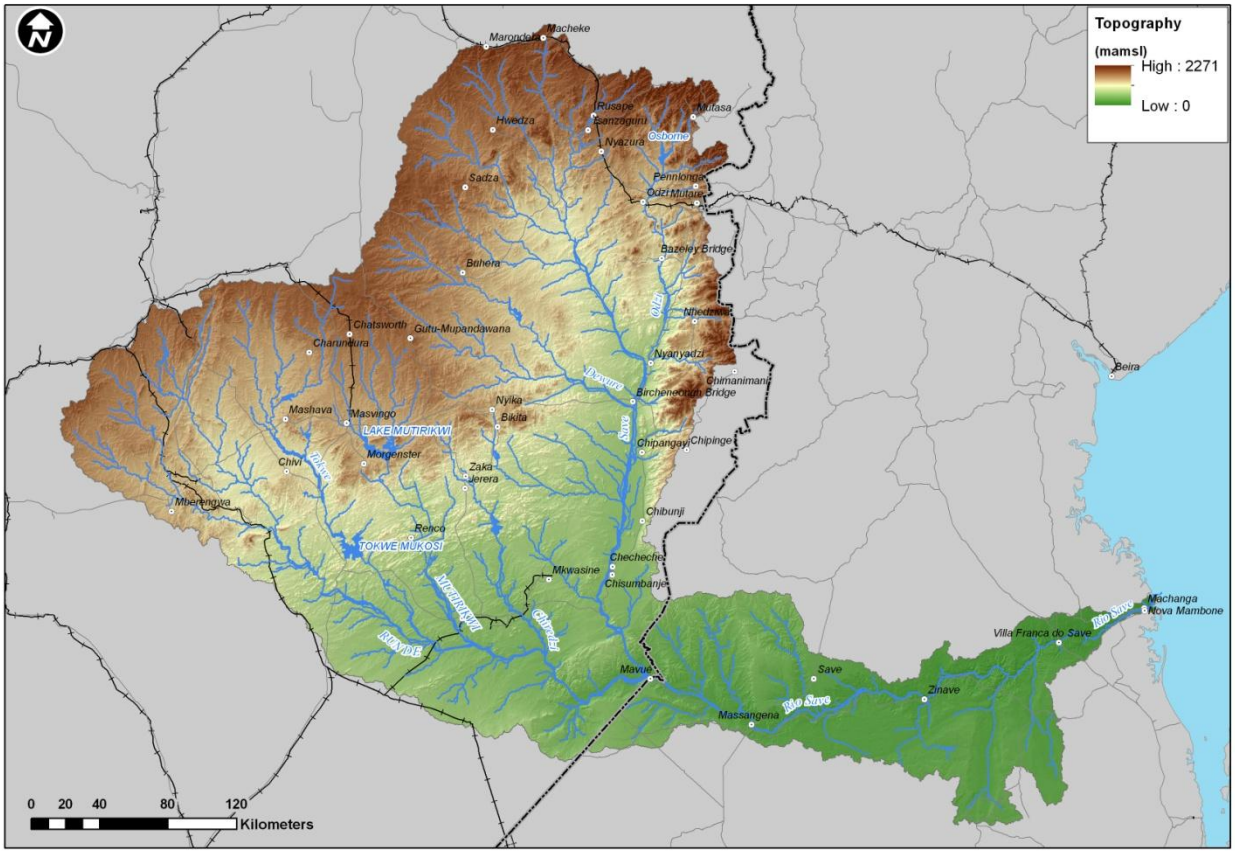

Figure 1 Topographic map of the Save River basin

[1] Unless otherwise indicated, all estimates of the river basin areas used in this report are based on our GIS analysis. Slightly different figures are used in the literature.

In Zimbabwe the basin stretches as far west as the vicinity of the town of Gweru. The north the edge of the basin extends to the town of Marondera, about 75 km southeast of Harare. The eastern boundary of the basin coincides with the Zimbabwe-Mozambique border from the town of Mutare in the north and southwards through the Chimanimani Hills, which form a major north-south oriented watershed, until some 100 km further south, where the Save river turns eastwards and crosses into Mozambique.

In Zimbabwe the Save River basin covers approximately 22% of the country's land area. It consists of two catchments, the Save and Runde, which are roughly the same size. The Save River drains the northeastern part of the basin while the Runde drains the western part of the basin.

In Mozambique the basin consists of a 50-100 km wide strip of land extending eastward until the river flows into the Indian Ocean. In Mozambique the basin covers an area of 17,300 km^2, or about 2% of the land area of the country.

2.2 Geology

The northern and western part of the basin is geologically part of an old and stable tectonic plate (craton) and the geology is generally younger the further southwards and eastwards. A simplified geological map is found in Figure 2 and a more detailed map in Annex 1. Soils types are described in Annex 1 Section 3.3.

Central region

The highlands of the northern and western parts are thus underlain by granites, migmatites and gneisses (3200–2500 million years). Interspaced in these are ancient greenstone belts, ultramafic complexes, alkaline ring complexes and intrusive dolerites which criss-cross the terrain in the form of sills and dykes.

Great Dyke

In the west, the basin covers a section of the North-South trending Great Dyke (2575 million years), which is a unique and large ultramafic, layered igneous complex. It has a width of 5 to 20 km and stretches more than 500 kilometres in a north-south direction.

Save-Limpopo

Further southeast, the geology changes into meta-sedimentary rocks belonging to the Limpopo Belt (early Proterozoic, that is <2500 million years), which are followed by Karoo (200 million years) volcanic rocks further south, and then by more recent sediments and soils in the low-lying areas.

Eastern highlands

The Save River originates in a relatively high-lying plateau 1,000-1,750 m above sea level. The plateau is underlain by cratonic granites and gneisses. This plateau area also included rounded hills, underlain by younger granites (2.5 billion years old). To the south of Mutare, the elevation drops relatively rapidly to an elevation of about 750 meters, after which the river flows along a flat valley underlain by granites.

To the south of the Birchenough Bridge the river valley narrows as it enters into an area underlain by Karoo age volcanic rocks, and the river descends fur-

ther, from 500 to 250 metres. The valley and flood plains are covered by recent (less than 1 million years old) alluvial sediments.

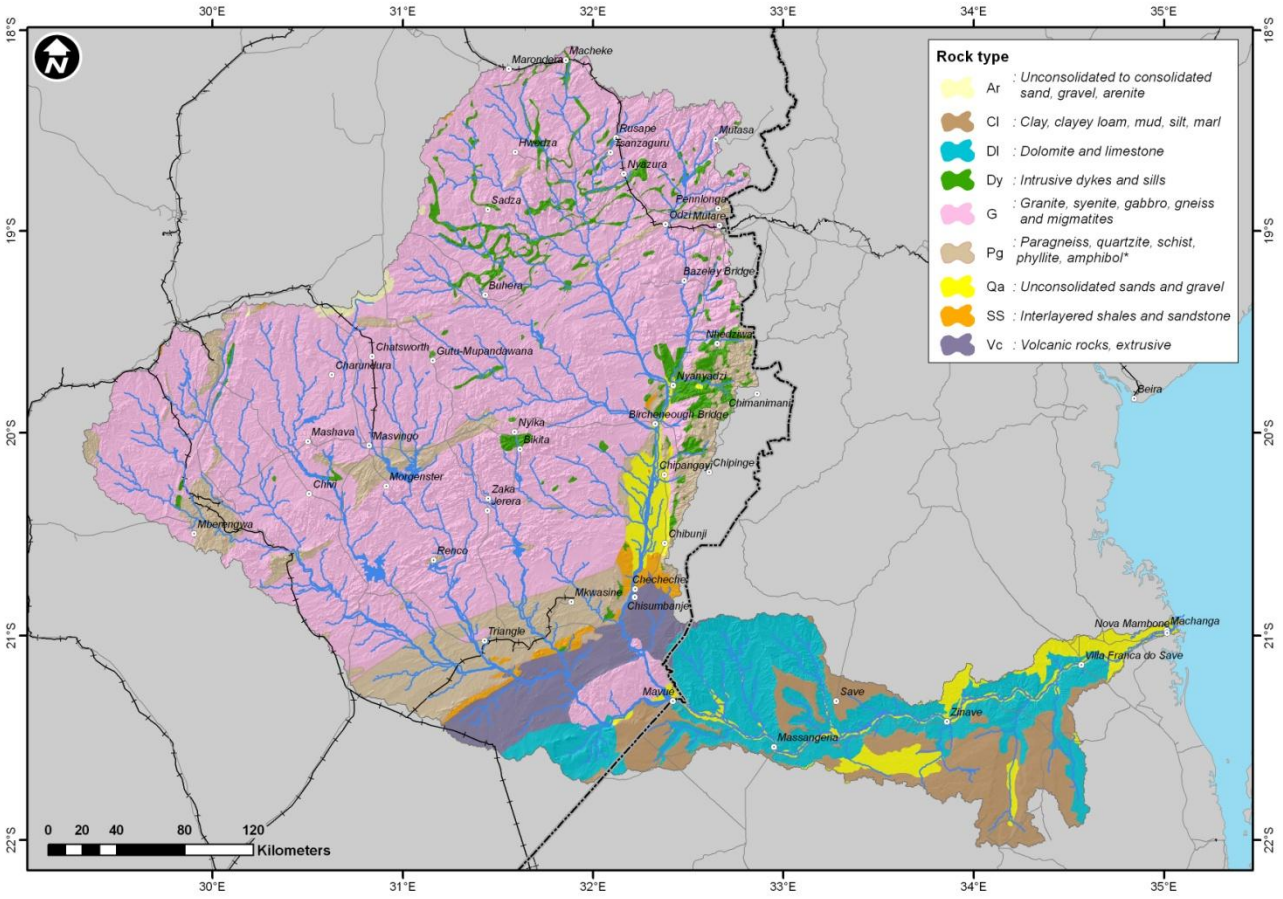

Figure 2 Geology of the Save River basin (SADC Hydrogeological Map, Sweco et al., 2010)

Southeast

In the southeast, the Save Basin is drained by a few large rivers, most notably among which are the Tokwe and the Rundu. These rivers originate in the central plateau which is defined by the cratonic gneisses and granites. In this area, there are also the intrusive rocks of the Great Dyke. Further southeast, the geology changes into meta-sedimentary rocks of the Limpopo Belt before flowing over Karoo volcanic rocks for the last 70 km to the border with Mozambique

Mozambique

In Mozambique, the Save River flows over a relatively flat area less than 250 meters above sea level. The river valley here is defined by young sedimentary sandstone and calcareous rocks about 100 million years old, as well as some younger sandstones and limestones (less than 30 million years old). The last 50 km of the basin is defined by flat-lying sand and coastal dunes.

Mineralisations

The main mineralisations in the basin are found in the greenstone terrains, in the Great Dyke and associated with serpentine and ultramafic complexes. The Great Dyke hosts deposits of chromite and platinum group elements. Serpentinite and ultramafic complexes are found associated with the Masvingo, Bel-

ingwe and Gweru-Shurugwi greenstone belts. In these there are important deposits of asbestos and chromite.

2.3 Climate

There are distinct climatic differences in the basin which may be described into three regions:

- Zimbabwean Eastern Highlands
- Highveld
- Lowveld

The mean annual temperatures are shown in Figure 3 below while the distribution of annual rainfall in the Save basin is shown in Figure 4. Monthly data are mapped in Annex 1. The maps are based on data from the Climate Research Unit, UK (New *et al*., 2002). Evaporation and runoff are discussed in more detail in chapter 6 and in Annex 3.

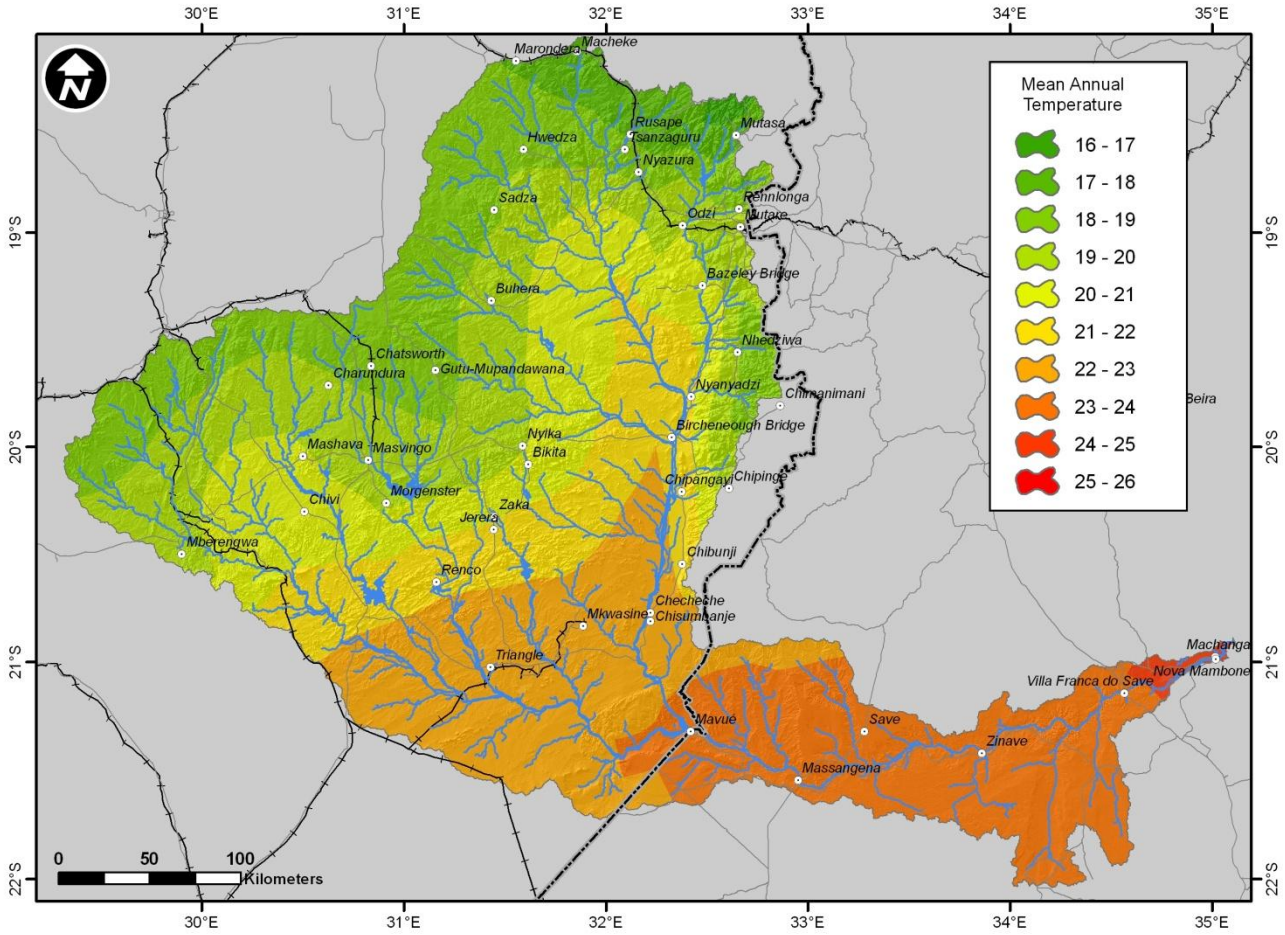

Figure 3 Mean temperatures

Highlands

The Zimbabwean Eastern Highlands is temperate and mountainous. As the south-easterly monsoon blows from the Indian Ocean across Mozambique it drops its moisture in the mountains which therefore has a high and predictable rainfall of up to 2000 mm/year.

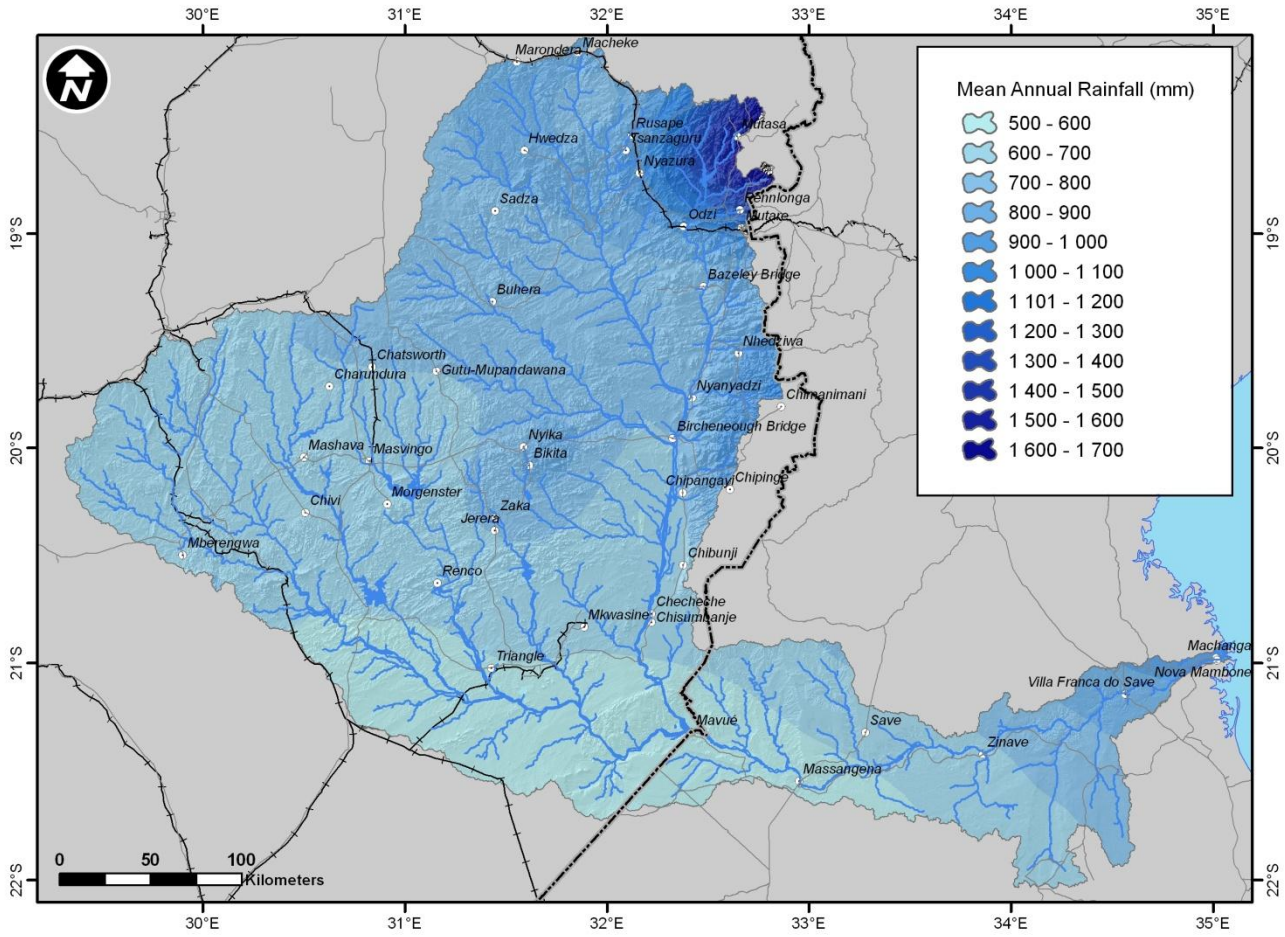

Figure 4 *Rainfall distribution in the Save basin*

Highveld

The Save continues across the Highveld, which is a plateau over 600 m altitude. The climate is tropical or subtropical but relatively cool due to the altitude. There is a warm rainy season (November to March) followed by a cool, dry season (April to mid-August) and then a hot, dry season (mid-August to October).

Lowveld

From the Highveld, the Save flows to the Lowveld where the climate is generally warm and humid. The basin is in the southern inter-tropical zone and is influenced by the anticyclone area in the Indian Ocean. There are two seasons; a hot and humid season from October/November until March/April and a cooler and drier season from April/May to October/November.

The rainfall here is extremely variable and drought is the norm although severe floods do occur from time to time.

2.4 Land cover

Figure 5 below provides an overview of the land cover in the basin

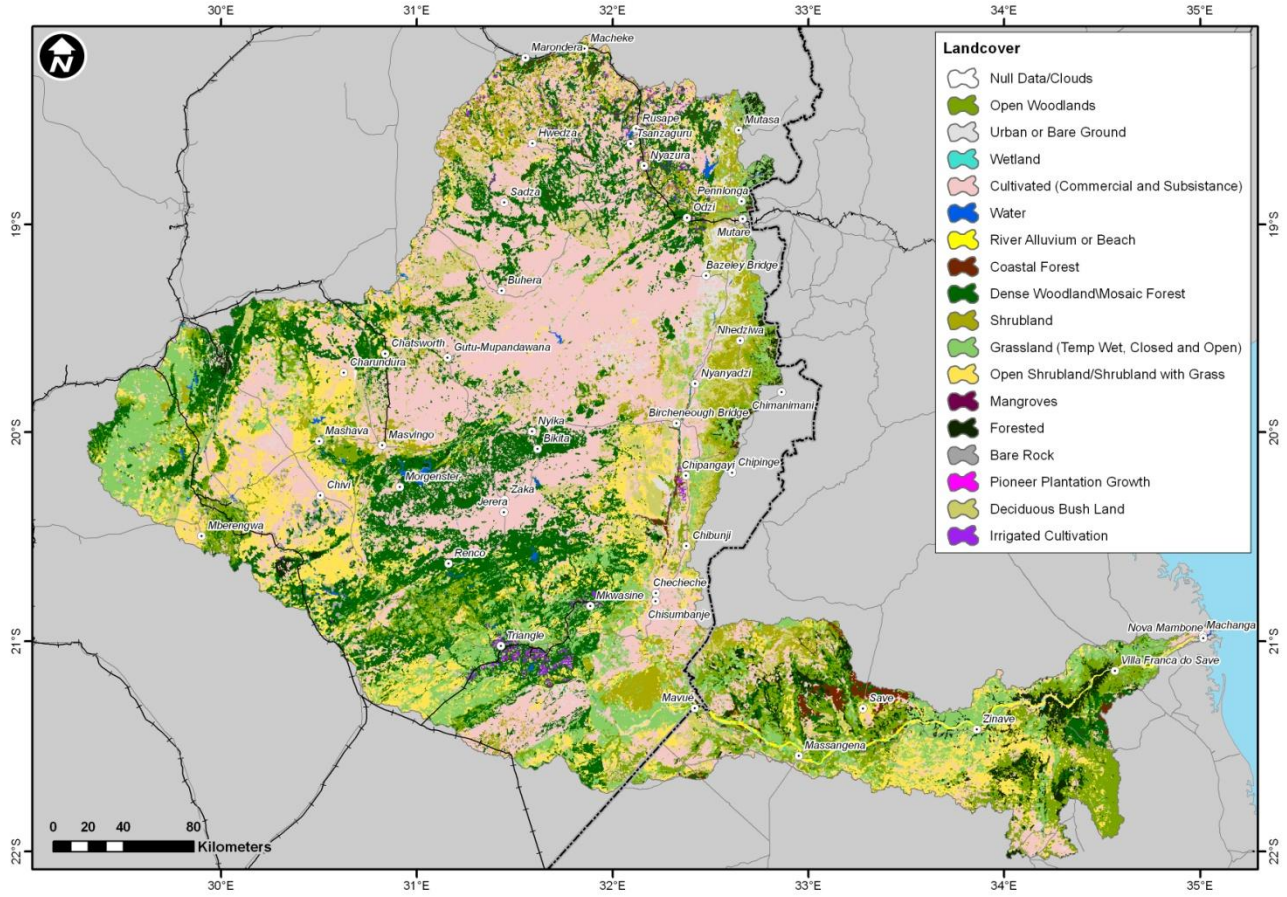

Figure 5 Main forms of land cover in the basin

The map in Figure 5 is based on a dataset generated by the Monograph team from 2007 *Landsat* satellite imagery. The methodology is described in Annex 1 which also contains detailed maps.

The dominant land use in the basin is agriculture, which accounts for 33% of the land cover; the remainder is largely forest (26%) or different forms of bush land, scrubland or grassland (38%).

2.5 Ecological regions and land use

2.5.1 Classification

The basin falls within seven terrestrial eco-regions defined by WWF and shown on Figure 6 below.

The freshwater ecosystems are described in chapter 4.

Land use is described in more detail in Annex 1 which also contains a vegetation map prepared by the consultants based on remote sensing imagery.

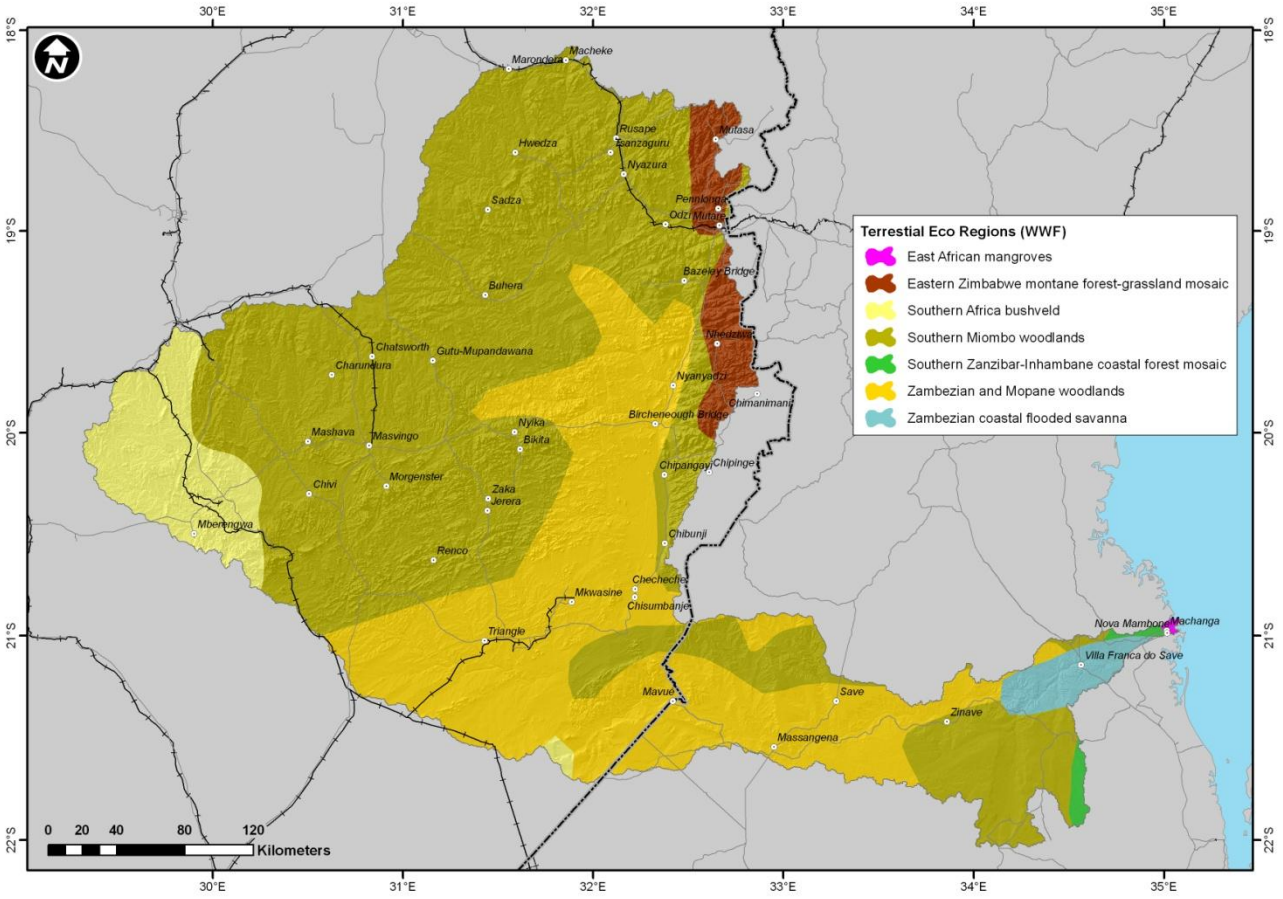

Figure 6 Terrestrial eco-regions (WWF)

2.5.2 Classification of eco-regions, Zimbabwe

The terrestrial eco-regions defined by WWF correspond to eco-regions defined for Zimbabwe as shown in Table 1.

Table 1 Eco-regions in the basin

WWF terrestrial eco-region	Zimbabwe eco-regions
Southern miombo woodland	Central
Zambezian and mopane	Central, Zambezi and Save Limpopo
Southern Africa bushveld	Central and Save Limpopo
Eastern Zimbabwe montane forest-grassland	Eastern Highlands

The Save basin lies mainly in the Save-Limpopo eco-region, the Central eco-region and a small part in the Eastern Highlands eco-region.

Eastern highlands

This eco-region occupies the central portion of Zimbabwe's eastern boundary with Mozambique. It forms a narrow belt of mountainous landscape with a north-southern orientation along the Zimbabwe – Mozambique border.

The vegetation is mainly moist forest and upland grassland. Forest areas consisting of high, medium and low altitude forest areas. The grassland or submontane grassland comprises open grassy hills.

A large portion of the eastern highlights consists of alien species such as the Black Wattle, Mexican Pine and Australian black wood which are grown commercially. In most parts of the eastern highlands these exotic species have invaded and suppresses indigenous species.

Land use consists of agricultural activities that include large-scale plantations of tea, coffee, exotic forests (pines and wattle), horticultural crops such as apples, peaches, bananas and yams and dairy farming (Chipinge).

Central eco-region

The central eco-region includes the Highveld and the central watershed. The eco-region is a broad, high altitude area centred along the northeast trending ridge, stretching from Plumtree to Chivhu to Rusape and northwards through Harare to Guruve. The eco-region is the largest of the five eco-regions with a total area of approximately half the country (Chenje *et al*., 1998).

This eco-region consists of:

- Higher area above 1,500 m, including Harare-Rusape and the higher altitudes of Ndanga-Bikita highlands
- Lower area below 1,500 m
- The Great Dyke

One of the key landforms in the central eco-region is the Great Dyke which is rich in mineral resources.

The main vegetation is the Zambezian miombo woodland dominated by Msasa and Munondo. The woodland is normally between 6-10 m high with a discontinuous layer of shrubs, herbs and grasses in wetter regions (Chenje *et al*, 1998). In dryer areas vegetation consists of 2-6 m high tree and shrub savannah consisting mainly of *Acacia spp* and *Combretum spp*.

Main land uses in this eco-region are cattle ranching (e.g. Mwenezi), intensive crop production and dairy farming (e.g. Marondera, Rusape).

Save – Limpopo

This eco-region consists mainly of flat landscape, with an average landscape of between 300-900 m above sea-level. On the deep fertile soils the vegetation is tree savannah, while on shallower soils it is the shrub savannah. Vegetation is

between 2-6 meters high with sparse grass cover consisting of Lovegrasses. Other species in the eco-region are the Fever tree and Illa Palm along the river valleys and on pans. Mopane is common on salt-rich soils in the low altitude hot areas as is Baobab (Figure 7), Marula, *Combretum spp*, *Acacia spp* and *Terminalia spp*. (Chenje et al, 1998).

The main land use is tourism, mainly in the Gonarezhou National Park which covers almost 60% of the eco-region.

Other large-scale land uses are large-scale cropping under cultivation, i.e. large plantations of sugar cane, cotton and citrus fruits on Triangle, Hippo Valley and Mkwasini Estates. Chiredzi and Hippo Valley as well as Mkwasini Estates account for 41,470 ha of irrigated land in Masvingo Province (Scones *et al.*, 2010). Water for irrigation for these plantations is obtained from Lake Mutirikwi in Masvingo, Manyuchi dam in Mwenezi, Muzhwi dam in Tokwe and Manjirenji Dam. The Manyuchi Dam supplies the Mwenezi Estates which is a stand-alone unit in Triangle. There is also significant cane development for green fuels in the Middle Save and Chisumbanje Estates supplied by the Rusape Dam, Osborne Dam and Siya Dam.

Dryland farming includes the cultivation of drought-tolerant small grains such as sorghum and millet. Small gardens, either next to a homestead or along a river or stream are common as a source of livelihood and subsistence.

Figure 7 Baobabs are a characteristic landscape element

2.5.3 Ecology and vegetation, Mozambique

Sandveld

The sandy plains that make up the majority of the inland area, including the Zinave National Park, are vegetated by Mopani veld and a number of vegetation types and in general, this can be described as sandveld vegetation.

Sandveld areas are very rare within Zimbabwe, making them important areas for biodiversity conservation. Grasses consist of both perennial and annual species, their proportions depending on rainfall and grazing pressure. Production of grasses can vary tenfold from one year to the next in response to rainfall variability.

Within the sandveld, shallow ephemeral pans are a common feature. These are sometimes sodic. They are normally fringed by grassland (MITUR, 2003).

The major land use in this part of the basin is agriculture. Most of the land is operated under intercropping of food crops, including maize, cassava, cowpea, peanut, sweet potato and rice. The basin also has a large number of fruit trees, coconut palms and cashew. The sale of timber, firewood, reeds and coal are another important source of income for people in the basin (MAE, 2005).

Mangrove

Mangrove forests and bush and dunes colonise the coastal area.

3 The people and the economy

3.1 Settlements

The population in the Save River basin lives in rural communities, small towns, a few urban centres and provincial capitals, business centres, estates, plantations and commercial farms.

A map of the administrative districts is found in Annex 2 (Figure 13).

Zimbabwe

The most important towns and cities in the basin are Mutare, Masvingo, Zvishavane, Shurugwi and Chiredzi. Some towns, such as Zvishavane, are organised around mines and other large settlements are the sugar estates in Chiredzi and Triangle.

A growing number of people are moving into urban centres in search of employment and a higher standard of living, but in 2002 about 85% still lived in rural areas and in growth points (Figure 8). Important rural areas are Chipinge, Mutare Rural, Buhera and Chiredzi districts.

Figure 8 Nyanyadzi, a growth point north of Birchenough Bridge

At district level there are economic hubs known as growth points which are similar to small towns. Growth points are run by rural district councils. The settlements are mainly found along or near main roads, water sources or in areas of high agricultural production.

Figure 9 Rural settlement, Mozambique (near Jassefa, Mabote District)

Mozambique

In Mozambique larger settlements are Massangena near the border with Zimbabwe and Nova Mambone (Figure 10) at the coast. However, most people live in scattered rural village communities (Figure 9).

Figure 10 Nova Mambone, Mozambique

3.2 Population

Zimbabwe

The Zimbabwean population in the basin in 2010 has been estimated at approximately 3,070,000. This figure is based on the census carried out in 2002 by the Central Statistics Office (CSO). Estimates for 2010 have been projected from the 2002 census data using the official CSO natural rate of increase of 1.01%. The population living in the basin was estimated for each ward based on

the area of the ward within the hydrological unit (a map is included in Annex 2 Figure 13). The estimated basin population is presented in Table 2.

Table 2 Population in the Save River basin, Zimbabwe

Province	District	Total population 2002	Population in basin 2002	Population in basin 2010
Manicaland	Buhera	404,053	220,051	238,472
	Chimanimani	114,071	62,572	67,811
	Chipinge	325,941	176,068	190,808
	Makoni	398,779	176,282	191,039
	Mutare	459,132	209,499	227,037
	Mutare Urban	340,932	158,317	171,571
	Mutasa	123,135	68,687	74,437
	Nyanga	20,246	4,985	5,402
	Rusape	25,014	25,014	27,108
Manicaland Total		**2,211,303**	**1,101,475**	**1,193,685**
Mashonaland East	Chikomba	187,732	90,364	97,929
	Hwedza	174,685	66,067	71,598
	Marondera	100,329	38,891	42,147
	Marondera Urb	51,847	33,127	35,900
	Murehwa	11,109	6,685	7,245
	Seke	1,982	100	108
Mashonaland East Total		**527,684**	**235,235**	**254,927**
Masvingo	Bikita	263,771	157,840	171,054
	Chiredzi	483,642	172,840	186,431
	Chivi	302,358	159,360	172,701
	Gutu	357,895	200,125	216,878
	Masvingo	459,408	194,468	210,748
	Masvingo Urb	69,490	69,490	75,307
	Mwenezi	97,495	47,721	51,715
	Zaka	387,433	185,100	200,596
Masvingo Total		**2,421,492**	**1,186,133**	**1,285,429**
Matabeleland South	Insiza	47,496	11,037	11,961
Matabeleland South Total		**47,496**	**11,037**	**11,961**
Midlands	Chirumanzu	125,498	50,716	54,961
	Gweru	60,642	7,058	7,649
	Mberengwa	108,951	53,152	57,580
	Shurugwi	184,816	73,064	79,180
	Shurugwi Urban	33,726	16,863	18,275
	Zvishavane	141,765	64,800	70,225
	Zvishavane Urb	35,128	35,128	38,069
Midlands Total		**690,526**	**300,761**	**325,939**
Grand Total		**5,898,501**	**2,834,640**	**3,071,941**

Source: Consultant's estimates based on CSO, 2002

Mozambique

In Mozambique, six districts in four provinces fall partly within the Save basin. Within these districts, 11 administrative posts are fully or partly located within

the basin. The 2010 population in the basin was estimated based on the 2007 census using the same area-based calculations as in Zimbabwe but projected with the growth rates for the four provinces. These vary from 1.1 to 3.7%.

Figure 11 shows a map of the population densities for each hydrological unit (sub-zone) in the entire basin.

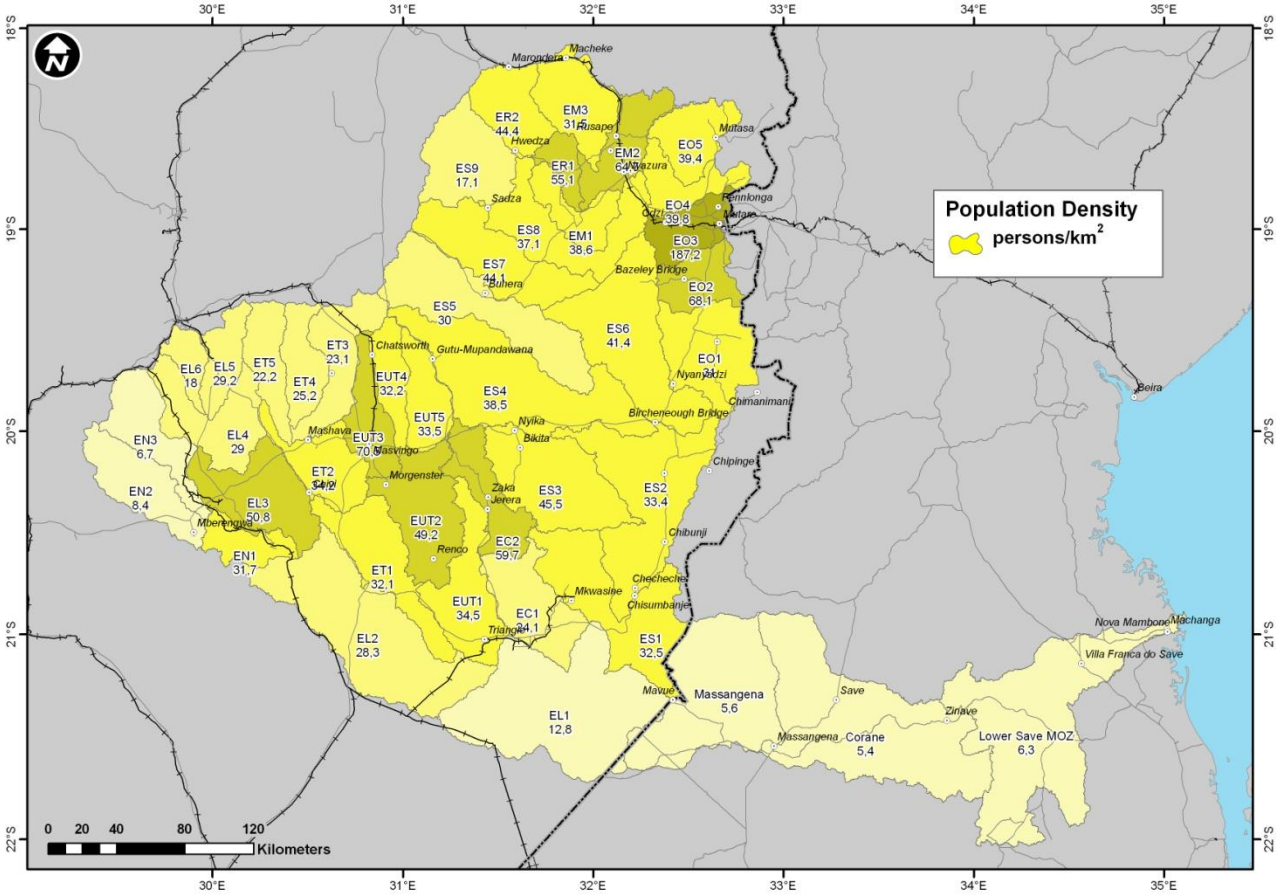

Figure 11 Population density of the Save River basin

The 2010 population in the Mozambican part of the basin is estimated to be 99,870 (Table 3).

Table 3 Population in the Save River basin, Mozambique

Province	District	Administrative Posts in the basin	Total population 2007	Population in basin 2007	Population in basin 2010
Gaza	Massangena	Mavue	25,504	1,758	1,833
		Massangena	18,808	2,037	2,123
Inhambane	Inhassoro	Inhassoro	45,597	4,868	5,031
	Govuro	Save	15,860	10,972	11,338
		Nova Mambone	18,634	426	440
	Mabote	Zinave	29,704	11,870	12,266
		Zimane	7,294	128	132

Province	District	Administrative Posts in the basin	Total population 2007	Population in basin 2007	Population in basin 2010
		Mabote	45,174	6,843	7,071
Sofala	Machanga	Machanga	27,517	10,110	10,856
Manica	Machaze	Save	84,582	23,421	26,118
		Chitobe	149,290	20,304	22,642
Total			**467,964**	**92,736**	**99,870**

Source: Consultant's estimates based on 2007 census

Uncertainties

The population estimates are inevitably somewhat uncertain. As mentioned the estimates are based on the area proportion of each administrative unit located in the basin. One source of error is therefore that the population density is not uniform within each ward or administrative post. In addition there is considerable uncertainty about the basic population figures and growth rates due to migration, the impact of HIV/AIDS and other factors.

3.3 Economy

The economy of the Save river basin is largely based on agriculture, livestock production, mining, exploitation of wildlife, forest resources and fishing. Irrigated cash crop production is economically very important in Zimbabwe. The majority of the basin population relies on subsistence rain-fed agriculture and a few cash crops for their livelihood.

Women play an important role in subsistence agriculture in both urban and rural areas, as they contribute a large amount of time and labour in farming and in exploitation of natural resources such as forests and water.

Zimbabwe

In Zimbabwe, agriculture and associated activities constitute the largest occupations (about 80% according to official statistics), followed by services, mining and construction. Most people are self-employed, but formal employment in the agricultural sector is significant on commercial farms and estates in Mutare, Chimanimani, and the Lowveld. The two sugar estates in Chiredzi and Triangle both employ approximately 10,000 people.

Many work as artisanal mining, particularly seasonally to supplement agricultural incomes. In addition there is formal employment in major mines. The Unki Mines, Mimosa Platinum and Zimasco mines alone employ more than 5,000 people. The Shabane mine employs approximately 1,200.

Box 1 Important sources of income by province, Zimbabwe

Manicaland:	livestock sales, casual labour, handicrafts, gold panning
Mashonaland East:	cash crop sales, vegetable gardening, causal labour, gold panning
Midlands:	gardening, petty trade, beer brewing, selling curious, gold panning
Masvingo:	beer sales, gold panning, remittances from migrant workers and peanut butter production
Matabeleland South:	sale of Mopane worms, cash income from farm labour in South Africa, hunting wild game, cross-border trading, gold panning, buying and re-selling vegetables, petty trade, selling livestock, cattle heading, remittances

Source: FAO/WFP, 2008

Sources of income for the self-employed include activities such as petty trade, retailing and artisan. Other sources of income are gardening through the sale of tomatoes, vegetables, other horticultural crops such as apples, peaches, bananas and yams as well as the sale of thatch grass, firewood and fish (Figure 12). Gold panning is particularly common in areas around Chimanimani, Chipinge, Mutasa and Nyanga.

Tourism is also a source of income. Attractions are the City of Mutare and its surroundings, Chimanimani, various dams and lakes in Masvingo Province and Great Zimbabwe National Monuments as well as Gonarezhou National Park.

Agriculture in Zimbabwe

According to the Poverty Assessment Survey (2003), 85% of rural households had access to land for cultivation. Among rural households, 68% did not fully utilize their land due to drought, lack of seed or fertilizer, lack of draught power or lack of ploughing implements.

Maize is the main crop. Other food crops are groundnuts, sorghum, cowpea, tubers, finger and pearl millet, while cotton, soybeans, tobacco and paprika are grown as cash crops. In dryer areas such as Insiza in Matebeland South, sorghum and pearl millet are significant. Cash crops such as tobacco, citrus fruits, bananas, apples, timber, tea and coffee are mainly cultivated in the north-eastern part of the basin.

The main livestock animals are cattle, goats, pigs, sheep and poultry. Many households in Midlands and South Matebeland own cattle and in South Matebeland, Masvingo, and Manicaland many households have goats.

Figure 12 Reservoirs can also be used for recreation and fishing, Mutirikwe, Zimbabwe

Mozambique

In rural Mozambique, the subsistence economy is still dominant. The main activity in most of the districts in the basin is rain-fed agriculture. An average family farm consists of 1.6 hectares. Small irrigation systems are located along the banks of the Save River.

Livestock has a prominent place in the local economy. Livestock is mostly raised by individual households. Raising of beef cattle and other livestock is increasing in the basin.

Agriculture is the most important activity in the coastal area, mainly in the districts except in Machanga District in Sofala Province, where the main activity is fishing. Fishing is practiced by most of the population in the coastal zone.

In Massangena District fishing takes place along the Save River, but it is not significant in the overall economy of the district. Its impact in the few places where it is practiced improves the diets of local households. Fishing is carried mostly by men using nets and hooks.

3.4 Poverty

Poverty is widespread in the basin. Female-headed households are more vulnerable to poverty. Definitions of poverty are complex and vary from one study to another. Figures are difficult to compare from one assessment to another, especially across national borders.

The socio-economic and political environment that prevailed in the Zimbabwe during 2000-2010 greatly influenced incomes and livelihoods. According to the Poverty Assessment Survey Study (2003) the proportion of households below the food poverty line (very poor) increased from 20% in 1995 to 48% in 2003. The poorest people in 2003 were those working in the mining and quarrying sector, followed by agriculture, hunting, forestry and fishing (Ministry of Public Service, Labour and Social Welfare, 2003).

The framework for development and recovery in Zimbabwe is provided for by the Medium Term Plan (MTP) 2010-2015. The plan aims at restoration and transformation for economic growth with a special focus on poverty reduction by delivering broad-based and equitable economic growth and development (Government of Zimbabwe, 2009).

In Mozambique poverty incidence is very high in the six basin districts, ranging from 75% to 90%, except for Machaze at 37%. In 2009 the national poverty level was 54.7% and 55.1-62.5 % in the four provinces. These high levels of poverty can be attributed to the effects of the long civil war and the continued isolation of some districts such as Mabote, Inhassoro, Massangena and Machanga since the Peace Agreement in 1994. The local agricultural production has not been integrated into the regional and national marketing system and the infrastructure is poorly developed.

The government's Local Initiatives Investment Fund is used by district governments to promote socio-economic development through such activities as small-scale irrigation, purchasing improved seeds and promoting marketing of crops to support the development of local communities.

3.5 Infrastructure

Roads

In Zimbabwe the road network is generally well developed, whereas in Mozambique road transport in the basin is difficult. The national highway crosses the Save River and secondary roads connect the provincial capitals, but most other roads in Mozambique are dirt roads, many in poor condition.

Water

Water resources are extensively developed in Zimbabwe which has many dams and irrigation canals (Figure 13), while irrigation is largely undeveloped in the Save basin in Mozambique.

Figure 13 Recording flow in an irrigation scheme, Zimbabwe

Power and telecommunication

The power grid is extensive in Zimbabwe, while many villages in Mozambique are unconnected. In Zimbabwe fixed lines or mobile networks are expanding in rural areas. Coverage with mobile networks is also rapidly expanding in Mozambique, but in many areas coverage is still inadequate.

Education

Formal education through schools as well as informal education through e.g. village *indabas* (chiefs) can influence people's perceptions and behaviour in the use of natural resources in particular the management of and conservation of water and the importance of clean water supply and good sanitation facilities.

In Zimbabwe, provision of formal education is a shared responsibility between local authorities, trust and church organisations and the government. All districts in the basin have basic education, primary and secondary school facilities. Zimbabwe has one of Africa's highest literacy levels. The literacy rate for males is 97% while for women it is 96%.

In Mozambique, some 98% of the schools in the basin districts are primary schools. The largest number of schools is in Machaze and Machanga districts. Many new schools have been constructed in recent years, and the number of students has been increasing, particularly the number of girls attending school. According to UNESCO estimates for 2009, 55% of the population over 15 years are literate.

3.6 Access to water, sanitation and health

3.6.1 Access to water and sanitation

Clean water plays an important part in the general health and wellbeing of people. The underlying cause of diarrhoea, cholera and dysentery is the lack of safe drinking water, inadequate sanitation and poor hygiene practices.

Water supply to households

In Zimbabwe, the main sources of water for domestic use in rural areas are protected and unprotected wells, boreholes, rivers and dams. Nationally, the percentage of population without access to safe water increased from 23% in 1995 to 25% in 2003. In Masvingo Province 43% of the population were without access to safe water (PASS, 2003).

Urban areas are supplied by the local authorities that purchase raw water from ZINWA and treats and distributes it to consumers. While water is provided free in the rural areas, water is a significant expenditure in urban areas (10% of household expenditure).

In Mozambique, the most common sources of water are boreholes with hand-pumps and wells with hand-pumps. The largest numbers of water sources are in Inhambane Province, particularly in Govuro District. There are estimated to be at least 1,000 drinking water sources in the basin in Mozambique.

Sanitation

In rural communities pit latrines are the most common form of sanitation. Pit latrines are also found in urban areas which are not covered by public sewerage systems. Blair toilets are commonly used in Zimbabwe. In Mozambique, ventilated pit latrines have been introduced in schools and health centres. Many rural communities still use the bush.

The Millennium Development Goals for Zimbabwe target include achievement of 73% access to safe sanitation in rural areas by 2015. According to the Poverty Assessment Study Survey (2003), 58% of the rural population has access to safe sanitation.

Water-related diseases

Diarrhoea is the most common water-related disease and a frequent cause of infant death. Zimbabwe experienced a major outbreak of cholera in 2008-2009.

Malaria is widespread in the low-lying areas of Zimbabwe and in Mozambique.

HIV/AIDS has a major impact on the communities with a prevalence of around 20%. It is related to socio-economic factors but not directly to water.

3.6.2 Health care

Health institutions are important in providing services and interventions for ill health and disease. They are also important in educating people on the prevention of diseases such as cholera, dysentery and diarrhoea.

In Zimbabwe, health care is provided through district, provincial or general hospitals and rural health centres, rural hospitals and urban clinics. There is at least a polyclinic which offers primary health care to communities from villages in the district and at least a district hospital and a provincial hospital in the provincial capital. The most widely spread form of health provision are clinics and rural health centres.

In Mozambique, there are 33 health centres in the basin districts, normally with a few beds, and 54 health posts (dispensaries) which are basic facilities without beds. There are no hospitals in the basin. Patients often travel long distance.

3.6.3 Gender roles in water and sanitation

Access to land and water and control of resources is normally more restricted for women than men. Because of the historic social construct of gender, women are the principal providers for the family in rural Mozambique. Women produce food, fetch water and manage the sanitation needs of the family, although they are at a disadvantage with respect to access to water. In rural areas in particular, it is common knowledge that most human labour for agriculture is by women.

Figure 14 Women traditionally fetch water

In the family, women and girls are mainly responsible for collecting and transporting water (Figure 14). On average, female members of a household make four trips a day seven days a week to carry 20 - 25 litres of water (a bucket or jerry can is the most commonly used container for carrying water).

4 Rivers, lakes, dams and wetlands

4.1 Freshwater eco-regions

Rivers, lakes, dams and wetlands are important sources of water and of livelihood for the basin population. Wetlands are rich in biological diversity. The freshwater ecosystems are divided into regions as shown in Figure 15 below.

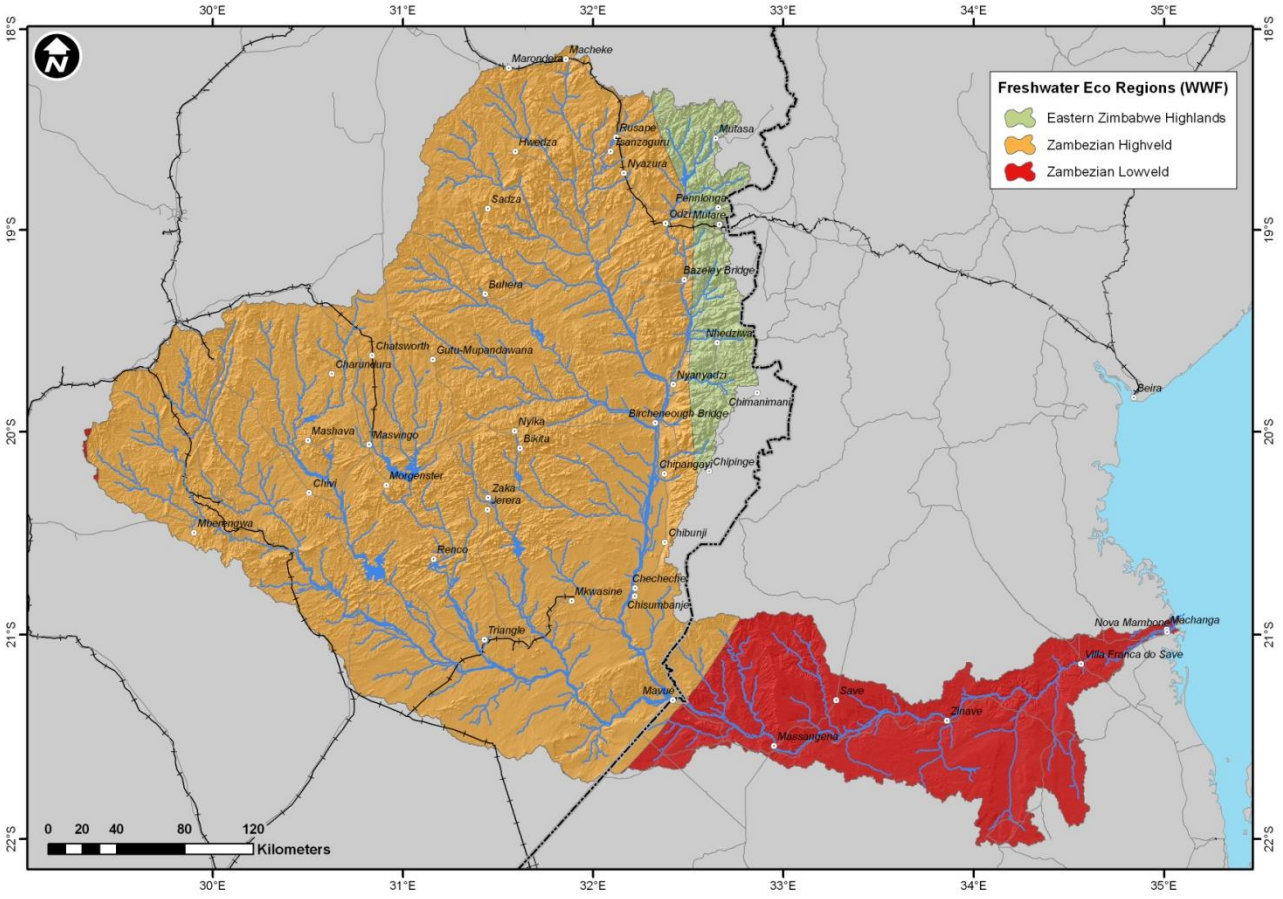

Figure 15 Freshwater eco-regions in the basin (WWF)

Eastern Zimbabwe Highlands eco-region

The Save River originates in the highlands in eastern Zimbabwe. The streams are narrow torrents with rocky substrate. Floodplains and swamps are rare.

Springs and small lakes are, however, numerous at high altitudes. Dambos, which are seasonally waterlogged grasslands found in the valley bottoms, are found on granites and granitic gneisses along the headwaters of many of the streams (Chabwela, 1994).

Four endemic fish have been described from this region and the highlands are also rich in amphibians, including rare and range-restricted amphibians of which three are endemic (Day, 2011).

The river valleys and riparian woodlands of the ecoregion are important for a number of bird species and nine Important Bird Areas occur in the highlands, mainly in forest-grassland mosaic habitats (Childes and Mundy, 1998; Parker, 2001). The endangered blue swallow (*Hirundo atrocaerulea*) is found here. It will only construct nests within the vicinity of wetlands. Breeding pairs of the vulnerable wattled crane (*Grus carunculatus*) also occur.

Zambesian Highveld

The Zambezian Highveld is a plateau with an altitude of over 600 m. The aquatic habitats found on this plateau are large and small rivers, numerous dambos, a few artificial reservoirs, and isolated floodplains. The headwater streams of the Highveld are small and clear but revert to swollen and turbid rivers after the rains (Dallas, 2011).

Perennially waterlogged dambos are widespread and cover large areas. Most dambos occur at an altitude above 1200 m. Most streams depend on dambos for their dry season flow (Magadza, 2000). The Chipinda Pools is a cluster of large perennial pools in Gonarezhou National Park. The Save-Runde floodplain, which includes the Tamboharta Pan, is one of the few floodplain areas the ecoregion (Chabwela 1994). Both the Chipinda Pools and the Save-Runde floodplain are rich in bird life and provide watering areas for several large mammals (Fishpool and Evans, 2001).

The numerous dambos are known to provide cover and food for indigenous terrestrial fauna and migratory birds (Katerere 1994).

Zambesian Lowveld

From the Highveld, the Save flows to the lowveld ecoregion below 600 m altitude. The Save River is seasonal, with winter low-flows confined to streams within the channel (Figure 16) and summer flows overflowing the channel into adjacent floodplains along the lower reaches.

Many species are found in fresh, brackish and saline waters and several species such as eels spend part of their life cycle in the freshwater coastal rivers and streams. About 120 freshwater fish species, including 22 endemics, inhabit this region (Dallas, 2011). Interesting endemics include the brightly-colored turqoise killifish (*Nothobranchius furzeri*) that is limited in distribution to the ephemeral pans of the Gonarezhou National Park in Zimbabwe (Skelton, 1993).

The extensive inland and coastal wetlands support rich aquatic fauna. Large numbers of wetland birds also congregate at the many wetlands.

Figure 16 *Villa Franca do Save. The national highway EN1 crosses here (the only road crossing in Mozambique). A key hydrometric station is located here. The stretch is typical for Save River in Mozambique. (Source: Google Earth)*

4.2 Lakes

There are only few natural lakes in the basin. However, there are many small and large dams on the Zimbabwean side. Lake Mutirikwi, a reservoir in Masvingo, is Zimbabwe's largest inland water body. The largest reservoirs are:

- Osborne, Odzi sub-catchment
- Ruti, Devure sub-catchment
- Siya, Lower Save
- Mutirikwi
- Muzhwi, Tokwe
- Manjirenji, Chiredzi

Further details on the reservoirs in Zimbabwe are provided in section 7.2 and in Annex 4.

There are no dams associated with the Save in Mozambique, but there are several small irrigation schemes that use water from the river, which is accumulated in small ponds in the riverbed during the dry season.

In addition there are several lakes and small bodies of water near the river, including:

- Lake Zinave (Inhambane Province)
- Lake Banamana (Inhambane Province)
- Lake Nhamecununga (Manica Province)
- Lake Bangui (Manica Province)
- Lake Nhatingulube (Inhambane Province).

Figure 17 Lakes are also hippo habitats, Zinave National Park

4.3 Wetlands

There are two main types of wetlands in the basin: riverine and palustrine.

River system wetlands

Riverine wetlands are composed of small, localised floodplains and swamps. The confluence of the Save and Runde rivers is an example of such a wetland type. The confluence of these two rivers is a small flood plain area containing perennial pools. The pools are more pronounced in the Runde River in the Gonarezhou National Park. Another set of pools are found upstream of the Pombazi River, a tributary of the Runde River.

Figure 18 In Mozambique the Save River is for most of the year confined to a shallow stream within a wide and deep channel, Zinave National Park

Palustrine wetlands

These consist of springs, pans, pools, lagoons and dambos. Dambos are found mainly in the highlands and at headwaters of most streams, especially in the central eco-region, e.g. Zvishavane, Masvingo, Rusape and Buhera.

Wetlands - Dambos

Dambos are a type of stream headwater wetland commonly found in Southern Africa. They are seasonally waterlogged bottom lands and cover approximately 1.28 million ha, in Zimbabwe, a quarter of which are found in communal areas. Most informal irrigation usually occurs in dambo areas where water can be obtained without large capital intensive measures. Water supply in dambo areas is a combination of residual moisture and shallow lift groundwater, deprived in part from recharge water that infiltrates into the upland catchment and flows laterally underground to the dambo areas

Source: Owen et al (1995)

In Mozambique the Save River is for most of the year confined to a shallow stream within a wide and deep channel (Figure 18). The wetlands on the Mozambican side of the river are all located south of the river. Two wetlands are located in Inhambane Province, the Banine Wetland and the Machachuvane Wetland. They are rich in biodiversity (Figure 19).

Figure 19 The African jacana is a typical wetland bird, Zinave National Park

5 Environmentally sensitive and protected areas

5.1 Location of protected areas

Many especially valuable nature areas and cultural sites in the basin are protected in different ways. The protected areas are mapped in Figure 20 below.

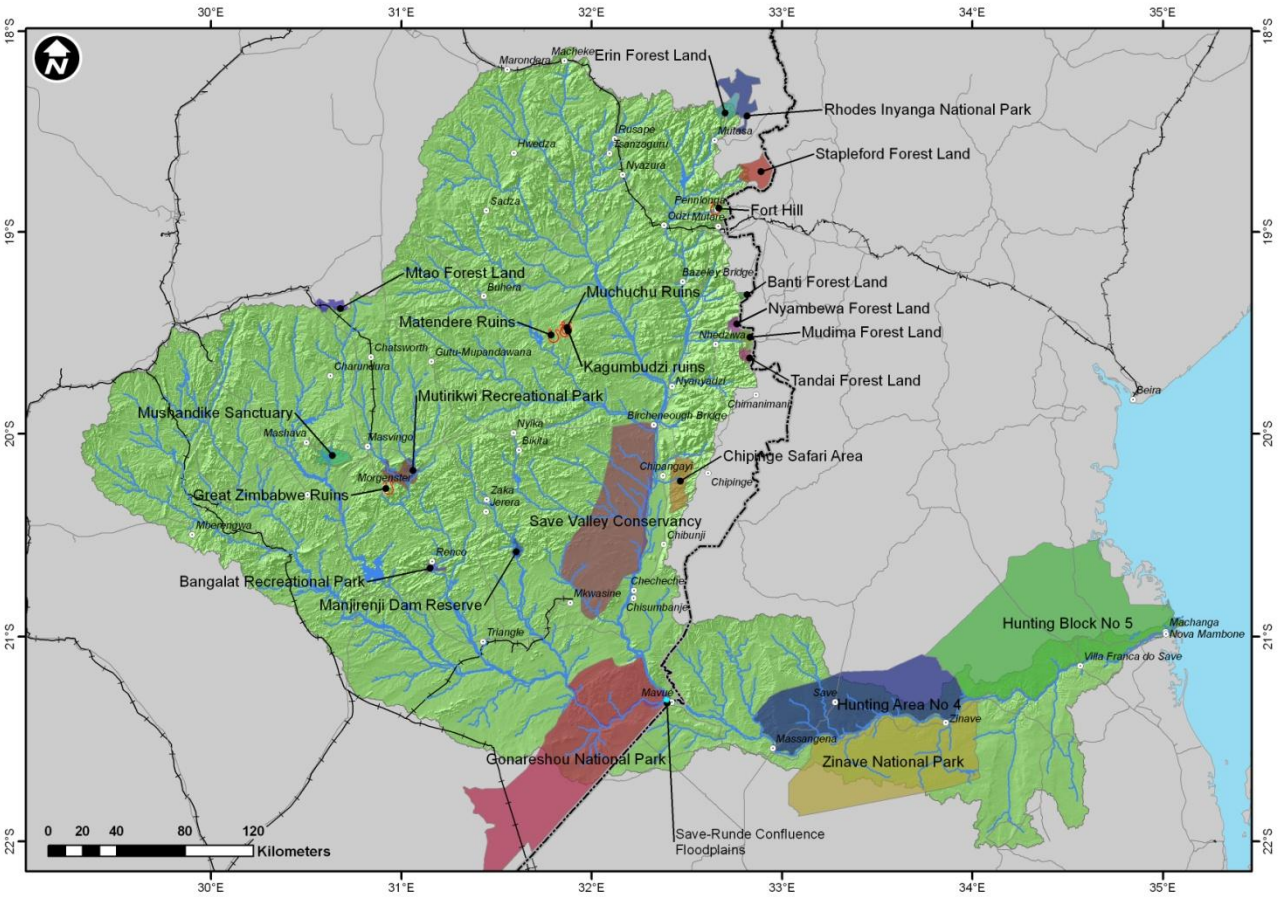

Figure 20 Protected areas

5.2 Protected nature

5.2.1 Gonarezhou National Park

The Gonarezhou National Park is located along the border with Mozambique and is part of the Great Limpopo Transfrontier Park. The Save, Runde and Mwenezi rivers flow through the park, forming pools and natural oases from which hundreds of species of birds, wildlife and fish gather to feed and drink.

Gonarezhou is particularly famous for its elephants. Other wildlife includes Buffalo, Impala, Kudu, Giraffe, Zebra, Hippopotamus, Nile crocodile, Sable and Reedbuck. The park has a diverse habitat, from forested floodplains to natural pans, riverine thicket to mopane scrub, sandveld forest to sandstone cliffs (Figure 21).

The park is also an important bird habitat - there are over 400 bird species in the park, including Bateleur Eagle, Tawny Eagle, Brown Snake Eagle, Martial Eagle, Lappet faced Vulture, Peregrine Falcon and Dickinson's Kestrel.

Figure 21 Gonarezhou National Park (source: Google Earth)

The Save-Runde confluence is located in the Gonarezhou National Park. It contains a number of perennial pools.

The Killifish, a threatened fish in Zimbabwe, has been reported in the pans in Gonarezhou National Park.

5.2.2 Rupembi swamps

The Rupembi swamps extend into Mozambique, where the area of the swamp is larger. A number of interesting grass species are found in the swamp, including *Sporobolus concimilis* and *Tricalysia jasminifolia.*

5.2.3 Save Conservancy, Zimbabwe

The Save Valley Conservancy links the Save River and mopane forests with granite hills and grassy plains and the start of the highveld miombo woodland in the west. A variety of wildlife is found in this diverse habitat, and the area is renowned as a birding destination.

5.2.4 Zinave National Park

The Zinave National Park is located in Mabote District in Inhambane Province. The Save River defines the northern boundary of the Park. The area represents a transition between the tropical wet and dry areas.

The Zinave National Park is part of the Great Limpopo Transfrontier Conservation Area that is shared between Mozambique, South Africa and Zimbabwe.

It has an area of about 3,700 km^2. Four communities with a total of 700 families depend on the park's natural resource base.

At the time of its formation in 1976 the park had protected species like the ostrich, giraffe and zebra. Now only few large mammals remain as a result of armed conflicts and uncontrolled hunting (Figure 22). The park is being rehabilitated and some species, including the giraffe, will be reintroduced.

Figure 22 In the evening large troops of baboons use the dry river bed. Zinave National Park

The Zinave National Park is also important for certain species of mammals (e.g. springhare) and birds that are confined to the sandveld. These are also the

only areas in which very rare species of fish are found, such as the lungfish and killifish (*Nothobranchius*).

The park is classified as an Important Bird Area (IBA) and several endemic and migratory species can be found.

5.2.5 Other protected areas

Zimbabwe

There are five other smaller national parks, sanctuaries and protected recreational areas in the basin as well as a number of protected forests. Chirinda Forest in Chipinge near Mt. Selinda with a total area of 606 ha is the largest protected forest in the Zimbabwe. It is the southernmost tropical rainforest with a wide variety of plant species.

Mozambique

Large hunting blocks border the lower stretch of the Save River in Mozambique.

5.2.6 Mangrove forests

The best known mangroves are located near the mouth of the Save River in Machanga District, at the point where the river enters the Indian Ocean. Mangroves and mudflats provide local people with building material, firewood, medicines and other products (Figure 23). Parts of the original mangrove area have been cleared for shrimp farming and salt production is another competing form of land use in the coastal area.

Figure 23 Mudflats provides food for people and birds alike, Mozambique, near the estuary

5.3 Cultural and archaeologically protected sites

There are a number of archaeological sites of importance including buildings, cultural heritage sites and bushman paintings.

Great Zimbabwe

The most important archaeological site of importance is the Great Zimbabwe (stone houses) National Monument, which is also a UNESCO World Heritage Site (Figure 24). The Great Zimbabwe National Monument is located approximately 25 km east of the town of Masvingo and covers an estimated area of 80 ha.

Figure 24 Great Zimbabwe

Other sites in Zimbabwe

A number of other sites of archaeological and historical importance in the basin in Zimbabwe are indicated on Figure 20.

Zinave National Park

The Zinave National Park contains some sacred sites, some dating from the time of the Sochangana Empire in the 19th century. There are other mystical places such as the grotto where the hyenas are born, which enrich the park with stories and legends.

Gudu Gudu Sacred Forest

The Gudu Gudu Sacred Forest is another historic sites in the Save basin in Mozambique. It is surrounded by great mysticism associated with ancestor cults.

6 Water resources

6.1 Hydrological units

In Zimbabwe the Save basin falls under two Catchments, Save and Runde. These are administrative units that are based on the hydrological boundaries, but with some minor adjustments for practical reasons. The Catchments are further subdivided into Sub-catchments. Again these largely follow the hydrological watershed boundaries, but with some adjustments (see Figure 16).

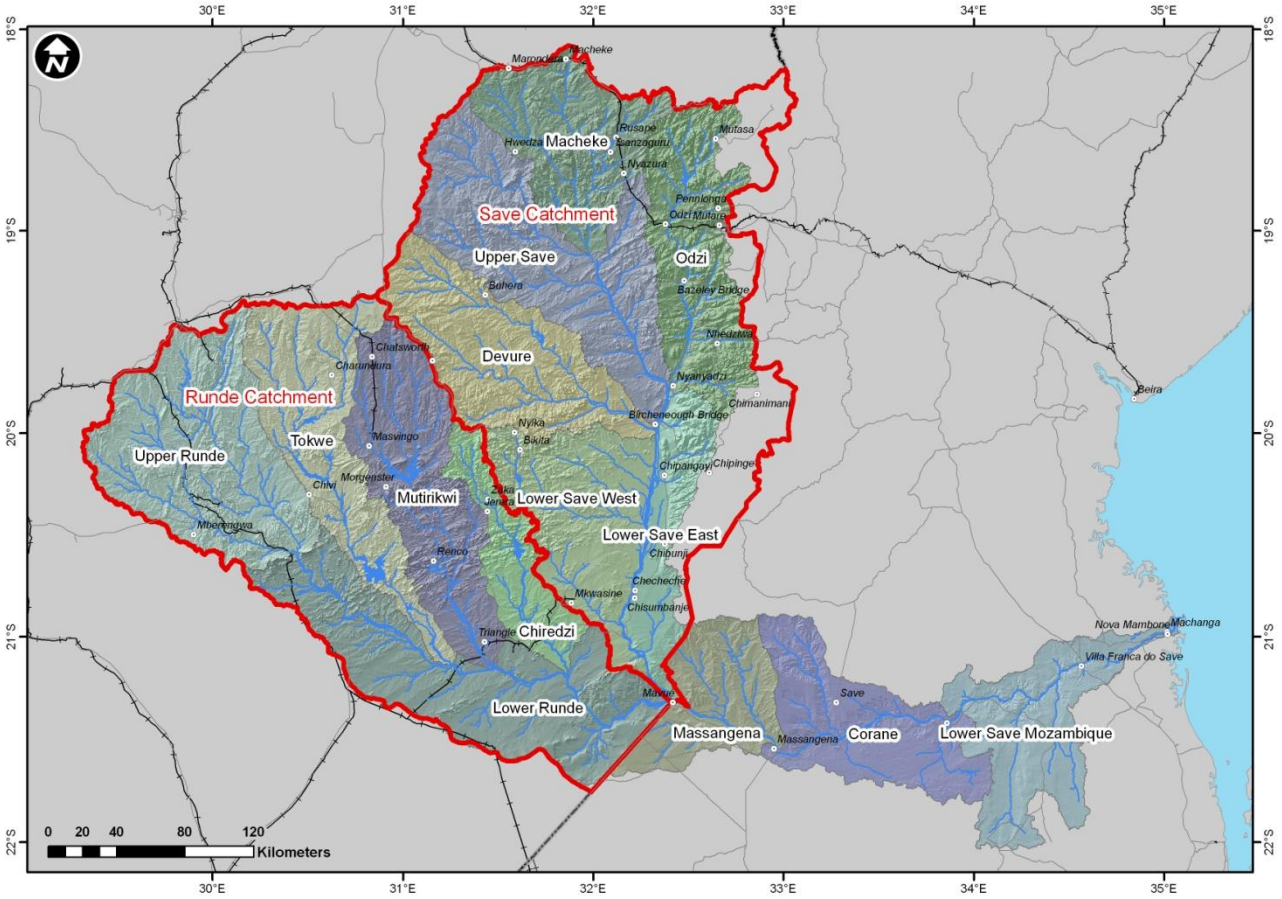

Figure 25 Catchments, sub-catchments (Zimbabwe) and subbasins (Mozambique)

For the hydrological analysis the basin is divided into smaller units called sub-zones, which is the term used in Zimbabwe. The sub-zones are hydrological units, which in most cases are divided according to the location of major confluences, dams or runoff station. The only exception is where the national borders cut off the sub-zones. The sub-zones are shown in Figure 26.

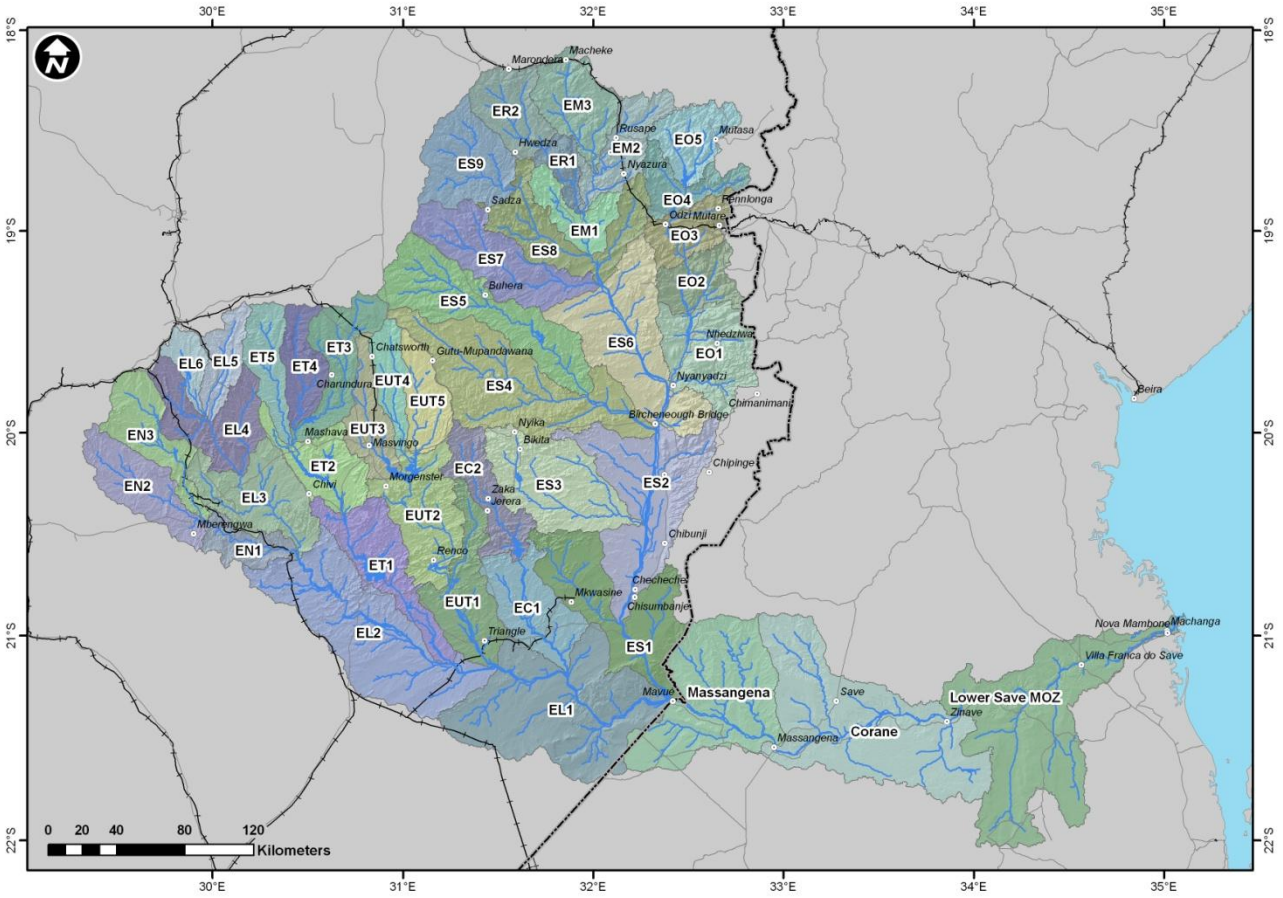

Figure 26 Sub-zones of the Save River basin

Points of interest

The hydrological assessment of the Save River basin is presented for each sub-zone as well as points of special interests. Points of interests (POI) are major confluences, existing dams or planned dam sites. Other interesting points are flow at the border and at the estuary. In total 16 points have been selected and are shown in Figure 27.

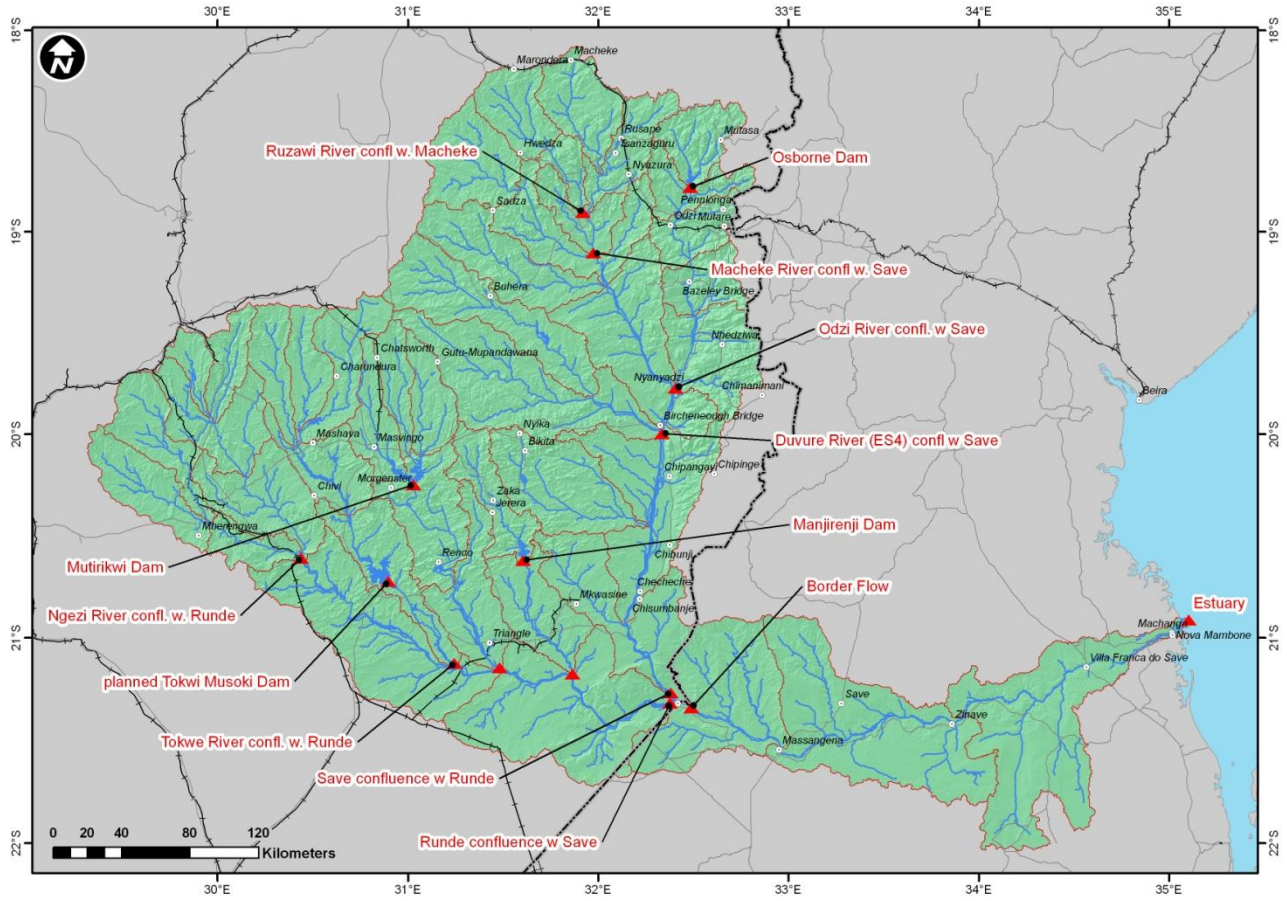

Figure 27 Points of interest

6.2 Hydrometeorological data

6.2.1 Rainfall

Rainfall data are crucial for assessment of water resources. Data from Zimbabwe is patchy with very dense data availability for the Odzi and Tokwe river basins, while otherwise rather sparse coverage. Data is also limited up to 1996, since the data is sourced from studies conducted some 10 years back.

Rainfall data in Mozambique is monitored by both the meteorological services (INAM) and the water authorities (DNA and the ARAs). For the Save River Basin in Mozambique rainfall data have been collected from DNA, which have a good coverage of data for this part of the country.

The number of identified rainfall stations with available data was 206 of which 14 in Mozambique. However, several of these stations only have data for a few years or have a lot of gaps in the measurements. Only limited data are available in digitized format. The data are described in more detail in Annex 3.

The distribution of rainfall is shown in Figure 4. The map is based on climate models, DEM and synoptic stations and shows the same pattern as the observed data from the basin.

For most of the basin, rainfall is quite unpredictable in terms of duration and quantity. Nevertheless, the general distribution throughout the year is rather similar as seen for the six stations in Figure 28.

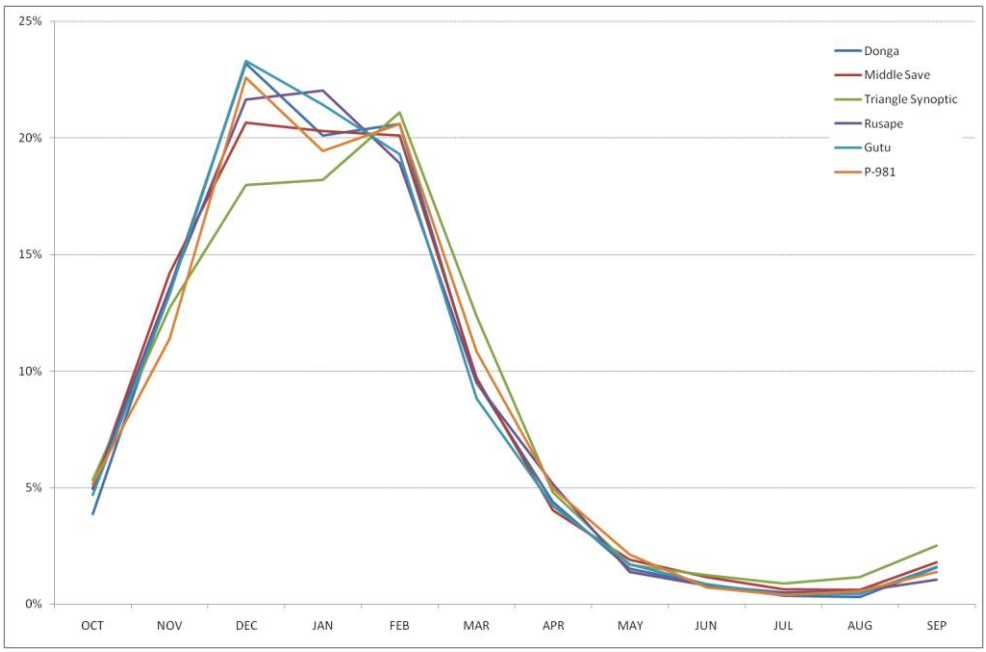

Figure 28 Mean monthly rainfall distribution as percentage of MAP for six rainfall stations spread out over the Save River basin

6.2.2 Evaporation

Evaporation data are used to estimate losses of water from a river catchment to the atmosphere. Data were obtained from 17 stations, 4 in Mozambique and 13 in Zimbabwe. This includes some stations outside the basin.

6.2.3 Runoff

Data on river flows are essential for all surface water resource assessments. They comprise the source for estimations of mean annual runoff (MAR) and probability of extreme high and low flows. Runoff is also needed for calibration and validation of hydrological models, which can be used to prolong data series and thereby improve the input for water resources estimations.

In Zimbabwe 365 hydrometric stations are registered at ZINWA for the Save and Runde River basins. However, a majority of these stations are only used locally for monitoring water levels. 86 of these stations have historical runoff data for the Save and Runde Rivers according to ZINWA. Most of these runoff stations are constructed weirs or flumes, which enables the rating curves to be calculated theoretically. Coverage in time is fairly good in Zimbabwe, where

some of the oldest stations started measurements in the 1920s. The majority of runoff data is however concentrated to the period after 1960.

According to the DNA files there are 5 hydrometric stations in the Mozambican part of Save River Basin. However, only three of them have established rating curves. These stations are important since they summarise the river flow of almost the whole Save River Basin.

6.3 Surface water modelling

Purpose

Hydrological modelling computes the river runoff with the help of rainfall data and geographical information on the river catchment. The benefit is that rainfall records normally are longer than the corresponding flow records, which enables the possibility to calculate very long flow series. These long flow series are used for instance to get reliable estimates of the long term water resources in a river basin or reliable estimates of available water at a planned dam site. Long flow series are essential in areas where the climate shows distinct cycles, as in southern Africa where climate cycles of 7-15 years duration are commonly seen.

Pitman model

For the hydrological modelling of the Save River basin the Pitman model has been applied. The model was setup for the entire Save River basin including all the major tributaries. The basic unit used for the model set up was the sub-zone.

The Pitman model is a lumped rainfall-runoff model simulating the movement of water through an interlinked system of catchments, river reaches, reservoirs and irrigation areas using a monthly time step. It uses 11 parameters to define the hydrological processes. The whole catchment is subdivided into hydrologically uniform sub-catchments. The sub-catchments are connected together by means of routes. The model calculates the rainfall-runoff relationship of a particular sub-catchment using monthly rainfalls. The outflows from these sub-catchments are then aggregated to present the net effect of the total catchment. In order to obtain a representative model it is necessary to calibrate the model by adjusting the model parameters to achieve agreement between simulated and observed flows.

Abstraction

The model needs to be adjusted with the amounts abstracted from both dams and directly from the rivers. Most river abstractions are made from tributaries to the main river. Water abstraction is most commonly used for irrigation, but a smaller amount of water is also used for water supply to urban centres. Water abstraction has been assumed to equal the given water permits in each sub-zone.

Calibration

The model has been calibrated for the major stations in the Save River basin which were judged as reliable.

Overall the model was found to simulate MAR for the Save River basin satisfactory. Errors in MAR are often a result of its inability to reproduce high run-off peaks. However, even though the model fails to generate some peaks it still

describes the river dynamics very well and there was a good correlation between the simulated runoff and the observed runoff. For more information please refer to Annex 3.

6.4 Runoff

6.4.1 Annual runoff

The results of the modelling are presented below. Figure 18 shows the estimated areal runoff in mm for the various parts of the basin.

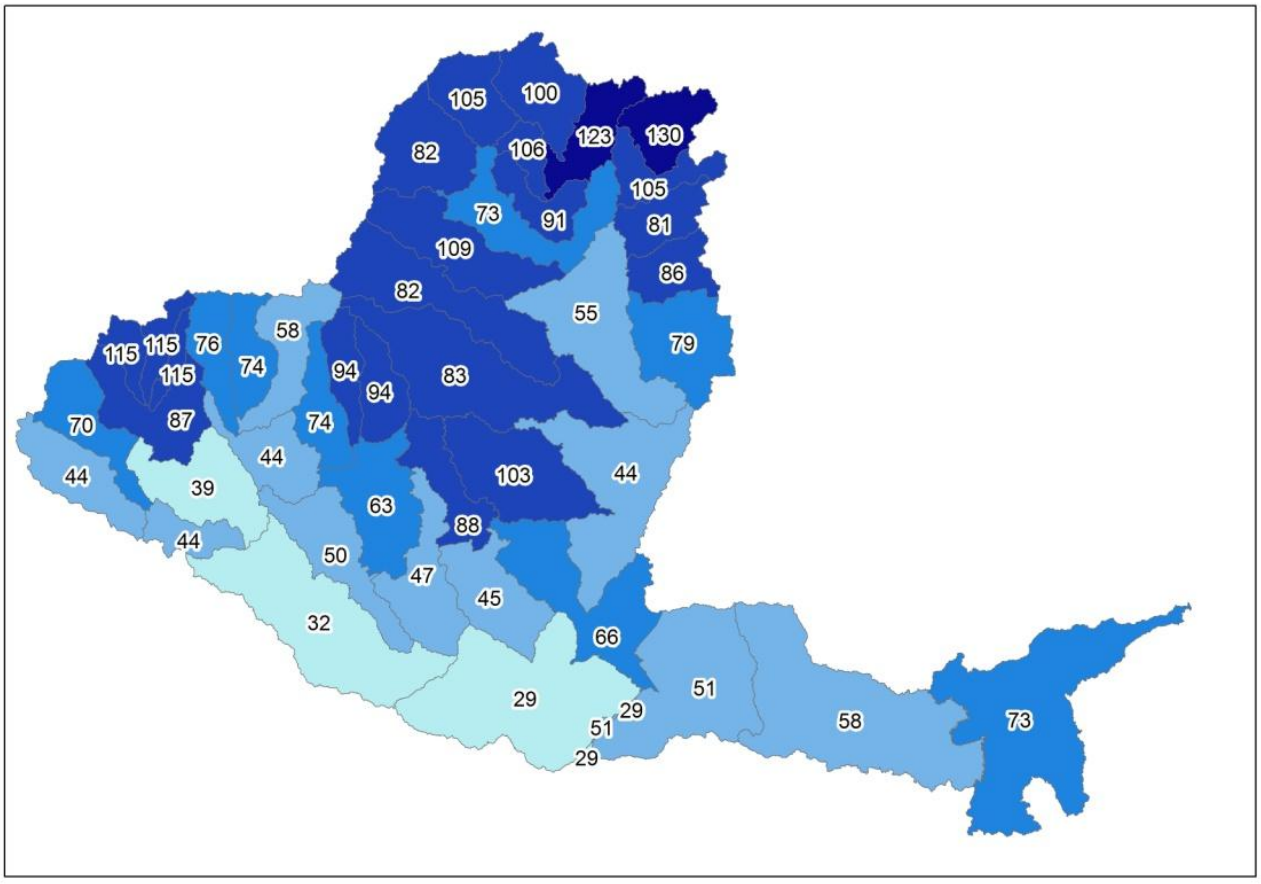

Figure 29 Estimated areal runoff (mm) in the Save River basin, based on the years 1960-96

It is seen that the upper parts of the basin have high runoff, whereas the semi-arid areas in the southern part of the Zimbabwe decrease the specific runoff from Zimbabwe. Zimbabwe represents about 83% of the total basin area and produces 85% of the runoff. Mozambique covers 17% of the Save River basin and produces 15% of the runoff.

In Table 4 below the natural MAR for a number of interesting points is presented. These points include the border flows, the confluence flows, flow available for the major dams and the flow at the estuary.

Table 4 Estimated runoff at point of interests, based on 1960-96 data

	Point of Interest	Area [km^2]	MAR (Mm^3)	MAR (m^3/s)	Percentage of total MAR
Confluence	Ruzawi River at Macheke River	2 152	226	7	3%
	Macheke River at Save River	6 620	695	22	10%
	Odzi River at Save River	7 327	691	22	10%
	Duvure River at Save River	8 125	668	21	10%
	Save River at Runde River	43 682	3 555	113	52%
	Ngezi River at Runde River	4 512	244	8	4%
	Tokwe River at Runde River	7 942	462	15	7%
	Mutirikwi River at Runde River	8 057	538	17	8%
	Chiredzi River at Runde River	3 536	225	7	3%
	Runde River at Save River	40 934	2 267	72	33%
Dams	Osborne Dam	1 380	180	6	3%
	Tokwe Mukosi Dam (planned)	7 126	421	13	6%
	Mutirikwi Dam	3 951	330	10	5%
	Manjirenji Dam	1 480	133	4	2%
Other	Border flow	85 078	5 834	185	85%
	Estuary	101 895	6 885	218	100%

Comparison with previous studies

In this study we estimate the annual natural flow (MAR) at the national border to be 5,834 Mm^3. This estimate is about 10% lower than previous studies (Masvimavi, 2006). The 2006 study was a national study, whereas the present study is a more detailed assessment for the Save basin and the discrepancy can be explained by different methodologies. The previous study might be biased by over-representing relatively wet areas. The differences are further discussed in Annex 3.

6.4.2 Seasonal flow

The monthly flows for the points of interest are shown in Figure 30 below which shows monthly flows as percentage of MAR.

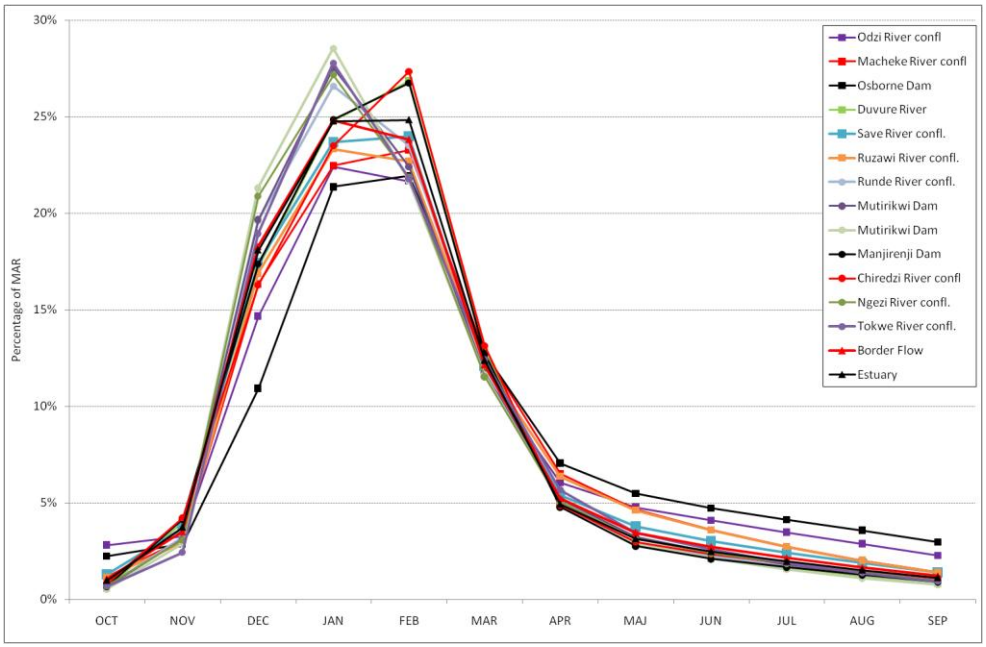

Figure 30 *Monthly natural flow distribution for the points of interest. About 80% of the annual flow occurs during a period of 4 months.*

Duration Curves

Duration curves have also been computed from the simulated monthly runoff series at the points of interests. Table 5 lists the monthly flows with 50%, 90% and 99% exceedence.

Table 5 *Flows with 50%, 90% and 99% exceedence of the time*

Type	Point of interest	Area [km^2]	MAR [Mm^3]	50%	90%	99%
				[Mm^3/month]		
Confluence	Odzi River with Save River	7 327	691	25.6	9.7	4.6
	Ngezi River with Runde River	4 512	244	4.8	1.5	0.7
	Macheke River with Save River	6 620	695	21.9	5.5	3
	Devure River with Save River	8 125	668	11.5	2.8	1.6
	Chiredzi River with Runde River	3 536	225	4.5	1.3	0.7
	Tokwe River with Runde River	4 352	462	10.3	2.8	1.4
	Save River with Runde River	43 682	3555	100	30	17
	Ruzawi River with Save River	2 152	226	6.7	1.7	0.9
	Runde River with Save River	40 934	2267	46	14	7.2
Dams	Osborne Dam	1 380	180	7.3	2.8	1.5
	Mutirikwi Dam	3 951	330	11.1	2.9	1.5
	Manjirenji Dam	1 480	133	2.4	0.6	0.4

Type	Point of interest	Area [km^2]	MAR [Mm^3]	50%	90%	99%
				[Mm^3/month]		
	Mutirikwi Dam	3 951	330	5.37	1.4	0.7
	Tokwe-Mukosi Dam	7 126	421	9.02	2.5	1.3
Other	Border Flow	8 5078	5834	149.1	46.2	26.0
	Estuary	101 895	6885	162	51	28

6.5 Groundwater assessment

6.5.1 Assessment background

Why

Groundwater is a key element in the hydrological cycle and an assessment of the resource is therefore important in any water resource project.

In terms of utilisation groundwater is not as important as surface water, but a large majority of the rural population within the basin depend on groundwater for domestic water supply and groundwater from mid-Save alluvial deposits has historically played an important role for commercial irrigation schemes.

Previous studies

In Zimbabwe, the groundwater conditions within the Save River basin are described and quantified in the Save and Runde Outline Plans (ZINWA, 2009). Another important source of information is the National Master Plan for Rural Water Supply and Sanitation, Vol. 2.2 Hydrogeology (Interconsult, 1985), including the National Hydrogeological Map (4 sheets). The groundwater resources assessment, development and management of the Save Alluvial Aquifer are described by Sunguro (2003). In Mozambique, groundwater conditions of the Save River basin are not well documented. Regional information is found in the National Hydrogeological Map and its Explanatory Notes (Ferro and Bouman, 1987). A groundwater characterisation on a basin level should ideally be based on uniform data, evenly distributed within the basin boundaries. One such source is the SADC Hydrogeological Map (SWECO et al, 2010). This map is the first transboundary and seamless map of its kind for the SADC region depicting groundwater occurrence on a sub-regional level.

Data

Relatively good borehole data is available for the Save River basin. A list of 5 128 boreholes has been obtained for the Save River basin, and 3 129 boreholes (61%) have a water level measurement however only one has an Electrical Conductivity reading. The distribution of boreholes is shown in Figure 31. These boreholes are likely only a fraction of the true number of boreholes within the basin.

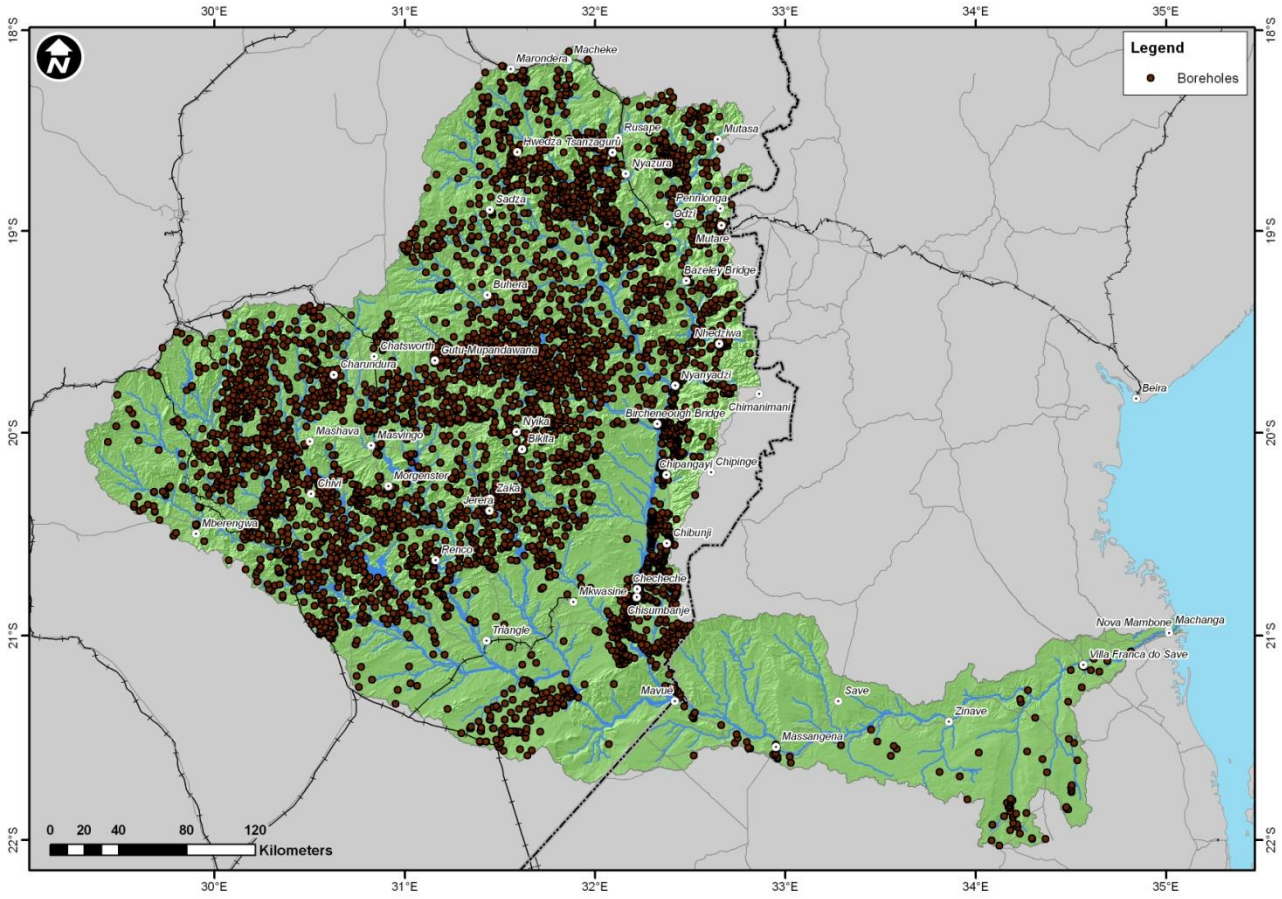

Figure 31 Borehole distribution within the Save River basin

Boreholes have not been recorded in a uniform and standardised manner. The recorded yields are likely to overestimate the long-term yield as a vast majority of the records probably are derived from airlift yields. Consequently, borehole records should be used with some caution.

5,087 boreholes have been used in the statistic analysis of borehole depths and yields. The data indicate that about 50% of the boreholes are between 38 m and 55 m deep with a median depth of 46 m.

About 50% of the boreholes are reported as “dry”. The median yield, including the dry boreholes, is about 0.2 l/s, and the reported total range of yields is 0-100 l/s.

6.5.2 Hydrogeological setting

SADC has prepared a hydrogeological map (SADC HGM, SWECO et al., 2010) based on a geological map compiled by the South African Council for Geoscience (Hartzer, 2009), see Appendix 1 of Annex 1). Within the Save River basin there are 8 hydro-lithological groups present, these are listed in Table 6 and also shown on Figure 32.

Table 6 Lithological units, area and percentage coverage within the Save River basin

Rock type		Area (km^2)	% of basin area
1	Granite, syenite, gabbro, gneiss and migmatites	61657	60.4
2	Paragneiss, quartzite, schist, phyllite, amphibolite	10366	10.1
3	Dolomite and limestone	9834	9.6
4	Clay, clayey loam,mud, silt, marl	6519	6.4
5	Intrusive dykes and sills	4521	4.4
6	Unconsolidated sands and gravel	4046	4.0
7	Volcanic rocks (extrusive)	3976	3.9
8	Interlayered shales and sandstone	971	1.0
9	Unconsolidated to consolidated sand, gravel and arenite	267	0.3

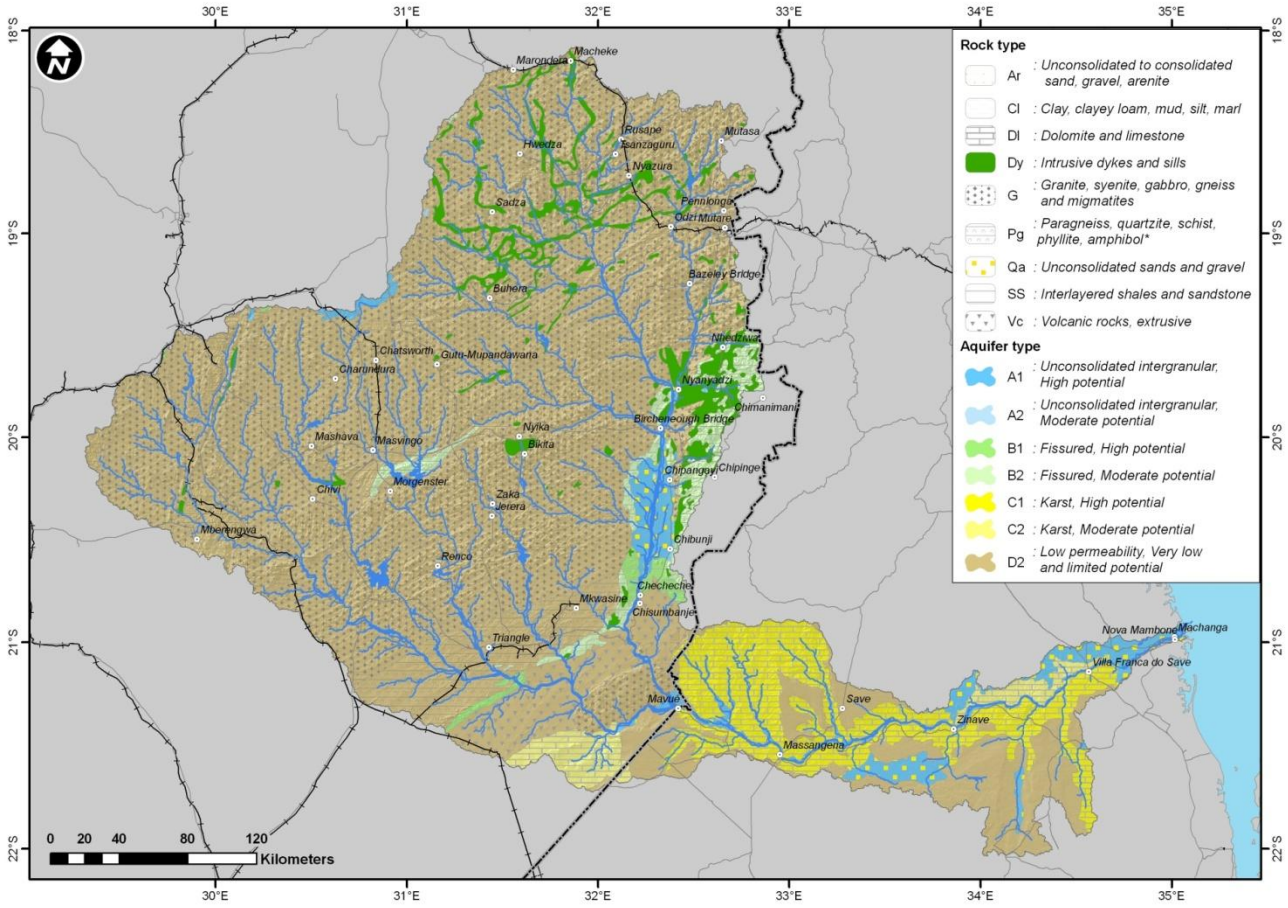

Figure 32 Hydrogeology of the Save River basin

Granite, syenite, gabbro, gneiss and migmatites
The granitic terrain may host secondary aquifers. Primary aquifers typically do not occur in granitic terrains, unless in deeply weathered river channels. The secondary aquifer is likely to occur as open fractures within the granites and groundwater may also occur in weathered zones at depths of approximately up to 80 m.

Typically granites and boreholes drilled in granites have the following characteristics:

- Low yielding aquifers
- Borehole success rate can be very variable
- A successful borehole yield is considered to be > 1 l/s
- Groundwater levels are in the order of 20-30 m below ground levelGroundwater quality is typically good with an EC < 30 mS/m
- Hydraulic conductivity is variable, from 1 x 10^{-7} m/s to 1 x 10^{-5} m/s.

Para-gneiss, quartzite, schist, phyllite and amphibolite
This third, most common, grouping may host secondary aquifers. The degree of weathering can be high, the groundwater potential low, and the groundwater quality poor due to the relative ease with which these formations weather.

The exceptions, however, are the quartzites. The quartzites are characteristically very competent and brittle, thus fractures and joints are typically widespread throughout quartzite. If the quartzites are folded they can be exposed at surface and these will be high recharge zones with fair hydraulic conductivities (10^{-5} m/s) and good water quality although, due to the lack of buffering capacity, the pH is low and the groundwater corrosive. Fracture flow predominates and borehole success can be highly variable. The quartzite layers have not been mapped separately in the geological data set available for this project but it can be mapped in the field and targeted as a water source. Springs may occur at the contact between the quartzites and the other more weathered lithologies.

Dolomite and limestone
The geological grouping is of limited extent although it can often host the third type of aquifers, namely 'karstic' aquifers. Due to the occurrence of dissolution cavities this geological grouping often results in very high aquifer hydraulic conductivity and aquifer storage. Also spring flow can emanate from a dolomitic setting. The groundwater chemistry is also typically good although the pH is usually elevated. The main drawback with karstic aquifers is that they are very vulnerable to contamination due to the high recharge rates and hydraulic conductivity. Hand dug wells can often access the groundwater in this setting.

Clay, clayey loam, mud, silt and marl
These lithologies contain very limited groundwater and are essentially non-aquifers.

Intrusive dykes and sills
The intrusive dykes and sills are very important from a hydrogeological perspective. Often successful boreholes are drilled into the contact zone between

the host rock and the intrusive dyke/sill. These intrusive volcanics can act as barriers to groundwater flow and thus groundwater moves down gradient along the contact zone. When targeting such geological features for groundwater abstraction, the contact zone should be intercepted at an approximate depth of 70 m to 100 m.

Unconsolidated sands and gravel

This lithological grouping comprises primary aquifers. Relatively high-yielding aquifers should be found within this grouping although the limited amount of rainfall available for recharge may be a limiting factor in the long term.

The groundwater levels are anticipated to be shallow as this is more the discharge portion of the Save River basin. Hydraulic conductivity is relatively high (10^{-3} m/s) and the water quality acceptable. The primary aquifers may well support groundwater-dependent ecosystems and are most likely the most accessible for rural water supply via hand dug wells. The mid-Save Alluvial Aquifers belong to this lithological group.

Volcanic rocks, extrusive

These normally comprise low to medium potential aquifers. Possible groundwater target zones include lava flow contacts, buried weathered surfaces and fractures. Groundwater yields of between 0.1 and 2.5 ℓ/s can be obtained from boreholes sited scientifically. Rest water levels and groundwater quality are typically highly variable.

Inter-layered shale and sandstone

The inter-layed shale and sandstone can host secondary aquifers and these aquifers may also be confined. The inter-layered nature of the group generally means that groundwater recharge is low if flat lying, or if within the sandstone layers it may be quite high if there is significant folding and deformation of the layering. Alternating shales and sandstone implies high variability for all hydrogeological parameters. The characteristics depend largely on the tectonic history of this layer.

Typically the groundwater potential of inter-layered shales and sandstones is low as this grouping is characterised by, very low groundwater recharge, very low hydraulic conductivity, low specific storage and poor water quality.

Unconsolidated to consolidated sand, gravel and arenite

This lithological grouping comprises primary aquifers within the unconsolidated portion of this grouping. Relatively high-yielding aquifers are found within this grouping.

The groundwater levels are anticipated to be shallow. Hydraulic conductivity is relatively high (10^{-3} m/s) and the water quality acceptable. The primary aquifers may well support groundwater-dependent ecosystems and are most likely the most accessible for rural water supply via hand dug wells.

6.5.3 Aquifer types

The hydro-lithological units have been further grouped into four different aquifer types, namely:

- Fissured
- Karst
- Low permeability, and
- Unconsolidated intergranular.

These aquifer types are classified based on their development potential as high potential, moderate potential, and low potential. The distribution of the various aquifer types and their associated potential are shown in the Save Hydrogeological Map (Figure 32)

The '*high potential'* (13% of the Save River basin) aquifers occur in association with:

- Unconsolidated sands and gravel
- Dolomite and limestone
- Interlayered shales and sandstone

The 'high potential' areas occur within eastern Zimbabwe and along the Save River in Mozambique. In the unconsolidated intergranular' aquifer setting groundwater can most probably be accessed by means of hand dug wells.

The '*moderate potential'* aquifers (8% of the Save River basin) occur in association with:

- Paragneiss, quartzite, schist, phyllite, amphibolite
- Dolomite and limestone

This groundwater needs to be accessed by drilling boreholes and the degree of success of drilling boreholes is very variable. The moderate potential aquifer occurs in the central portion of the Save River basin.

The '*very low yielding aquifers*' (79% of the Save River basin) are associated with the low permeability rock types. They occur extensively throughout the Save River basin.

6.5.4 Groundwater recharge

Groundwater recharge is influenced by many factors such as climate, slope, vegetation, soil, depth to the groundwater level, nature of the vadose zone material, flow paths and aquifer material as discussed in Annex 3.

Recharge for the Save River basin was estimated from the geology using standard rates from recharge studies completed in southern Africa (Bredenkamp et al, 1995). The groundwater recharge per sub-zone is shown in Figure 33. The groundwater recharge is highest in the coastal zone.

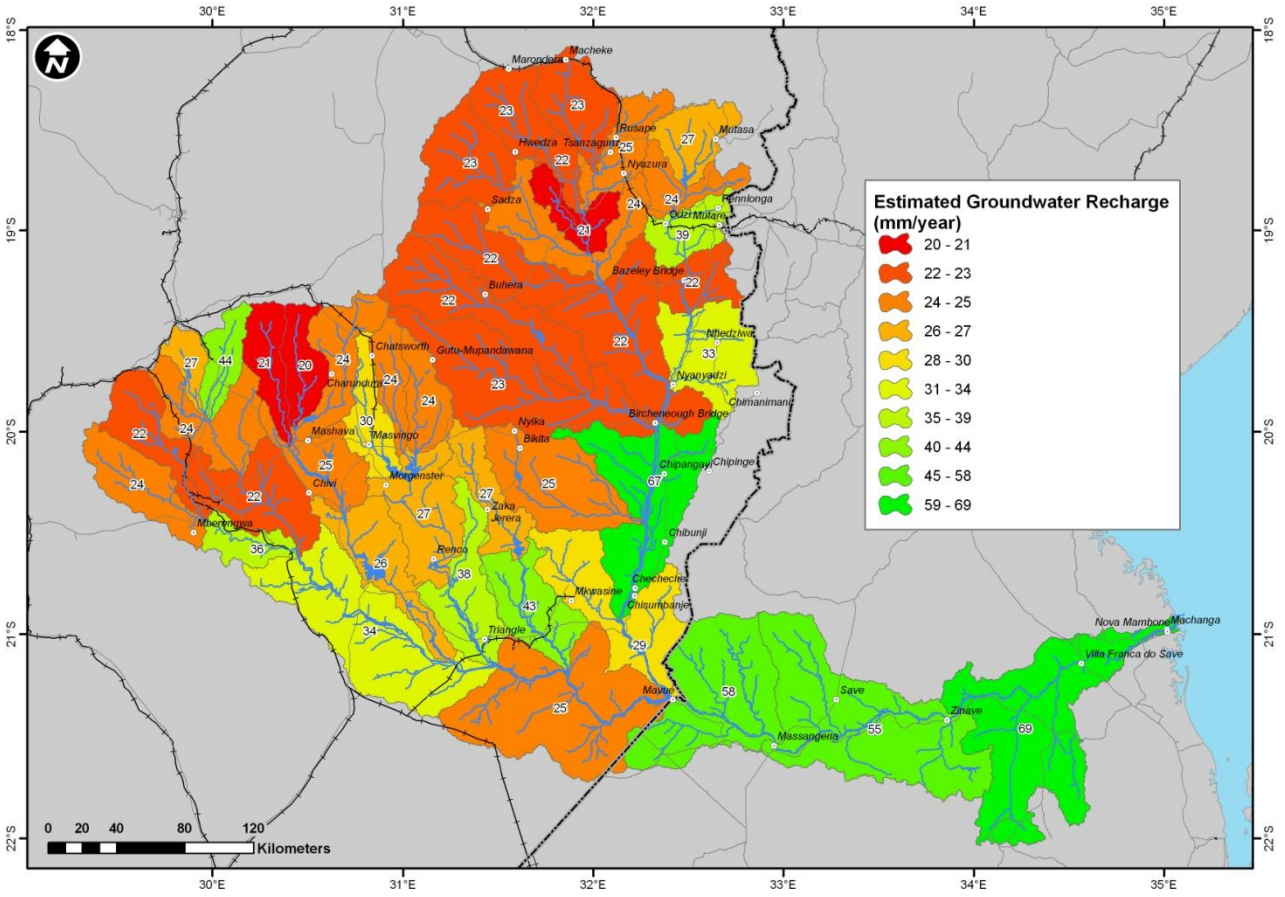

Figure 33 Groundwater recharge for the Save River basin

6.5.5 Aquifer storativity

Aquifer storativity is also an important component of hydrogeological characterisation. Based on the lithologies within the Save River basin and average values obtain from literature, storativity values have been assigned per hydrolithology.

6.5.6 Aquifer potential

The groundwater held in storage has been accumulated over time due to relatively small inflows. Water resources planners have a number of development options varying from exploiting the aquifer system on a sustainable basis and not depleting the storage, to mining the aquifer to supply large short-term water demands. Utilisation of water held in storage or part thereof is referred to as 'mining'. This project provides the sustainable yield of the groundwater for resource planning and development purposes and thus aquifer potential is based on groundwater recharge.

The aquifer potential is the volume of groundwater that is potentially available for abstraction on a sustainable basis and taking into consideration the volumes of water held in aquifer storage and the recharge from rainfall. The feasibility

of abstracting this water is limited by many factors due mainly to the physical attributes of a particular aquifer system, economic and/or environmental considerations. One of the most important of these is the inability to establish a network of suitably spaced production boreholes to 'capture' all the available water in an aquifer system or on a more regional scale. The factors limiting the ability to develop such a network of production boreholes includes the low permeability or transmissivity of certain aquifer units, accessibility of terrain to drilling rigs, unknown aquifer boundary conditions etc. Aquifer transmissivity is the main controlling factor.

The annual groundwater exploitation potential (AGEP) of water that can be drawn from an aquifer can be estimated by the formula:

$$AGEP = Q_R \times R \times A_R$$

Where:

Q_R = the rate of recovery, i.e. the proportion of recharge that can be abstracted through boreholes. The rate of recovery is mainly governed by the interconnectivity of conductive structures, number and distribution of boreholes, and transmissivity.

R = annual aquifer recharge.

A = the area over which recharge to the aquifer can take place.

The final link required in determining groundwater potential within the basin is to relate the "rate of recovery" to the hydro-lithologies. Table 7shows the approximate borehole yields per hydro-lithology.

Table 7 Approximate maximum borehole yields per hydro-lithology

Rock type	Average borehole yield (m^3/hr)	Average borehole yield (ℓ/s)	Rate of recovery (%)
Granite, syenite, gabbro, gneiss and migmatites	~ 6	1.6	60
Paragneiss, quartzite, schist, phyllite, amphibolites	~ 2.2	0.6	40
Dolomite and limestone	~ 36	3.6	70
Clay, clayey loam,mud, silt, marl	0.4	0.1	10
Intrusive dykes and sills	~ 10.8	3	70
Unconsolidated sands and gravel	~ 15	4.2	70
Volcanic rocks, extrusive	~ 7.2	2	60
Interlayered shales and sandstone	~ 3.6	1	50
Unconsolidated to consolidated sand, gravel, arenite	~ 12	3.3	70

Using this method, the annual groundwater exploitation potential per sub-zone has been estimated (Figure 34).

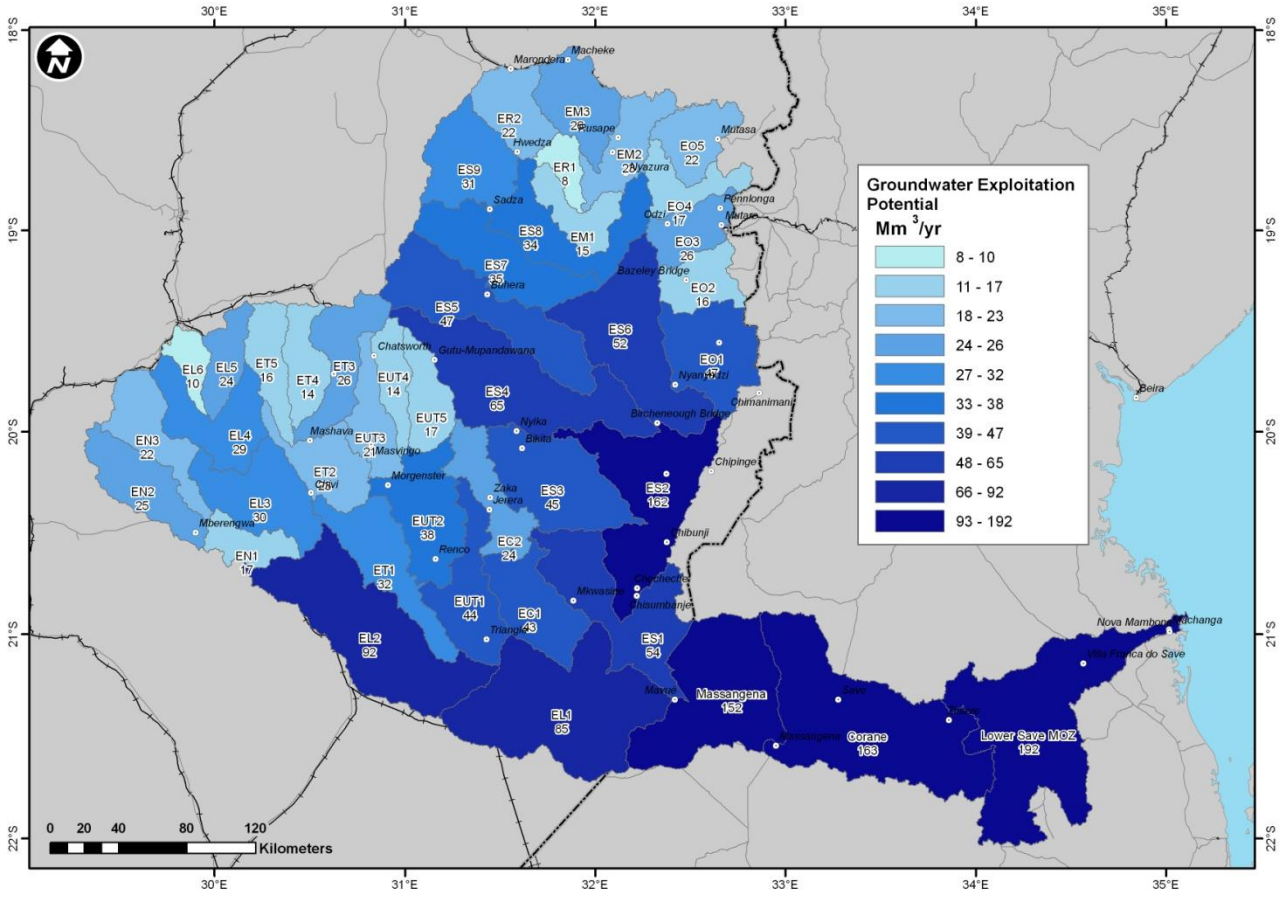

Figure 34 Groundwater exploitation potential (Mm^3/yr)

The total groundwater exploitation potential (AGEP) of the Save River basin is according to these calculations 1,900 Mm^3/yr.

This estimate is lower that the groundwater potential of approximately 3,870 Mm^3/yr presented in the Save and Runde River Systems Outline Plans (2009). The estimates in the outline plans were derived from a weighted average of the mean borehole yields for the different geological units and by assuming a borehole density of one borehole/km^2.

6.5.7 Groundwater quality

Approximately 70% of the population in the Save River basin uses groundwater as their source of drinking water. Thus groundwater protection measures are important as well as the complete analysis of groundwater (including microbiological content) of domestic supply boreholes on a regular basis.

It is anticipated that groundwater quality deteriorates from the higher lying recharge areas to the lower lying coastal regions. This is due to the increasing length of the groundwater flow path, resulting in more rock-groundwater interaction, as well as the proximity to the coast (where the precipitation has higher

salinity content and groundwater gradients are lower). The threat of sea water intrusion in coastal areas is also an issue.

6.5.8 Vulnerability to drought

There is no established method for describing groundwater vulnerability to drought. The resilience is related to the depth to groundwater, the groundwater recharge rates and the aquifer storage. Shallow groundwater levels are susceptible to "evaporative" losses and in times of high air temperatures and low rainfall, groundwater levels can naturally decline quite significantly. In addition where groundwater recharge and groundwater storage is low, especially in areas where groundwater is currently being abstracted, these aquifer systems are significantly impacted by drought conditions. In addition intergranular aquifers are more susceptible to impact by drought conditions, as opposed to fractured and confined aquifer systems.

For the Save River basin the intergranular aquifers, with shallow groundwater levels and existing groundwater abstraction are the most vulnerable to drought conditions. The situation is exacerbated if natural groundwater recharge and storage conditions are relatively low for the unconfined aquifer. The more resilient aquifers in the basin are the higher recharged granites, gneisses, quartzites and sandstone.

With more detailed borehole and groundwater data the development of a groundwater drought vulnerability map will be feasible. This topic is also being addressed on a regional scale under the SADC Groundwater Drought Management Programme and this work, when completed, must also be taken into account in the Save River basin management.

6.6 Comparison of surface water and groundwater resources

The mean annual runoff for the entire basin is estimated at 6885 Mm^3/yr (see Table 4). The potential for exploitation has not been estimated as this depends on the feasibility of building reservoirs for storing water, evaporation from the reservoirs and required environmental flow.

In comparison the estimated groundwater exploitation potential (AGEP) is estimated at 1900 Mm^3/yr. Full exploitation of the groundwater potential will reduce surface runoff and low flows.

For domestic water supply, groundwater is generally preferable to surface water because:

- Groundwater is less susceptible to contamination and is generally of good quality that requires little or no treatment
- Groundwater is less susceptible to drought

- Groundwater resources is less costly to develop, to operate and to maintain
- Groundwater has less variable chemical properties.

Moreover, new groundwater supplies can be developed in less time than larger surface water schemes as there are generally no major environmental concerns or high investments that may delay the process and the resource may be developed gradually as the demand increases. However, the groundwater potential in the river basin is restricted by the hydrogeological setting. Of the entire Save River basin 79% is classified as having a very low groundwater potential, 8% has a moderate potential and the remaining 13% has a high groundwater potential as highlighted in Figure 32.

Similarly, the feasibility of using surface water depends on local topography and technical and economic options for reservoir construction.

7 Water use and water demand

7.1 Estimating the demand

The water demand in the basin has been estimated for the different sectors for each of 43 hydrological units (sub-zones) based on a combination of historical water consumption records, reservoir yields and unit rates.

For the basin as a whole irrigation and livestock account for as much as 95% of the demand as shown in Figure 35 below.

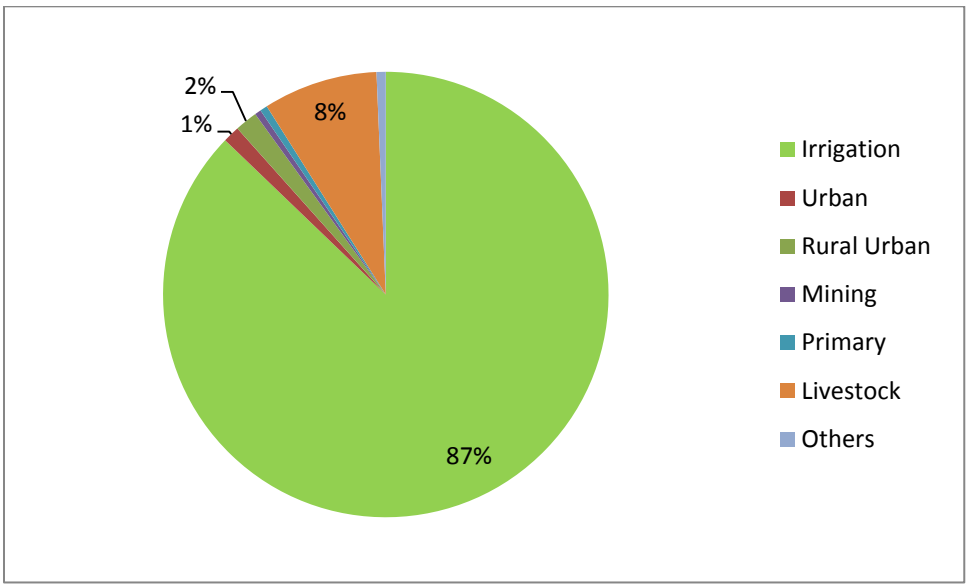

Figure 35 Water use by sector (excluding environmental flow)

The main uses of water and the methodology used to estimate the demand is described in the following sections for each of the major uses. Details are provided in Annex 4.

7.2 Irrigation

By far the largest users of water in the basin are irrigation schemes, plantations, and estates. Irrigation accounts for 87% of all water use.

The major irrigators and/or irrigation schemes in the Save basin are Tanganda Tea estates, Middle Sabi irrigation scheme and Chisumbange irrigation scheme. Commercial farmers dominate the Macheke sub-catchment, while communal farmers and small-scale irrigation projects dominate the Devure, Upper Save and Lower Save areas (Save Catchment Outline Plan, 2005). The irrigation schemes in the Save Catchment are listed in Table 8 and further details are provided in Annex 4.

Table 8 Irrigation schemes in the Save Catchment, Zimbabwe

Name	Sub-catchment	Volume committed (ML)	Area Under Irrigation (ha)
Middle Sabi	Lower Save East	5034	10,000
Rupangwana	Lower Save East	7.5	8
Chinyamatumwa	Lower Save West	50	35
Mashoko	Lower Save West	10	21
Tawona	Lower Save East	165	262
Fuve Panganayi A	Lower Save West	296	8
Fuve Panganayi B	Lower Save West	296	78
Fuve Panganayi C	Lower Save West	296	53
Fuve Panganayi D	Lower Save West	296	150
Bonde	Devure	280	364
Devure	Devure	272	330
Nenohwe	Odzi	106	100
Nyanyadzi	Odzi	400	440
Chibuwe	Lower Save East	304	357
Chisumbanje	Lower Save East	5	5
Arda Chisumbanje	Lower Save East	2400	2,400

Source: ZINWA Save, 2010

The major water users in the Runde catchment are sugar estates (Hippo Valley, Triangle, Mukwasini) in the Mutirikwi and Chiredzi sub-catchments. Table 9 below shows some of the irrigation schemes in the Runde catchment.

Table 9 Irrigation schemes in the Runde sub-catchment

Name	Sub-catchment	ha	Water source	Type
Chilonga	Lower Runde	141	Runde River	Pumping
Musvuugwa	Lower Runde	58	Runde River	Pumping
Makonese	Lower Runde	61	Makonese dam	Pumping
Rupike	Mutirikwi	100	Tugwane Rupike dam	Pumping
Mabvute	Chiredzi	70	Mabvute dam	Pumping
Zananda	Tokwe	16	Zananda dam	Pumping

Name	Sub-catchment	ha	Water source	Type
Hama/Mavhaire	Tokwe	96	Hama dam	Pumping
Gonye	Tokwe	3	Gonye dam	Pumping
Magudu	Mutitikwi	51	Magudu dam	Gravity
Mhende	Tokwe	78	Mhende dam	Gravity
Musaverema	Lower Runde	36	Musaverema dam	Gravity
Banga	Lower Runde	51	Banga dam	Gravity
Mapanzure	Mutirikwi	45	Gozho dam	Gravity
Mushandike	Tokwe	624	Mushandike dam	Gravity
Mabwematema	Upper Runde	100	Mabwematema dam	Gravity
Nyatare	Chiredzi	20	Nyatare dam	Gravity
Mugumba	Tokwe			Pumping

Source: ZINWA Runde, 2010

Previously Zimbabwe had a large production of tobacco and cereals as well as plantation crops (i.e. forestry, tea and coffee). The development focus of the Medium Term Plan 2010-2015 is revitalisation of the agricultural sector. The main elements of the plan are:

- Increasing irrigation capacity
- Increasing access by farmers to agricultural services such as extension support, skills enhancement through training, new and improved technologies and agricultural finance, ensuring that women have equal access to these services.
- Supporting establishment and strengthening of community-based farmers association which foster interaction, provide for research, technical and marketing support for farmers as well as facilitating the development of their own extension services.

Implementation of these recommendations will increase the demand for water, especially for irrigated agriculture.

Demand estimates

In Zimbabwe abstraction of surface water exceeding 5,000 m^3/yr requires a permit as does groundwater abstraction other than for "primary" use. Abstractions have to be recorded. The permit database has been used as the primary source for estimating the irrigation demand. For large dams the demand assessment has been based on 10%-yields, which is defined as the amount the reservoir can deliver in 9 years out of 10. Irrigation schemes are usually designed based on the 10%-yield. Permits are issued based on the yield and the entire dam yield is usually committed in the form of permits.

At present some users are not fully utilising their allocations, but since the water has been allocated this has been regarded as the current irrigation demand. It totals 3,586 Mm^3/yr.

For the projection, it is assumed that all allocations will be fully used by 2015 and that the growth rate after 2015 is 3% per year in accordance with the RSOPs and information from the agricultural extension service, AREX.

ZINWA has calculated that for the Odzi Catchment, the total volume required for future use is 360,944 ML, while the available uncommitted water is only 69,446 Ml (Table 10)

Table 10 Planned projects, Odzi sub-catchment, Zimbabwe

Proposed Future Water Projects	Volume Required (ML)	Area to be irrigated (ha)
Chsumbanje Irrigation Expansion	320,186	21,346
Marange Irrigation Scheme	24,000	200
Chitora Irrigation Scheme	552	46
Zonwe Irrigation	240	20
Svinurai Irrigation	300	25
Mukweda Proposed Irrigation Scheme	9,660	805
Nyanyadzi Nenhowe irrigation Schemes Expansion	3,156	263
Nyanyadzi Proposed Water Supply	750	
Oil Refinary Proposed Water Supply	100	
Checheche Proposed Water Supply	800	
Mukahanana Irrigation Scheme	1,200	100

In Mozambique, the currently irrigated area is only 32 ha. However, it is planned to increase the irrigated area and schemes in Govuro and Mabote are expected to be implemented soon, each covering 1,000 ha. By 2030 the irrigated area will be 10,000 ha. The demand is assumed to be 17,000 m^3/ha, which will bring the demand to 170 Mm^3/yr.

7.3 Livestock

Livestock is the second largest consumer and accounts for about 8% of the demand. The demand was estimated based on the numbers of livestock at district level multiplied with unit consumption rates for each type of livestock as described in Annex 4. For Zimbabwe the current consumption was estimated at 342 Mm^3/yr while for Mozambique it is only 0.1 Mm^3/yr. The projected increase in demand is presented in Table 11.

7.4 Urban and "urban rural" demand

Most large urban areas in Zimbabwe are supplied by treated surface water and the actual consumption is recorded by bulk meters. These records were used to

estimate the current consumption. The future demand was projected using estimated growth rates for each area which ranged from 0 to 4.7%.

Rural service centres include Birchenough Bridge, Hauna, Odzi, Macheke, Headlands, Buhera, Chimanimani, Lundi, Siboza, Ndanga, Zaka, Chivi, Gata, Mashava, Chirumanzu and Mhandamabwe. The water supply to rural service centres is mainly through boreholes.

For smaller towns, growth points or service centres ("rural urban areas") consumption is usually also recorded with bulk meters, but the records had many gaps. Consumption was therefore estimated by grouping the centres and estimating the rate for each group. Based on the consumption records a growth rate of 1.73% was used for the projection.

For Mozambique, urban consumption (i.e. Nova Mambone) was estimated based on unit rates plus an assumed physical loss of 35%. Future urban consumption was estimated to increase due to population growth of 4% plus as a result of improved service. However, for the basin as a whole the urban water demand in Mozambique remains insignificant.

The current consumption for the urban and rural urban sector was estimated at 117 Mm^3/yr, increasing to 223 Mm^3/yr by 2030.

7.5 Rural "primary" demand

Rural households without piped water (Figure 36) do not require a permit and consumption was therefore estimated from population statistics multiplied with standard per capita consumption rates.

Figure 36 Hand pump, Zimbabwe

For Zimbabwe a population growth rate of 1.01% was used as this is the rate used by ZimStat. The consumption was set at 20 l/c/day. For Mozambique the consumption was assumed to be 30 l/c/day and population growth rates were also higher (1.1-3.7%, see Annex 2).

For the basin as a whole, rural primary consumption was estimated at only 22 Mm^3/yr (Table 11).

7.6 Mining

The major mines in the basin are Bikita Minerals, Redwing, Dawn Mine, Dorowa Minerals, Unki Platinum Mine (under construction), ZIMASCO Chrome Mine, Mimosa Platinum Mine, Shabane and Gaths asbestos mines, Renco Gold Mine and Valley Mine.

Current water demand was estimated from issued water permits and projected demand by assuming an annual growth rate of 1.01% for the sub-zone where mining currently takes place. The current demand was estimated at 19 Mm^3/yr.

7.7 Other uses

"Other uses" includes institutions outside urban areas, hydropower and camps. A coffee processing industry in the Save Catchment is apparently the only industry the basin with a water permit (Save Catchment Council, 2005). The water consumption of this category amounts to 27 Mm^3/yr.

7.8 Current consumption and projected demand

Excluding environmental flow requirements, the total current demand is estimated at 4,114 Mm^3/yr and, with the assumptions used, this is projected to increase with 53% by 2030 as shown in Table 11 below.

Table 11 Current and projected water demand by sector

Sector	Total water demand (Mm^3/yr)			
	2010	2015	2020	2030
Irrigation	3,586	3,628	4,216	5,586
Urban	50	64	82	129
Rural urban	67	74	81	94
Mining	19	20	21	23
Primary	22	23	24	27
Livestock	342	359	378	418
Others	27	29	30	34
Total	4,114	4,198	4,832	6,311

The geographical distribution of the current demand is shown in Figure 37 below.

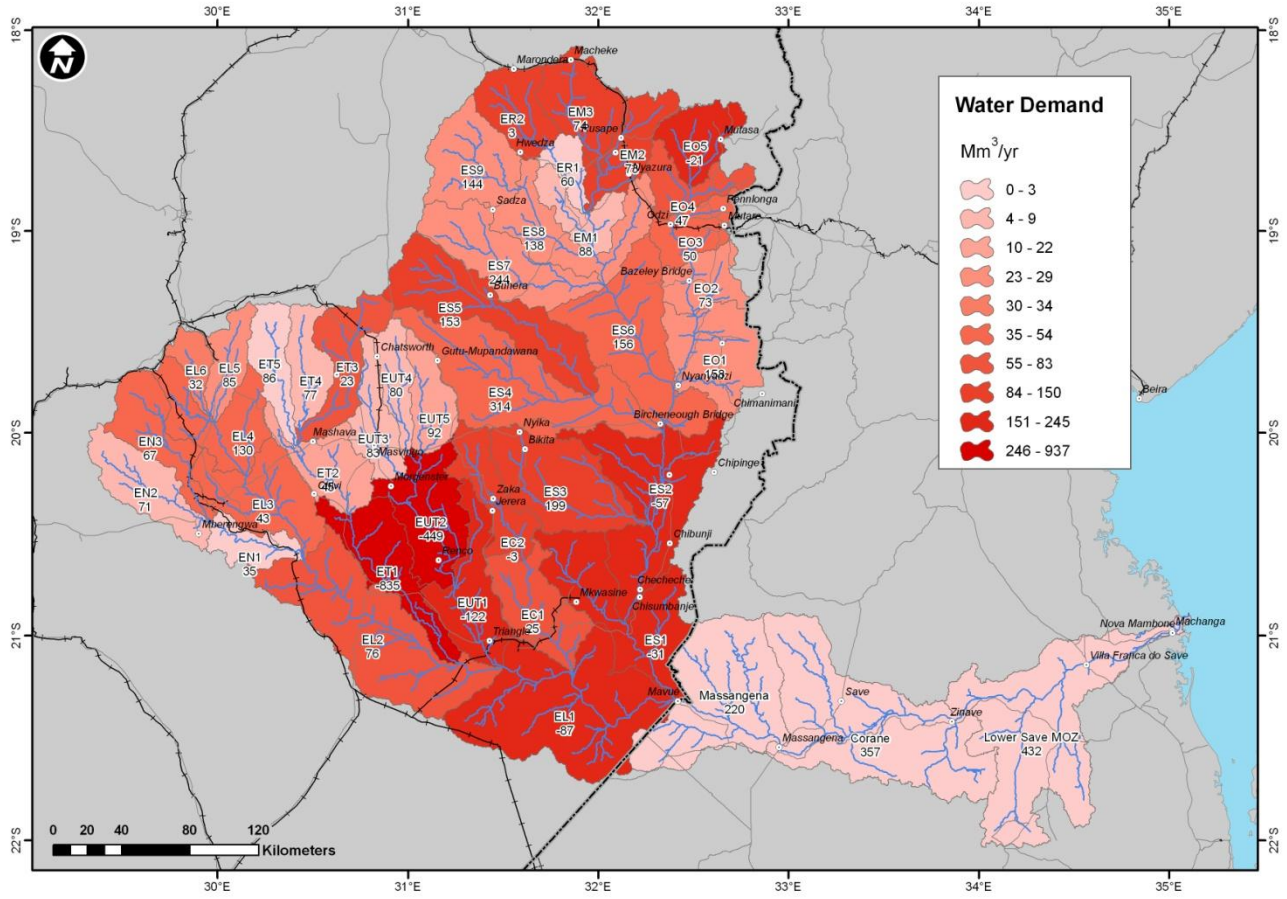

Figure 37 Geographical distribution of the water demand, 2010

7.9 Environmental flow

7.9.1 What is environmental flow?

When planning water resources development projects, key questions are how much water that should remain in the river after extraction and how the residual flow should be managed. The amount of water released downstream after a dam or abstraction point and the resulting flow regime, i.e. the environmental flow management, have important implications for downstream water users and the river ecology and may also considerably affect the economic feasibility of the development project.

These questions have been discussed for many years and numerous studies have been carried out in order to assess the ecological impacts of modification of the natural hydrological flow regime and to find ways to best balance the interests of the various stakeholders. Setting environmental flow requirements

is an integral part of integrated river basin management. Environmental flow requirement is in addition to the amounts allocated to downstream users.

Box 2 Environmental flow management

Environmental flow management provides the water flows needed to sustain freshwater and estuarine ecosystems in coexistence with agriculture, industry, and cities. The goal of environmental flow management is to restore and maintain the socially-valued benefits of healthy, resilient freshwater ecosystems through participatory decision-making informed by sound science. Groundwater and floodplain management are integral to environmental flow management.

From the declaration of the 10th International River Symposium and Environmental Flows Conference held in Brisbane in 2007 http://waterplanning.org.au/related-research/the-brisbane-declaration-on-environmental-flows

The first thorough studies on environmental flow focused at the protection of salmon and trout in Europe and North America and in meeting the habitat requirements of these particular species, but eventually it has been recognised that the entire river ecosystem should be maintained as well as the needs of downstream water users who directly or indirectly depend on the river flow.

While the principles of integrated river basin management are generally recognised, it remains a challenge to translate the principles into management regulations for environmental flow. This is not only due to conflicts of interests between various stakeholders, but also because it is difficult to accurately assess the ecological implications of flow modifications.

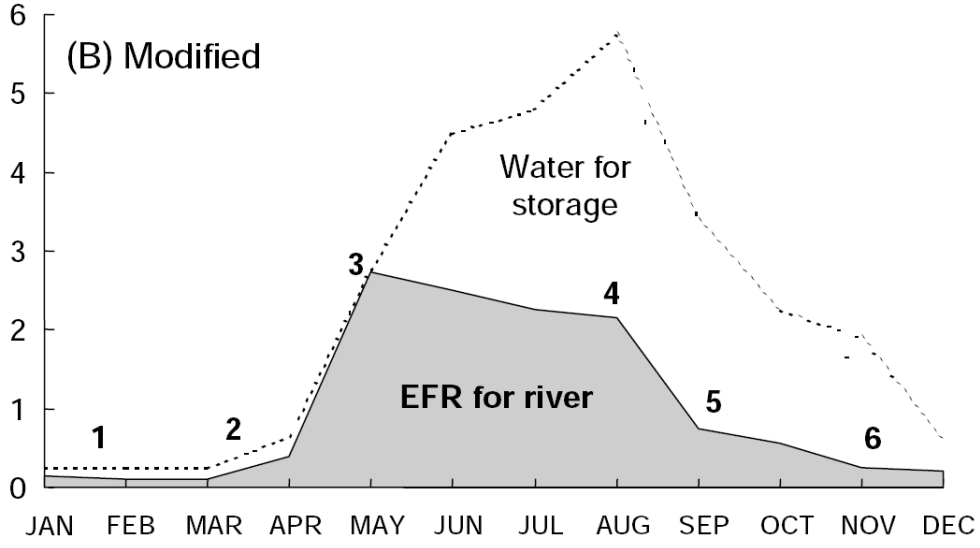

Figure 38: Example of environmental flow requirements compared to natural flow. The numbers refer to various features of the river's hydrology (King et al. 2008)

Simple environmental flow regulations may state that certain minimum flows must be released at all times or during the dry season. However, it is generally acknowledged that protection of the river ecology and the habitats of key species require varied flow regimes that include flooding at certain times and flushing at other periods. Newer regulations are therefore often complicated as Figure 38 above indicates. These notes give a brief review of the methodologies and practices of some countries[2].

7.9.2 Methods for setting environmental flow

A review (Tharme, 2003) of environmental flow methodologies used in 44 countries identified some 207 methodologies that could be classified in four groups as:

- Hydrological
- Hydraulic rating
- Habitat simulation
- Holistic

These methodologies vary considerably in terms of complexity, expertise required and costs. They represent stages in the development of environmental flow assessment methodology as well as a progression from relatively simple methods to more complex and costly approaches. The choice of methodology depends on the purpose of the work which may vary from recognisance level assessments to detailed EIAs of controversial projects. The four types of methodologies are briefly described below:

Hydrological methods

The hydrological methods rely on naturalized historical flow records and often determine environmental flow as a minimum flow that is a percentage of the natural (unregulated) flow fixed at an annual, seasonal or monthly basis. This approach is simple, does not require field work and uses national guidelines that may be available. However, the method is rather crude and does not take the actual characteristics of the particular river into consideration and the guidelines may not be appropriate to the specific situation. In many countries such methods are only used for recognisance level studies.

Hydraulic rating

As a further development of the hydrologic method, the morphology of the river channel is taken into consideration and the river level is modelled for various discharges. Parameters such as river depth or wetted perimeter can therefore be determined for various sections of the river. This assessment may focus on river sections or habitats that are considered particularly important. The assessment may include plots of flow versus extent of the critical habitat that will be affected.

[2] For detailed reviews see http://www.eflownet.org; Tharme (2003) and Dyson et al. (2008)

Habitat simulation

The next level includes more detailed mapping of the habitats at selected stations. The assessment includes a simulation of how changes in flow regime, temperature, water quality and sedimentology will affect the habitats and the organisms of concern, taking into account the different phases of their life cycles. This requires expert assessment of the impacts of the various parameters on the habitats and organisms.

Holistic methodologies

The holistic ecosystems approach is widely used in South Africa and Australia which lack the high-profile freshwater fisheries of North America. The approach emphasises protection of the entire riverine ecosystem and requires considerable multidisciplinary expertise and input. The South African Building Block Method (King *et al.* 2008) is an example of a holistic approach. This is the most complicated methodology and typically requires extensive studies by a range of scientists over several years.

7.9.3 Current practices in Zimbabwe

Under Zimbabwe's Water Act and Environmental Management Act, water is made available for primary purposes and the needs of aquatic life and ecosystems. Traditionally 5% of mean annual runoff (MAR) is reserved for environmental flow.

The seasonal river flows at selected stations are shown in Figure 30. The low flows are of special ecological concern. For the national border, the median of the annual minimum flows is 41.6 Mm^3/month (16 m^3/s) as shown by the red line in Figure 39 below.

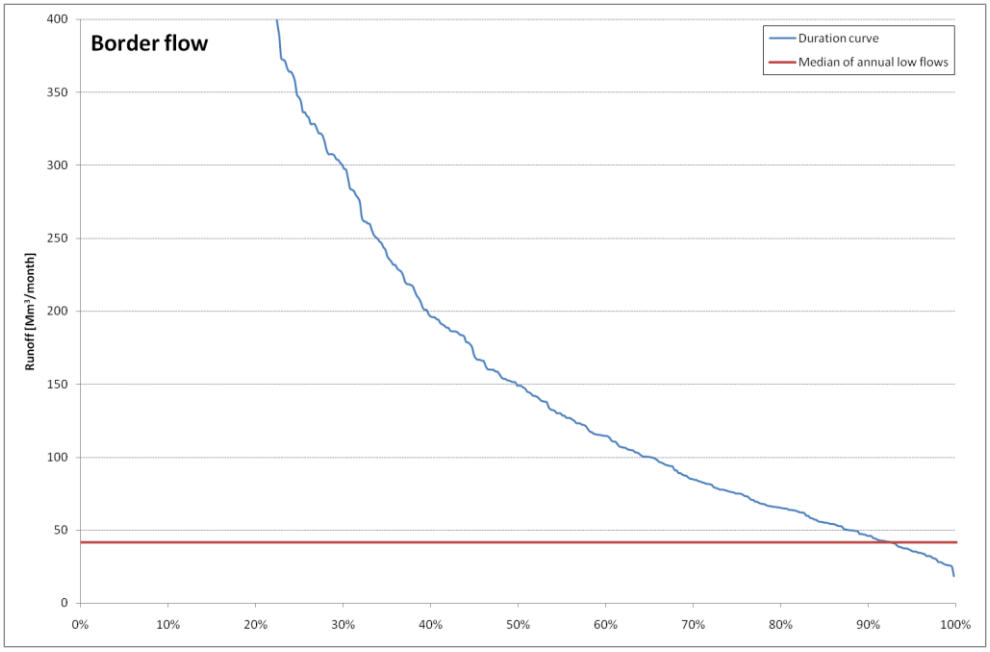

Figure 39 Duration curve for the flow at the border between Zimbabwe and Mozambique

At the border, the MAR is 5,834 Mm^3/yr corresponding to 486 Mm^3/month. If the Zimbabwean practice of reserving 5% of MAR for environmental flow was applied at the border, this would only amount to 24.3 Mm^3/month or 58% of median minimum flow. This is approximately equal to the flow that the natural river exceeds 99% of the time (namely 26 Mm^3/month, see Annex 3 Table 13).

7.9.4 Current practices in Mozambique

In Mozambique, there are no established standards for environmental flow requirements. The environmental flows to be considered are instream flows and estuarine freshwater flow. A recent study (CONSULTEC, 2010) for ARA-Sul recommended a reserve of 15% of the natural flow for use by the environment. This percentage is applied on a monthly basis to what would be the naturally occurring flows, e.g. the flow occurring in the absence of human interference.

In comparison South Africa typically reserves 20% of MAR as environmental flow.

7.9.5 A case study

A case study of the Rusape River has been reported by Love (2006). It is based on 30 years of daily hydrological data upstream and downstream of the Rusape Dam which were analysed with the South African DRIFT software using the building block method (Figure 40).

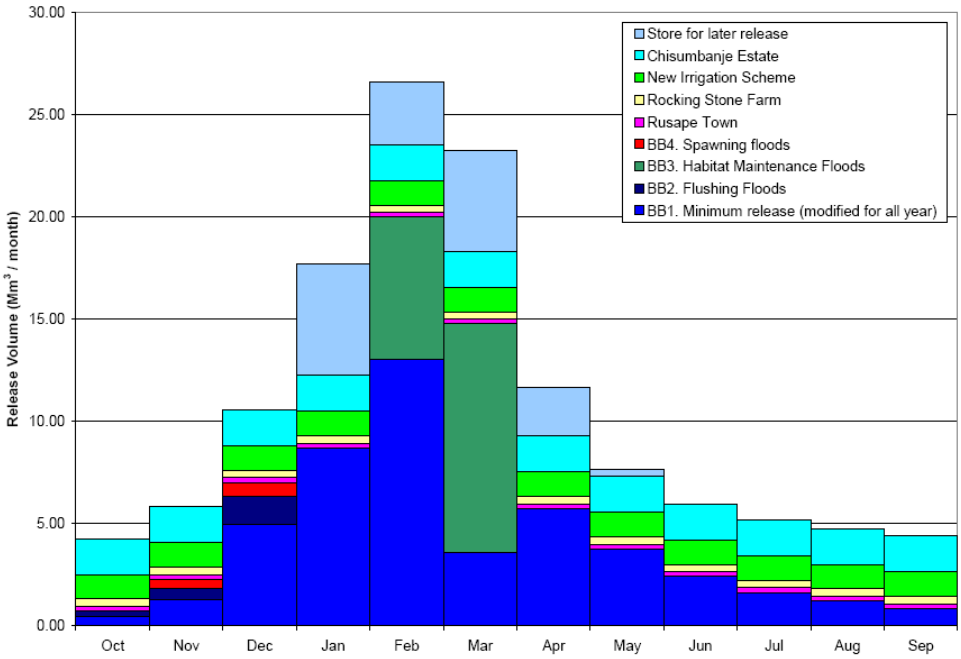

Figure 40 Example of a scenario using the building block method (Love et al. 2006)

The study indicated that supply to existing Chisumbanje Estate and a planned new irrigation scheme could only be met if environmental flow requirements were reduced compared to those initially recommended by the method.

The scenarios were preliminary as ecological field studies were not carried out during the study. Nevertheless the paper provides a good illustration of the issues and a possible approach to addressing the diverse pressures on a limited resource.

8 Balancing demand and resource

8.1 Current water balance

The total water resource in the entire basin (MAR) is estimated at 6,885 Mm^3/yr. For Zimbabwe the MAR is estimated at 5,834 Mm^3/yr. As discussed in Annex 3 this is about 10% lower than previous estimates.

The map below (Figure 41) compares MAR to estimated demand in 2010.

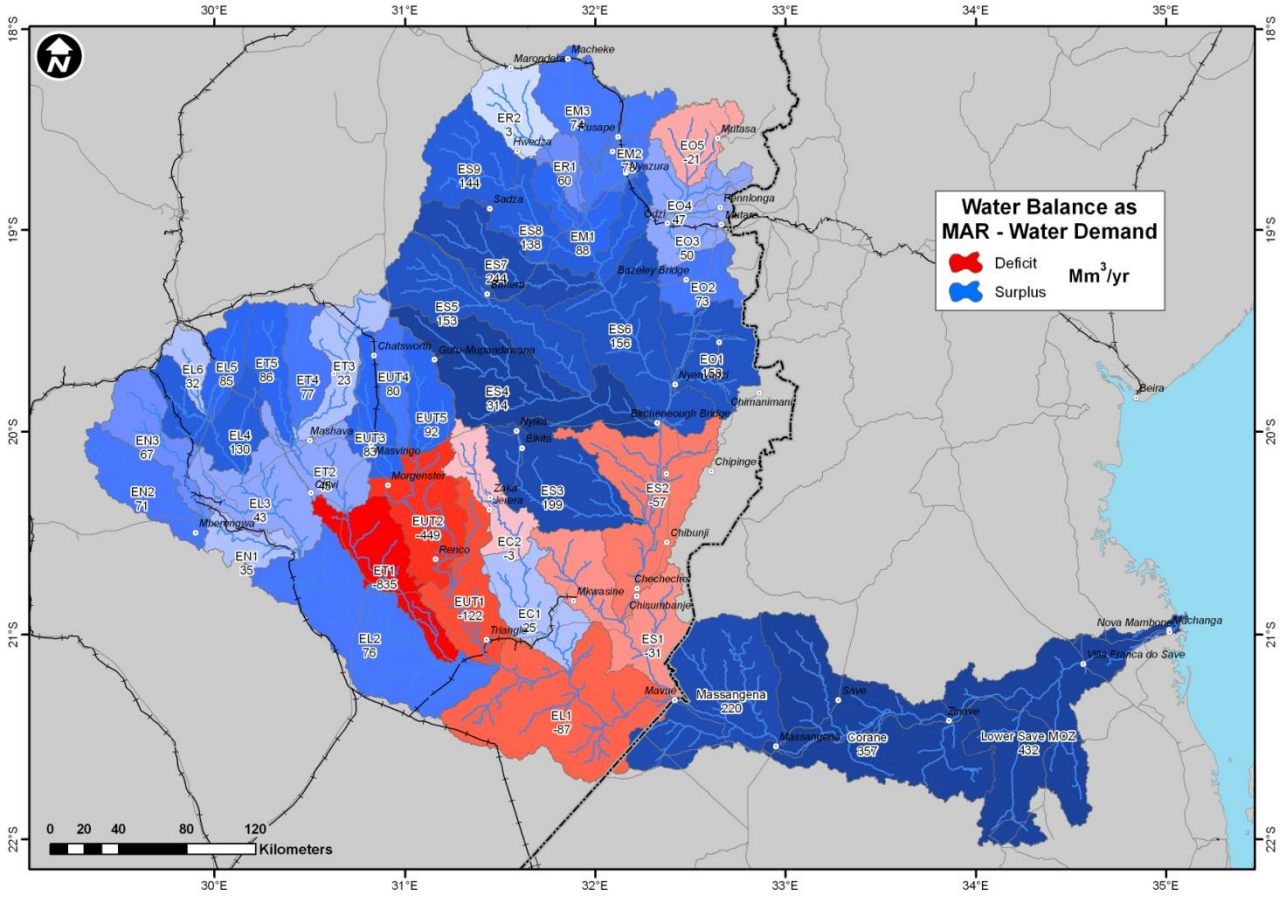

Figure 41 Water balance calculated as MAR less 2010-demand and 5% environmental flow

The water balance has been calculated as the water resource less the estimated demand. The environmental flow requirement currently used in Zimbabwe (5% of MAR) has been included in the demand in Figure 41.

There are several sub-zones in the basin, where demand exceeds the available resource. This is possible where the upstream sub-zones have sufficient surplus to cover the deficits and there is adequate storage.

8.2 Recent developments

The current consumption of water is lower than the historical consumption because irrigation demand in Zimbabwe is reduced because of the economic situation in recent years. However, agricultural production is picking up and irrigation demand will therefore gradually increase to "normal" levels. The demand estimates have taken this into consideration.

A number of new projects are on the way in Zimbabwe. These include an ethanol plant in the Chisumbanje and middle Sabi that Green Fuel is currently building. In its first phase, this plant will be supplied by estates with 11,500 ha of cane. The production is expected to more than double in a second phase[3] which will equal Triangle and Hippo Valley.

The Tokwe-Mukorsi dam is under construction and scheduled for completion in 2012.

Planned projects include the Kondo dam on the main stream of Save River and Chitowe and Tende in the Runde Catchment. If built these projects would gradually increase the total storage capacity and thus the share of the MAR than can be utilised for irrigation and other demand. They would also increase security in dry years to the extent that storage volumes may exceed annual run-off.

According to the Zimbabwe Hydrological Update (11.03.2011) the current combined storage capacity in the Runde Catchment is 2,247 Mm^3 and in Save Catchment it is 771 Mm^3 and the reservoirs are in a normal season filled 60-68% (Runde) and 55-71% (Save). The combined storage is thus 3,019 Mm^3 or 52% of the MAR in Zimbabwe.

In Mozambique there are also some irrigation development projects underway, but these are smaller and the water balance currently less stressed.

These scenarios will be examined during the next phase of the project.

[3] Zimbabwe Development Democracy Trust, 14 March 2011

9 Water quality

9.1 Water quality monitoring in Zimbabwe

Programme

To ensure the water quality in the surface water bodies in Zimbabwe, the ambient water quality monitoring programme was initiated in 1999. This program has strategically placed monitoring points on rivers in Zimbabwe to monitor the effects of effluents on water quality in the rivers. Annex 1 presents the detailed data as well as maps of the monitoring stations. Sampling and analysis is carried out by the EMA laboratory in Harare.

Bands

The results of monitoring are used to regulate permits. Permits are classified into four bands - blue, green, yellow and red - according to environmental hazard. The threshold values for the bands can be seen in Annex 1. The parameters that usually cause the need for a red permit are shown in Table 12 below.

Table 12 Threshold values for selected parameters

Parameter	Units	Blue	Green	Yellow	Red
TSS	mg/l	≤ 25	≤ 50	≤ 100	≤150
Phosphate	mg/l(P)	≤ 0.5	≤ 1.5	≤ 3	≤ 5
DO	%	≥60	≥50	≥30	≥15
Manganese	mg/l	≤ 0.1	≤ 0.3	≤ 0.4	≤ 0.5
COD	mg/l	≤ 60	≤ 90	≤ 150	≤200
Nickel	mg/l	≤ 0.3	≤ 0.6	≤ 0.9	≤ 1.5

9.2 Water quality status

9.2.1 Overall

Generally, water quality in the basin is not good, with many samples in the red band. There is a clear trend towards deteriorating water quality from 2002 to 2010.

9.2.2 Macheke

Macheke River generally has good water quality, with the exception of 2009, where there appeared to be problems with metals such as iron, nickel and manganese. In 2009 there were also problems with biological oxygen demand and dissolved oxygen below the confluence with Ruzawi River. In 2010 both monitoring points showed blue band values for all parameters except absorbed oxygen, which is in the green band.

Ruzawi River shows no indication of the BOD problems seen in the Macheke River. This suggests that the BOD originates from a source between the confluence and the place of measuring on the Macheke River.

The Rusape River showed good water quality within the blue and green bands except for some iron, nickel and manganese problems in 2009. Earlier analyses of these parameters are not available at time of writing.

The main potential sources of pollution in the sub-catchment are the Dorowa mine and the city of Rusape. These sources have the potential to cause high loads of COD, BOD, phosphates, nitrates and TSS. The metals are most likely a result of mining activities.

9.2.3 Odzi

Odzani River was in the blue band in 2010. Odzi River was in the yellow band in 2002 and 2009 for COD and for iron in 2009.

Sakubva and Dora rivers both have problems with DO, TSS, COD and BOD as a result of effluents from the Gimboki Sewage treatment facility.

The Mutare River (ER5, ER55) seems to have a good water quality.

The problems in the catchment stem mainly from the Gimboki sewage treatment works, which is not functioning. Another problem in the catchment is illegal and accidental discharges within the City of Mutare as well as gold panning.

9.2.4 Devure

Samples from the Devure River showed good water quality. Possible pollution sources in the sub-catchment include mine waste and domestic waste from Bikita minerals and sewage from Nyika Growth Point and Bikita RDC.

9.2.5 Upper Save

Mwerihari River and Upper Save River both exhibit slight increases in suspended solids after Dorowa Minerals mine where the river flows through the minings and tailings dam. There is, however, possible pollution from mine waste from the Dorowa phosphate mine and the two other mines.

9.2.6 Lower Save

A sample from the Lower Save River showed green band values. There is a likelihood of pesticide and fertilizer pollution from agricultural activities as well as pollution by sewage from the Birchenough Bridge settlement, hotel and hospital.

9.2.7 Runde

Runde River shows some problems with iron, TSS and turbidity from mines in Shurugwi, Zvhishavane and Mbengera district. TSS is from gold panning and siltation from poor land use practices. Gweru introduces industrial waste, urban waste and sewage, leading to high levels of COD and BOD as well as phosphates.

9.2.8 Tokwe

Tokwe River experiences poor land use practices around Shurugwi and Chirumanzu and pollution discharge from mines and panning which leads to problems with iron, TSS and turbidity.

9.2.9 Mutirikwi

Mutirikwi River has high levels of iron, TSS, BOD, COD and turbidity due to discharges from mines, urban centres, commercial farms, and communal areas. The City of Masvingo pollutes the river with industrial waste, urban waste and untreated sewage, which leads to high COD and BOD levels near the city.

9.2.10 Chiredzi

Chiredzi River is generally clean.

9.3 Sources of water pollution

The most important sources of water pollution are:

- Urban wastewater
- Industrial wastewater
- Rural settlements
- Large scale agriculture
- Subsistence agriculture
- Commercial mining
- Gold panning
- Soil erosion

9.3.1 Urban settlements

Urban settlements cause water pollution through direct discharges of treated or untreated industrial, commercial and domestic wastewater into rivers or drains

as well as through non-point sources. Often sewers are inadequate in at least parts of the urban areas and are not properly maintained.

Sanitary conditions are therefore a concern in urban areas as well as for downstream water users. Sewage spreads virus and bacteria with risks for the health of water users. Inadequate sewers and malfunctioning wastewater treatment plants result in discharge of water with high levels of organic matter, BOD and COD, which results in very low levels of dissolved oxygen in the receiving water body as well as pathogens and faecal bacteria.

A common problem in cities is inadequate solid waste management. As a result, trash accumulates in drains. Sometimes sewage flows in urban drains as well, causing a severe health risk and odour nuisance.

Most sewage treatment works in the Save basin are in a poor state, and many are discharging almost raw sewage. A particularly bad case is the Gimboki sewage treatment facility in Mutare. It is meant to take pre-treated sewage from other facilities in the city, but the other facilities have broken down, and the inflow from them completely overloads the facility. As a result, the monitoring programme shows that while the quality of the water in Sakubva River is acceptable upstream of the Gimboki sewage works, after the works the COD levels are extremely high and only drop slightly after the river drains into the Dora River.

9.3.2 Industrial wastewater

The composition of industrial wastewater depends on the type of industry. Typical urban industries include breweries, tanneries, transport enterprises and paper factories. In Mutare industrial sewage contains oil discharges from transport companies, low pH (3-5) from paper and timber industry, low pH effluent from breweries (pH 2-4) and high pH from soft drink production (pH 11) as well as fruit seeds from food production (Musvosvi, 2002).

In some cases industrial wastewater is discharged directly into streams and rivers rather than to a municipal treatment plant.

In Inhassoro District, there are seafood processing industries, mainly shrimp. Seafood processing usually produces wastewater rich in organic matter.

9.3.3 Rural settlements

Rural areas in the basin are found in small villages and around larger centres or growth points. Water supply and sanitation in rural areas is a challenge for rural district councils and has resulted in high number of cases of water borne diseases due to lack of funding for maintenance and new construction.

Sanitation in rural settlements is usually pit latrines. In Mozambique, rural settlements are usually not connected to sewers and often lack adequate sanitation. This can lead to diffuse pollution with organic matter and nutrients.

Some growth points have sewer lines connected to treatment facilities such as oxidation ponds.

9.3.4 Large-scale agriculture and agro-industry

Large-scale commercial agriculture is by far the largest water user in the basin (Figure 42) and also has the potential to cause severe pollution of surface waters. Use of fertilizers adds nitrates and other inorganic salts to groundwater and surface water. Pesticides also cause pollution.

Figure 42 Irrigation in Triangle. The plots are supplied by siphons from concrete canals.

Large-scale agriculture is closely linked to agro-industry, which may cause other water quality problems. Settlements of workers on plantations also require wastewater treatment facilities similar to domestic wastewater treatment in towns. In addition, pollution from spills of oil and chemicals occur.

Large-scale agriculture is found mainly in the middle and lowveld in Zimbabwe, where the main crops are sugar cane and cotton. Irrigation schemes are located along the lower Save River as well as between Birchenough Bridge and Chiredzi.

Sugar cultivation

By far the most important commercial crop in the basin is sugar cane. The sugar estates are mainly located near the two sugar mills of Triangle and Hippo Valley. A new large cane plantation has been initiated in the lower Save by Green Fuel in cooperation with the Agricultural and Rural Development Authority.

Water draining from the soil is lead away from the fields in ditches and then collected and in many cases reused. However, to prevent accumulation of salts, part of the drainage water is discharged to rivers.

Sugar mills

Sugar mills are supplied with cane from the Hippo Valley and Triangle estates as well as from outgrower schemes. The cane is milled to produce sugar at both Triangle and Hippo Valley. The effluent from the mills is either mixed with raw water and used for irrigation or discharged to ponds for settling and evaporation. During storms the ponds may overflow to streams.

Ethanol production

Leftover molasses from Hippo Valley is driven to Triangle where there is an ethanol factory (Figure 43). The waste product from the ethanol production is stillage, which is stored in dams until it is used for fertilizer or applied to roads in the dry season to prevent dust nuisance.

Figure 43 Ethanol plant, Triangle

Diluted stillage from the mills is also used as fertilizer and pumped directly to the fields. The pipes are subject to corrosion due to the high temperatures and the low pH of the stillage. Spills have been known to occur into streams from both burst pipes and spill from dams. The main problems in 2010 regarding water quality have been:

- Blocking of effluent pipe from factories leading to spill
- Spillage of stillage
- Overflow of spillage from fields
- Diesel spills from trucks
- Sewage overflows in villages
- Sewage pipes bursted

The estates employ a large number of people who live and work in the field and factories. The estates provide sanitary facilities for the workers and their families and are responsible for wastewater treatment.

Hippo Valley

Hippo Valley's monitoring shows instances where discharges from the three sewage ponds have values corresponding to the red class due to too low values of dissolved oxygen and high total suspended solids. One pond also showed problems with phosphorus. The mill effluent is seen to also be low in dissolved

oxygen and too in high phosphorus and suspended solids. All categories are the red class. The power plant effluent is also low in dissolved oxygen and has elevated suspended solids.

Triangle

Triangle monitors their effluents and results show red class for Sec 6 Danda ponds, Smuts Dam, Dundar out, stillage into dam, boiler effluent and factory effluent. The parameters determining the red class are COD and suspended solids. Generally, Triangle sewage ponds are in good condition except for two. Triangle monitors the streams on the estate. The results from the Mutirikwi River indicate that the level of TSS decreases as the water flows through the estate (maybe because of weirs and dams). The COD remains the same, while TDS and conductivity increases significantly. The Cheche River results do not show any clear trend. Kamba River results are all from within the estate and shows that TSS is a problem parameter. The streams are all in the blue and green class, most likely due to dilution.

Impacts

According to the Environmental Management Agency ambient water quality monitoring in both the Runde and Save sub-catchments currently do not indicate alarming levels of nitrogen (N) and phosphorus (P), although there is evidence that there has been over the years, an increase in nutrient levels in the country's rivers.

9.3.5 Subsistence agriculture

Small gardens and crop fields are present wherever people live. Fertilizer is to some degree used on the fields, but also manure is used. If this is applied prior to the rainy season there is a risk of diffuse surface water pollution. Subsistence agriculture does not usually involve chemicals.

In communal areas, poor agricultural practices have resulted in erosion and siltation of the rivers resulting in loss of storage capacity. According to a study by Elwell and Stocking (1978) soil loss from agricultural catchments through erosion ranged from between 1-20 t/ha/yr. Studies undertaken by Magadza (1995) indicate that in the Save sub-catchment storage capacity lost each year amount to 265 million m^3, which is equivalent to the storage capacity of the Mazvikadeyi Dam.

Stream bank cultivation

Gardens are often placed close to the water and this contributes to river bank degradation, erosion and increases sediment load in rivers. In Zimbabwe stream bank cultivation is very common especially along large rivers. This has contributed to toward siltation.

An increase in sediment particles in the river causes several problems to occur. The deposition rate increases and siltation of lakes and dams occur at a faster rate and impacts the entire aquatic food chain.

9.3.6 Deforestation

In rural areas deforestation has been a persistent problem. The persistent electricity power cuts in Zimbabwe in recent years have resulted in deforestation as trees have been cut both in urban areas and its environs.

Examples where urban deforestation is evident is Dangamvura and Christmas Pass mountains in Mutare which have been heavily deforested by firewood vendors.

In tobacco farming districts such as Mutare and Makoni, large areas of indigenous forests have been destroyed to provide fuel for curing tobacco.

Masvingo and Manicaland provinces are densely populated provinces, have high deforestation rates and experience fuel wood deficits, with Gutu district being the worst affected. The average rate of soil erosion in 1997 in communal areas was estimated to be 8.4% (Chenje et al, 1998).

Where the vegetation cover is poor such as areas of Chivi, Bikita and Gutu districts severe soil erosion has resulted in the development of gullies (Figure 44).

Figure 44 Gullies at Manjarenji Dam

Also in Mozambique, collection of fuel wood causes significant deforestation as selling of fuel wood often is the most important income alternative for the rural communities. Fuel wood is often the main source of domestic fuel for poor families in urban centres and particularly their suburbs. Deforestation is associated with opening new areas for cultivation, erosion of arable land along rivers, fires and uncontrolled cutting of trees for the production of charcoal and firewood, which further diminish the capacity of agricultural soils.

Timber logging in the eastern highlands has also contributes to erosion and siltation of rivers.

Fire

Fires are significant in shaping the landscape in Zimbabwe (Figure 45). Fires have serious impacts in that they change the vegetation cover and increase erosion.

In Mozambique, the major causes of slash and burn are related to the expansion of shifting cultivation, timber exploitation and overexploitation of forests for firewood and charcoal, collection of cuttings, over-grazing and uncontrolled fires. Cleaning paths and trails of surrounding villages and hunting small mammals are also highlighted as causes of fires.

Figure 45 Fires are significant in shaping the landscape

9.4 Mining

9.4.1 Mining activities in the basin

The Zimbabwean part of the Save river basin covers areas with numerous and, in some cases, world class mineral deposits which since long have been of interest for mining and prospecting companies, as well as being mined by local, artisanal and small-scale miners (ASM). The mining activities and the associated environmental concerns are described in greater detail in Annex 1.

Both Mozambique and Zimbabwe have a considerable number of informal miners, mainly involved in mining for gold or gemstones. In Zimbabwe, these are referred to as *amakorokoza*, in Mozambique, *garimpeiros*. In both countries, considerable efforts are being made to entice these to register, apply for licenses and to become part of the formal economy.

The main mineral deposits in the basin are situated within the greenstone terrains, in the Great Dyke and associated with serpentinite and ultramafic complexes on the Zimbabwean side of the basin. Conversely, there are no known significant deposits in the Mozambican parts of the basin.

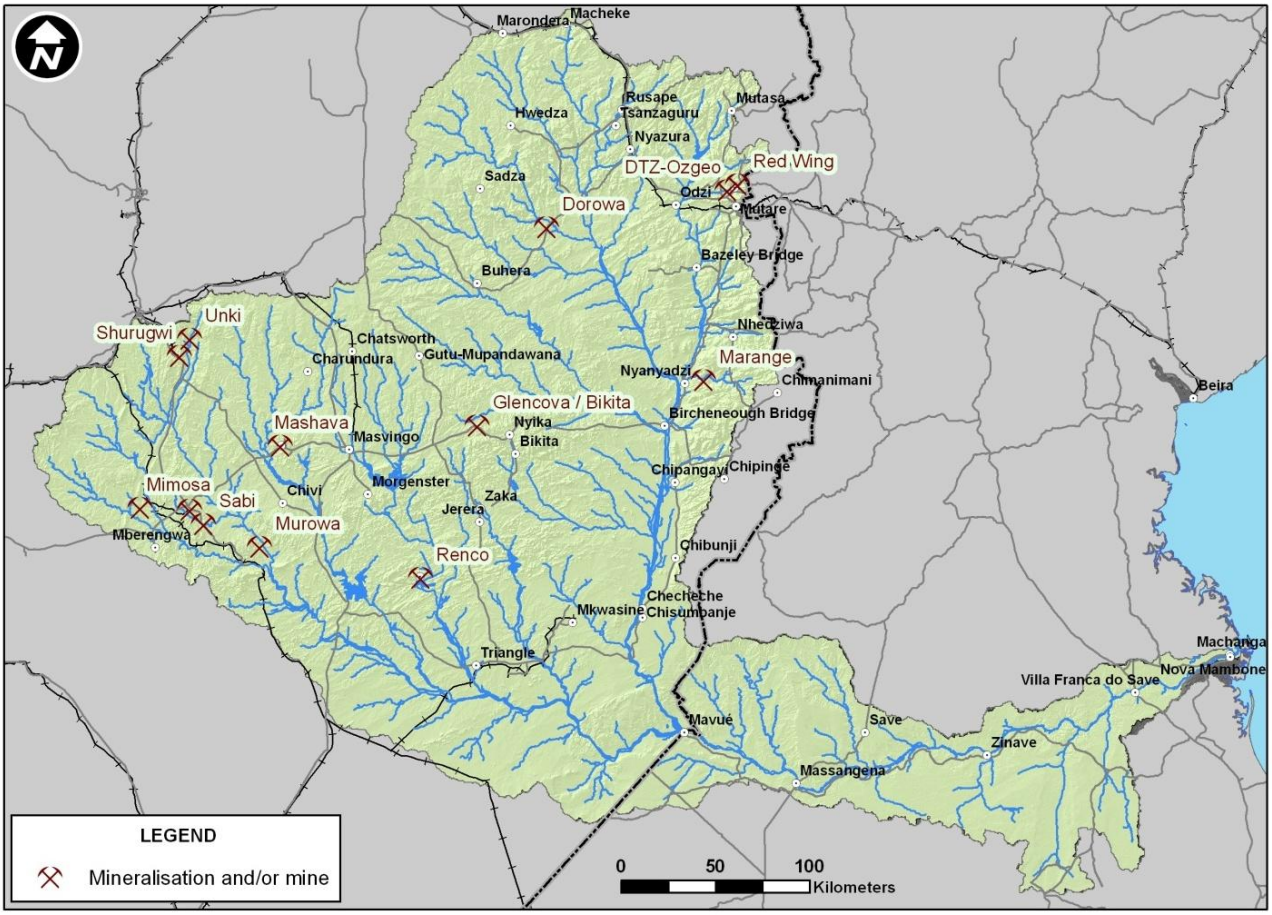

Figure 46 Active and/or recently active mines in the Save basin

The greenstone belts host a variety of mineral deposits of base metals and, most importantly, gold. The name greenstone comes from the green hue of some of the metamorphic minerals present. There are five main greenstone terrains in the Save basin, all named after nearby cities and/or villages namely:

- Manica-Mutare greenstone belt
- Masvingo greenstone belt
- Belingwe greenstone belt
- Gweru-Shurugwi greenstone belt
- Felixburg greenstone belt

Mining in Zimbabwe generally, and in the Save basin specifically, has experienced an extended period of decline with several formal, large mining operations closing down. However, the Zimbabwean part of the Save basin area is

again attracting a bit of interest in terms of development and exploration, mainly with a focus on platinum group elements, diamonds, chrome and gold. In Mozambique, interest is limited to diamond exploration in areas downstream or near the Marange diamond fields.

The formal, larger mines and projects in the Save basin are shown in Figure 46. These mines and projects include gold mines in the greenstone belts, platinum and chromite mining in the Great Dyke, diamond mining from kimberlites and placers, and a variety of industrial mineral mines (e.g. asbestos, phosphate, lithium, etc.).

In addition to these large operations, Zimbabwe and the Save basin also has a well-developed small-scale mining industry. Small-scale in this case refers to small, formal, mechanised operations and which are especially common in the gold and chromite sector. These small-scale miners have registered their mining claims with the MMMD, and they operate, or at least attempt to, within the confines of the Mines and Minerals Act, 1961. The number of such claims in the Save basin could be several hundred or, possibly, a thousand or more.

9.4.2 Abandoned or inactive mines

There are a large number of abandoned or dormant mines in the Save basin. These are mostly present in the greenstones, in the Great Dyke or in the serpentinite and ultramafic complexes.

By far the most numerous are the old gold mines in greenstone terrains, many of which may now be considered for reopening, as mentioned above. In addition to these, there are numerous smaller operations that have once been worked and then abandoned. In the part of the basin underlain by the Great Dyke, there are many dozen smaller and larger works left behind by former mining, especially those related to chromite mining.

9.4.3 Informal and artisanal activities

Zimbabwe has a large number of small-scale miners – *amakorokoza.* Most of these are involved in gold panning in rivers in, and downstream of, the Greenstone belts, as well as in the area surrounding Shurigwi. The activities are determined by a combination of the actual presence of gold, its current high price and a lack of alternative livelihoods.

Mercury is commonly used in addition to the pans and sluice boxes. There are also a substantial number of artisanal miners that access eluvial or primary gold in soils or harder rock. This type of mining is generally done by hand using simple technology in the form of shovels, picks and wheelbarrows. The ore accessed is weathered and oxidised and excavated from relatively superficial deposits. Mechanized drilling equipment and explosives are not used, and very little earth moving machinery is used. The treatment of the ore is done through grinding or simple mills. The principal method for subsequent processing is

panning, and mercury is commonly used to improve the efficiency of gold retrieval.

Miners are mostly young men from local communities.. ASM activities are associated with problematic characteristics such as use of manual unskilled labour, lack of finance for development, primitive technologies, low productivity, insufficient safety precautions and poor knowledge of the geology or deposits being mined. Nevertheless, ASM is a significant source of livelihood for a many people.

It is very difficult to estimate the number of ASM miners, since these activities are often informal and unregistered, the terrain is often difficult to access, and many are not "full-time" miners, but combine this activity with other livelihoods such as subsistence agriculture. Nevertheless, estimates do exists that can give an order of magnitude. Recent estimates of the number of informal miners in Zimbabwe are more than 400,000 (CASM, 2005) or up to 500,000 (CFC, 2008). These suggest that the number of ASM miners in the Save basin could be in the tens of thousands. MMSD (2001) further provides some estimates of the number of panners in streams in the basin. Thus, around Shurugwi there were more than 100 per km of river course; in the upper Odzi the corresponding number was estimated at <50, and in the other greenstone belts of the basin at 50-100 per km.

9.4.4 Impacts on the water quality and aquatic ecology

Mining activities may cause significant environmental impacts including contamination of water resources through discharge of processing chemicals or waste into streams and rivers. They may also be caused by the failure (catastrophic or partial through leakage and seepage) of tailings dams and other waste storage facilities. Adequate storage and control of waste and tailings is therefore usually the most important construction at any mine site for preventing downstream environmental impacts.

Groundwater

Impacts may also be related to pumping at mines, with an associated lowered groundwater table. Other possible impacts are the abstraction of surface water and associated diminished downstream flow of a stream or river. Furthermore, impacts on water quality may be caused by removal of vegetation, and opening new areas to erosion, which causes an increase in the sediment loading of downstream areas.

ARD

Rocks or mine tailings that contain appreciable amounts of sulphides have the potential to cause Acid Rock Drainage (ARD). ARD is generated when sulphide minerals oxidise, releasing sulphuric acid and metal ions into solution. Typically, ARD is formed in abandoned mine adits or in tailings impoundments and waste rock deposits. The serious effects of ARD upon water quality and aquatic biota are well known. It has been shown to lead to serious problems for decades or even centuries if acid is generated and not neutralised. ARD will, however, not develop in areas where the ore or the surrounding bedrock and soils have properties that will neutralise any acidity that may occur.

Figure 47 *Abandoned gold mines are common in the greenstone terrains of the Save river catchment. This picture shows the abandoned Champion mine, a previous As and Au producer near Mutare. Paste pH of a tailings sample taken from this site in August 2010 was 2.8, indicating that ARD (Acid Rock Drainage) is being generated and suggesting that it may be a considerable source of contamination of the nearby Odzi river.*

Explosives

Furthermore, use of explosives is common in mining and these, being nitrogen based, often give rise to substantial discharge of nitrate, which usually are difficult to manage adequately.

Tailings

The risk of failure of tailings and waste facilities is found in most types of mining. In large mining operations, risks are related to the sudden failure of a large dam or storage facility, which can cause serious downstream impacts. Smaller and less well capitalised operations quite often utilise inadequate technology or materials for managing tailings which can give rise to failures involving the escape of smaller amounts of material. The risk associated with tailings dam failures are especially serious in operations which create significant amounts of fine grained and highly liquefied waste. In the Save basin, such operations primarily include the gold mines and platinum mines.

Gold and base metals

The impacts on water quality that relate to the gold and base metal mines in the Zimbabwean greenstone have been considered in a number of studies. Thus, the overall conclusion is that since the ores in question contain sulphides, and the carbonates in the host rock are insufficient to buffer the acidity that is generated when these are exposed to air, the waste materials created do cause ARD and

the concomitant release of toxic metals and metalloids that are contained within the ore minerals such as As, Cu, Pb, Sb, and Cd.

The amount of ARD that is released depends heavily on the management of the waste (tailings and waste rock) and related seepages. However, to completely avoid ARD forming in a mine that relies on extracting sulphidic ore is practically impossible. Studies to date have compared downstream water quality with discharge standards or guidelines for drinking water quality (e.g. WHO), and concluded that element concentration dilutes rather rapidly downstream, so that risks related to human health are only significant near the source. However, it should be remembered that aquatic organisms are much more sensitive than humans to low concentration of metals/metalloids in water. Thus, impacts related to increased metal and metalloid levels downstream of Renco and Sabi, and other smaller gold mines in the Save basin are likely to be more significant and over a greater stretch of river.

Another issue relates to the possibility of spills of *cyanide* at gold mines that use this process. Cyanide is very toxic, and if discharged into waterways, will have a drastic impact on aquatic biota. Oon the positive side, cyanide is a highly unstable compound which will break down into harmless constituent parts. Thus, with proper management, there should be no discharge of cyanide into watercourses.

Diamonds

The mining and processing of diamonds rely on gravity separation or extraction from a heavy mineral concentrate. No harmful chemicals are used in these processes. Hence, possible impacts on water quality relate to increased sedimentation and turbidity due to discharges of tailings from the processing. In the case of Murowa, the impacts are small or negligible as tailings are captured in what seems to be adequate tailings management facilities. However, in the case of the Marange diamond fields, the impacts are significant, or even severe. This relates to the fact that the operations here are geographically spread out, and that there are insufficient measures in place.

Chromium

Chromium mines target what is essentially pure chromite seams in the Great Dyke or chromite pods in the ultramafic complexes. Processing is limited to washing, and no chemicals are used. The potential for impacts on water quality is thus cantered on turbidity and increased sedimentation. Flocculants are generally used in washing plants, and impacts are unlikely to be significant.

Platinum

Large-scale platinum mines are unlikely to cause significant downstream impacts. Process chemicals for flotation are mostly inoffensive, and the inert nature of waste rock and tailings and there is very little (or no) discharge of water from such facilities due to the recirculation of process water.

Phosphate

Possible impacts of the Dorowa phosphate mine include eutrophication, spread of radioactivity from uranium and/thorium in waste rock or sediment; dusting, and seepage of trace metals in the ore. However, the levels of radioactivity and concentrations of potentially harmful elements are low, and impacts are correspondingly small, although studies have revealed somewhat a higher level of iron, manganese, nitrates and phosphates, as well as conductivity and total

hardness downstream of these mines. Furthermore, there is some evidence of eutrophication leading to excessive growth of bulrush in downstream areas.

Asbestos

The asbestos mines that are presently not operating do not produce any materials that are harmful to water quality or aquatic organisms. However, the mines have been left without any rehabilitative measures being applied, with the consequence that there is now dusting and erosion from the tailings. This will, to some extent, cause increased turbidity and sedimentation in areas downstream and/or downwind. However, since the material is inert, it will in all likelihood not cause any other toxic effects.

Another issue is the potential for human health effects due to exposure to asbestos fibre. This risk remains unquantified. The fibres mined in the Save basin are so called “long” fibres, and not the short ones that are more harmful to humans.

9.4.5 Artisanal and small-scale gold mining

ASM is causing extensive impacts on river water quality in the basin.

Figure 48 *Artisanal gold miners seldom rehabilitate the areas where they have worked, leading to erosion and reduced river banks stability being impact related to these types of activities, in addition to the spread of mercury and the siltation of rivers and streams related to ore washing*

Gold panning is especially important in the Odzi, Devure, Chiredzi and upper Runde tributaries, where the main impacts relate to increased suspended sediment loading and turbidity. Elevated levels of metals, metalloids and mercury are also encountered. Other ASM activities, such as the extraction of material

from hillsides and river banks is also causing extensive erosion and silting of rivers.

Similarly, as washing of ore extracted as eluvial or hard rock gold is often done in or next to rivers, leading to greater turbidity downstream. Impacts are more severe in the dry season when the rivers do not carry much suspended material and when dilution effects are less pronounced.

In addition to impacts directly related to mining, there is also significant microbiological and other human waste related contamination in areas with high concentration of ASM activity, due to the transient and informal nature of these activities, and poverty in which miners and their dependants live in.

A survey carried out in Mashonaland Central in 1995 revealed that approximately 46% of panners operated in river beds or channels while a majority (57%) used horizontal tunnelling methods. Horizontal tunnelling results in undercutting and collapse of river banks, particularly during the rainy season, causing vegetation loss, erosion and siltation.

The Environmental Management Agency in Masvingo has been monitoring illegal gold panning activities and associated impacts and has documented these impacts. A summary of some of the rivers affected and impacts is highlighted in the table below:

Table 10 Impacts of panning and other small-scale mining

Activity	Location	Area and stretch of river affected	Damage in 1990s	Damage by 2010
Small-scale mining	Chivi District, Takavarasha and Chikota area Bodha-Munaka.	8.7 ha and 10.5 km along the Runde River	Excavation of open pits, destruction of vegetation and gully formation	Destruction of vegetation around river banks and bed, gully formation and siltation
Small-scale gold mining	Shongamit ward, 28	15.2 ha and 8 km along the Tokwe River	Destruction of river bank and bed. Also land clearance for temporary shelters	Same as in the 1990s
Mineral panning	Odzi river	800 m	Low damage	Severe
Mineral panning	Marange		Low damage	Very severe

Source: Environmental Management Agency, Masvingo, 2010

9.4.6 Abandoned mines

There are a large number of abandoned mines in the basin. Abandoned mines are prone to erosion and the release of contaminants (e.g. metals, metalloids and excessive turbidity) to downstream water bodies.

The largest numbers of abandoned mines are represented by old gold mines in the greenstone belts. There are also abandoned base metal mines and arsenic mines in this area. Very few, if any, of these mines have been rehabilitated. These abandoned mines are, especially problematic, as many of them are associated with sulphidic ore bodies and hence possible formation of ARD. Investigations elsewhere in Zimbabwe suggest that associated impacts on water quality (lowered pH, high concentration of sulphate and metals and metalloids) are often serious.

Figure 49 *Mashaba mines. The operations are at present (November 2010) not operating and the previous owner are undergoing a process of investigation. Although asbestos mines do not pose a significant threat to water quality or aquatic ecosystems, their rehabilitation will be very costly, should it not be possible to restart operations.*

9.4.7 Risk ranking

The above sections are summarised in Table 10 below in terms of which are the possible impacts on water quality and aquatic ecosystems that relate to different types of mining in the Save river basin. The table also provides an indicative ranking of the risk of such impacts. Risk is defined as the probability of an event occurring, timing of its impact or importance. Scores are given on a simple scale: low, intermediate, or high.

Table 13 *Main types of mining in the Save river basin, associated impacts and an indicative risk ranking for each impacts (1-low; 2-intermediate; and 3-high)*

Type of mine		Main environmental issues and provisional risk ranking
FORMAL MINING	Gold and base metal mining	ARD (3) CN discharges (2) Tailings impoundment failure (2) Siltation and turbidity (2)
	Alluvial gold mining	Siltation and turbidity (2) River bank erosion (2) Tailings impoundment failure (1)
	Kimberlitic diamond	Tailings impoundment failure (1) Siltation and turbidity (1)
	Chromite mining	Tailings impoundment failure (1) Siltation and turbidity (1)
	Platinum mining	Tailings impoundment failure (2) Siltation and turbidity (1)
	Eluvial & alluvial diamonds	Siltation and turbidity (2) River bank erosion (2)
	Industrial mineral operations	Siltation and turbidity (1)
INFORMAL	Gold panning	Siltation and turbidity (3) Hg contamination (2) River bank erosion (2)
ABANDONED	Gold and base metal mines	ARD (3) Siltation and turbidity (2)
	Chromite mines	Siltation and turbidity (2)
	Industrial minerals	Siltation and turbidity (1) Eutrophication (1)

The impacts that pose the greatest risk to water quality and aquatic ecosystems are ARD from both active and abandoned gold mines, and siltation and turbidity caused by informal gold panners.

9.4.8 Mitigation of mining impacts

The Save river basin includes areas that are very promising for gold, chromite, platinum, diamonds and base metals, which means that mining will remain an important activity in the basin, and one that will have a continued effect on the river system. Management of the Save river basin will have to consider both the problems and opportunities created by mining.

Mitigation of the impacts of mining on the Save basin should be based on a strategy that: (i) strengthens ability of the relevant authorities to supervise and control on-going mining operations; (ii) investigations that determine in what order, and to what extent, existing abandoned mines should be rehabilitated to achieve the maximum cost-benefit in safeguarding water quality; and (iii) efforts to improve awareness and expertise among miners and the local popula-

tion, so that they and their political representatives can put pressure on miners to improve their environmental performance.

For large-scale mining and prospecting activities, existing laws and regulations are generally adequate for managing these activities. Potential dangers and problems are foreseen and catered for in the existing legal frameworks. Implementation becomes a matter of ensuring that the relevant institutions have the capacity to enforce these frameworks and to adequately control the mining companies. For example, the issue of ensuring that there are adequate plans and resources for rehabilitation once mining has finished is very important, as can be seen by the current situation where there is a considerable environmental liability associated with ailing asbestos mines.

There are a large number of small-scale formal miners in the basin, especially in the gold and chromite sectors. These miners should be trained to become more environmentally aware and responsible. This needs to be combined with the above-mentioned efforts to strengthen the capacity and commitment of authorities to supervise, control and enforce existing laws and regulations.

The artisanal and informal mining sector, the *amakorokoza*, are mainly driven by poverty, and will continue to exist as long as there is a lack of alternative livelihoods in the basin. This suggests that the only way to completely avoid the environmental, social and human health problems that are intimately associated with this type of activity is to ensure an overall positive economic development in the basin.

In the meantime, problems caused by these mines persist, and there is an urgent need to mitigate, manage and control them. At the same time, ASM activities are inherently difficult to control. At present, no reliable data exists on the number of miners, incomes and benefits to the local economy, and the seriousness and impact of their associated environmental impacts. Estimates of the number of people involved in ASM appear exaggerated and/or unreliable, and are not an adequate basis for making policy and management decisions.

Without good baseline data, efforts to manage environmental impacts are unlikely to be successful. Thus, the first priority is to carry out a proper census and baseline study to assess the situation. Such studies need to be followed up regularly to provide a good enough basis for management decisions.

The use of mercury in ASM is a serious issue, especially since very little effort is being made by individual miners to prevent the introduction of mercury into the environment. There are ways to minimise the escape of mercury by using retorts. Continuous efforts are needed to ensure that such retorts are used to a greater degree as long as the *amakorokoza* exist.

There are a large number of abandoned mines in the basin which can cause significant impacts on downstream water quality. The severity and extent of the impacts are, however, unknown. A project is therefore required that includes the following components: (i) an inventory of all significant abandoned mines in the area; (ii) a risk screening of the sites thus identified followed by envi-

ronmental investigations at selected sites; (iii) identify and cost rehabilitation plans for sites that pose the greatest environmental risk; (iii) a cost-benefit ranking of sites to be rehabilitated. Such a project should be followed by a second phase where rehabilitation is carried out at the main prioritised sites.

All mining companies must realise the need to invest in adequate environmental measures to ensure that mining is carried out responsibly and to avoid future problems related to abandoned mines. This can be achieved by promoting local government involvement and by overall improving the public's understanding of the sector. When local people see environmental contamination as unacceptable, the political will to do something about it will follow, as will the mine operators' desire to comply with existing legislation due to increased community pressure. Thus, overall efforts to improve awareness among the public of the environmental performance that is expected form miners in schools and other suitable forums will greatly contribute to the long-term sustainable management of the river basin.

10 Flood

10.1 The 2000 flood

Cyclones in the region frequently result in floods from major rivers and from the coast. Cyclone Eline caused floods in both countries, but Mozambique was particularly affected and the 2000 flood was unprecedented in living memory.

Due to the terrain and the combination of wind and a storm surge caused by cyclone Eline, the impact was particularly severe in the coastal area where 32,726 persons were in emergency (displaced or in need of food or medical assistance) in Govuro District of Inhambane Province and 47,281 persons in Machanga District of Sofala Province. The impact was much smaller 20 km inland as the river is here incised in a valley.

Satellite images indicate the extent of the floods. Figure 50 shows satellite imagery taken 29 January 2003 by Landsat 7 bands 5,4 and 3 (red, green and blue) as presented by NASA and Dartmouth College. At this time the Save River was confined to its channel. Figure 51 is dated 1 March and shows how the river had filled its floodplain and overflowed the delta after the passage of Cyclone Eline. A large flood area can be seen near the river mouth.

Nova Mambone experienced severe flooding. Residents informed the monograph team that the flood came as a surprise, because it did not come from the river, but from the inland area. Many were rescued by helicopter.

The exact flood level has not been established, but it exceeded 9 m at the station E47 at Vila Franca de Save between 7 and 8 February 2000 and again on 25 February and probably for several days after that. SMEC (2004) estimated the likely maximum level at 10 m. The bridge was not cut off, but further north the road was submerged, presumably due to local floods rather than overflow from the river.

The 9.0 m level at E47 corresponds to a flow of 14,815 m^3/s and SMEC (2004) estimated that the 2000 flow reached 17,500 m^3/s and was the largest flood for 70 years.

Analysis using the log Pearson 3 distribution estimated that for E47 in a given year there is a 10% likelyhodd that the maximum flow will reach 11,000 m^3/s

and 1% likelyhood that it willreach 27,700 m^3/s The flow at the Zimbabwe border is estimated to be 88-91 % of the E47 flow.

Figure 50 The Save River is confined to its channel on 29 January 2000, Mozambique

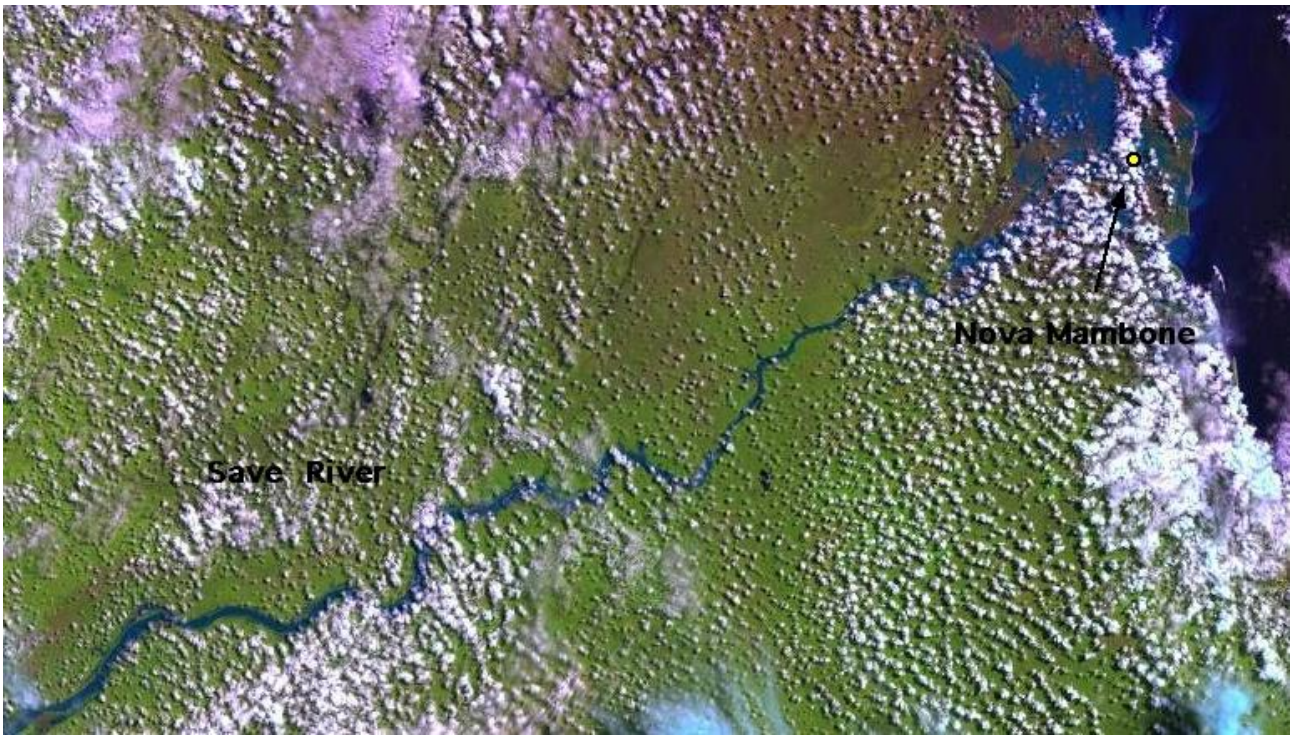

Figure 51 Satellite imagery from the same area on 1 March 2000 after the passage of Cyclone Eline shows extensive floods near the coast

10.2 Flood estimates

In the water resources study presented in Annex 3 the hydrological data was analysed in order to estimate the flood magnitude. For smaller infrastructure the estimates are based on the regionally derived specific flows for a 100 years recurrence period, while for the design of large dams the Regional Maximum Flood (RMF) is proposed. For the points of interest this analysis gives the values presented in Table 14 below.

Table 14 RMF for POIs in the Save River basin

Type	Point of Interest	Area km^2	K-value	RMF m^3/s	RMF $m^3/s/km^2$	Q100 $m^3/s/km^2$
Confluences	Ruzawi River at confluence with Macheke	2 152	5.2	5 751	2.7	0.5
	Macheke River at confluence with Save	6 620	5.2	9 863	1.5	0.3
	Odzi River at confl with Save	7 327	5.1	9 415	1.3	0.2
	Duvure River confl Save	8 125	5.2	10 882	1.3	0.2
	Save confluence Runde	43 682	5.2	24 397	0.6	0.1
	Ngezi River confl Runde	4 512	5.1	7 424	1.6	0.4
	Tokwe River confl Runde	7 942	5.2	10 764	1.4	0.3
	Mutirikwi River confl Runde	8 057	5.2	10 838	1.3	0.3
	Chiredzi River confl Runde	3 536	5.2	7 299	2.1	0.4
	Runde confl Save	40 934	5.1	21 874	0.5	0.1
Dams	Osborne Dam	1 380	5	3 715	2.7	0.5
	Tokwe Mukosi Dam (planned)	7 126	5.2	10 218	1.4	0.3
	Mutirikwi Dam	3 951	5.2	7 699	1.9	0.4
	Manjirenji Dam	1 480	5.2	4 805	3.2	0.4
Other	Border flow	85 078	5	29 168	0.3	0.1
	Estuary	101 895	5	31 921	0.3	0.1

It is noted that while SMEC estimate the 100-year flood at E47 at 27,700 m^3/s, the present study arrives at 30,000 m^3/s. These estimates are very close.

11 Climate change

11.1 What do we know?

Climate change is the cause of much debate and studies worldwide and in southern Africa. Unfortunately due to a general lack of conclusive results many interpretations and "guesses" can be found in the literature. The scientific advances are rapid in the climate change field and it is therefore essential to base any prediction on the latest publications. A number of recent publications are of interest for the southern Africa climate change:

- South Africa's Second National Communication under the United Nations Framework Convention on Climate Change, Department of Environmental Affairs of South Africa, November 2010.

- Study on the Impact of Climate Change on Disaster Risk in Mozambique: Synthesis Report, National Institute fro Disaster management (INGC), ed. By van Logchem B and Brito. R., May 2009.

- Climate Change Implications for Water Resources in the Limpopo River Basin, Zhu. T and Ringler, C. International Food Policy Research Institute, Paper 00961, April 2010.

- An assessment of sensitivity of Save and Runde surface water supplies to climate change impacts. University of Zimbabwe. January 2009

These documents summarises the latest situation on climate change research and give the current best prediction of the effect in southern Africa.

All predictions on climate change are still based on downscaling of Global Climate Change Models (GCMs). The downscaling methods become more and more reliable. However, DEA (2010) emphasises that the GCM poorly represents escarpments and local topography that is fundamental for the local climate, especially rainfall. This is the reason why new and more complex pictures of the effects of climate change are regularly published as the downscaling techniques are improved.

The earlier prediction that climate change will cause generally much drier conditions in southern Africa is now replaced with a much more diverse picture

where many areas seems to get wetter conditions. However, dynamic downscaling through a regional model is still work in progress and we are therefore likely to see further modifications on the local effects of climate change in southern Africa.

On a general level, however, the different GCM and downscaling techniques used toady agree on some basic predicted changes in southern Africa as a consequence of climate change:

- A general increase in temperature in the whole region, but mostly in the interior of the continent.
- Increased rainfall during the rainy season in the eastern part of southern Africa, while dryer conditions are expected in the interior
- Decreased soil moisture during the dry season as a result of higher temperatures and evaporation

11.2 Predictions for the Save basin

The predictions scenarios for the three joint river basins managed by ARA-Centro and ZINWA Save/Runde are very different. The Pungwe and Buzi rivers are likely to get increased rainfall and runoff, while the Save River will get significantly lower water resources. The Eastern Highlands seems to be a divide for the effects of a future climate change.

INGC (2009) give the best description of the future impact of climate change on the Save River Basin. According to the INGC there is a forecasted decrease in rainfall over most of Zimbabwe. Runoff is assumed to decrease by 10 to 25% up to 2060. Figure 52 shows the assumed future effects on river flows in Mozambique and Zimbabwe caused by a changed climate. It indicates that the Zimbabwean part of the Save River Basin will get a decreased runoff while the Mozambican part of the basin will experience an increase in runoff.

What is also very relevant for the Save River Basin is that both historical trends and the GCM models predict higher intensity of cyclones that are the main cause for large floods in the basin. The Cyclone Eline in 2000 created the highest flood levels since observation started in the Save River. Historical trends also indicate more frequent cyclones, although the GCM models contradict this.

In conclusion, a potential future climate change will most likely cause a more variable climate in the Save River Basin. The estimated MAR based on 1960-96 will probably be lower in the future. Droughts may therefore be more common and rainfall will start later after the dry season. Floods may be more severe and maybe more frequent.

11.3 Implications

The hydrological assessment in Annex 3 is based on the assumption that the historical situation will prevail in the future. To get a good spatial description of the water resources in the Save River Basin the years 1960-96 were used to simulate the average condition and variation in runoff, rainfall and evaporation (since these years had good coverage of input data). The assessment may therefore overestimate the water resources for most of the basin.

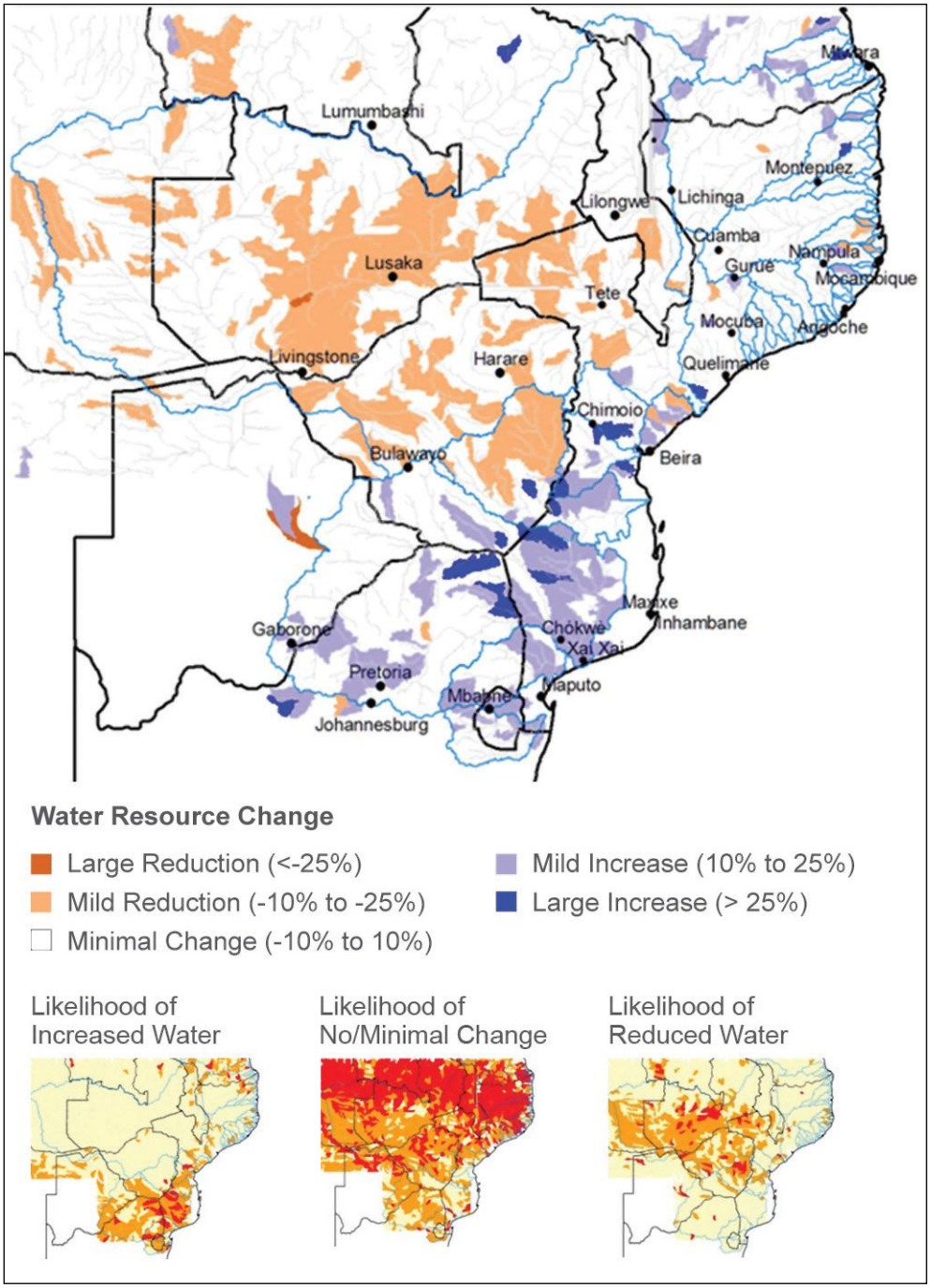

Figure 52 Average changes in the river flow based on seven GCMs.

Source: INGC (2009).

As a result, there will be an increased need for dam infrastructure to store the increased rainfall during the longer dry season and more efforts to mitigate floods.

In the optimisation of the dams extra safety marginal must be taken in the system analysis when using the historical runoff from 1960-96 as a basis to compensate for the expected longer dry seasons. Spillway design should also be made with extra care assuming larger floods in the future.

12 Water governance

12.1 International and regional level

12.1.1 International law and agreements

In today's globalised world, water is considered a natural resource to be shared equitably among communities and between nations. This requires cooperation, under a framework of interdependence and joint management by riparian states. Two global and regional conventions and protocols are particularly relevant for the management of shared rivers by Zimbabwe and Mozambique:

- The United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses, 1997
- The Revised Protocol on Shared Watercourses in the SADC, 2000.

12.1.2 UN convention on international watercourses

The United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses applies to uses of international watercourses and of their waters with respect to their protection, preservation and management. It promotes the formulation of watercourse agreements between international basin states in respect of particular water courses in line with or in accordance with agreed adjustments to the provisions of the convention.

Principles

Its main principles are summarised as follows:

1 The provisions under Article 5 allow for the entitlement of every affected watercourse state to negotiate or become party to any watercourse agreement and that applies to the entire or part of an international watercourse and to participate in any relevant consultations.

2 Article 6 of the convention requires the equitable utilisation of an international water course to take into account geographic, hydrographical, hydrological, climatic, ecological and other factors of a natural character, including social and economic needs, the dependent populations, the impacts of water uses, the development and protection of water resources as well as

the economic value of water. It sets the tone on the scope of water resources management strategies with regard to the development and use of international watercourses.

3 The watercourse states are obliged to take all appropriate measures not to cause significant harm to other watercourse states when utilising international watercourses in their territory is outlined in Article 7, including the provision for compensation of the aggrieved state where necessary.

4 Article 8 provides for the formation of joint commissions between watercourse state to provide a platform for inter-state co-operation in order to attain optimal utilization and adequate protection of an international watercourse.

5 The need for the collection and regular exchange of data is addressed under Article 9, and is a key aspect of co-operation between the watercourse states.

6 The prioritisation of water uses in the absence of agreement between water source state and the manner in which conflicts shall be resolved are enunciated in Article 10, with special consideration being given to vital water needs.

7 Articles 11 to 19 deal with the manner in which communication between states shall be managed with regard to the exchange of information concerning planned measures, the timing and scope of notifications, the conditions for consultations and negotiations, procedures to be followed in the absence of notification and where there is a need for urgent implementation of planned measures.

8 The manner in which the watercourse shall be protected, preserved and managed is outlined under Articles 20 through to 26, which address ecosystem protection and conservation, pollution control, alien species, protection of the marine environment, and issues concerning joint management and regulation of the international watercourse, including the safe operation maintenance and protection of installations thereon.

9 Articles 27 and 28 deal with the prevention and mitigation of harmful conditions related to flooding, disease epidemics, siltation, erosion and saltwater intrusion, and the management of emergency situations including the joint formulation of contingency plans in response thereof.

10 Articles 29 to 33 address miscellaneous issues concerning, national security, discrimination and procedures for dispute resolution.

11 The final part outlines the conditions for ratification of the Convention.

The convention provides a sound overarching international treaty for co-operation between basin states, as well as general guidance in the manner in

which international statutes and international basin development strategies can be formulated.

Status

The UN Convention on international watercourses has not been ratified by the two countries[4]. The convention has yet to take effect since too few countries have ratified it. However, since the SADC protocol is based on it, it provides guidance on interpretation of legal matters.

12.1.3 SADC Protocol on Shared Water Courses

The Revised Protocol on Shared Water Courses is a regional convention that operationalizes the tenets of the UN Convention by SADC states and includes the provisions of Agenda 21 of the United Nations Conference on Environment and Development. It requires member states to co-operate in the co-ordinated utilisation and environmentally sound development of the resources of the shared watercourses in order to support sustainable socio-economic development and to advance the SADC agenda of regional integration and poverty alleviation.

JWC

Of fundamental relevance to the development of the Save Water Resources Management Strategy is Clause (a) of Article 2 of the protocol which seeks to "promote and facilitate the establishment of shared watercourse agreements and Shared Watercourse Institutions for the management of shared watercourses". To this end, Mozambique and Zimbabwe established the Joint Water Commission (JWC) in Harare in December 2002. The JWC will provide advice on matters relating to the conservation, development and utilisation of the water resources of shared watercourses.

Sustainability, harmonised use, equity, information exchange

The general principles of the Protocol enunciated under Article 3, affirm the critical sustainability issues concerning watercourse systems related to the maintenance of unity and coherence of each system and its harmonised use by basin states, as well as proper balance between resource development and conservation of the environment. The article further addresses the need for information exchange between basin states, as well as equity in the utilisation of the shared watercourse system, and shared responsibility of its protection. It echoes the requirement under Article 6 of the convention for reasonable utilisation that considers all biophysical and socio-economic aspects of the basin.

Notification of planned measures

Article 4 addresses notifications regarding planned measures in line with the provisions in the Convention.

Institutional

Article 5 deals with institutional matters related to the execution of the Protocol. Of relevance to the Save Project is Clause 3 which requires watercourse states to establish watercourse commissions, water authorities or boards as appropriate to oversee the implementation of the provisions of this protocol within the purview of their agreements. Pursuant to this Clause, Mozambique

[4] http://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-12&chapter=27&lang=en

and Zimbabwe established the Joint Water Commission in Harare in December 2002. Its mandate is to advise the parties on measures and arrangements to determine potentially available water, existing utilisation levels, reasonable demand, relevant data and information, criteria for conservation, allocation and sustainable utilisation and prevention of pollution of the water resources of common water resources. In this regard, it plays a principal role in determining the efficacy of the Save Strategy.

Article 6 provides guidance on the formulation of agreements between watercourse states, their impact on the rights or obligations under the Protocol of Watercourse States that are not parties to such an agreement, including entitlements.

General procedures for dispute resolution are outlined under *Article 7*, and with reference to specific clauses in the main SADC Treaty. The rest of the Articles through to Article 16 deal with matters related to the administration of the Protocol.

Status

Mozambique and Zimbabwe have now both ratified the revised protocol.

12.1.4 Regional water policy

The regional water policy is a SADC instrument aimed at providing a framework for sustainable, integrated and co-ordinated development, utilization protection and control of national and transboundary water resources for the promotion of socio-economic development and regional integration. The policy is anchored in several SADC and international pronouncements.

Principles

Its principles are summarized below:

- The recognition of water as an instrument of peace, co-operation and regional integration.
- Effective public consultation with focus on people-centred planning.
- The rectification of historical imbalances and promotion of water supply for irrigation through the planning and construction of strategic infrastructure.
- Demand management, conservation and reuse of water to achieve efficiencies,
- The protection of the environment as a legitimate user of water, and the adoption of “the Polluter Pays” principle, taking into account equity and social justice.
- Education and capacity building.

- Waste management close to the point of generation, and preventing its movement across national and regional boundaries.
- Gender mainstreaming and addressing HIV/AIDS is water resources management at all levels.

Thematic areas

The policy covers nine thematic areas which are aimed at optimising development opportunities in the region. They will need to be recognised and adopted as essential elements of the Save water resources management strategy. The thematic areas cover the following aspects:

1 Regional co-operation in water resources management.

2 Water for development and poverty

3 Water for environmental sustainability

4 Security from water-related disasters

5 Water resources information and management

6 Water resources development and management

7 Regional water resources institutional framework

8 Stakeholder participation and capacity building

9 Stakeholder participation and capacity development.

12.1.5 Regional strategic action plans

The objectives of the protocol have been given practical effect through two SADC Regional Strategic Action Plans (RSAP), which are the main programmes of action for SADC water sector for the periods 1998-2004 and 2005-2010.

The RSAPs concretise the vision for joint management of water. As such the RSAP contains identified projects with the main focus to create an enabling environment for the joint integrated management of water resources in the region in support of the achievement of other regional objectives. Most of the projects had been or are in the process of being completed.

12.2 Zimbabwe

12.2.1 Legal framework

The national legal framework for water management is the Water Act Chapter 20:24 from 1998. All surface and groundwater in Zimbabwe is vested in the

State President. With the exception of primary water use, all other uses of water must be approved by the State.

Ministry of Water Resources Development and Management

The Department of Water Development (DWD), the Zimbabwe National Water Authority (ZINWA) and seven catchment councils are the statutory bodies entrusted with the sustainable management of water resources. All these fall under the umbrella of the Ministry of Water Resources Development and Management.

The organisational structure for water management in Zimbabwe is shown in Figure 53.

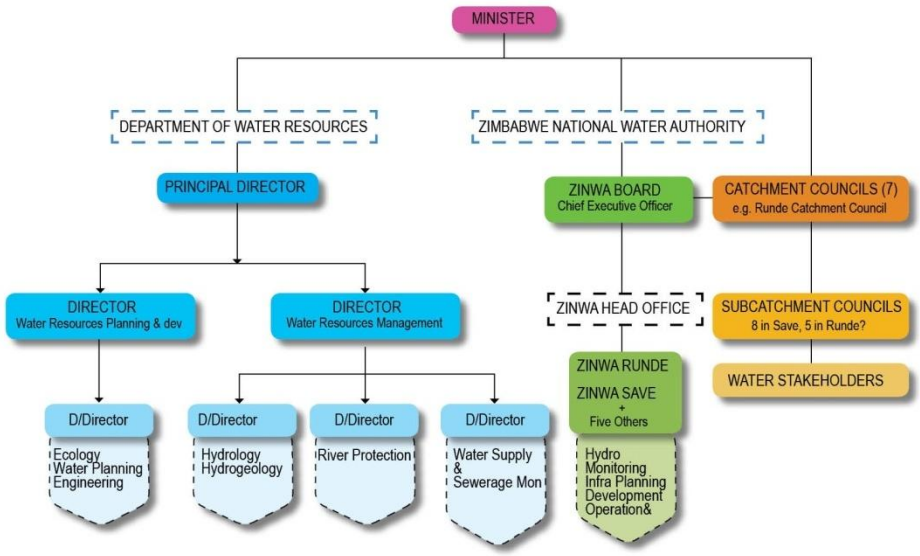

Figure 53 Ministry of Water Resources Development and Management (Zimbabwe)

Department of Water Development

The Department of Water Development (DWD) is established in terms of the Water Act Chapter [20:24] No 31/98. Its principal role is to assist the Minister of Water Resources Development and Management in carrying out the following statutory mandate:

- To develop of water policies, laws and regulations, and general directions to guide the orderly and integrated planning of the nation's water resources to ensure their optimum development, utilisation and protection.

- To ensure the availability of water to all citizens for primary purposes with due regard to environmental requirements.

- To ensure the equitable and efficient allocation of available water to all users.

The department's specific functions are summarised below.

1 Initiate and formulate policies for water resources planning, development and management, and wastewater and sewerage disposal, including medium and long term plans to cater for present and future requirements for growth points, rural service centres and urban areas.

2 Coordinate and supervise water resources infrastructural development in the country including the provision of dam safety guidelines and adequate water for irrigation.

3 The administration of national water resources management and wastewater and sewerage disposal policies.

4 Coordination of the provision of clear/treated water to growth points, rural service centres and urban areas including the setting of water tariffs in consultation with stakeholders.

5 Management of water quality standards for urban, industrial, mining and domestic consumption, and provision of guidelines on the maintenance and management of water and sewerage reticulation infrastructure.

6 Periodic inspections of water and sewerage reticulation infrastructure and equipment.

7 Participation in SADC regional water resources management including involvement in the formation of regional river basin institutions and provision of technical and advisory services.

8 Ensuring the compliance of national water resources policies with the bilateral, regional and internationally shared rivers agreements.

9 Monitoring the performance of ZINWA, catchment councils recommending legislative and policy changes, as necessary.

10 Monitoring water resources and the water quality situation in the country, and initiating water shortage declarations where necessary.

11 Proving guidelines on disposal of wastewater and sewerage, including the enforcement of its proper disposal.

12 Periodic inspections of wastewater and sewerage infrastructure.

The chief accounting officer for the Ministry of Water Resources, Development and Management is the Permanent Secretary, to whom the two directorates for Water Resources and Planning, and Water Resources Management report to through the Principal Director. The Director of Water Development is responsible for all water affairs, supported by a complement of seven staff members.

Catchments

The Water Act empowers the Minister to declare river systems, better known as catchments, which then fall under the control of a catchment council and the general technical supervision of the Zimbabwe National Water Authority.

For the purposes of the management of water resources, Zimbabwe is divided into seven catchments, which are predominately based on the major river basins in Zimbabwe, viz Save, Runde, Mzingwane, Mazowe, Sanyati, Gwayi and Manyame.

Zimbabwe National Water Authority (ZINWA)

The Zimbabwe National Water Authority (ZINWA) was established in terms of the ZINWA Act Chapter 20:25 No 11/98. Its main functions are:

- To advise the Minister on the formulation of national policies and standards on all matters related to water.
- To exploit, manage and conserve the nation's water resources in order to ensure security of supply, and to facilitate equitable access to water by all sectors, and its efficient utilisation, while minimising the impacts of drought, floods and other hazards.
- To provide specialist advice and technical assistance to local authorities and catchment councils in matters concerning the development, management and environmental protection of water resources.
- To provide design and construction services for new water works, and to operate and maintain water supply facilities owned or managed by ZINWA.
- To carry out hydrological and geographical surveys, including water related research, for the purposes of planning, development and exploitation of water resources, and to publish results thereof.
- To give effect to the joint management of international water resources, as determined by the Minister.

The main source of funding for ZINWA's operation are fees revenues accruing from the sale of water from rivers and water supply facilities owned or managed by ZINWA. Minor sources are fees charged for technical assistance, personnel, training, information and other services to government departments, local authorities, catchment councils, in connection with the exploitation, development, management and distribution of water resources.

ZINWA's requirements for financing capital expenditure for the development of water resources infrastructure are the responsibility of the Central Government through the Public Sector Investment Programme (PSIP).

Catchment Managers

ZINWA operates a Catchment Office in each of the seven catchments. Each Catchment Office is headed by a Catchment Manager, who is normally a qualified water professional. The Catchment Manager has been established in terms

of the Water Act with the following statutory functions conferred upon the post:

- The management and administration of the affairs of the catchment council.
- Assuming the functions of the catchment council, subject to appropriate delegation.

Catchment Councils

The Catchment Manager performs his duties under the direction of the catchment council, with supervision by ZINWA. The Catchment Manager's office provides technical and secretarial services to the respective catchment councils. It also supplies raw and clear water to farmers, mines, towns, growth points and other community settlements.

The Catchment Managers for ZINWA Save and ZINWA Runde are respectively responsible for the Save and Runde river basins. Their respective offices are located in Mutare and Masvingo towns.

The Catchment Councils (CC) are established by a statutory instrument under the Water Act, through the declaration of a River System by the Minister, and in consultation with ZINWA. Seven CCs have so far been established through Statutory Instrument (SI) 209 of 2000.

A catchment council is constituted from members of its sub-catchment councils. The principal functions of a catchment council are as follows:

- To prepare a Catchment Outline Plan (COP) for its river system in conjunction with ZINWA, for approval by the Minister.
- To determine and grant water use permits under criteria set by DWD.
- To regulate and supervise the exercise of rights to, and use of water in respect of its river system.
- To ensure proper compliance with the Act and to supervise sub-catchment councils.

Sub-catchment councils

A sub-catchment council (SCC) is established by the Minister through a statutory instrument under the Water Act for any part of a declared river system that falls under a CC. It is composed of elected representatives of the stakeholder groups in its area. The existing SCC's were established under SI 47 of 2000, Water (sub-catchment councils) Regulations for the seven declared river systems in Zimbabwe. Local water users committees still exist in some areas.

The sub-catchment council is the operational arm of the Catchment Council. Its main function is to regulate and supervise the exercise of rights to water within the area for which it was established. It also performs any other functions that may be conferred upon it in terms of the Water Act. The sub-catchment council

is funded from levies imposed on permit holders, as well as from fees for any services rendered by it.

12.2.2 Stakeholder involvement

The notion that stakeholders should have a say in the management of the water resources on which they depend is one of the building blocks of the concept of integrated water resources management. Stakeholders are all those with an interest in water resources management (Figure 54). The concept of integrated water resources management, and consequently that of stakeholder participation, has found its way into the national water policies and water laws of many countries, also into those of Zimbabwe.

In Zimbabwe the concept of the role of stakeholders in important decision making regarding water resources management has been incorporated into the Water Act of 1998 with the Catchment Councils, made up of stakeholders, being the ultimate decision-makers on the attribution of water permits in the basin.

Figure 54 Stakeholders

12.3 Mozambique

12.3.1 The Water Act

The fundamental legal document that regulates the water sector in Mozambique is the Water Act, law nº 16/91 approved by the Parliament in 1991. The law

- regulates the legal regime of inland waters
- defines the water resources that belong to the public domain
- determines the jurisdiction of the government in regard to water in the public domain
- establishes the principles for water management
- regulates the general regime of water use and its priorities
- defines the rights and obligations of water users and
- determines the institutional organization of the water sector.

Only water that is abstracted in limited amount (domestic use in rural areas, family's livestock) and not making use of mechanical equipment, considered as "water of common use" is not included in the public domain.

River basin basis

The law defines that water development should be planned and managed taking the river basin as the basic unit. It refers to the need for institutional coordination, involvement of stakeholders, compatibility with regional plans and due regard for environmental needs.

It requires regular updates of the water resources availability, the compulsory registration of all water users and the development of a national plan to guarantee in the future an adequate balance between water demand and water availability.

Licensing

Except water of common use, all other water abstractions must be registered and obtain a license (for provisional use, during a limited number of years) or a concession (for long term use). The licenses and concessions impose a number of duties to the beneficiaries, including the payment of water fees.

In terms of water use, first priority is given to domestic use. Basic environmental requirements appear as the second priority.

Water quality

The law pays special attention to the problems of water quality and measures to prevent pollution. The "polluter pays" principle is adopted. Specific regulations with parameters for water quality and for effluent discharges have been approved in sequence to the law. It also opens the possibility to declare areas in the vicinity of water sources (surface or groundwater) for domestic or urban water supply as "protection zones", severely restricting the activities that can be developed in these areas.

Charges

The law defines that all water users, except those of common use, must pay for the water in terms of the amount defined in the license or concession and also for the water effectively consumed. It also includes a tax related to hydraulic infrastructures. The discharge of effluents is also charged.

Institutional framework

The Water Act defines the basic institutional set-up of water management. The Ministry responsible for the water sector is the Ministry of Public Works and Housing (MOPH), through the National Directorate of Water (DNA). It creates a National Water Council (CAN), composed of Ministers with areas related to water, as an advisory council to the Government. Finally, it creates five regional water administrations (ARA), on the basis of groups of contiguous river basins, which are responsible for the daily operational management of water resources and for issuing licenses and concessions.

Regulations

One important regulation that followed the Water Act is the Regulation for Licenses and Concessions, only approved in 2007. It details the process by which a license or concession can be required to an ARA, the criteria for the evaluation of the request, the conditions to be imposed and other administrative aspects. It refers also to the licensing of hydraulic infrastructures as dams, dykes and water intakes.

12.3.2 Water management institutions

The water sector of Mozambique comprises many institutions, both public and private, that can be grouped in:

- those dealing with water resources management;
- those that represent water users, including the environment;
- those that are indirectly involved, particularly universities, research institutions and NGOs

Involved institutions

The Water Act defined MOPH, CAN, DNA and the ARAs as the water management institutions. In terms of water users, besides the myriad of private users, there are some governmental institutions of relevance as they promote the use of water in various areas. They are the Ministries of Agriculture, Energy, Industry, Fisheries, Tourism and Mineral Resources. The Ministry of Environmental Coordination is also relevant in terms of environmental flow requirements and nature conservation. The main institutions are shown in Figure 55)

MOPH and DNA, however, appear also on the side of water users as they are responsible for the area of water supply and sanitation. In this area, MOPH created other institutions, namely FIPAG for urban water supply (manages presently the eighteen largest urban water supply systems of the country, either directly or through some form of concession or management contracts with private operators), CRA (regulating council for water supply and sanitation) and AIAS (agency for water supply and sanitation of smaller urban systems). Details about the functions and organization of the water management institutions are presented below.

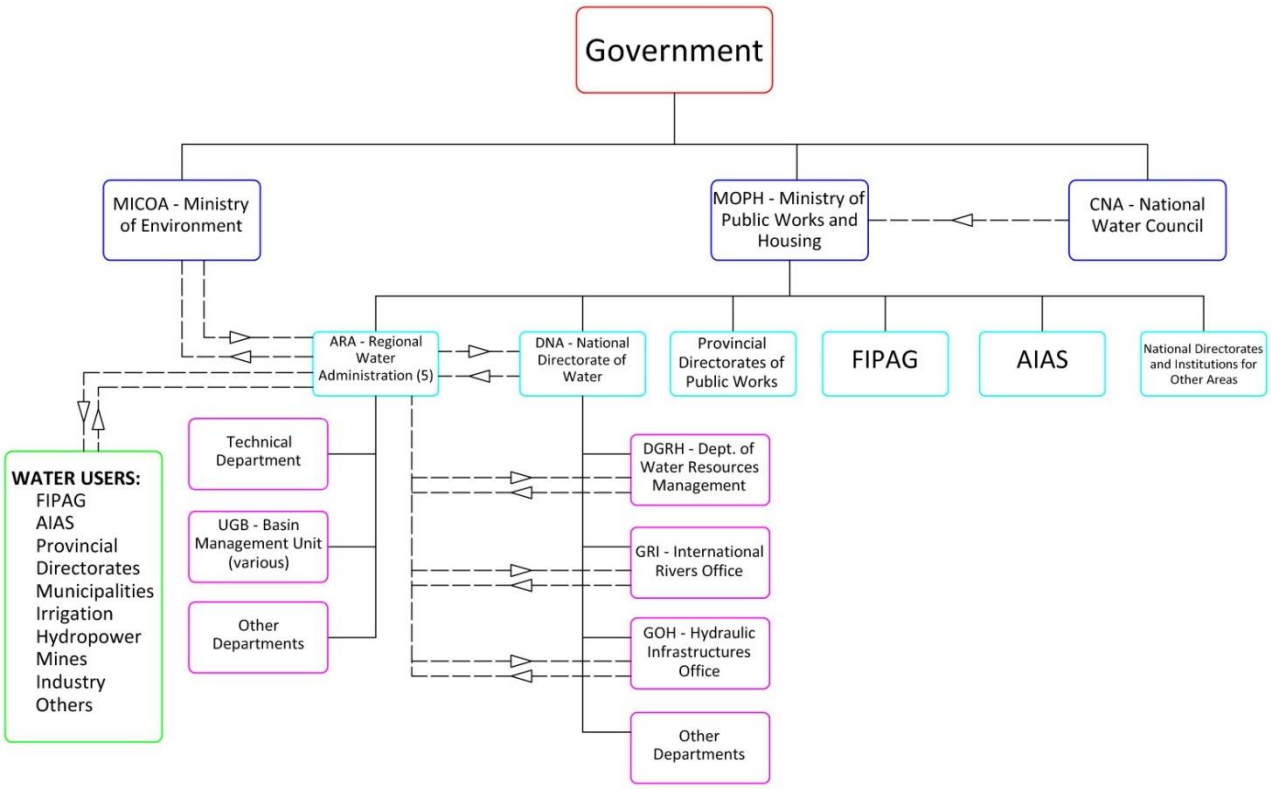

Figure 55 Organisation of the water sector in Mozambique

MOPH

MOPH is the ultimately responsible authority for water management in the country, including relations with other basin countries in shared river basins.

DNA

MOPH delegates responsibilities to DNA, whose main functions are:

- Definition of policies for water resources management, water supply and sanitation
- Inventory and assessment of water resources at national, regional and river basin, sustained by an information system
- Elaboration and implementation of plans and studies
- Investments in infrastructures for water management, water supply and sanitation
- Drafting of water legislation and supervision of its enforcement

DNA has a National Director and two deputies. This organ is supported by a consultative Technical Council. Besides the administrative and planning departments, DNA comprises:

- Department of water resources management

- Department of rural water supply
- Department of urban water supply
- Department of sanitation
- International rivers office
- Hydraulic infrastructures office

Of particular importance is the Department of Water Resources Management (DGRH) with the following responsibilities:

- Define policies and regulations for water resources management;
- Prepare river basin plans and monitor its implementation;
- Promote studies on water resources;
- Guarantee an adequate participation of Mozambique in the planning and management of shared river basins;
- Define the methodology for hydrologic data collection, processing, storage and dissemination of information;
- Promote the adoption of adequate standards of water quality and supervise its application;
- Promote environmental conservation, groundwater protection zones and safety of hydraulic infrastructures;
- Organize and update the register of hydraulic infrastructures in the country;
- Prepare flood warning systems and coordinate with other institutions involved in civil protection;
- Supervise the activities of the ARAs;
- Support the International Rivers Office in the preparation, implementation and supervision of compliance of agreements in shared river basins.

ARA

The ARAs were created by the Water Act and their legal status defined by the decree nº 26/91. Five ARAs were created: South, Center, Zambezi, Center-North and North. In 2003 the Save basin was moved from ARA-Sul (South) to ARA-Centro (Center) and the boundaries are now as shown in Figure 56. In spite of their legal creation in 1991, the effective start of operation of the ARAs was a slow process: ARA-Sul started in 1993, ARA-Centro and ARA-Zambeze in 1998, ARA-Centro Norte and ARA-Norte in 2008.

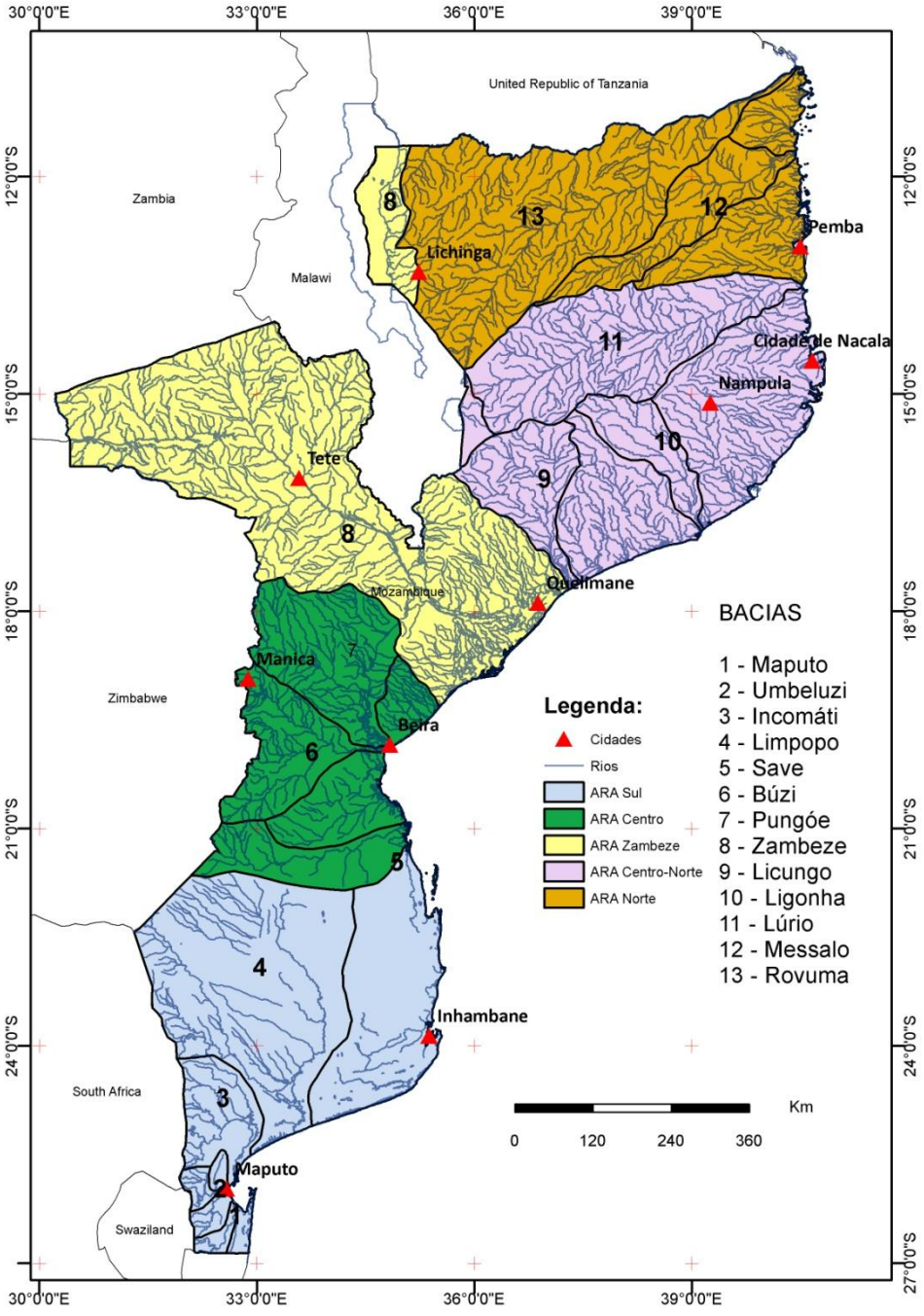

Figure 56 Geographical area of each ARA

The main functions of the ARAs are defined in their Statutes and can be summarized as:

- Participate in the plan of development of the hydrological network and implement it
- Issue licenses and concessions, including for effluent discharges
- Authorize construction of hydraulic infrastructures

- Collect hydrological data, maintain database updated
- Reconcile conflicts between water users
- Recognize and register common uses

Each ARA is guided by a management council that includes representatives of ministries, provincial governments, water users and members of staff. The director general is designated by the MOPH and runs the daily operation of the ARA.

Basin Management Units (UGB)

Each ARA is organized in Basin Management Units (UGB) where a Basin Committee has a consultative role. The Basin Committee is composed by representatives of the stakeholders and the director and other staff of the ARA and usually meet twice a year.

12.3.3 Water policies

There are two important policy documents: the Tariff Policy (1998) and the Water Policy (2007).

Tariff Policy

The Tariff Policy is applied to most types of water uses (domestic, public, industrial, irrigation and livestock, hydropower) as well as sanitation and environmental conservation.

It is guided by the principles of user-pays, polluter-pays, equity, efficient use of water, environmental protection, financial sustainability and involvement of stakeholders. The main objectives are to improve water resources management and the coverage and quality of water supply and sanitation services and guarantee the required financial investments and O&M funds.

The policy defines tariff systems for raw water, urban water supply, rural water supply, urban sanitation, irrigation and hydropower, detailing for each system the specific objectives, criteria and tariff structure.

Water Policy, 2007

The new Water Policy was approved by the government in 2007 after a major public debate. It is structured in four parts:

- Part 1 – Vision, main objectives, fundamental policies
- Part 2 – Water requirements
  - Water supply and sanitation
  - Socio-economic development
  - Environment
  - Floods and droughts management
- Part 3 – Water resources management
- Part 4 – Cross-cutting issues

- Economic and financial aspects
- Private sector participation
- Legal and institutional framework
- Capacity building

The policy defines overall targets for water supply and sanitation, taking into account the Millennium Development Goals set by the government and the long-term target of universal coverage and improved quality of service.

The policy stresses the need to use water as an important factor for socio-economic development, particularly for irrigation, hydropower, industry and livestock. The efficient use of water is also a concern.

The document presents guidelines regarding environmental protection, environmental flows and protection zones. It indicates measures to be considered to reduce the country's vulnerability to floods and droughts.

Regarding water resources management, particular attention is given to river basin plans, joint studies, negotiations and agreements for shared river basins and the need to accelerate the construction of hydraulic infrastructures, mainly storage dams and flood protection dykes.

The policy insists on the need to take into due consideration the economic value of water, the need for financial sustainability of the water management institutions as well as of the service providers. It calls for greater participation of the private sector and states some areas where this participation is particularly needed.

12.3.4 Stakeholder involvement

On the institutional side, there is an emphasis on continuing with the de-centralizing process in water management and for a greater involvement of stakeholders in water management at the river basin level. The consolidation of the ARAs and the creation and regular functioning of the Basin Committees materialise this objective.

13 Water management issues

13.1 Introduction

This chapter highlights the water resources management issues that are seen as most important on a basin scale. The following issues are discussed below and might be examined in the strategy phase:

- Access to safe water
- Water resources development and water balance
- Flood and drought management
- Urban wastewater management
- Mining impacts
- Soil erosion and sedimentation

13.2 Access to safe water

The access to safe water is a development priority, but many people are still without access to safe water. This is reflected in prevalence of waterborne diseases. In addition fetching water is major task in many households, especially for women. However, while access to safe water is a concern throughout the basin, the impact of local water supply is local as household use requires very little water.

13.3 Water resources development and water balance

Rainfall is seasonal and for most of the basin highly variable. Climate models predict that in the future rainfall will decrease in the Zimbabwean part of the basin, but increase in Mozambique. Drought may be more frequent and the dry season longer. This will increase the demand for water storage. Irrigation is by far the largest user of water in the basin and accounts for 87% of the total demand in 2010.

The obvious solution is to increase investments in irrigation infrastructure. A number of reservoir and irrigations projects also have been identified in both Zimbabwe and Mozambique and feasibility studies have been carried out at different levels.

At the same time, however, this study also indicates that the available resource is intensively utilised - even if one only allocates 5% for the environmental flow for the benefit of downstream users and the environment. There is therefore a need to examine the permits on a sub-zone basis. It is proposed to do that initially for the sub-zones where the demand calculated in this study is close to, or exceeds, the estimated resource.

13.4 Flood and drought management

The basin has experienced devastating floods. Historic data indicate that the frequency of cyclones is increasing, but the climate models say otherwise. Nevertheless there is already a need to improve flood forecasts, warning systems and measures such as emergency shelters and evacuation plans. In this respect it should be mentioned that the travel time for a flood from the Zimbabwe-Mozambique border to the coast is about 3 days. There is thus time to warn and prepare - provided systems and plans are in place.

Due the high variability of rainfall, droughts are relatively frequent and drought is therefore an important issue in water resources management.

13.5 Urban wastewater management

At present most urban sewerage systems and wastewater treatment plants are in a poor state and their discharge entails severe health risks and river pollution. This situation can only be addressed through investments in rehabilitation as well as in annual operation and maintenance.

13.6 Mining impacts

Mining is associated with pollution and often also with health risks for the miners. Of particular concern in terms of long-term water pollution is acid rock drainage, especially from gold mines. The use of mercury by small-scale and artisan miners is both an environmental and health concern. The cyanide process used by commercial mines is not an alternative for artisanal miners, but the use of borate or other methods might be and their feasibility might be examined. Other mining impacts such as land degradation, erosion and sedimentation are difficult to address as far as the informal sector is concerned.

13.7 Soil erosion and sedimentation

Poor land use practices results in soil loss and in sedimentation of rivers and reservoirs. This has direct implications for agriculture and also shortens the life span of reservoirs.

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