WMA 11/T50/00/3009 Volume 1

water affairs
Department:
Water Affairs
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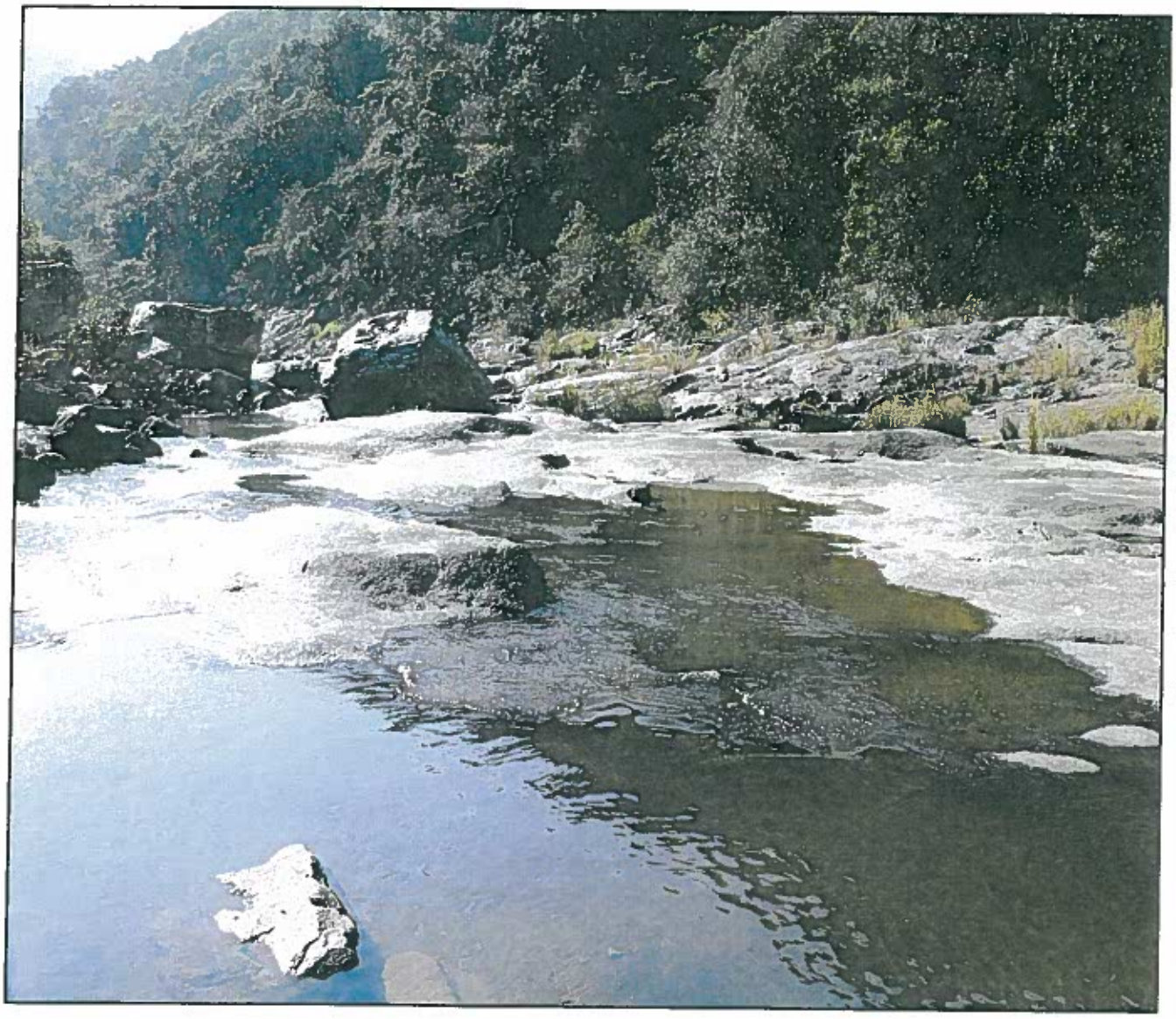

MZIMKHULU RIVER CATCHMENT WATER RESOURCE STUDY

WP9900

Main Report

Original

FINAL REPORT

MZIMKHULU RIVER CATCHMENT WATER RESOURCE STUDY

WP9900

Main Report

Report no.: WMA 11/T50/00/3009 Volume 1

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AUTHORS	:	Mr A Tanner
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MZIMKHULU RIVER CATCHMENT WATER RESOURCE STUDY (WP9900)

MAIN REPORT

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LIST OF REPORTS	
Title	**Report Number**
Main Report	**WMA 11/T50/00/3009 Volume 1**
Management and Development Options	WMA 11/T50/00/3009 Volume 2
Surface Water Resources	WMA 11/T50/00/3009 Volume 3
Groundwater Resources	WMA 11/T50/00/3009 Volume 4
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Hydrology	WMA 11/T50/00/3009 Volume 8
Land Use and Water Requirements	WMA 11/T50/00/3009 Volume 9

Executive Summary

INTRODUCTION

The Department of Water Affairs (DWA) commissioned this study of the Mzimkhulu River catchment, as there was a concern that the flows might have dropped below the requirements of the Ecological Reserve, as a result of heavy afforestation and irrigation developments in the catchment. The Department was under pressure to grant licences for further afforestation which, if allowed, would exacerbate the situation.

The main objectives of the study as defined in the inception phase are as follows:

- *To determine the existing and potential future water use in and from the catchment;*
- *To assess the opportunities and water available for future economic development, particularly the potential for additional plantation forestry;*
- *To reassess the hydrology and the water supplies available from existing sources; and*
- *To recommend possible schemes for meeting future requirements, including potential additional plantation forestry, as well as potential future usage requirements.*

This report describes the assessment of possible development scenarios.

CATCHMENT DESCRIPTION

The Mzimkhulu River catchment comprises tertiary catchments T51 and T52 with a total catchment area of approximately 6 668 km^2. A map showing the location of the catchment is shown in ***Figure 1.***

The Mzimkhulu River rises at a height of just over 3 000 m, in the Southern Drakensberg in the Ukhahlamba Drakensberg Park (Garden Castle Forest), a World Heritage Site. This area is preserved for its pristine, ecological, and historical nature. As it winds down to its way to the Indian Ocean at Port Shepstone, the river is joined by the Mlambonja, the Mzimkhulwana the Pholela, the Ngwangwane the Bisi and lower down, the (second) Mzimkhulwana River, as well as numerous smaller tributaries.

The upper part of the catchment is characterised by agricultural development, mainly under irrigation and fed by numerous farm dams. Tourism also plays a large role in the upper catchment. Some 800 km^2 of the upper catchment and upper reaches of the tributaries have been afforested.

The middle part of the catchment is predominantly rural tribal trust land and formed part of the previously independent Transkei, with scattered subsistence rural communities drawing water from run-of-river.

In the lower middle reaches, there are a number of rural water supply schemes, drawing water from local streams, boreholes and springs.

Lower down, the river enters a deep gorge, where it is joined by the Mzimkhulwana River, emanating from the Oribi Gorge Nature Reserve, a World Heritage Site and well known tourist attraction, with spectacular scenery.

The Mzimkhulu River and its tributaries offer a variety of "wild and scenic" sections, and is utilised in many recreational activities. Climate-wise, the Mzimkhulu River catchment falls within the summer rainfall region of South Africa. Rainfall is strongly seasonal with roughly 80% of rainfall occurring from October to March.

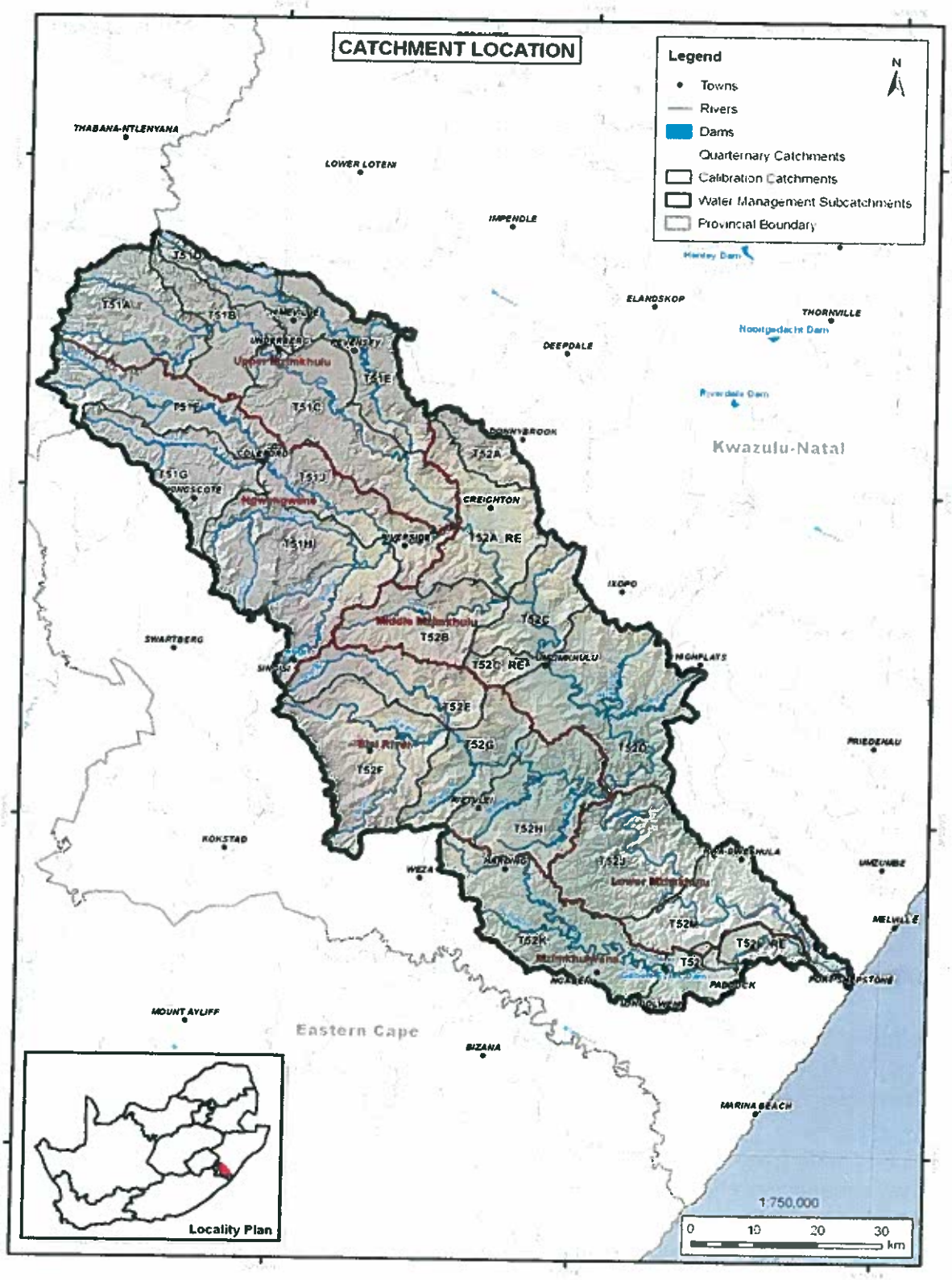

Figure 1: Map showing the location of the Mzimkhulu River catchment

Key Catchment Statistics:

- *Catchment Area: 6 668 km^2;*
- *Natural Mean Annual Runoff (MAR) 1 453 million m^3;*
- *Present Day MAR: 1 176 million m^3 per annum;*
- *Mean Annual Precipitation (MAP): 930 mm; and*
- *Length of main river: 353 km.*

For the purpose of this study, the catchment has been divided into six Water Management Sub-catchments, comprising the Upper Mzimkhulu, the Ngwangwane, the Middle Mzimkhulu, the Bisi, the Mzimkhulwana and the Lower Mzimkhulu.

LAND USE AND WATER USE

The Land Use and Water Requirements Report, Volume 9, deals with current water uses in the catchment, which in turn provide the basis for inputs into the hydrological model. This component of the Study has involved the extraction of data from satellite imagery in each of the 21 quaternary sub-catchments. The present day land use by the various water use sectors is shown in ***Figure 2.***

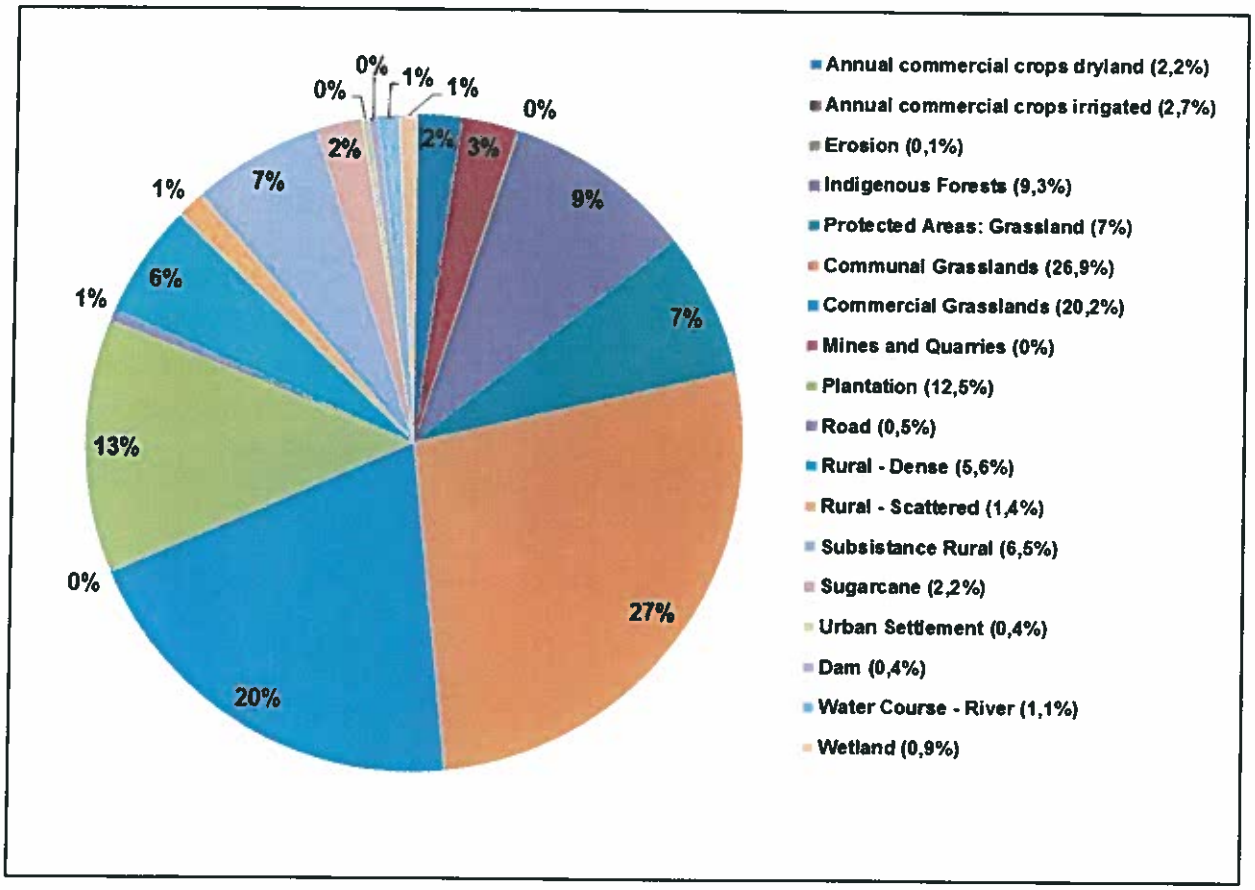

Figure 2: Percentage Land Use

Table 1 *and* ***Figure 3*** *below summarises the estimated total volume of water use by sector, in the Mzimkhulu catchment in 2010. The total estimated current water use is 277,7 million m³/a.*

Table 1: Total volume of water use by sector in 2010

Land Use	Total Water Requirement (Million m³/a)	Demand as percentages of total
Plantation Forestry	112,7	41%
Irrigation	86,6	31%
Alien Vegetation	39,7	14%
Rural, Urban, Industrial and Commercial	28,1	10%
Dryland Sugarcane	6,8	3%
Livestock watering	3,8	1%
Total water requirements	**277,7**	**100%**

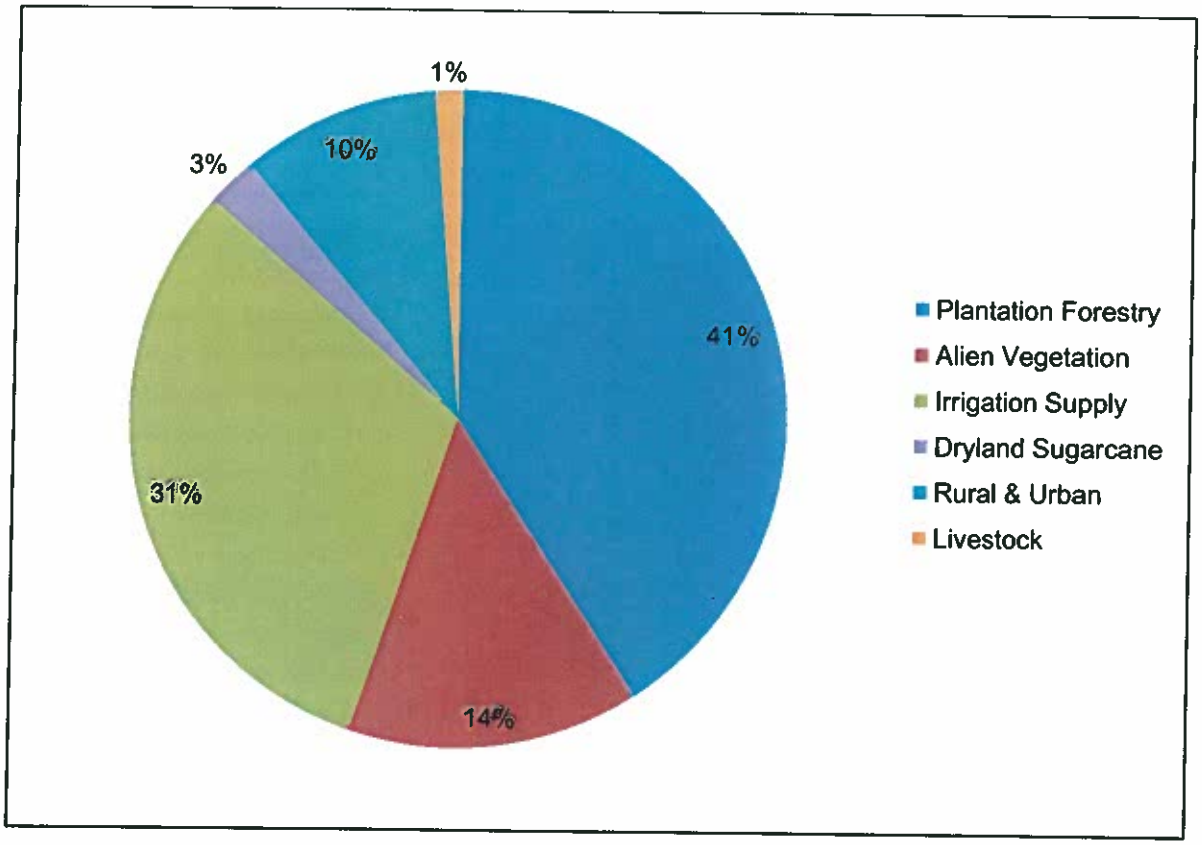

Figure 3: Breakdown of Water Use in the Mzimkhulu Catchment by Sector

POTENTIAL FOR PLANTATION FORESTRY DEVELOPMENT

To determine plantation forestry potential, a negative mapping process was carried out, examining the existing land use and the climatic, topographic and soil conditions required for forestry. Exclusion criteria related to Land Cover, the Ezemvelo KwaZulu-Natal Wildlife (EKZNW) Conservation Plan (C-Plan), Topographical, Hydrological and Agricultural factors were adopted. Plantation forestry growing potential, based on these factors, was established

*and classified, as set out in **Table 2** below. Figures take no cognisance of water availability, which is dealt with in the modelling results.*

Table 2: Plantation Forestry Potential

Suitability	Commercial potential (ha)	Small Grower Potential (ha)
Low	56 170	41 700
Medium	24 673	15 507
High	16 607	12 405
Total	**97 451**	**69 613**

Applying filtering criteria throughout the catchment, and using more conservative criteria where small growers were involved, resulted in potentially suitable areas of:

- *50 350 ha for all growers (inclusive of small growers);*
- *29 400 ha for small growers; and*
- *21 050 ha for the small growers in the Bisi and Middle Mzimkhulu WMSCs.*

In order to assess the impact of developing the additional areas of plantation forestry, four basic future development scenarios, each with a number of sub-scenarios were defined and the water resource implications were modelled. The four scenarios with the following increases in forestry and irrigation were:

i. 29 400 ha of forestry on land suitable for small growers;
ii. 21 050 ha of forestry on land suitable for small growers in the Bisi and Middle Mzimkhulu catchments;
iii. 50 350 ha of forestry throughout the catchment, with 29 400 ha of the land being suitable for small growers and a 20% increase in water use for irrigated agriculture; and
iv. As for Scenario 3 with a large dam to export water.

Projected future water use requirements and EWRs were included for each quaternary catchment. The water resource modelling assessed the impacts of increased land and water use, with and without mitigation provided by one of two dam options, in each scenario.

***Figure 4** provides a spatial view of areas in the catchment with poor, low, medium and high potential for forestry for all growers.*

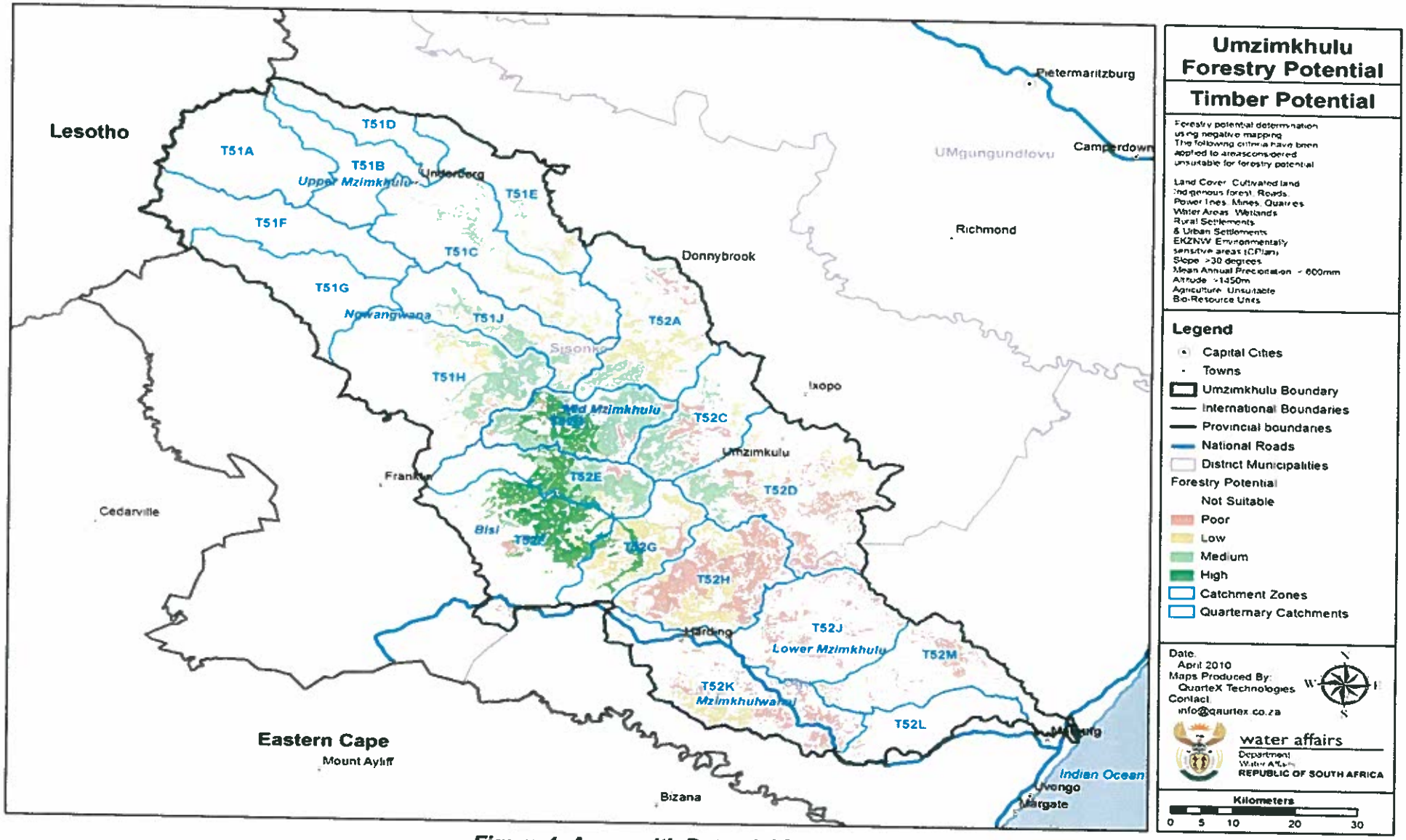

Figure 4: Areas with Potential for new Forestry

HYDROLOGY

The objective of the catchment hydrology task is to present the updated hydrology for the study area, in order to support the determination of existing and potential future water use, to assess the opportunities and water available for future economic development, and to recommend possible schemes for meeting future requirements with a specific focus on the potential for development of plantation forestry in the catchment. Monthly simulated runoff sequences are produced and used in the system yield analyses relating to present and future land-use development scenarios and development options.

The hydrology of the Southern KwaZulu-Natal Pre-Feasibility Study (SKZNPFS) (DWAF, 2002) which was for the period 1925 to 1998 was used as a point of departure and was updated with the latest land and water use information representing the 2007 hydrological year. The Water Resources Simulation Model (WRSM2000) was configured and calibrated with this information in order to generate monthly flow sequences.

Rainfall data is one of the most important data requirements for hydrological modelling and the density of the existing rain station coverage is low. The accuracy and reliability of rainfall information in the catchment could be improved with continued monitoring and maintenance of the existing stations. Re-instatement or re-opening of closed gauges in key areas is recommended, in order to improve the density and coverage of active rainfall stations in the network.

The flow monitoring network in the Mzimkhulu catchment is adequate for a general water resources assessment but should be improved, if significant new socio-economic developments, such as plantation forestry, are planned. It is important that existing flow gauges remain open and continue to be monitored and maintained. Additional flow gauges should be established on the Ngwangwane River just upstream of the confluence with the Mzimkhulu, as well as on the main stem downstream of Umzimkulu town in the lower catchment.

WATER QUALITY

A comprehensive assessment of the water quality situation was not part of the project because such an assessment was undertaken, with data up to 1999, as part of the SKZNPFS (DWAF, 2002). Since then about eight years of additional water quality data have been collected in the catchment and a brief review of the water quality situation was undertaken to determine if the water quality trends described previously have changed, or if new water quality issues have emerged since then. To compare findings, the catchment was divided into three parts and the data was analysed with the WQStat Plus statistical software package.

The study confirmed that the status quo in the upper catchment remained largely unchanged and that the conclusions drawn previously were still valid.

In the middle catchment, the study confirmed the status quo, but specific concerns were expressed about the state of the river near the town of Umzimkulu. It is recommended that a water quality survey be undertaken in that area to identify potential pollution sources and management interventions to address local impacts.

Previously, the finding was that the quality in the Mzimkhulwana River was not as good as that in the other basins. The previous recommendation, to improve monitoring in the lower basin is therefore strongly supported and the DWA is encouraged to review and maintain their water quality monitoring in the Mzimkhulu River catchment in order to track water quality changes as further development of the catchment continues.

RIVERINE ECOLOGICAL WATER REQUIREMENTS

The undammed nature of the Mzimkhulu River has been recognised by the National Freshwater Ecosystem Priority Areas (NFEPA) programme and the river is ranked as one of the most important for conservation in the region.

The Ecological Water Requirements (EWR) for eight selected riverine sites in the Mzimkhulu catchment, as well as for the estuary, was determined. Although the results of the modelling indicated that the current low flows do not always meet the recommended flows to maintain the Present Ecological State (PES) of the river, the overall conclusion, is that the state of the ecosystem in this catchment is unusually good for such a large river system. The river was also determined to be relatively resilient, the riverine environment being assessed as relatively unresponsive to an increase of up to 30 000 ha of additional forestry.

Before major developments in the catchment are given approval, the extent of the ecological impacts that would occur in smaller tributaries at a local scale need to be assessed.

There are also some uncertainties about the impacted low flows that would result from that additional area of forestry. It is recommended that, as a condition to any development new forestry, the following be undertaken:

- *Review of the calibration of key flow gauges;*
- *Additional EWR studies on smaller tributaries be undertaken and synchronised with these results (in progress via the Resource Directed Measures (RDM) office);*
- *Ongoing ecological monitoring at the EWR sites; and*
- *Resource Quality Objectives (RQO) should be set for the river using the newly published procedure. This would provide clear objectives for future management.*

This on-going monitoring will improve the confidence in the predictions and allow the effects of development to be properly monitored.

However the monitoring results are not required before some new plantation forestry can be approved.

Any new licence application for development would need to include information of potential impacts as provided by an Environmental Impact Assessment (EIA) process and potentially a Reserve study, conducted at a local level.

Developments which are small in nature and do not require EIA or Reserve studies, but which cumulatively may have a high impact, need to be considered in a larger context. This is especially so for small scale forestry developments. Co-ordination of the management of this larger impact should be the responsibility of DWA with support from the provincial environmental management authority.

ESTUARINE ECOLOGICAL WATER REQUIREMENTS

This study was undertaken without reliable or accurate mouth data for the estuary and when the majority of the work was completed, there was a low overall confidence in the hydrology. Then, near the end of the study, improved flow records were developed, the implications for the estuary were reviewed but the detailed assessments were not repeated.

Flows in the Mzimkhulu estuary are highly seasonal with average winter flows of less than 10 m^3/s and summer averages of about 80 m^3/s. Although shallow, with some intertidal areas in the lower reaches, localised depths of 6 - 8 m occur. Sediments are highly variable temporally and geographically and range from very soft muds to unstable, unconsolidated, coarse sand and gravels. The estuary, in terms of salinity penetration and tidal effects, extends for at least 9,5 km upstream but this is highly dependent on the level of river flow.

Indications are that mouth closure has become more frequent but in the absence of long term monitoring and with the confounding influence of artificial breaching, this finding would have to be treated with caution.

The present major human impacts on the system are; the loss of benthic habitat, resulting from bridge construction with associated rubble deposits and sand mining operations, which, apart from removing habitat, also mobilise fine sediments and contribute to their dispersal and re-distribution by river and tidal currents. Open mouth conditions can be maintained by adequate river flow, which does not necessarily disrupt salinity layering in the upper reaches.

Seven development scenarios based on, the four basic scenarios described above plus those scenarios with dams for mitigation or export of water, and the impacts of the simulated reductions in the water received by the estuary were assessed. Scores indicated that the system could be classified between a B (largely natural with few modifications) and a C (moderately modified).

Allowing the condition of the Mzimkhulu Estuary to decline from its current PES, would have implications, which would have a ripple effect on economic good and services provided by the adjacent marine environment, e.g. the marine fisheries and coastal sediments. Such changes need to be coupled to RQO which need to be set for the estuary using the newly published procedure. This would provide clear objectives for future management.

It is thus strongly recommended that decisions that affect the flow regimes of the Mzimkhulu Estuary carefully consider potential impacts on all users. Given its importance every effort should also be made to implement the measures required to mitigate the non-flow related impacts on the system, such as:

- *eradicate invasive alien vegetation from river banks and floodplains;*
- *remove derelict structures and rehabilitate banks to natural sediments;*
- *prohibit dredge spoil dumping in inappropriate areas;*
- *manage agricultural and industrial practices in the catchment to minimise nutrient and sediment loads entering the estuary; and*

Identified data gaps should also be addressed through improved and on-going monitoring.

GROUNDWATER RESOURCES

The Mzimkhulu River Catchment Water Resources Study was initiated to meet three main objectives, which all directly involve groundwater and its potential to be assessed as an integral part of the resource and its sustainable management:

- *determine the existing and potential future usage of water in the catchment, with reference to the potential of further afforestation;*
- *reassess the hydrology and water supplies available from existing sources; and*
- *investigate schemes for meeting future requirements.*

The following recommendations are made:

- *Groundwater exploration should be carried out from Rietvlei to the north and northwest and be continued:*
  - *Near the Centecow Mission,*
  - *Directly east of Creighton,*
  - *From west-southwest to northwest of Underberg.*
- *Basaltic, doleritic and argillaceous sedimentary rock areas throughout the area should also be investigated for localised water supply.*
- *Shallower soil profiles with increased clay contents could be investigated for localised water supply.*
- *The extreme southern areas of the catchment should not be prioritised for groundwater investigation.*
- *The extreme northern parts of the catchment should only be investigated further if no other viable water resources are available in the area.*

There is significant use of groundwater, primarily in the middle area of the catchment and particularly around Creighton and Underberg.

SURFACE WATER RESOURCES

The objective of the surface water resources task for the Mzimkhulu River Catchment Water Resources Study is to present the updated system yield analysis for the current supply system, as well as for future scheme development options in the catchment. The system was modelled for the period 1920 to 2007 in the WRYM-IMS, using updated hydrology estimates. The model indicated that that the Present day MAR has reduced from a natural state of 1 453 to 1 176 million m^3/a.

The model was configured to include future scheme developments which included five potential dam options and scenarios of increased plantation forestry, irrigation and urban and rural water use. Three scenarios of increased plantation forestry areas were considered:

- *An additional 29 400 ha for small growers throughout the catchment;*
- *An additional 21 050 ha for small growers only in the Bisi and Middle Mzimkhulu catchments; and*
- *An additional 50 350 ha all small and large growers throughout the catchment.*

In addition, a 20% increase in water use by irrigated agriculture was assumed in some scenarios. It was assumed that the future water use by 2030 for rural and urban domestic, industrial and commercial purposes would increase by 60% from current. Potential dam sites were included in the scenarios to provide mitigation for the impacts of increased water demands as a result of additional plantation forestry and irrigation in the catchment by releasing the EWRs for the Gibraltar site in the Lower Mzimkhulu catchment. In addition dams exporting surplus yield were modelled.

The results of the scenario modelling indicate that by providing storage, the impacts of increased plantation forestry and irrigation in the catchment can be mitigated by providing storage while maintaining current EWRs or improving them to meet the PES. Moreover, the dams would provide some surplus yield which could be exported or utilised within the catchment.

PROVIDING ADDITIONAL STORAGE

The development of one or more, new dams to mitigate the impacts, particularly on low flows, of additional forestry, or other water use in the catchment was considered. Reports from previous studies conducted by DWA, Umgeni Water and municipalities were studied. Some 20 possible dam sites had been previously identified on the main stream and tributaries of the Mzimkhulu River, shown in ***Figure 5.***

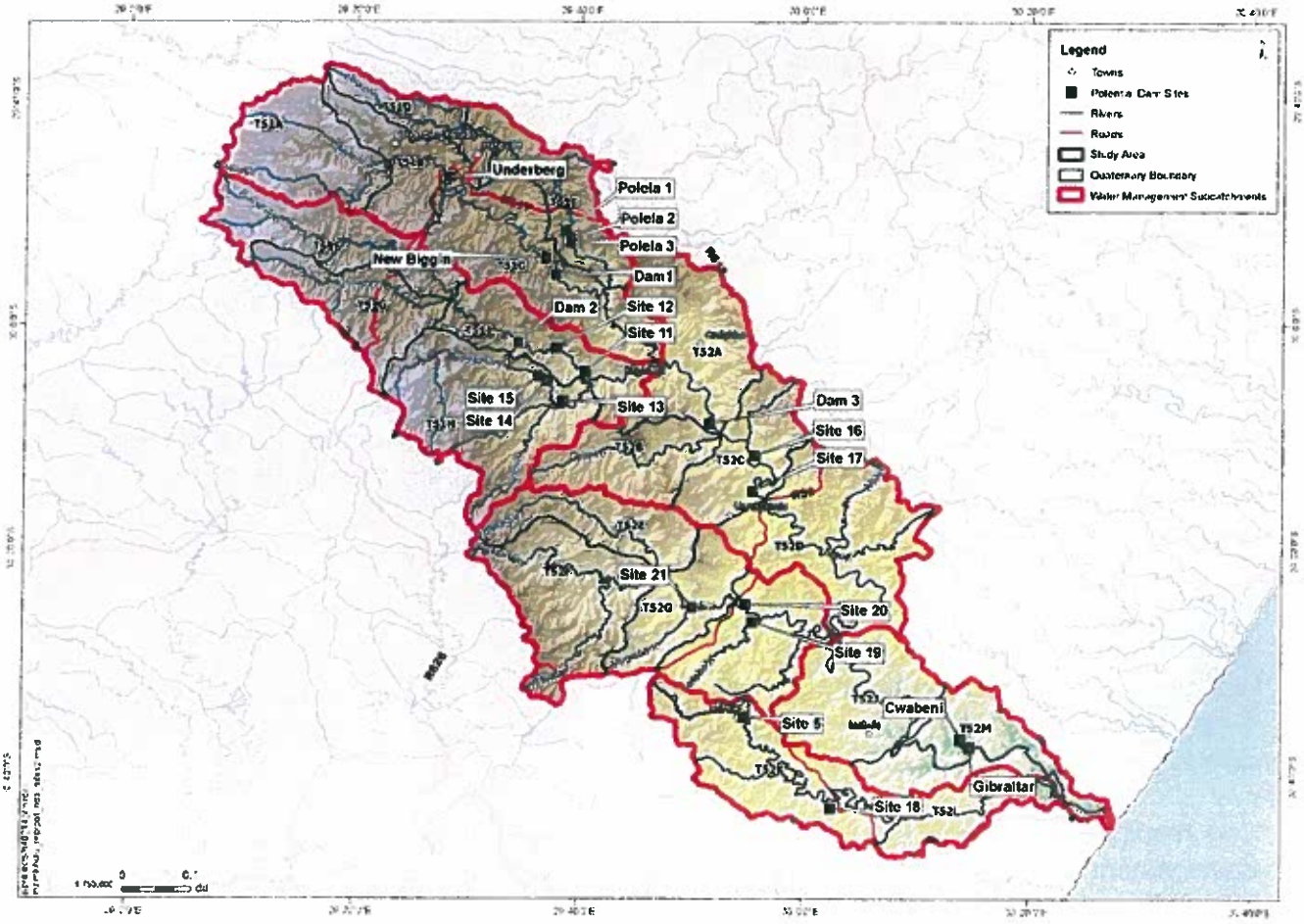

Figure 5: Previously identified Dam Sites

The sites were screened, using various criteria, the overriding one being locality. As the largest areas of forestry potential are situated in the Ngwangwane, the Middle Mzimkhulu and Bisi WMSCs, the sites on those rivers, were regarded as being best positioned to mitigate the impact of forestry on the low flows:

- *Site 12 on the Ngwangwane River, and*
- *Site 19 on the Bisi River.*

To test the impact on the river flows and water available to meet the EWRs a possible large dam with all the surplus yield being exported, a further two sites were selected.

- *Underberg, and*
- *New Biggin.*

CATCHMENT SCENARIOS

When taking into consideration the EWR, there is no historic firm surplus yield from the run of river flows, at quaternary sub-catchment level.

The future scenarios were developed, in order to test the impact of possible future developments within the catchment, on the flows downstream and to test the impact on the EWRs. All known urban and rural demands, projected to 2030, were included. A number of sub-scenarios were run, which are dealt with in the main text of this report and the Management and Development Options Report (WMA 11/T50/00/3009 Volume 2). In Scenarios 1 to 3, below, the dams are sized to meet the present day flows and the EWR at Gibraltar. A 0,5 MAR dam was also modelled, with the surplus yield assumed to be fully utilised or exported.

Future Scenario 1: All Small Growers

Scenario 1 assumes small grower plantation forestry expansion of 29 400 ha, and no increase in irrigated agriculture. Mitigated scenarios sized a dam at Site 12 on the Ngwangwane River, as described above.

The results of the modelling indicated that this relatively large additional plantation forestry development had minimal impact on the present day flows at the Gibraltar EWR site. The present day flows could be restored by a small 10 million m^3 dam (0,04 MAR) at Site 12 on the Ngwangwane River. A larger dam of 45 million m^3 (about 0,2 MAR) would restore the river to meet all EWR flows at Gibraltar. The larger 0,5 MAR dam produced a surplus of 80 million m^3/a.

Future Scenario 2: Small Growers, Bisi

Scenario 2 assumes plantation forestry expansion of 21 050 ha for small growers in the Bisi River catchment, with no increase in irrigated agriculture. Mitigated scenarios sized a dam at Site 19 on the Bisi River.

The results of the modelling indicated that this relatively large additional plantation forestry development had minimal impact on the present day flows at the Gibraltar EWR site. The present day flows could be restored by a dam of just less than 15 million m^3 (0,07 MAR) at Site 19 on the Bisi River. A larger dam of 45 million m^3 (0,2 MAR), on the same site, would restore the river to meet all EWR flows at Gibraltar. The 0,5 MAR dam produced a surplus of 30 million m^3/a.

Future Scenario 3: All Growers, Small and Large

Scenario 3 has an increased forestry area of 50 350 ha, for small and large growers, throughout the catchment, as well as a 20% increase in irrigated agriculture. Mitigated, scenarios were run to size a dam at Site 12 on the Ngwangwane River.

The larger area of additional plantation forestry, had limited noticeable impact on the present day flows at the Gibraltar EWR site and the Bisi site. In this case, the present day flows could be maintained by a small 16,5 million m^3 dam (0,07 MAR) at Site 12 on the Ngwangwane River. A larger dam of 48 million m^3 (0,2 MAR) would be able to meet all EWR flows at Gibraltar. The 0,5 MAR dam produced a surplus of 76 million m^3.

Future Scenario 4: Large Dam Scenario

Scenario 4 explored the impacts on the river and estuarine flows of a significant water resource development, either for export of water or to meet significant new demands. This scenario has the same land and water use as for Scenario 3.

Three cases were modelled, with various combinations of a large 1,0 MAR dam at Underberg, a 1,5 MAR dam at the New Biggin site and smaller dams, at the Bisi and Ngwangwane sites, the latter two, to meet the EWR flows at Gibraltar.

The results indicated that volumes of about 180 million m^3/a from the Underberg site and about 230 million m^3/a from the New Biggin site, could be made available for export, while meeting all EWR flows.

DISCUSSION

At the sites used for the EWR study the Mzimkhulu River was assessed to be in a good condition, somewhat better than expected. The aquatic environment also proved to be fairly resilient, being relatively unaffected by the proposed development of additional forestry and irrigation in the catchment. It emerged that there is limited risk to the environment in allowing a moderate degree of forestry development in the zones where forestry potential was identified. It was also shown that one only needs a relatively small dam to restore the present day flows.

Whilst the impact of moderate areas of additional forestry was relatively small at these sites, there may be considerably more severe impacts locally, on some of the smaller tributaries, which will need to be assessed when considering licence applications.

CONCLUSIONS

The overall conclusion is that the state of the ecosystem in this catchment, including the estuary, is generally good and the river is fairly resilient to some additional development in the catchment. By providing storage, the impacts of significant increases in the areas of plantation forestry and increased irrigation would not only be successfully mitigated, but the state of the river could be improved, to fully meet the EWRs at Gibraltar.

The cost estimates of the smallest possible dams at site 12 on the Ngwangwane River and site 19 on the Bisi River to meet all the EWRs at the Gibraltar site, are estimated to be R367 million and R265 million respectively.

Annual costs of redemption of the above loans, over a period of 40 years, at interest rates of 8, 10 and 12% for each of the dams, reduced to a per hectare cost for the three scenarios, vary from R410 to R1 890 depending on areas to be planted and interest rates. Considering that the gross marginal cost of timber production in the catchment, is estimated to be in the order of R2 500/ha/a, provided reasonably large areas of plantation forestry are planted, the mitigation costs of constructing a dam to restore the EWR flows, are within reach.

RECOMMENDATIONS

Short to Medium Term Actions (1 to 5 years)

(a) Water use licensing

- *A further 5 000 ha of afforestation can be planted without undue negative impact. Therefore invite and process licence applications for an initial area of 5 000 ha of plantation forestry in the Lower Ngwangwane, the Bisi and Middle Mzimkhulu Water Management Sub-catchments, with priority being given to small growers.*
- *There is a large amount of alien vegetation in the catchment. Removal of these can be replaced with equivalent afforestation.*
- *Even further afforestation can be done if negative flow impacts are offset with provision of strategically placed storage for releases in dry season.*

(b) Water resource development

- *Investigation of Cwabeni off channel storage must continue in order to have mechanism ready to address dry season water shortages in the short term.*
- *Carry out an initial comparison, including realistic time lines and lifetime economics between the Cwabeni off-channel storage dam and a storage dam on the Ngwangwane and Bisi Rivers, sized to supply Ugu District Municipality's requirements and mitigate the impacts of additional plantation forestry.*
- *Develop groundwater resources for remote rural and urban settlements and where yields are sufficient, also for small scale irrigation to provide food security.*

(c) Water resource management

- *Implement Water Conservation and Demand Management (WCDM).*
- *Validate and verify all registered water use in the catchment and eliminate unlawful use.*
- *Monitor to ensure compliance with licence conditions. Assess any new licence applications for development, considering information on potential impacts as provided by an EIA process and potentially a Reserve study conducted at a local level.*
- *Develop procedures or guidelines to link the removal of invasive alien vegetation to licences for additional forestry.*
- *Educate people in rural areas to prevent over-grazing.*
- *Implement Catchment Management measures, like Working for Wetlands and Working for Water to assist with meeting the Reserve.*

(d) Environmental

- *Initiate a programme to rehabilitate drained wetlands.*
- *Implement on-going ecological monitoring at the EWR sites. Ensure that the ecological state of the river does not deteriorate.*

- *Evaluate the findings of this EWR investigation together with the new Rapid EWR site investigations that were commissioned by DWA and the Water Research Commission (WRC) towards the end of this project. The results from this study will provide information on the Reserve situation in the smaller tributaries.*
- *As soon as possible determine and implement RQO following the newly published procedure, so that there can be clear objectives for the management of the river. Carry out on-going monitoring at the estuary, to allow the effects of development to be properly monitored.*

(e) Hydrological monitoring

- *Review the calibration of key flow gauges.*
- *Establish flow gauges and monitor flows at the lower ends of the Ngwangwane, the Bisi and the lower end of the Middle Mzimkhulu Water Management Sub-catchment (WMSC).*

Longer Term Management and Development Options

- *Having implemented the recommended monitoring, assess the impact on stream flow of the water use in the catchment, including that of the first areas of additional forestry, when at least 5 years monitoring is available and the additional forestry has been in place for at least 5 years.*
- *The hydrology should be updated and the model re-calibrated, paying particular attention to the Bisi catchment.*
- *Reassess the EWR results for the rivers and estuary.*
- *Based on the results for these assessments decide whether or not to invite and process licence applications in batches of 5 000 ha up to say 30 000 ha.*
- *Continue to monitor the inputs to reassess if further licences, potentially up to a total area of 50 000 ha of new plantation forestry can be issued.*
- *Small growers should receive priority.*
- *The impact on the water resource and the environment should continue to be monitored.*
- *Local impacts needs to be evaluated for each application and cumulative effects considered.*
- *If unacceptable impacts are observed and there is still a demand for more plantation forestry, the next recommendation is to undertake a pre-feasibility study to investigate a dam on the Ngwangwane or the Bisi River. The purpose of this dam would be:*
    - *To mitigate as far as possible, the impact of realising the full potential plantation area of 50 000 ha;*
    - *To restore the EWR flows'*
    - *The study should investigate whether there are sites upstream of those modelled on the Ngwangwane and the Bisi Rivers with more favourable capacity to MAR rations;*
    - *To meet the shortfalls at the Ugu's St Helen's Rocks abstraction works on the main river, which could do away with the need for the Cwabeni off-channel dam currently being investigated. This could avoid duplication and save the off-channel pumping costs.*
- *Identify the technical, economic and environmental feasibility of developing a dam.*

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Abbreviations

a	-	annum
BAS	-	Best Attainable State
CBD	-	Central Business District
C-Plan	-	Conservation Planning
DWA	-	Department of Water Affairs (previously DWAF)
DWAF	-	Department of Water Affairs and Forestry
EHI	-	Estuary Health Index
EIA	-	Environmental Impact Assessment
EIS	-	Estuarine Importance Score
EKZNW	-	Ezemvelo KwaZulu-Natal Wildlife
EWR	-	Ecological Water Requirements
GIS	-	Geographical Information System
GRIP	-	Groundwater Resources Information Project
IB	-	Irrigation Board
KZN	-	KwaZulu-Natal
MAP	-	Mean Annual Precipitation
MAR	-	Mean Annual Runoff
msl	-	Mean Sea Level
NFEPA	-	National Freshwater Ecosystem Priority Areas
NWA	-	National Water Act, Act 36 of 1998
PES	-	Present Ecological State
RDM	-	Resource Directed Measures
REC	-	Recommended Ecological Class
RQO	-	Resource Quality Objectives
SANBI	-	South African National Biodiversity Institute
SAPPI	-	South African Pulp and Paper Industry
SKZNPFS	-	Southern KwaZulu-Natal Pre-feasibility Study
WARMS	-	Water Use Authorisation Registration Management System
WCDM	-	Water Conservation and Demand Management
WMSC	-	Water Management Sub-catchment
WR2005	-	Water Resources of South Africa 2005
WRC	-	Water Research Commission
WRSM2000	-	Water Resources Simulation Model 2000
WRYM-IMS	-	Water Resources Yield Model – Information Management System

Scenario keys

U	-	Unmitigated – no dams
M	-	Mitigated by one or more dams
SG	-	Forestry potential for Small Plantation Growers
LG	-	Forestry potential for Large Plantation Growers
A	-	All forestry areas
Irr 20	-	Additional 20% irrigation water use
Bisi	-	Bisi in the Middle Mzimkhulu WMSCs
OCS	-	Off-channel Storage (Cwabeni Dam)

1. INTRODUCTION

The Department of Water Affairs (DWA) commissioned this study of the Mzimkhulu River catchment, as the natural river run-off, particularly during the low flow months and in dry periods, was no longer adequate to meet the demands in the lower catchment. There was a concern that the flows might have dropped below the requirements of the Ecological Reserve. This was largely attributed to heavy afforestation and irrigation developments without storage, in various parts of the catchment. The Department was under pressure to grant licences for further afforestation which, if allowed, would exacerbate the situation.

1.1 OBJECTIVES OF THE STUDY

The main objectives of the study as defined in the inception phase are as follows:

- To determine the existing and potential future water use in and from the catchment of the Mzimkhulu River.
- To assess the opportunities and water available for future economic development, particularly the potential for additional plantation forestry, while also considering other envisaged future requirements.
- To reassess the hydrology and the water supplies available from existing sources, which are mainly run of river, taking the ecological flow requirements into account, in order to determine to what extent the existing sources can meet the existing and potential future usage requirements.
- To recommend possible schemes for meeting future requirements, including potential additional plantation forestry, as well as interventions for moderating existing and potential future usage requirements.

This report describes the assessment of the possible development scenarios and is one of the deliverables in support of meeting these objectives.

1.2 CATCHMENT DESCRIPTION

1.2.1. Overview

The Mzimkhulu River catchment comprises tertiary catchments T51 and T52 with a total catchment area of approximately 6 668 km^2. A map showing the location of the catchment is shown in **Figure 1.1**.

The Mzimkhulu River (the great home of all rivers) rises in the Southern Drakensberg in the Ukhahlamba Drakensberg Park (Garden Castle Forest) at a height of just over 3 000 m in the upper part of Quaternary sub-catchment T51A. It is joined by the Mlambonja and Mzimkhulwana Rivers, after which it flows south of the town of Underberg.

It is later joined by the Pholela and Ngwangwane Rivers.

Some 800 km^2 of the upper catchment and upper reaches of the tributaries have been afforested. The DWA has put a hold on any further Licences for plantation forestry, because there are water shortages in the lower catchment during low flow periods.

The Mzimkhulu River then flows past the Northern and Eastern sides of the town of Umzimkulu. The Central Business District (CBD) is situated in the flood plain of the river and is subject to periodic flooding. This middle part of the catchment is predominantly rural tribal trust land and formed part of the previously independent Transkei. In this area, there are scattered subsistence rural communities drawing water from run-of-river. There is a great need for poverty alleviation and job creation in this area.

In the lower middle reaches, there are a number of rural water supply schemes, drawing water mostly from local streams, but also from boreholes and springs.

The river then enters a deep gorge, where it is joined by the Bisi River and lower down, the (second) Mzimkhulwana River. The Oribi Flats form a plateau between the gorges of the Mzimkhulu and the Mzimkhulwana Rivers, the latter, emanating from the Oribi Gorge Nature Reserve, a World Heritage Site and well known tourist attraction, with spectacular scenery.

The Mzimkhulu River drains tertiary sub-catchments T51 and T52, then winds its way to the Indian Ocean at Port Shepstone. The estuary used to be navigable, with difficulty, in days gone by and provided a sea link (hence the prefix "Port") with Durban, prior to the construction of the coastal railway line.

1.2.2. Conservation of the "Wild and Scenic" Beauty of the River

The Mzimkhulu River and its tributaries offer a variety of "wild and scenic" sections, and is utilised in many recreational activities specifically for these wild and scenic areas. Recreational use of the catchment includes, canoeing, white water kayaking and rafting, mountain biking, fly-fishing, birding, hiking, horse-riding, climbing and many more. Further several areas of the catchment are characterised by nature reserves and other areas of ecological sensitivity, identified and detailed in the environmental studies. While many areas are conserved for their ecological biodiversity, or ecological functions, supported by the sciences; "Wild and Scenic" incorporates these as well as 'sense of place' (i.e. the emotional experience) of the particular area. 'Sense of place' refers to an interaction between person and place.

With regard to the Mzimkhulu River, "wild and scenic" sense of place is defined as being areas of pristine environment or little disturbance/impacts and areas of natural beauty. It is the specific 'wild and scenic' ambience of these areas that draw the users to these areas. The upper catchments of the Mzimkhulu River and its tributaries are located within the Ukhahlamba Drakensberg Park, a World Heritage Site. This area is preserved as for its pristine, ecological, and historical nature. The entire Drakensberg Mountain Range is considered as "wild and scenic". The sections downstream of the Drakensberg Park to the trout farms upstream of Underberg are undisturbed and should be maintained - the river cuts through ancient rock formations. The dense riparian habitat along the rivers gives

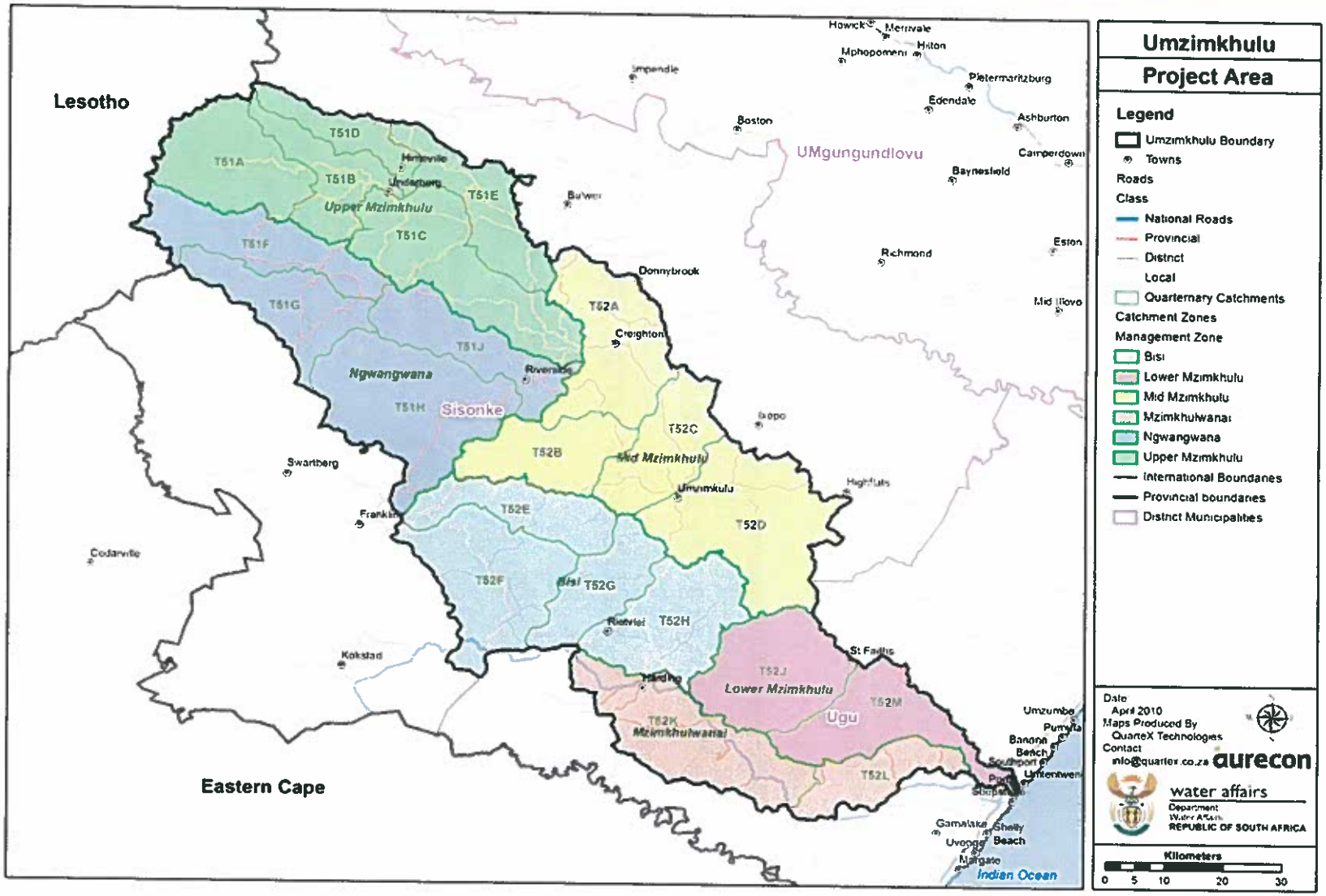

Figure 1.2: Project Area, showing the Quaternary sub-catchments and the six Water Management Sub-catchments

2. LAND USE AND WATER USE

2.1 INTRODUCTION

This report presents the land and water use components of the Mzimkhulu River Catchment Water Resources Study. The report deals with current water uses in the catchment, which in turn provides the basis for inputs into the hydrological model.

The land use component of the Mzimkhulu River Catchment Water Resources Study has involved the extraction of data from satellite imagery in each of the 21 quaternary sub-catchments, which comprise the catchment. Further investigation was required into each of the identified land uses, in order to establish water use for each of the classes of land use.

Different methodologies were developed as the project progressed, to enable members of the land use and hydrological teams to extract relevant data from a wide variety of different sources. This report provides an explanation of the methods used and the outputs produced on current water use in the Mzimkhulu River catchment.

2.2 SUMMARY OF KEY OUTPUTS

2.2.1. Land use

The volumes of water consumed by the various water use sectors in the catchment are discussed in the Land Use and Water Requirements Report, *(WMA 11/T50/00/3009 Volume 9)*. The present day land use is shown in **Figure 2.1**.

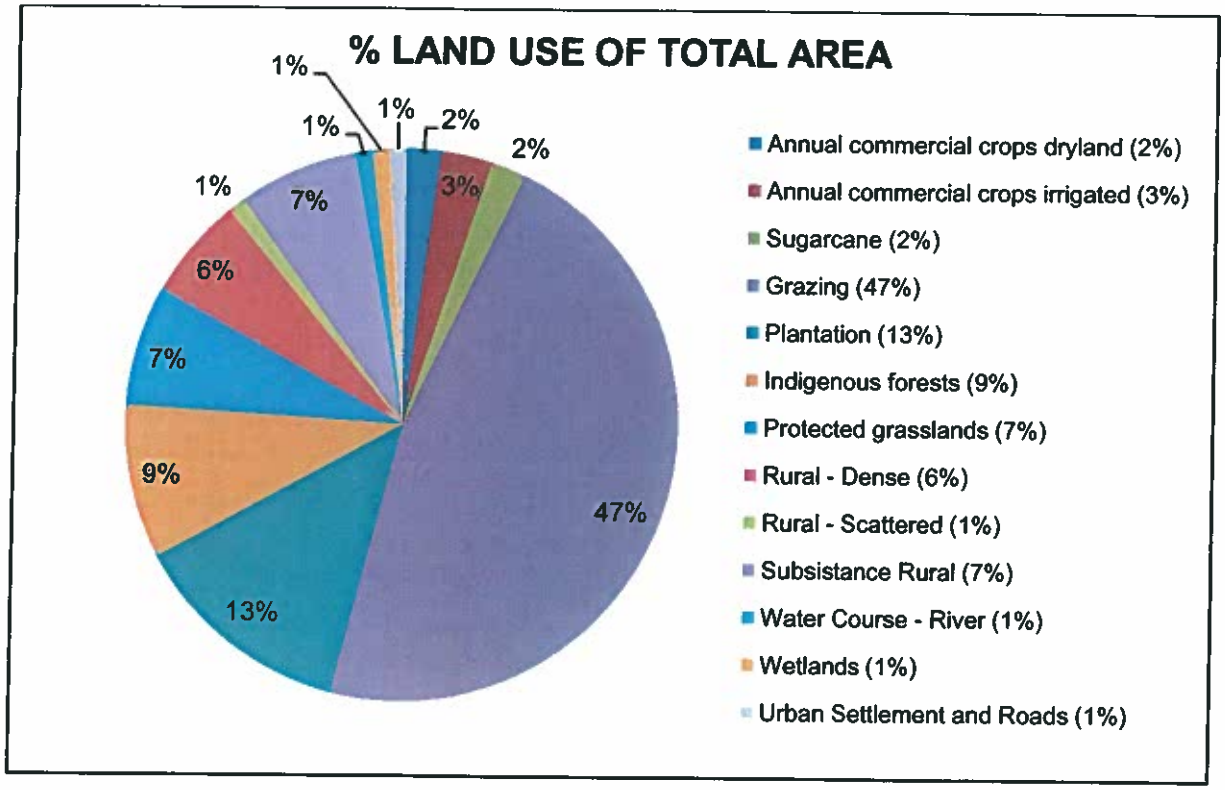

Figure 2.1: Percentage Land Use of total Area

2.2.2. Human Settlement:

The volumes consumed in urban areas in the catchment (excluding Port Shepstone) amount to 3,0 million m^3/a, based on the population living in these towns. In contrast, rural settlement accounts for 6,2 million m^3/a, which estimate is inclusive of differentials in consumption associated with a range in levels of service. Together, human settlement in the catchment currently accounts for 9,1 million m^3/a. The total water use for Port Shepstone, which is outside the catchment but supplied from it, is 16,7 million m^3/a.

2.2.3. Industry and Commerce:

Volumes consumed for industries and quarries located in rural areas of the catchment amount to 1,52 million m^3/a, whilst that in the urban areas is 53 400 m^3/a in 2009. The consumption figures for commerce are confined to the urban areas and in 2009 were estimated to be 760 000 m^3/a.

2.2.4. Agriculture (dryland and irrigation):

Dryland arable consumption, apart from sugar and plantation forestry, has been treated in the same way as natural grasslands, where consumption has been factored into baseflow as a pre-existing use.

In contrast, irrigation represents a significant water user, based on abstraction from rivers and dams in the catchment. The factors in the land and water use section of the report used in determining irrigation demand on different crop types were derived from the following sources: Irrigation Boards (IB's), the Department of Water Affairs', Water Use Authorisation Registration Management System (WARMS) database and communication with the Department of Agriculture (Section 4.3 Table 35). The final factors used in the modelling were based on those built into the Pitman Model where the above data was used for comparative and verification purposes.

2.2.5. Plantation Forestry Potential:

In order to determine the commercial forestry potential, a negative mapping process was used. The details are contained in the Land Use and Water Requirements Report, *(WMA 11/T50/00/3009, Volume 9)* of this study.

The study examined the existing land use and the climatic, topographic and soil conditions required for forestry and exclusion criteria related to the following factors were adopted:

- Existing land use;
- Ezemvelo KwaZulu-Natal (KZN) Wildlife Conservation Plan (C-Plan);
- Topographical Factors;
- Hydrological Factors; and
- Agricultural Factors.

In addition, the potential of the soils to grow timber was determined, using the soil type, depth, clay content and Bioresource unit slope, giving rise to four classes of

iii. 50 350 ha of forestry throughout the catchment, with 29 400 ha of the land being suitable for small growers and a 20% increase in water use for irrigated agriculture.
iv. As for Scenario (iii) with a large dam to export water.

Each has a number of sub-scenarios as shown in **Table 2.3**, giving a total of 15 future development scenarios. More details are given in Chapter 9 and in the Management and Development Options Report *(WMA 11/T50/00/3009, Volume 2)*.

Table 2.3: Summary of Future Development Scenarios

Scenario	FS 1U_OCS (SG A)	FS 1M 1 (SG A)	FS 2M 2 (SG Bisi)	FS 3U OCS (LG A + Irr 20)	FS 4a (M: LG A)	FS 3M 1 (LG A + Irr 20)	FS 4c (M: LG A Full)	FS 4c (M: LG A Low)
River EWR Scenario Number	1	2	3	4	5	-	6	7
Estuary EWR Scenario number	3	4	5	6	2	7	1	-
Increased forestry	29 400 ha	29 400 ha	21 050 ha	50 350 ha	50 350 ha	50 350 ha	50 350 ha	50 350 ha
Increased demand from irrigated agriculture	NIL	NIL	NIL	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)	20% (15,6 million m^3/a)
Cwabeni OCS	Yes (and No)	No	No	Yes (and No)	No	No	No	No
Dam at site 12 (Ngwangane)	No	0,5 MAR Operated to meet all EWRs at Gibraltar in all months		None	0,17 MAR Operated to support the dam at site 19 to meet all EWRs in all months at Gibraltar – surplus yield exported	0,5 MAR Operated to meet EWRs at Gibraltar and surplus yield exported		
Dam at site 19 (Bisi)	No	No	0,18 MAR Operated to meet all EWR flows in all months at Gibraltar	No	0,18 MAR Operated to meet all EWR in all months at Gibraltar – surplus yield exported	No	0,5 MAR Operated to meet all EWRs in all months at Creighton and Gibraltar. Surplus yield exported or used.	0,5 MAR Operated to meet EWRs in low flow months at Creighton and Gibraltar. Surplus yield exported or used.
Dams for water use or export					1,0 MAR at Underberg All yield exported out of the basin. Export 180 million m^3/a.		1,5 MAR dam at New Biggin All yields exported out of basin. Export 227 million m^3/a.	1,5 MAR All yields exported out of basin. Export 227 million m^3/a

NOTES:

1. In all scenarios the base is present day infrastructure, forestry and irrigation agriculture.
2. In all scenarios the growth in urban and rural domestic water use is a 30% increase up to 2030 and includes the coastal strip, supplied by Port Shepstone, with seasonal demands.
3. Scenario 4b was defined but not modelled.

3. HYDROLOGY

3.1. INTRODUCTION

The objective of the catchment hydrology task for the Mzimkhulu River Catchment Water Resources Study is to present the updated hydrology for the study area in order to support the determination of existing and potential future water use, to assess the opportunities and water available for future economic development, and to recommend possible schemes for meeting future requirements with a specific focus on the potential for development of plantation forestry in the catchment. Monthly simulated runoff sequences are produced which are used in the system yield analyses relating to present and future land-use development scenarios and scheme development options.

3.2. GENERAL APPROACH

The hydrology of the Southern KwaZulu-Natal Pre-Feasibility Study (SKZNPFS) (DWAF, 2002) which was for the period 1925 to 1998, was used as a point of departure and it was updated with the latest land and water use information, representing the 2007 hydrological year. The Water Resources Simulation Model (WRSM2000) was configured and calibrated with this information in order to generate monthly flow sequences using the following approach:

- Capturing and processing spatial data for use in the Pitman model including rainfall, evaporation, irrigated areas and crop types, afforested areas and alien vegetation areas, water demands, abstractions and return flows, transfers and farm dam information.
- Sub-catchment configuration informed by previous studies and availability of spatial data and observed flow gauge data.
- Calibration of the Pitman model in WRSM2000.
- Produce long term naturalised flow sequences.

3.3. RESULTS

A summary of the calibration results for the Mzimkhulu River sub-catchments is shown in **Table 3.1**. Wherever possible the calibrated flows are based on longer flow records, than in previous studies and the naturalised flow sequences (1920-2007) for the Mzimkhulu River sub-catchments appear to compare well with the estimates from the previous study (SKZNPFS), with a difference of 11% in the T51 tertiary catchment and 5% in the T52 tertiary. There are larger differences on a quaternary level and these can be attributed to inter alia, changes in land use areas and more up to date land use information, longer observed flow records on which to calibrate, different combinations of rainfall stations, updated software and techniques for streamflow reductions and calculation of irrigation demands. The Natural and Present Day MARs per quaternary sub-catchment are shown in **Table 3.2**.

3.4. CONCLUSIONS AND RECOMMENDATIONS

The key objective of this task was to update and extend the naturalised streamflows and water requirements to the 2007 hydrological year to take forward to the system model for scenarios analysis, which has been achieved.

Rainfall data is one of the most important data requirements for hydrological modelling and the density of the existing rain station coverage is low. The accuracy and reliability of rainfall information in the catchment could be improved with continued monitoring and maintenance of the existing stations. Re-instatement or re-opening of closed gauges in key areas, specifically in the low-lying areas of the Ngwangwane and Middle Mzimkhulu catchments is recommended, in order to improve the density and coverage of active rainfall stations in the network.

The flow monitoring network in the Mzimkhulu catchment is adequate for a general water resources assessment, but should be improved if significant new socio-economic developments, such as plantation forestry, are planned. It is important that existing flow gauges remain open and continue to be monitored and maintained. It would be useful to monitor flows for the tributary of the Ngwangwane River, just upstream of the confluence with the Mzimkhulu, as well as on the main stem downstream of Umzimkulu town in the lower catchment. The quality of the observed data is fairly good for most flow gauges however the records are relatively short because many of the gauges were closed during the independence of the Transkei and re-opened afterwards.

4. WATER QUALITY

A comprehensive assessment of the water quality situation was not envisaged as part of the project because such an assessment was undertaken, with data collected up to 1999, as part of the SKZNPFS (DWAF, 2002). Since then, about eight years of additional water quality data have been collected in the catchment and a brief review of the water quality situation was undertaken to determine if the water quality trends described previously, have changed, or if new water quality issues have emerged since then. To compare findings, the catchment was divided into three parts, shown in **Figure 4.1**, and the data was analysed with the WQStat Plus statistical software package.

4.1. UPPER BASIN

It was previously found that *"the land use and the water quality data both indicate good water quality with no significant signs of pollution, or any adverse trends in water quality. Treatment of abstracted water should not pose any problem. No additional monitoring is considered necessary due to the fact that water pollution is unlikely. The current water quality data available is considered sufficient at this stage"*. This study confirmed that the status quo remained largely unchanged in the upper basin and that the conclusions drawn previously were still valid.

4.2. MIDDLE BASIN

It was previously found that *"the data indicate good water quality with no signs of pollution and should not be difficult to treat to potable water standards. There is a greater percentage of agricultural activity and urban land that warrants additional data collection to improve assessment of water quality. Sampling at the DWAF site T5H007Q01 or at a site on the river above Umzimkulu town is recommended."* This study confirmed the status quo but specific concerns were expressed about the state of the river near the town of Umzimkulu. It is recommended that a water quality study be undertaken in that area to identify potential pollution sources and management interventions to address local impacts.

4.3. LOWER BASIN

It was previously found that *"the overall water quality in the Mzimkhulwana River is not as good as that in Basins 1 and 2, which could be due to agricultural activities. The prediction would be poorer water than in the upper basins. The water quality is considered to be moderate and should be suitable for consumption after treatment. Sampling of the Mzimkhulu River above its confluence with the Mzimkhulwana River is recommended. Additionally, the Mzimkhulwana River should be sampled either at the DWAF site (T5H012Q01) or just before its confluence with the Mzimkhulu River."* In the lower basin (Basin 3) water quality monitoring stopped in 1996 making it impossible to draw meaningful conclusions about a possible change in status.

A previous recommendation to improve monitoring in the lower basin is strongly supported and the DWA is encouraged to review and maintain their water quality monitoring in the Mzimkhulu River catchment in order to track water quality changes as further development of the catchment continues.

5. RIVERINE ECOLOGICAL WATER REQUIREMENTS

5.1 INTRODUCTION

The Riverine Ecological Water Requirements are dealt with in detail in the Riverine Ecological Water Requirements Report, *(WMA 11/T50/00/3009, Volume 5)* of this Study. This investigation was initiated by pressure for expansion of, in particular, the forestry industry, with numerous applications for planting additional forestry having been put on hold, pending the findings of this study. There was a prior perception that the resources in the catchment were already overdeveloped, based largely on the fact that water resources had become limiting at the lower end of the river, where Port Shepstone at times does not have adequate supplies. The Mzimkhulu River Catchment Water Resources Study was required to assess the availability of water and the pressures being placed on this water, in the different parts of the catchment.

Against this background, the objective of the river EWR (or Reserve) determination was to quantify the requirements of the river environment for a quantity of water, as is required by the National Water Act, Act 36 of 1998, (NWA). The Ecological Reserve is considered by the NWA to be one of only two rights to access to water; the other being the basic human needs Reserve. The rationale behind this is that the EWR represents the actual resource, and to damage this would be to damage the potential for other users to have access to the water.

The study commenced in 2009 and the field work and scenario assessment were completed in early 2011. The work was based on the 2010 hydrology and modelling of the impacts of future development scenarios on the flow regimes. On 12 March 2011 revised hydrology became available and the impact of the future developments on the flow regimes was re-assessed. The implications of the possible development scenarios using the 2010 hydrology on which the EWR work was based and an assessment of the implications of the March 2011 flow regimes are discussed below.

5.2 APPROACH TO THE DETERMINATION OF THE EWR FOR THE RIVER

The approach that has been followed is essentially to reproduce the methods that have been applied previously to other catchments and thus have been approved by the Resource Directed Measures (RDM) office of DWA. While these methods have been seen to evolve over time, the most recent examples of the Vaal and Crocodile West EWR determinations have been used to illustrate the latest thinking.

The EWR determination has been carried out with a mixture of approaches, with the INTERMEDIATE approach applied to five of the sites and the RAPID III approach applied to the remaining three sites. The former approach undertakes the investigation at a greater level of detail, entailing a more extensive survey as well as two visits to each site. The latter approach is confined to a single site survey using a reduced number of methods. The latter naturally has a lower confidence in terms of the results that are produced. The EWR sites are shown in **Figure 5.1**.

5.3 THE PRESENT ECOLOGICAL STATE OF THE MZIMKHULU RIVER

Surveys were conducted twice at five of the sites and once for three of the sites, where intensive ecological data and information was collected to describe the PES of the river and its major tributaries. The results of this investigation are summarised in **Table 5.1**.

Essentially the main river and its tributaries are in a "B category" or higher indicating that the ecosystem is in a near natural or only slightly transformed state. This, despite the fairly heavy developments that have taken place in the upper catchment and the degradation of many parts of the catchment due to poor land-use practices, particularly in the middle parts of the catchment. It has to be cautioned though, that this conclusion could be misleading as the investigation was carried out on the main-stem river as well as the downstream, larger portions of some of the main tributaries. No investigation was carried out where the tributary size is small, and where local impacts may be severe. For example, small streams amongst extensive forestry plantations or irrigation schemes, may present a different story. However, the results do indicate that the river overall, its main artery, remains in good condition.

Despite the developments that have taken place, the water quality remains relatively good. This is largely due to the nature of the developments in the catchment which are generally non-polluting and because of the relative isolation of settlements from open water. Possibly the greatest risk from a water quality point of view lies in the town of Umzimkulu which discharges effluent of questionable quality directly to the river. A more important reason for the degradation that has taken place is the large amounts of water being removed from the water resource. While the minimal degradation suggests that these volumes of water were surplus to the needs of the ecosystem, it is probably that the point where more serious degradation will start to happen is being approached.

5.4 DETERMINATION OF THE ECOLOGICAL WATER REQUIREMENTS

A process was followed to determine the EWR for the sites being investigated, and also to extrapolate this to the remaining quaternary catchments which were not investigated. This determination describes the quantity of water, its volume and timing of flow that is necessary to maintain the ecosystem in a defined condition. In this study the first assessment was the water required to maintain the river in its PES. It was found that only a portion of the available water was necessary to maintain the river in this state, as summarised in **Table 5.1**. This ranged from 21 to 43% of the natural flow in the tributaries to between 21 to 30% for the main Mzimkhulu River. The assessment breaks this down to show the amount of water that is needed during the low flow seasons (i.e. the maintenance baseflow) as well as in the form of floods. It also considers the reduced volume that is needed to sustain the river during drought periods, which in semi-arid regions such as this are necessary for the maintenance of biodiversity in rivers.

5.5 ECOLOGICAL CONSEQUENCES OF OPERATIONAL SCENARIOS

A number of possible development scenarios were developed by other parts of this Mzimkhulu River Catchment Water Resources Study and are presented in detail in other volumes. Essentially, the development scenarios entailed the development of between 20 000 and 50 000 ha of forestry in the areas most suitable for forestry development (mainly the mid-altitude parts of the catchment), as well as the development of additional

Table 5.1: Summary of the Ecological Water Requirements for the Mzimkhulu River and Tributaries

Quaternary catchment	River	EWR site number	EWR site name	Level	PES	REC	EIS	Natural MAR (n) (million m^3)	% MAR (n) Maintenance Low Flow	% MAR (n) Maintenance High Flow	% MAR (n) EWR	% Drought Low Flow
T51C	Mzimkhulu	EWR2i	Callaway	Intermediate	B	B	M	261	13	12	25	5
T52A	Mzimkhulu	EWR3i	Creighton	Intermediate	B	B	M	870	20	3	23	4
T52D	Mzimkhulu	EWR5i	Middle Mzimkhulu	Intermediate	B	B	M	1 085	16	6	22	5
T52M	Mzimkhulu	EWR6i	Gibraltar	Intermediate	A/B	A/B	M	1 384	25	5	30	6
T51E	Pholela	EWR9r	Pierr	Rapid 3	B/C	B/C	M	110	19	10	29	7
T51F	Nwangwane	EWR8r	Coleford	Rapid 3	C	C	M	117	12	10	22	6
T52G	Bisi	EWR14r	Welverdiend	Rapid 3	A/B	A/B	M	195	31	12	43	12
T52L	Mzimkulwana	EWR17i	Oribi	Intermediate	B	B	H	43	18	12	30	6

unusual for South Africa, to have a river in such good condition. The river also proves to be relatively resilient, being relatively unresponsive to the proposed developments of forestry and irrigation in the catchment. This resilience is based on a combination of the presently good condition of the river, the good water quality, which is not expected to deteriorate much, and the lack of special or unique aspects in the components of the ecosystem. This is supported by the continuous flow of good quality and quantity of water from the headwaters in the pristine Ukhahlamba Drakensberg Mountains and the presently undammed nature of the river. The developments that propose a large dam to be constructed on the mainstem Mzimkhulu, have the largest potential impact on the ecosystem, with those dams planned for tributaries having much less impact. Avoiding construction of dams on the mainstem river, would also support conservation initiatives, where the undammed nature of the Mzimkhulu River has been recognised by the National Freshwater Ecosystem Priority Areas (NFEPA) (South African National Biodiversity Institute (SANBI), 2008) programme and the river is ranked as one of the most important for conservation in the region.

There are a number of limitations to this assessment which have been described in the report. While none of these constitute a "fatal flaw" in the investigation, there are some areas of uncertainty that should be resolved before major developments in the catchment are given approval. There are also uncertainties about the extent of the ecological impacts that would occur in smaller tributaries at a local scale. While the project has taken the overall catchment impacts into consideration, these local impacts need to be assessed as part of any development plan.

It is recommended that, as a condition of allowing any new forestry or irrigation development the following are undertaken:

- Review of the calibration of key flow gauges, as discussed in the Surface Water Resources Report *(WMA 11/T50/00/3009, Volume 8)*.
- Ongoing ecological monitoring at the EWR sites, especially the RAPID III sites, and upgrading them to intermediate category.
- Ongoing monitoring at the Estuary, as discussed in the Estuarine Ecological Water Requirements *(WMA 11/T50/00/3009, Volume 6)*.

This ongoing monitoring will improve the confidence in the predictions and allow the effects of development to be properly monitored, but the monitoring results are not required before some new plantation forestry can be approved.

However the monitoring results are not required before some new plantation forestry can be approved.

Any new licence application for development would need to include information of potential impacts as provided by an Environmental Impact Assessment (EIA) process and potentially a Reserve study conducted at a local level. The Reserve information provided in this report cannot be construed to cater for all local level situations.

Developments which are small in nature and do not require EIA or Reserve studies, but which cumulatively, may have a high impact, need to be considered in a larger context. This is especially so for small scale forestry developments. Co-ordination of the management of this larger impact should be the responsibility of DWA with support from the provincial environmental management authority.

6. ESTUARINE ECOLOGICAL WATER REQUIREMENTS

6.1 ASSUMPTIONS AND LIMITATIONS

This study was undertaken with the following assumptions and limitations:

- The historical information describing the situation of mouth closure in the estuary is poor, this is due to the lack of reliable historical water level records but this is also confounded by the artificial breeching of the mouth. A water level recorder was installed after the monitoring programme was complete and only two months prior to the EWR workshop at the end of the study; and
- The overall confidence in the hydrodynamics of the estuary, and therefore the overall assessment, is Low. This is because of:
    - The lack of historical water level records;
    - The lack of good records of the state of the mouth (open or closed) and the artificial breaching; and
    - The lack of a flow record just upstream of the estuary.

Criteria for confidence limits attached to statements in this study were as follows:

Table 6.1: Criteria for confidence limits

LIMIT	DEGREE OF CONFIDENCE
Very Low	If no data were available for the estuary or similar estuaries (i.e. < 40% certain)
Low	Limited data were available and estimates could be out by >60% (40% certain of estimate)
Medium	If reasonable data were available for the estuary and estimates could be out by 20-60% (i.e. 40-80% certain of estimate).
High	If good data were available for the estuary and estimates are probably not more than 20% out (i.e. >80% certain of estimates)

The accuracy of the predicted abiotic states for the Mzimkhulu Estuary (and hence biotic characteristics) and the distribution of these states under the Reference condition, present state and different flow scenarios, depends largely on the accuracy of the simulated runoff data and measured flow data.

Geographical boundaries

The geographical boundaries for the Mzimkhulu River Estuary are:

Downstream boundary : Estuary mouth (30°44'21.68"S, 30°27'27.52"E);
Upstream boundary : 9,5 km from the mouth to the extent of tidal influence; and
Lateral boundaries : 5 m contour above Mean Sea Level (msl) along each bank.

6.2 PRESENT ECOLOGICAL STATUS OF THE MZIMKHULU ESTUARY

6.2.1 Overview

A present day MAR of 1 176 million m^3/a, which constitutes 81% of the natural MAR of 1 453 million m^3 per annum places the Mzimkhulu River in the top three KwaZulu-Natal rivers, exceeded only by the Thukela and slightly ahead of the

category status (scoring range 76 - 90) on a scale from A to F reflecting a system "largely natural with few modifications".

Table 6.2: Estuarine Health Index Scores allocated to the Mzimkhulu Estuary

Variable	Weight	Score	Weighted Score
Hydrology	25	84	21
Hydrodynamics and mouth condition	25	78	20
Water quality	25	72	18
Physical habitat alteration	25	75	19
Habitat Health Score			**77**
Microalgae	20	90	18
Macrophytes	20	80	16
Invertebrates	20	70	14
Fish	20	80	16
Birds	20	80	16
Biotic Health Score			**80**
ESTUARINE HEALTH SCORE			**79**
Present Ecological Status			**B**

On a national scale Estuarine Importance is "highly important", "important" or is indicated as having "low to average importance". As shown in **Table 6.3**, the Mzimkhulu Importance Score was 84 falling in the range 81-100 of "highly important".

The Estuarine Importance Scores (EIS) allocated to the Mzimkhulu Estuary were as follows:

Table 6.3: Estuarine Importance Scores

Criterion	Score	Weight	Weighted score
Estuary Size	80	15	12
Zonal Rarity Type	30	10	3
Habitat Diversity	100	25	25
Biodiversity Importance	76	25	19
Functional Importance	100	25	25
ESTUARINE IMPORTANCE SCORE			**84**

This was based largely on the estuary's role as a nursery ground, as a movement corridor and as a conduit for catchment derived detritus, nutrients and sediments to the coastal zone.

6.3 RECOMMENDED ECOLOGICAL CLASS

The recommended Ecological Reserve Category (REC) represents the level of protection assigned to an estuary.

For estuaries, the first step is to determine the 'minimum' REC, based on its PES. The relationship between EHI Score, PES and minimum REC is set out in the table below.

caused by the dams can be very significant for the estuary, and ranged from 60% to 80% of the reference MAR.

These generated EHI scores between 74 and 79 which left the system on the borderline (75-76) between B and C (moderately modified) with four retaining a B status and two (Scenarios 1 and 6) dropping to a C. The results are summarised in **Table 6.6**.

Table 6.6: Summary of the 2010 estuary flow scenarios evaluated in this study

Scenario name	Estuary Scenario No.	MAR (million m^3)	Percentage MAR remaining	Est. Health Score Index	Ecology reserve categories
Natural		1 452,5	100,0		
Present		1 199,5	82,6	79	B
FS4c	1	865,4	59,6	74	B-
FS4a	2	955,6	65,8	75	C+
FS1U_0CS	3	1 165,0	80,2	76	B-
FS1M1	4	1 078,3	74,2	79	B
FS2M1	5	1 139,0	78,4	79	B
FS3U_OCS	6	1 130,5	77,8	74	C
FS3M1	7	1 051,6	72,4	78	B

6.5 RECOMMENDED ECOLOGICAL WATER REQUIREMENT

The evaluation of the Water Use Demand Runoff Scenarios is used to derive the recommended EWR. Thus the recommended EWR is defined as the runoff scenario (or a slight modification thereof) that represents the highest reduction in river inflow that will ensure the estuary remains in the Ecological Reserve Category.

Given the changes to flow which have already occurred, it would be impractical to improve the condition of the Mzimkhulu Estuary to a Category of A. Using flow alone, the condition could be improved by 8% (from 79 to 87%). Even if, non-flow related mitigation measures, such as reducing agricultural impacts on the floodplain, reducing the application of fertilizers in the catchment and were also implemented the condition would not reach a Category A.

Thus, the BAS for the estuary is a Category B.

Most of the scenarios evaluated in this study, resulted in a decrease in the EHI score for the Mzimkhulu Estuary. This was due mainly to the reduction in both low flows and floods resulting in a change in the mouth status as well as the physico-chemical states within the system.

These results were reassessed in light of the changes made to the hydrology data during March 2011. This sensitivity analysis indicated that the percentage change from the previous hydrological modelling were all less than 2% and should therefore not change the findings of the previous assessment significantly. The revised hydrology indicated that the Present State is slightly different as both low flow states (1: Closed mouth and 3:

Table 6.9: Summary of the monthly flow (in m^3/s) distribution under Scenario FS2M1

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99	77,6	146,8	191,1	207,4	235,7	392,1	140,8	109,9	73,0	27,5	17,3	68,1
90	20,5	63,5	110,5	132,5	168,1	130,0	77,9	32,2	13,6	12,6	7,8	6,9
80	14,3	36,1	84,9	109,3	112,6	107,5	59,1	20,3	10,2	6,7	5,7	6,2
70	10,8	28,9	68,7	88,5	100,1	87,3	48,9	17,7	8,6	6,4	5,5	6,0
60	9,2	24,9	53,3	75,3	89,9	77,9	39,5	15,4	7,8	5,8	5,0	5,7
50	8,3	19,7	40,4	70,6	82,4	66,3	33,6	13,4	6,7	5,1	4,2	5,1
40	6,8	16,3	35,9	60,7	72,6	56,7	30,4	10,6	5,3	3,9	3,5	4,2
30	5,0	12,0	25,7	53,5	59,9	50,6	26,6	8,	4,1	2,8	2,5	3,1
20	3,3	6,6	20,6	37,4	45,8	37,8	19,5	7,2	2,9	2,0	1,8	2,2
10	2,2	3,1	9,7	28,2	33,8	27,4	14,9	5,3	2,2	1,7	1,3	1,6
1	1,8	2,0	2,9	10,0	14,5	11,7	5,8	3,5	1,8	1,4	1,2	1,3

Table 6.10: Summary of the monthly flow (in m^3/s) distribution under Scenario FS3M1

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99	74,9	139,5	184,3	199,2	235,7	386,8	136,5	106,9	70,1	26,7	15,0	68,8
90	19,2	51,5	93,4	125,7	164,5	125,7	75,2	30,1	11,8	11,3	7,9	7,5
80	12,7	31,3	75,8	98,9	108,9	105,7	57,3	18,2	9,7	6,7	5,7	6,2
70	10,0	24,1	59,7	79,6	95,3	83,8	47,2	15,7	8,5	6,4	5,5	6,0
60	9,2	19,5	43,7	66,4	83,8	73,5	36,8	13,3	7,8	5,8	5,0	5,7
50	8,3	16,4	33,5	60,7	72,8	61,4	31,1	11,5	6,7	5,1	4,2	5,1
40	6,8	13,9	29,7	55,1	72,8	52,6	28,7	9,5	5,3	3,9	3,5	4,2
30	5,0	9,8	21,2	43,8	68,1	47,4	25,0	7,9	3,9	2,8	2,5	3,1
20	3,3	5,8	16,2	29,4	54,9	35,1	17,2	5,9	2,7	2,0	1,8	2,2
10	2,2	3,3	7,8	20,8	39,8	24,1	12,9	4,5	2,1	1,7	1,3	1,6
1	1,8	2,0	2,9	7,0	10,3	9,0	4,6	2,5	1,8	1,4	1,2	1,3

In addition operational guidelines are provided to assist in setting management objectives regarding important aspects of estuarine condition such as mouth state and water chemistry and these should be used in conjunction with the recommended water use scenarios to ensure that the estuary remains within the desired REC.

Allowing the condition of the Mzimkhulu Estuary to decline from its current PES has the following implications:

- Reduced numbers of estuarine dependent fish and invertebrate species, particularly those that use the estuary as a spawning and nursery ground.
- Reduced cueing effect to estuarine dependent invertebrate and fish species, and a possible reduction in diversity and abundance of fish in the estuary and along the coast.
- The estuary has also been selected for full protection at a provincial level and partial protection at a national level and changes to the status of the estuary will affect the core set of estuaries selected to satisfy biodiversity conservation targets.

These are also likely to have a ripple effect on economic good and services provided by the adjacent marine environment, e.g. the marine fisheries and coastal sediments.

Thus, it is strongly recommended that decisions that affect the flow regimes of the Mzimkhulu Estuary carefully consider potential impacts on all users. Given its importance

7. GROUNDWATER RESOURCES

The report: Groundwater Resources is contained in (*WMA 11/T50/00/3009, Volume 4*) of the study.

7.1. BACKGROUND

The Mzimkhulu River Catchment Water Resources Study was initiated to meet three main objectives, which all directly involve groundwater and its potential to be assessed as an integral part of the resource and its sustainable management:

- determine the existing and potential future usage of water in the catchment, with reference to the potential of further afforestation;
- reassess the hydrology and water supplies available from existing sources; and
- investigate schemes for meeting future requirements.

7.2. OBJECTIVES

The broad objectives of this component were to assess the potential groundwater resources of the catchment in an attempt to relate borehole yields to geological formations, including water quality and potential for recharge, as well as identifying potential aquifer formations and related structural features. Once accomplished, this would allow for the assessment of the potential for further groundwater development to supply rural and domestic use requirements, specifically in the rural areas of the middle and lower parts of the Mzimkhulu River catchment.

7.3. METHODOLOGY

Relevant groundwater data, which were either collected from the field area or were sourced from in-house data bases and regional databases (Groundwater Resources Information Project – GRIP), were utilised in conjunction with geographical information systems (GIS) and digital mapping data to establish an understanding of the groundwater system in the Mzimkhulu River catchment.

The yields of existing boreholes are shown on **Figure 7.1.** There is significant use of groundwater, primarily in the middle area of the catchment and particularly around Creighton and Underberg.

Typically then, the occurrence and availability of groundwater was determined by employing the following factors:

- Topography and drainage;
- Rainfall and climate data;
- Population data (indicative of current usages);
- Vegetation types and consequent water requirements;
- Petrology (aquifer types);
- Geological structures;
- Soils (potential, depths and clay content);
- Groundwater yields;
- Recharge areas; and
- Depth to groundwater.

Physical and chemical groundwater data and the afore-mentioned associated data were mapped out within the catchment such that the availability and occurrence of groundwater could be investigated. The data / maps were 'over-layered' with the ultimate purpose of this practice to identify the areas within the Mzimkhulu River catchment that could be investigated for the supply of greater volumes of chemically suitable groundwater, and the geological structures / lithology these areas correlate to.

7.4. CONCLUSIONS

The following conclusions were made:

- Elevated groundwater yields occur to the north of Rietvlei, directly east of Creighton and from west-southwest to northwest of Underberg.
- Rainfall recharges the shallow aquifers in these areas and it is intercepted by the boreholes in the catchment.
- Populations (both rural and urban) are situated within these areas, such that groundwater supply to these communities appears viable.
- The principle high-yielding geological formations are the Drakensberg basalts, the Karoo dolerites and the closely-bedded argillaceous Karoo Supergroup rocks.
- Dolerite dyke and sill contacts and observed lineaments act as the main pathways for groundwater movement and to a certain extent, storage
- Areas underlain by shallower soil profiles and soils with increased clay content typically exhibit higher yields.
- Magnesium (Mg), nitrate (NO_3) and fluoride (F) are the only potentially problematic determinants in the groundwater, with these three 'peaking' in the southern areas of the Mzimkhulu River catchment.

7.5. RECOMMENDATIONS

The following recommendations are made:

- Groundwater exploration should be carried out from Rietvlei to the north and northwest and be continued:
  - near the Centecow Mission,
  - directly east of Creighton,
  - from west-southwest to northwest of Underberg.

8. SURFACE WATER RESOURCES

The objective of the Report, Surface Water Resources *(WMA 11/T50/00/3009, Volume 3)*, of the Mzimkhulu River Catchment Water Resources Study, is to present the updated system yield analysis for the current supply system as well as for future scheme development options in the catchment.

The WRYM-IMS has been used to update the Mzimkhulu River system configuration to include present day land and water use, for the period 1920 to 2007, as well as the EWR for each quaternary catchment.

The model was then configured to include future scheme developments which included five potential dam options and scenarios of increased plantation forestry, irrigation and urban and rural water use. Areas for potential forestry development were determined through a negative mapping approach which assessed the catchment according to timber growing potential characteristics. Three scenarios of increased plantation forestry areas were considered:

- An additional 29 400 ha for small growers throughout the catchment;
- An additional 21 050 ha for small growers only in the Bisi catchments; and
- An additional 50 350 ha for small and large growers throughout the catchment.

In addition a 20% increase in water use by irrigated agriculture was assumed in some scenarios. It was assumed that the future water use by 2030 for rural and urban domestic, industrial and commercial purposes would increase by 60% from current. Potential dam sites were included in the scenarios to provide mitigation for the impacts of increased water demands as a result of additional plantation forestry and irrigation in the catchment by releasing the EWRs for the Gibraltar site in the Lower Mzimkhulu catchment. In addition dams exporting surplus yield were modelled.

Initially the detailed assessment of the impacts of the different scenarios on the EWR sites in the catchment were determined using the 2010 hydrology and the 2010 flow scenario results are presented in Appendix B of Report, Riverine Ecological Water Requirements *(WMA 11/T50/00/3009, Volume 5)*. When the March 2011 hydrology became available, the effects of the most important development scenarios were re-modelled and the new results are presented in the body of Report, Volume 5. The results of the scenario modelling indicate that the impacts of increased plantation forestry and irrigation in the catchment can be mitigated by providing storage while maintaining current EWRs or improving them to meet the PES. Moreover, the dams would provide some surplus yield which could be exported or utilised within the catchment.

9. MANAGEMENT AND DEVELOPMENT OPTIONS

Various options for expansion of forestry were considered in future development scenarios as discussed below. Future infrastructure developments were also taken into account in assessing the future water demands on the catchment.

- The proposed Cwabeni off-channel Dam, about 20 km upstream of Ugu District Municipality's abstraction point at St. Helen's Rocks, to address sporadic shortages in supply to Port Shepstone.
- Future water exports, to the Mhlabatshane Regional Water Supply Scheme, which will require a small volume water to be exported to the adjacent catchment, as from 2015.
- The possibility of future augmentation of the Mgeni System, via the Mkomazi River;
- Increased supply to the coastal towns and resorts to the north and south of Port Shepstone.
- Any increase in urban an irrigation water use or plantation forestry areas, would reduce the river flows, particularly the low flow. Any significant export of water would also change the flow regimes. It is probable that these would have a negative impact on the environment which was assessed.

9.1 WATER RESOURCE MANAGEMENT AND INTERVENTIONS

9.1.1. Development Options – Providing Additional Storage

The development of one or more, new dams to mitigate the impacts, particularly on low flows, of additional forestry, or other water use in the catchment was considered. Reports from previous studies conducted by DWA, Umgeni Water and municipalities were studied. Some 22 possible dam sites had been previously identified on the main stream and tributaries of the Mzimkhulu River, shown in **Figure 9.1**.

The sites were screened, using various criteria, the overriding one being locality. As the largest areas of forestry potential are situated in the Ngwangwane, the Middle Mzimkhulu and Bisi WMSCs, the sites on those rivers, were regarded as being best positioned to mitigate the impact of forestry on the low flows:

- Site 12 on the Ngwangwane River, and
- Site 19 on the Bisi River.

To test the impact on the river flows and water available to meet the EWRs a possible large dam with all the surplus yield being exported, a further two sites were selected.

- Underberg, and
- New Biggin

9.2 CATCHMENT SCENARIOS

Present day land and water use requirements and the riverine EWRs to maintain the PES, extrapolated to each quaternary sub-catchment for the present day system were imposed on the system. Two scenarios were run for the present supply system, with and without the Cwabeni off-channel storage, which is currently being investigated. When taking into consideration the EWR, there is no historic firm surplus yield from the run of river flows, at quaternary sub-catchment level.

The future scenarios were developed, in order to test the impact of possible future developments within the catchment, on the flows downstream and to test the impact on the EWRs. All known urban and rural demands, projected to 2030, were included.

9.2.1. Future Scenario 1: All Small Growers

Scenario 1 assumes small grower plantation forestry expansion of 29 400 ha, and no increase in irrigated agriculture. A number of sub-scenarios were run, with and without the off-channel storage at Cwabeni, as well as mitigated scenarios with a dam at Site 12 on the Ngwangwane River, sized and operated to meet either the EWR or the present day flows at Gibraltar. A 0,5 MAR dam was also modelled, with the surplus yield assumed to be fully utilised or exported.

The results of the modelling indicated that this relatively large additional plantation forestry development had limited impact on the present day flows at the Gibraltar EWR site. These flows could be restored by a small dam of about 10 million m^3 dam (0,04 MAR) storage at Site 12 on the Ngwangwane River. A larger dam of 45 million m^3 (0,2 MAR), would meet all recommended EWR flows at Gibraltar. The larger 0,5 MAR dam produced a surplus of about 80 million m^3/a.

9.2.2. Future Scenario 2: Small Growers, Bisi

Scenario 2 assumes plantation forestry expansion of 21 050 ha for small growers in the Bisi and Middle Mzimkhulu River catchments, with no increase in irrigated agriculture. A dam at Site 19 on the Bisi River was included to mitigate the impacts of increased plantation area. Three scenarios were run with the dam to

9.3 DISCUSSION

At the sites used for the EWR study the Mzimkhulu River has assessed to be in a good condition, somewhat better than expected. The aquatic environment also proved to be fairly resilient, being relatively unaffected by the proposed development of additional forestry and irrigation in the catchment. It emerged that there is limited risk to the environment in allowing a moderate degree of forestry development in the zones where forestry potential was identified. It was also shown that one only needs a relatively small dam to restore the present day flows.

The developments, in which a large dam is constructed on the mainstem Mzimkhulu, have the largest potential impact on the ecosystem, with those dams planned for tributaries having much less impact. Avoiding construction of dams on the mainstem river, would also support conservation initiatives, where the undammed nature of the Mzimkhulu River has been recognised by the NFEPA (SANBI, 2008) programme and the river is ranked as one of the most important for conservation in the region.

The scope of the project made provision for a limited number of EWR sites. These sites are on the main Mzimkhulu River and on the larger tributaries. Whilst the impact of moderate areas of additional forestry was relatively small at these sites, there may be considerably more severe impacts locally, on some of the smaller tributaries, which will need to be assessed when considering licence applications.

9.4 CONCLUSIONS

The overall conclusion is that the state of the ecosystem in this catchment, including the estuary, is generally good and the river is fairly resilient to some additional development in the catchment. By providing storage, the impacts of significant increases in the areas of plantation forestry and increased irrigation, would not only be successfully mitigated, but the state of the river could be improved, to fully meet the EWRs at Gibraltar. Additional storage would also provide some surplus yield, which could be exported or used. A large storage dam could be considered to export water to a neighbouring catchment or the surplus used to boost additional development within the catchment.

The cost estimates of the possible dams at site 12 on the Ngwangwane River and site 19 on the Bisi River were based on the smallest possible dams to meet all the EWR requirements at the Gibraltar site. On each of the sites, a dam with storage volume of 42 million m^3 was assumed for costing purposes and costs are estimated to be R367 million and R265 million respectively.

Annual costs of redemption of the above loans, over a period of 40 years, at interest rates of 8, 10 and 12% for each of the dams, were reduced to a per hectare cost for the three scenario, as shown **Table 9.1**.

(c) Water resource management

- Implement Water Conservation and Demand Management (WCDM).
- Validate and verify all registered water use in the catchment and eliminate unlawful use.
- Monitor to ensure compliance with licence conditions. Assess any new licence applications for development, considering information on potential impacts as provided by an EIA process and potentially a Reserve study conducted at a local level.
- Develop procedures or guidelines to link the removal of invasive alien vegetation to licences for additional forestry.
- Educate people in rural areas to prevent over-grazing.
- Implement Catchment Management measures, like Working for Wetlands and Working for Water to assist with meeting the Reserve.

(d) Environmental

- Initiate a programme to rehabilitate drained wetlands.
- Implement on-going ecological monitoring at the EWR sites. Ensure that the ecological state of the river does not deteriorate.
- Evaluate the findings of this EWR investigation together with the new Rapid EWR site investigations that were commissioned by DWA and the Water Research Commission (WRC) towards the end of this project. The results from this study will provide information on the Reserve situation in the smaller tributaries.
- As soon as possible determine and implement RQO following the newly published procedure, so that there can be clear objectives for the management of the river. Carry out on-going monitoring at the estuary, to allow the effects of development to be properly monitored.

(e) Hydrological monitoring

- Review the calibration of key flow gauges.
- Establish flow gauges and monitor flows at the lower ends of the Ngwangwane, the Bisi and the lower end of the Middle Mzimkhulu Water Management Sub-catchment (WMSC).

9.5.2. Longer Term Management and Development Options

- Having implemented the recommended monitoring, assess the impact on stream flow of the water use in the catchment, including that of the first areas of additional forestry, when at least 5 years monitoring is available and the additional forestry has been in place for at least 5 years.
- The hydrology should be updated and the model re-calibrated, paying particular attention to the Bisi catchment.
- Reassess the EWR results for the rivers and estuary.
- Based on the results for these assessments decide whether or not to invite and process licence applications in batches of 5 000 ha up to say 30 000 ha.
- Continue to monitor the inputs to reassess if further licences, potentially up to a total area of 50 000 ha of new plantation forestry can be issued.
- Small growers should receive priority.

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